CENSUS TECHNIQUES FOR SOUTHERN REEDBUCK *Redunca arundinum* ON FORESTRY LANDS IN THE DRAKENSBERG/NATAL MIDLANDS

Component A: LITERATURE REVIEW

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I hereby declare that this dissertation, "Census Techniques for Southern Reedbuck *Redunca arundinum* on Forestry Lands in the Drakensberg/Natal Midlands" is original work done between January 2003 and November 2003 at the Centre for Environment and Development in partnership with the School of Botany and Zoology (University of Natal). This study has not been published or submitted towards any other degree at any other university.

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Glossary of terms used

Accuracy is "a measure of how close a census estimate lies to the true number of animals in a wildlife population" (Collinson, 1982). Therefore, accuracy refers to the size of the deviation from the true mean. "Accuracy is a measure of bias error (Caughley & Sinclair, 1994).

Bias reduces the repeatability of a census technique by systematically distorting the results (e.g. male reedbuck may be more conspicuous than female reedbuck, thus biasing the results in favour of male reedbuck). This is usually in one direction. See sampling error.

Census is defined as a count, which includes details as to population structure, sex, age, etc. for a specific species in a specific area.

Cohesive behaviour is the degree to which an animal aggregates (e.g. in winter when the carrying capacity drops reedbuck aggregate on winter pastures) – mean grouping behaviour.

Forestry landscape is made up of a mosaic of large planted areas separated by corridors, firebreaks, and wetland and riparian areas.

Harvesting (of reedbuck) includes both translocation and hunting (i.e. the removal of reedbuck from resident populations).

Physiognomy indicates the structural composition of the vegetation (e.g. open or closed woodland, plantation forest or open grassland (Collinson, 1982).

Posture refers to "whether animals lie down and/or remain motionless either at certain times of the day or when approached by an observer" (Caughley & Sinclair, 1994).

Precision refers to "the size of the deviation from the mean obtained by applying the sampling procedure repeatedly" (Collinson, 1982). "Precision is a measure of sampling error" (Caughley & Sinclair, 1994).

Repeatability is "a measure of how constant the magnitude and direction of bias in a census estimate remains from census to census" (Collinson, 1982). "If a set of estimates has little scatter the estimates are described as repeatable" (Caughley & Sinclair, 1994).

Sampling error often distorts the census results, but not always in the same direction, thus balancing itself out according to a normal distribution.
Standard deviation measures the relative variability of two sets of measurements.
Stratification involves the identification of defined groups within the data and the resultant separation into separate data sets for analysis (e.g. stratification into different reedbuck habitats).
Value addition involves the application of economic value to a resource.

1. INTRODUCTION

Conservation outside of protected areas through sustainable management and value addition is essential in modern biodiversity conservation strategies. Due to the provision of baseline data for comparison monitoring forms an integral part of the sustainable management of natural resources, and species and area specific census techniques form the foundation upon which sustainable management practices can be developed.

A census technique is a counting method that includes details such as population structure, sex ratio, age structure, etc. of a given species in a given area (Davis & Winstead, 1980). For the purposes of this study the given species is the southern reedbuck *Redunca arundinum* and the given area is the Drakensberg/KwaZulu-Natal Midlands. This study specifically aims to test census techniques developed for reedbuck on forestry lands in the Drakensberg/KwaZulu-Natal Midlands. The prescribed census technique(s) is paramount in the sustainable management of utilized reedbuck populations. The link between census techniques and sustainable management is that with high repeatability census techniques can provide the data required to monitor population status, prescribe sustainable harvesting quotas, and monitor the influence of management systems. Effective monitoring validates and supports management systems, and the derivation, testing and prescription of standardized census techniques forms the initial step towards the sustainable management of the reedbuck populations in the Drakensberg/KwaZulu-Natal Midlands. However, monitoring requires coordination at a local level so as to ensure the integrity and applicability of census results, and this study determines to provide management recommendations towards the coordination of reedbuck management at a local level.

In this study, management constraints restricted the census techniques tested to those that were simple, cost effective, time efficient and have a high repeatability over time.

Reedbuck populations in the Drakensberg area have historically been limited by the low winter carrying capacity of seasonally inundated wetlands (Howard, 1983). Over the past 50 years, the landscape of these areas has changed through commercial afforestation, the planting of winter pastures (e.g. *Lolium spp.*), the delineation and conservation of wetland and riparian areas on forestry lands, and the burning and maintenance of grassland corridors and firebreaks within the forestry landscape. This land-use mosaic has been able to support increasing reedbuck populations in the Drakensberg/KwaZulu-Natal Midlands through the provision of reedbuck habitat and winter forage (Howard, 1983; Howard, 1986). Basically, the forestry lands provide suitable habitat for reedbuck and adjacent agricultural lands provide essential winter forage for these populations (S. De Jager *pers. comm.*, 2003). As a result, the cohesive behaviour of reedbuck has become more seasonal, with reedbuck congregating on irrigated winter pastures after the first significant frosts when indigenous grasses become dormant. This interrelationship highlights the necessity for partnership and coordination between these two rural land-uses in the sustainable management of reedbuck populations in the Drakensberg/KwaZulu-Natal Midlands. This relationship is not absolute, as a comparatively large reedbuck population exists on the Mondi Forests Mount Shannon estate in the Boston conservancy, where there are no immediately adjacent winter pastures. This could be as a result of recruitment from adjacent areas with winter pastures or other factors (e.g. sufficient winter forage in intermittent wetlands). Further research into the feeding behaviour and winter physiology of the reedbuck population on the Mount Shannon estate would provide valuable insight into the ecology of this population. Forestry lands do not include winter pastures, and thus an estate that did not have adjacent winter pastures was chosen as the case study site. For the purposes of this study the Mount Shannon estate was used as a case study site for the testing of census techniques for reedbuck on forestry lands.

Howard (1983) developed an integrated approach to the management of southern reedbuck on farmland in KwaZulu-Natal, and was originally motivated by the Farm

Game Section of the Natal Parks Board (under the broad heading "Problem Animals on Farmland"). As a problem animal reedbuck were viewed as becoming a potential threat to agricultural productivity. Winter pastures (especially *Lolium spp.*) are of economic value to dairy and cattle farmers, and thus increasing reedbuck populations (in the absence of prior winter forage restrictions) and their impact on winter pastures were earmarked for management through harvesting (i.e. hunting and translocation). This perception highlights the necessity for the sustainable management of reedbuck populations and value addition through harvesting. Harvesting should be encouraged, so as to enhance the value of the reedbuck resource on farmlands (Howard, 1983). The initial step towards the sustainable management of reedbuck populations is the development and testing of census techniques that provide reproducible data on population structure and status, thus ensuring sustainable harvesting quotas and management prescriptions.

This study was motivated by Mondi Forests in an effort to ensure the sustainable management of reedbuck populations on Mondi estates in the Drakensberg/KwaZulu-Natal Midlands. "Multiple Resource Utilisation" (MRU) forms an integral part of Mondi's environmental protection initiatives and allows for the sustainable utilization of natural resources available on Mondi lands (Pott, 1996). Reedbuck harvesting forms part of the MRU programme, and can only persist if reedbuck populations are managed on a sustainable basis - this sentiment is reflected in the Mondi Forests Hunting Policy (Pott, 2003). The testing and prescription of applicable census techniques for reedbuck on Mondi estates in the Drakensberg/Midlands area forms the initial step, thus allowing for the derivation of sustainable harvesting quotas. These harvesting quotas cannot be confidently applied to reedbuck populations without active coordination between neighbouring landowners, because of the relatively large home ranges, degree of dispersion and the movement of reedbuck off forestry lands onto winter pastures. For example, a census could be done on forestry lands, thus obtaining a count of 100 animals with a resultant hunting quota of 20 animals, but prior to the hunting season 40 animals are translocated off winter pastures at night on a neighbouring property, thus meaning 60% of the resident reedbuck population is harvested with the original intention of sustainable management. The development of a framework for the coordination of reedbuck management is essential, in that it would allow reedbuck census data to be adjusted according to harvesting activities on adjacent farms, for the inauguration of a census database, and to coordinate hunting and translocation activities.

Accurate game counts are essential in wildlife management, and thus numerous wildlife census techniques have been developed. Fieldworkers often apply incorrect or inefficient census techniques within a given context and for application to a specific species (Collinson, 1985). A framework for selecting wildlife census techniques by Collinson (1982) was used in the preliminary development and identification of applicable census techniques that were then refined using work done by Beavers & Ramsey (1998); Lancia, Nichols & Pollock (1996); Marchant (2000); Knott & Venter (1990); Reilly & Haskins (1999); Peel & Bothma (1995); Bothma, Peel, Pettit & Grossman (1990); Perrin & Everett (1999); Caughley & Sinclair (1994) and Caughley (1977). The census techniques were further refined through the consideration of reedbuck behaviour, habitat preference and spatial organization.

In the selection of an appropriate census technique, the initial step is the consideration of the research objective or management requirements for which census information is required (Caughley, 1977; Collinson, 1982; Collinson, 1985; Caughley & Sinclair, 1994). The research objective of this study is the derivation and testing of reedbuck census techniques for forest managers, with the primary objective of sustainable harvesting and conservation. According to Collinson (1982), if the research objective is "sustained yield harvesting or conservation", an absolute estimate with at least moderate accuracy, cost dependent on time/cost considerations and a high repeatability over time is required. For the purposes of this study the census techniques tested were designed for private landowners, and thus had to be simple, cost-effective, and able to reproducibly develop the data required for a reedbuck management database.

The primary parameter in the assessment of the census techniques for sustainable management is precision or repeatability, whereby a small standard error is indicative of high repeatability (Bothma *et al.* 1990; Caughley & Sinclair 1977). Repeatability is a measure of how constant the magnitude and direction of bias in a census estimate remains from census to census (Norton-Griffith 1978 *in* Collinson 1982). High repeatability allows for inferences to be made concerning population status, even though a census technique with a high repeatability may yield results that do not nearly approach the true or inferred size of the population. An integral part of the repeatability of a census technique is the bias in each census (Collinson 1985). Bias does not simply refer to sample error only, and includes inaccuracies that arise from factors such as observer error and bias, instrument error, weather and visibility, animal behaviour and vegetation condition that violate the underlying assumptions of the census technique (Collinson 1982). Ideally, the bias should be close to zero and constant from census to census, and in this study was minimised through the strict standardisation of methods. Repeatability was not considered to be an exclusively statistical concept, and was considered with reference to estimates obtained from sampling and non-sampling census techniques.

A secondary parameter in the assessment of the census techniques for sustainable management is accuracy. Accuracy is a measure of how close a game count is to the actual population size (Collinson 1982). Accurate census estimates are required for the calculation of stocking rates (animal standing biomass) and harvesting quotas (Bothma *et al.* 1990). Reedbuck are harvested on forestry lands, and thus sustainable harvesting quotas from accurate census estimates are a necessity. A prerequisite for evaluating the accuracy of a census technique is known population size (Collinson 1985). In this study, the control was the minimum population estimate and control range obtained from the non-sampling counts.

Our census allowed for data collection on population structure, sex ratios and animal behaviour. The repeatability and accuracy of these results were evaluated in much the same way as the population estimates.

In the past Venter (1979) made use of total aerial counts, night counts from a vehicle and strip counts (e.g. King's census method, Kelker's Index, and Anderson and Pospahala's method) to census reedbuck on the Eastern Shores of Lake St Lucia. Howard (1983) made use of total ground counts, night pasture counts and Petersen estimates to census reedbuck in the Underberg district of the Natal highlands.

Collinson (1985) makes reference to sampling and non-sampling census techniques, highlighting the distinction between census techniques in which the results are taken as the minimum population size and census techniques (e.g. line transect) in which the results are taken as a sample used to estimate the population size. The non-sampling census techniques could be referred to as systematic.

The following census techniques were tested on the Mount Shannon estate in this study:

(i) Dawn Flush Counts (DFC);
(ii) Night Habitat Counts (before frost) (NHCa);
(iii) Night Habitat Counts (after frost) (NHCb); and

Non-sampling

(iv) Line Transect Counts (LTC).

Sampling

These techniques are supported by the literature review, and are simple and complementary. The line transect method as put forward by Bothma *et al.* (1990) and Peel & Bothma (1995) could provide an accurate sampling strategy for the estimation of reedbuck populations on forestry estates (if the method is adapted to accommodate the specific characteristics of the forestry landscape (e.g. corridors and wetland areas) and reedbuck behaviour. The repeatability, applicability and accuracy of the results from the sampling and non-sampling census techniques were critically evaluated, and compared with each other and historical game counts on the Mount Shannon estate (Section 5).

OBJECTIVE OF STUDY:
The objective of this study is to identify, standardise and test census techniques for southern reedbuck *redunca arundinum* on forestry lands in the Drakensberg/KwaZulu-Natal Midlands, so as to identify a census technique/s for use in future management.

AIMS OF STUDY:

- To identify current and possible census techniques for reedbuck on forestry lands in the Drakensberg/KwaZulu-Natal Midlands;
- To critically assess these census techniques as regards compatibility with reedbuck ecology, the forestry landscape, management requirements, etc.;
- To develop standardised census techniques to be tested;
- To determine the requirements of the census techniques;
- To develop the standardised census techniques;
- To choose a case study site;
- To test the identified and standardised census techniques;
- To identify through statistical analysis which of the census techniques performed the best; and
- To prescribe census techniques for management of reedbuck populations on forestry lands in the Drakensberg/KwaZulu-Natal Midlands.

2. PREVIOUS RESEARCH

2.1 Previous research on southern reedbuck *Redunca arundinum*

Previous research done on reedbuck was used to develop an understanding of reedbuck ecology, outline problems related to management and utilisation, and record and assess the census techniques used in previous studies. The core studies done on reedbuck ecology and management include Jungius (1971a; 1971b), Venter (1979), and Howard (1983; 1984a; 1984b; 1986; 1987). Howard (1983) developed an integrated approach to the management of reedbuck on farmland in KwaZulu-Natal. This Ph.D. thesis provided useful insights into the relationship between reedbuck ecology, monitoring and management. Venter (1979) examined the ecology of reedbuck on the Eastern Shores of Lake St Lucia and his results provide useful data as regards reedbuck home ranges and core areas, population dynamics, age and sex determination, and census techniques.

2.2 Previous research on members of the Reduncinae

Species of the subfamily Reduncinae are medium to large-sized antelope, the males with medium-sized to long ridged horns, either bowed, lyrate or hooked (Skinner & Smithers, 1990).

The subfamily Reduncinae include the following:

- Southern reedbuck *Redunca arundinum*;
- Mountain reedbuck *Redunca fulvorufula*;
- Waterbuck *Kobus ellipsiprymus*;
- Red lechwe *Kobus lechwe*; and
- Puku *Kobus vardonii*.

Previous research done on species of the subfamily Reduncinae was used for the purposes of comparison with research on reedbuck, and to provide insight into other census and monitoring techniques. The core studies done on species within the subfamily Reduncinae include the red lechwe *Kobus lechwe* lechwe (Williamson, 1979) and waterbuck *Kobus* ellipsiprymus (Melton, 1978).

2.3 Previous research on similar antelope species in the Drakensberg area

Previous research done on similar antelope species in the Drakensberg area was used for the purposes of comparison with research on reedbuck, to aid in highlighting problems related to wildlife management in these areas, and to provide insight into other census and monitoring techniques.

The core studies done on similar antelope species in the Drakensberg/Midlands area include the oribi *Ourebia ourebi* (Everett, 1991; Perrin & Everett, 1999; Marchant, 2000) and eland *Taurotragus oryx pallas* (Scotcher, 1982).

3. CONCEPTUAL FRAMEWORK OUTLINING THE CONTEXT OF THE STUDY

This conceptual framework (Fig. 1) illustrates the interaction of the three primary factors influencing southern reedbuck *Redunca arundinum* population status, and these include the external factors (e.g. poaching, hunting, translocation and introduction), management policy and practices, and habitat quality. Factors such as predation, natality, adult and juvenile mortality, poaching (e.g. snares and hunting with dogs), emigration/immigration, and disease are assumed within the context of this project as being constant, and thus are not considered as influential factors.

Figure 1 illustrates the influence of management practices (e.g. forest management and resource utilisation) and climatic conditions on habitat quality that coupled with reedbuck habitat preference influences the size and status of the reedbuck population in a specific area (e.g. Mount Shannon). Basically, habitat quality is dictated by the vegetation composition, vegetation structure, island biogeography and habitat area. These factors are influenced by management practices such as pasture management, forest operations, delineation of corridors and wetland/riparian areas, and degree of disturbance. External factors such as immigration/emigration, hunting, poaching, translocation, and introduction must also be accounted for when assessing the factors influencing a resident population of a specific area.

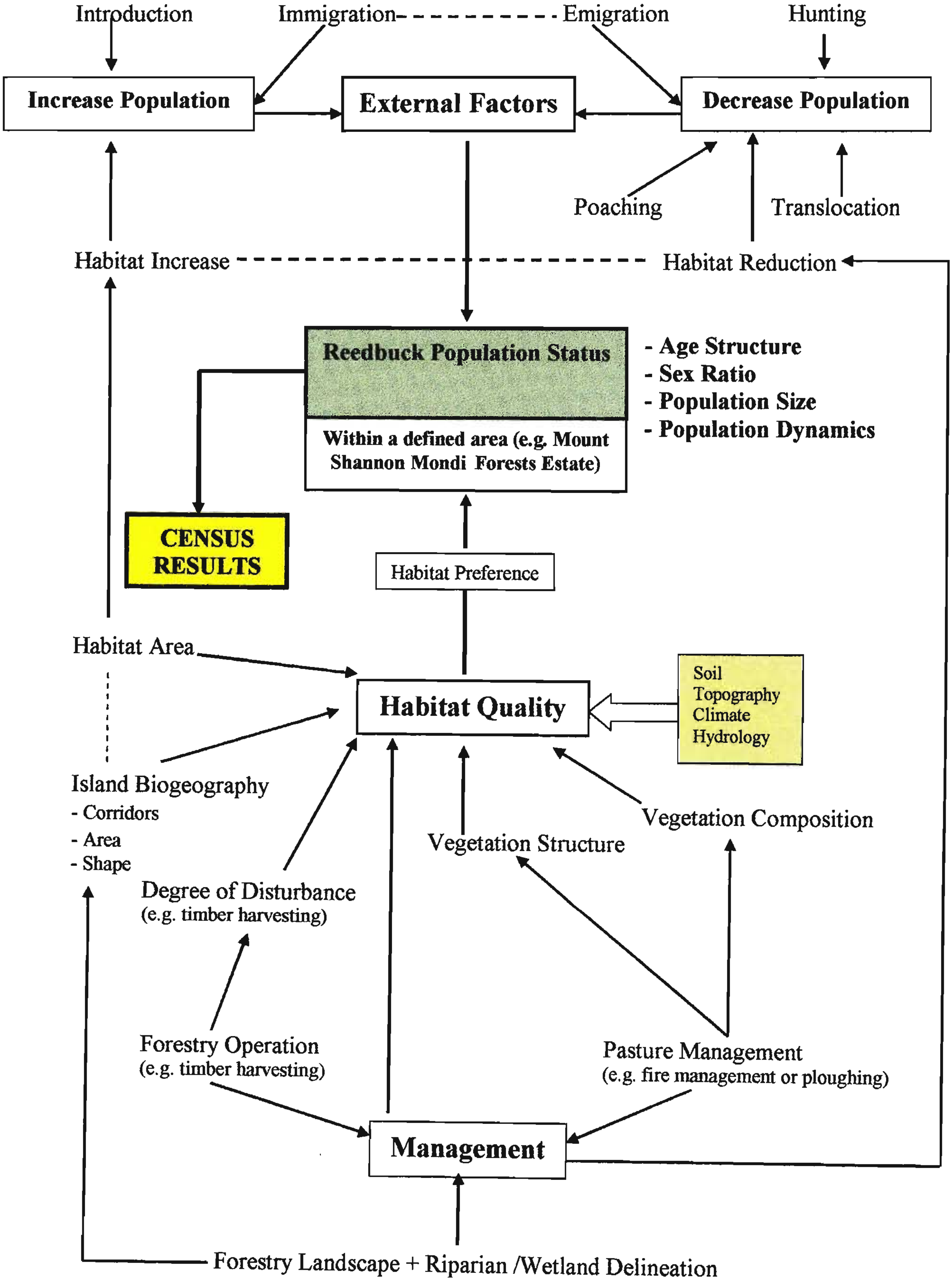


Figure 1. CONCEPTUAL FRAMEWORK CONTEXTUALISING CENSUS RESULTS ON FORESTRY LANDS

The census results obtained during the course of a census technique (as far as possible) are a reflection of the inter-relationship of these factors and their influence on the reedbuck population status, size and composition.

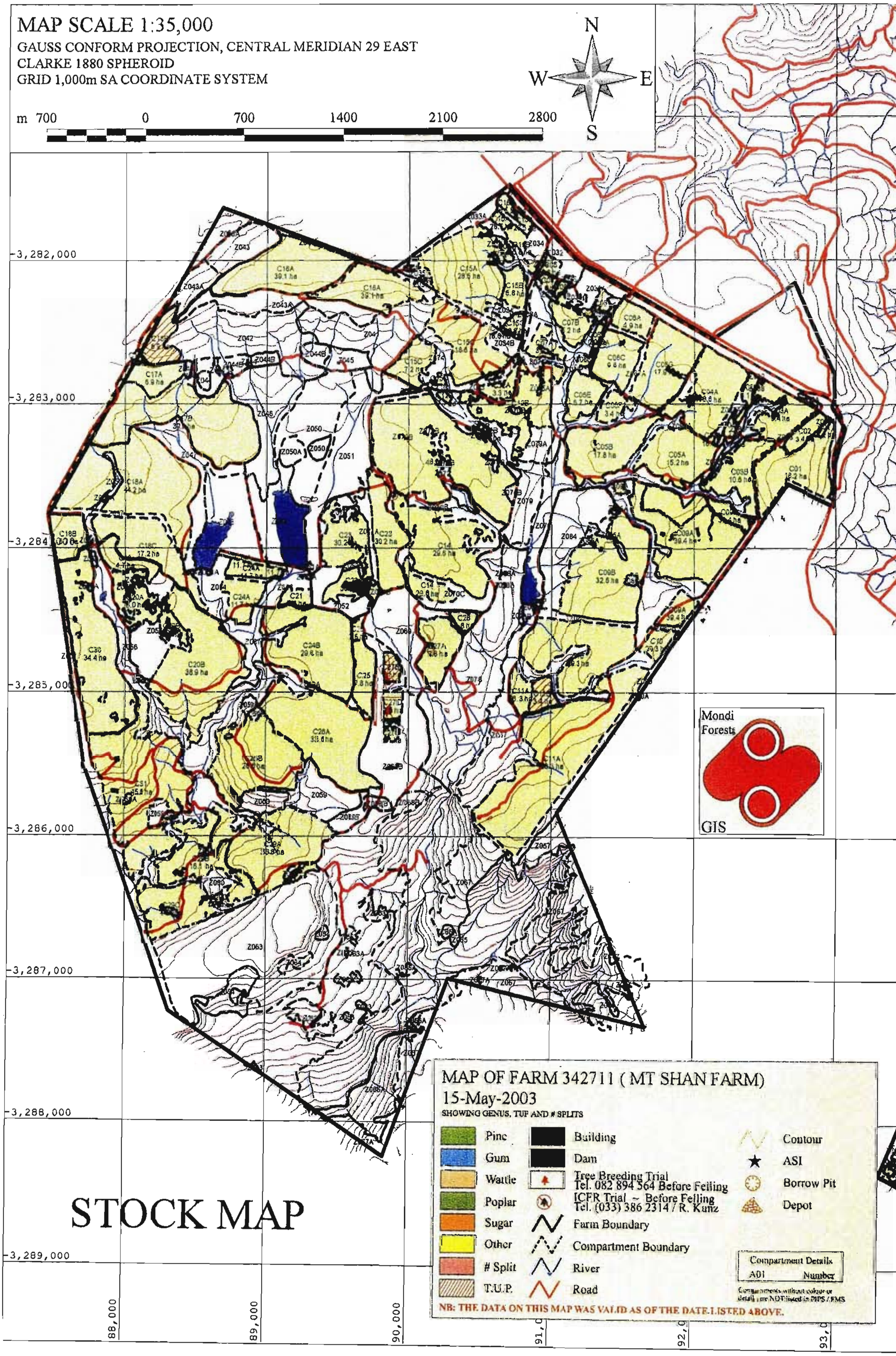
4. STUDY SITE: MONDI FORESTS MOUNT SHANNON ESTATE

Three estates (i.e. the Mount Shannon, Goodhope and Linwood estates) in the area (all with similar characteristics) were chosen as possible case study sites to test reedbuck census techniques, and the Mount Shannon estate was chosen as it lies at the interface between the Drakensberg and Natal Midlands, has no immediately adjacent winter pastures, has defined grassland, riparian and wetland areas, had no timber harvesting operations over the study period, and is a forestry estate that is utilised for hunting and translocation.

The Mount Shannon estate is located in the Boston conservancy (South 29^{o}39’ to 29^{o}43’; East 29^{o}54’ to 29^{o}57’). The total area of the estate is 2226 hectares, with a total planted area of 1114 hectares, a total conservation area of 1057 hectares, and a total road area of 55 hectares (Fig. 2). Figure 2 is a stock map illustrating the different land-uses on the Mount Shannon estate, and the extent (47%), location and orientation of the conservation area – the development of a GIS spatial representation of the potential reedbuck habitats did not fall within the scope of this study. The estate was registered as Natural Heritage Site (no. 269) in 1996, and as a Site of Conservation Significance (no. 95 and 96) in 1995. In 1996 the estate was nominated by the Forest Owner’s Association (FOA) for an award as one of the best achievers in the field of cultural and wildlife asset management and provision of recreational facilities. The Mount Shannon estate has in the past been associated with Ezemvelo-KZN Wildlife (EKZN), the SA Crane Foundation, the Conservancies Association, the FOA, and the KZN Hunter’s and Game Conservation Association. This study has formed an association between Mondi Forests and the Centre for Environment & Development (University of Natal).

The Mount Shannon estate is representative of the region (i.e. good example of veld type 45 (Natal Mistbelt)) and the forestry landscape, and has a comparatively large reedbuck population that is hunted annually, and thus was chosen as the study site for testing reedbuck census techniques in the Drakensberg/KwaZulu-Natal Midlands. There are no gaps in the game count results (Table 1) for the Mount Shannon estate and the census results indicate that the population may be decreasing, thus making it necessary to ascertain whether this was due to poor repeatability of the census techniques or other factors (e.g. excessive hunting off-take, reduced habitat, management prescriptions, etc.). Timber harvesting operations were not active on the estate at the time of the study, and thus census results could not be biased by these activities. This study determined to develop and test census techniques on forestry lands, thus excluding the influence of winter pastures on seasonal behaviour. There are no immediately adjacent winter pastures (e.g. *Lolium spp.*) in or around the Mount Shannon estate.

Figure 2. STOCK MAP OF THE MONDI FORESTS MOUNT SHANNON ESTATE


MAP SCALE 1:35,000
GAUSS CONFORM PROJECTION, CENTRAL MERIDIAN 29 EAST
CLARKE 1880 SPHEROID
GRID 1,000m SA COORDINATE SYSTEM
m 700 0 700 1400 2100 2800
N
W E
S
-3,282,000
-3,283,000
-3,284,000
-3,285,000
-3,286,000
-3,287,000
-3,288,000
-3,289,000
88,000
89,000
90,000
Mondi Forests
GIS
MAP OF FARM 342711 (MT SHAN FARM)
15-May-2003
SHOWING GENUS, TUP AND # SPLITS
Pine
Gum
Wattle
Poplar
Sugar
Other
Split
T.U.P.
Building
Dam
Tree Breeding Trial Tel. 082 894 564 Before Felling
ICFR Trial ~ Before Felling Tel. (033) 386 2314 / R. Kunz
Farm Boundary
Compartment Boundary
River
Road
Contour
ASI
Borrow Pit
Depot
Compartment Details
A01 Number
NB: THE DATA ON THIS MAP WAS VALID AS OF THE DATE LISTED ABOVE.
STOCK MAP

Upon consultation with EKZN, the KZN Hunter's and Game Conservation Association and Mondi Forests it became apparent that Mount Shannon was favoured as a study site.

Table 1. HISTORICAL GAME COUNTS FOR THE MOUNT SHANNON ESTATE

Year	Game count result
1989	71
1990	74
1991	74
1992	72
1993	41
1994	39
1995	48

(Burden *unpublished*, 2003)

5. INADEQUACIES OF HISTORICAL GAME COUNT RECORDS

As a precursor to this study an assessment and critical analysis of present counting methods was necessary, so as to identify problems related to the current system. Game count records were available for the Boston and Merrivale conservancies and extended from 1989 to 1997. The original recording sheets were obtained from Doug Burden[1] at the Mondi Forests Technical Division. These game counts were conducted for mountain reedbuck *Redunca fulvorufula*, southern reedbuck *Redunca arundinum*, oribi *Ourebia ourebia*, and bushbuck *Tragelaphus scriptus*. For the purpose of this study, only the reedbuck counts for Boston and Merrivale were evaluated, but the other counts exhibited similar limitations.

[1] D. Burden. Mondi Forests. 179 Loop Street, P.O. Box 39, Pietermaritzburg, 3200.

Table 2. SUMMARY OF REEDBUCK GAME COUNTS FOR BOSTON CONSERVANCY FROM 1989 – 1995

Estate	1989	1990	1991	1992	1993	1994	1995
Netherby	19	31	28	18	47	37	33
Virginia/Woodlands Park	9	8	5	21	14		
Edzek/Cheviot/Norwood			0		19	3	19
Trelyon	9	17	33		31	18	43
Calderwood	9	8	13	12	46	12	
Mount Shannon	71	74	74	72	41	39	48
Noncheza		0	0	0			
Elandshoek	31	10	57	47	60	63	72
Goodhope/Flemington			47	36	23	23	
Boston House	18	5	9	31	16	10	5
Endeavour/Fairview	8	36	44	37	46	27	17
Rockeries/Montshonga	0	6	6	3	16	32	8
Rockeries	4	4	5	4			
Seven Streams		6	2	8	7	13	11
TOTAL (no. of counts)*	178(10)	205(11)	323(15)	289(13)	366(13)	277(12)	256(10)

*The number in brackets next to the total population indicates the number of counts

[grey box] = No count

[yellow box] = Mondi Estate

Table 3. SUMMARY OF REEDBUCK GAME COUNTS FOR MERRIVALE CONSERVANCY FROM 1992 – 1997

Estate	1992	1993	1994	1995	1996	1997
Ashley Grange	23	32	65	14	57	29
Shaywhen	89	60	52	53		
Mount Ashley	56	54	71	58	98	92
Linwood	95	54	49	92	110	96
Eseldene						
Groot Vallei	51	46	46	42	52	46
Wahroonga		2			1	
Stirling	32	24	18		4	
Glencall				47	91	83
Goodwill				77		92
Adamshurst						
Homewood					0	0
Claudia					6	
Lakeside						15
TOTAL (no. of counts)*	346(6)	272(7)	301(6)	383(7)	419(9)	453(8)

Shaywhen combined with Mt. Ashley (1995)

Eseldene combined with Linwood

*The number in brackets next to the total population indicates the number of counts

= No count

= Mondi Estate

Counting methods applied on these forestry estates were individual night or dawn counts from a vehicle in May, June or July with no standardized census route. These counting methods were recommended in 1989 by Ezemvelo-KZN Wildlife (formerly the Natal Parks Board) (Burden *pers comm.*, 2003)[2]. Upon examination of the results from the game count data sheets and consultation with managers, the following critical issues become apparent. There are numerous gaps in the data presumably as a result of changes in management personnel, management objectives or time and budget constraints. These gaps in the game count data reduce the value of earlier or later game counts in the area, as without previous data from a standardized census

[2] D. Burden. Mondi Forests. 179 Loop Street, P.O. Box 39, Pietermaritzburg, 3200.

technique the influence of management and ecological changes cannot be related to population status (i.e. increasing, stable or decreasing). The historical game count records were not imputed into a database that could be used for management and research purposes, so as to accurately follow population trends and the influence of changing management practices (e.g. alteration of burning regime). Game counts were conducted between the 21st of May and the 17th of July (i.e. a 2-month window). This window is too wide, and reduces the repeatability of the game counts due to the changes in vegetation and climatic conditions over this period of transition between summer and winter. The time of day and length of census were not standardized, as some counts were conducted at night and others at dawn, and the time taken ranged from two to four hours. Upon investigation of the census routes used on the estates it was found that routes were not always known or mapped. Managers and conservancy guards knew this information or were familiar with it, and thus changes in ownership, management or staff resulted in the alteration of the census route. Changes in ownership, management or staff also resulted in the alteration of the counting methods, time taken, time of day, and the time of year. Basically, the census process seems to be personality driven, thus making the provision of a standardized census technique a priority to avoid these sources of error.

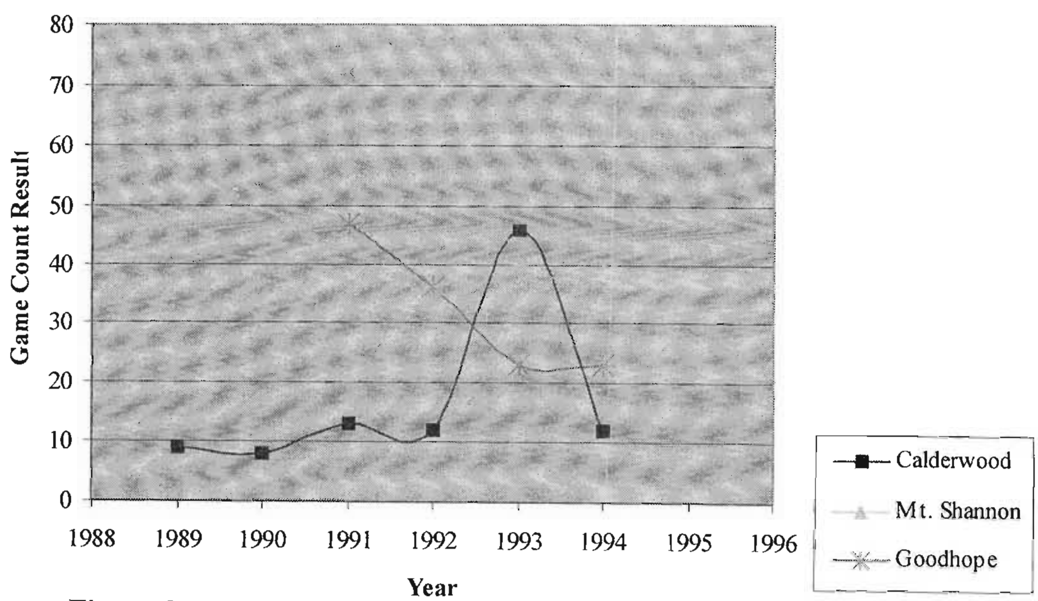


Figure 3. Observed trends in the reedbuck populations on Mondi Estates in Boston Conservancy

The fluctuations observed in Figure 3 illustrate the apparent low repeatability of the current reedbuck counting methods on Mondi Forests estates in the Boston Conservancy. These counting methods are widely applied in other areas and conservancies in the Drakensberg/KwaZulu-Natal Midlands (S. De Jager *pers. comm.*, 2003). Between 1992 and 1993 the reedbuck population on the Calderwood estate increased from 12 to 46 (380% increase), and then by 1994 the population had returned to 12. The presence of this outlier result is indicative of the poor repeatability of the counting process. The Calderwood and Mount Shannon estates are not adjacent, and thus the decreases in the Calderwood population and the increase in the Mount Shannon population could not have been due to recruitment between these estates, and must have been due to other factors (e.g. emigration, poor management practices, hunting, poaching, etc.) or poor repeatability in the counting process. Without the necessary data on the circumstances within which these counts were conducted no absolute judgements can be passed, but these fluctuations are indicative of a problem.

6. CONTEXTUALISING REEDBUCK MANAGEMENT

6.1 Conservation status

The southern reedbuck *Redunca arundinum* as per the Ezemvelo-KZN Wildlife (EKZN Wildlife) "Guide to Hunting in Natal" is scheduled as "Protected game" in KwaZulu-Natal (Rowe-Rowe, 1994; EKZN Wildlife, 2003), and is included in the list of endangered large mammals compiled for the South African Red Data Book, where its status is described as "rare, common locally in parts of Zululand" (Skinner *et al.*, 1978). The southern reedbuck is, therefore, considered to be of conservation value, and thus requires comprehensive monitoring and management within and outside of protected areas. In terms of the Nature Conservation Ordinance of 1974 (Ord. 15 of 1974) the scheduling of reedbuck as protected game means that EKZN Wildlife can regulate reedbuck harvesting through a system of permits and licences. The coordination of reedbuck management at a local level could be build into this licence and permit system or become the responsibility of organizations such as the

KwaZulu-Natal Hunting and Conservation Association and the KwaZulu-Natal Game Ranchers' Association.

6.2 <u>Population status and distribution</u>

Bothma (1975) stated that the southern reedbuck *Redunca arundinum* were stable throughout its range in central and southern Africa, however noting that it had disappeared from 80% of its former range in South Africa (Zaloumis & Cross, 1974; Howard, 1983). This occurred predominantly due to habitat loss and excessive hunting due to the perceived impact of reedbuck on agricultural productivity.

Howard (1983) conducted the Gamequest questionnaire survey to ascertain the population status and distribution of southern reedbuck in KwaZulu-Natal, and found that reedbuck were: "Widely distributed" in Zululand (as far south as $28^{o}45'$ S and as far west as $31^{o}15'$ E) where they appeared to be declining in the coastal areas and increasing inland; "widely distributed" in the Drakensberg and Midlands where they appeared to be stable or increasing; and absent or rare in other parts of KwaZulu-Natal (where sightings probably represented introduced animals).

The Gamequest survey highlighted the importance of the Drakensberg/KwaZulu-Natal Midlands in reedbuck distribution and population status, as these areas contained the highest incidence of increasing reedbuck populations (predominantly on forestry and agricultural lands) (Howard, 1983). This data is 20 years old, and thus research is required to update information on the status and distribution of reedbuck populations in KwaZulu-Natal.

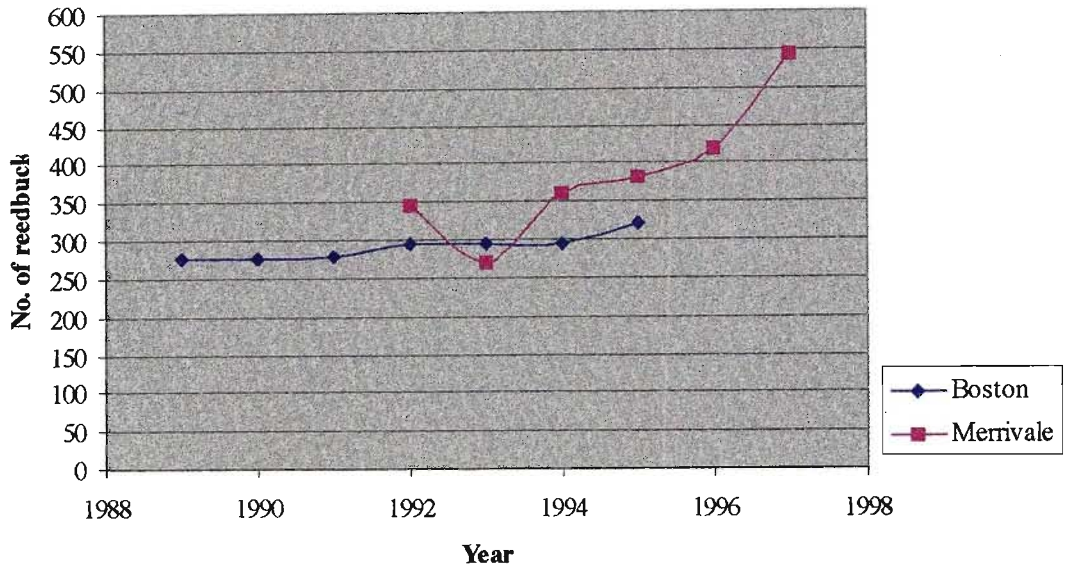


Figure 4. Historical game count totals for reedbuck in the Boston and Merrivale conservancies

Figure 3 highlights the possibility that according to the census data from 1989 – 1995 reedbuck populations on Mondi Forests estates in the Boston conservancy are decreasing. The population status must be assessed and investigated through the application of standardized census techniques and the development of a reedbuck management database. According to the historical game count totals for the Boston and Merrivale conservancies, the reedbuck populations in these areas are increasing (Fig. 4). This is in part due to the difference in the number of game counts from year to year. The results observed in Figure 4, although highlighting a trend, are not reliable. As pointed out, a new coordinated system of standardized census techniques is required to extract reliable relationships from these systems.

6.3 Reedbuck ecology

An understanding of reedbuck ecology is essential as a precursor to the design and application of effective census techniques relative to a specific landscape, suite of threats (e.g. hunting with dogs), and management policy. For the purposes of this study the habitat preference, social organisation and spatial distribution of reedbuck were examined, so as to allow for the effective design and application of census techniques.

6.3.1 Habitat preference

Within the forestry landscape there are areas that are seldom or never frequented by reedbuck, and conversely there are areas in which reedbuck congregate (e.g. wetland/riparian areas) or are often found. Therefore, the delineation of areas of reedbuck habitat is essential in the census process. Stratification forms part of the sampling strategy, thus making the identification of preferred habitat types a prerequisite.

Under natural conditions reedbuck are found in wetland areas and early seral habitats, which provide forage throughout the year and an abundance of rank herbaceous cover (Howard, 1983). These two elements are essential to support reedbuck, and areas in which either of these are absent are not expected to support viable populations.

Previous reedbuck habitat preference research was completed by Jungius (1971a; 1971b), Venter (1979), and Howard (1983; 1986; 1987). These studies obtained complementary results, with Venter (1979) and Howard (1983; 1986) utilising a quantitative assessment of habitat preference. Venter (1979) made use of scan sampling during King's census method applied to a Habitat Preference Index, while Howard (1986) made use of a Habitat Preference Index (including Coefficients of Association).

The relevant findings concerning reedbuck habitat preference include the following:

(a) Venter (1979) found that overall the two most preferred habitats are short and medium open shrubland, and the two least preferred habitats were pine plantations and vlei/wetland areas. Venter (1979) also found that the two most preferred habitats by grazing reedbuck were recently burnt[3] short open shrubland and recently burnt hygrophilous grassland, and the two least preferred were high density[4] pine plantation and medium density[5] pine plantation. For resting animals Venter (1979) found that reedbuck preferred the two habitats preferred for grazing, and least preferred recently burnt

[3] Recently burnt = less than 12 months previously (Venter, 1979).
[4] High density pine plantation = <1370 stems/hectare (Venter, 1979).
[5] Medium density pine plantation = 650 – 1370 stems/hectare (Venter, 1979).

medium open shrubland and low density[6] pine plantation. The study also found that the two predominant activities were grazing and lying down (i.e. hiding). The above results were obtained on the Eastern Shores of Lake St Lucia.

(b) On farmland in KwaZulu-Natal reedbuck preferred winter pastures and adjacent cover in winter, and vleis and broken veld in summer (these habitats can provide adequate forage and shelter simultaneously in summer) (Howard, 1986). Howard (1986) also found that open veld was avoided at all times of year, as a result of the provision of inadequate cover. Howard (1986) developed a multiple regression equation that accounted for 87.4% of the variation in reedbuck numbers using a stepwise multiple regression analysis. Low woody cover was the most significant variable and it was found that for the Underberg district the equation predicted that for each additional 3 ha of low woody cover there would be an additional 2 reedbuck on the farm. Pine plantations less than four years old could provide low woody cover, and thus these findings are important for reedbuck management on forestry estates. The above results were obtained on a complex of about twenty farms in the Polela valley in the Underberg district.

(c) Junguis (1971a) too found that there was a change in preference between summer and winter, whereby low-lying hygrophilous grasslands were the preferred habitat in summer and high-lying short and medium shrubland in the winter months. These results were obtained in the Kruger National Park.

The two elements put forward by Howard (1983) are evident in all the previous research into reedbuck habitat preference. In the context of the forestry landscape these habitat requirements are provided by the wetland/riparian areas, young pine plantations, low woody cover, grassland corridors, areas with associated pastures, and firebreaks. As part of the autumn burns the firebreaks and grassland corridors are burnt, thus providing fresh growth prior to the first frosts in May. *Lolium spp.* pastures on adjacent agricultural lands function to supplement reedbuck forage requirements in the Drakensberg area (where available). The Mount Shannon estate does not have winter pastures immediately adjacent, however, following a site inspection the presence of relict *Lolium spp.* pastures was noted in grassland areas,

[6] Low density pine plantation = >400 stems/hectare (Venter, 1979).

and these may function as supplementary forage for the comparatively large population on this estate.

Table 4 outlines in order of priority those habitat types that were focussed on and those identified for omission. The identification of preferred habitat for reedbuck on forestry lands was essential in the plotting of census routes and stratification. The following are the seven reedbuck habitat types identified on forestry estates in the Drakensberg/Midlands area: low woody cover; wetland/riparian areas; grassland corridors; firebreaks; areas with associated *Pennisetum clandestinum* pastures; and young pine plantations (0-2 years). Selected from these were the four reedbuck habitat types identified on the Mount Shannon estate (accounting for the requirements of census techniques to be tested), and these include: wetland/riparian areas; grassland corridors; firebreaks; and areas with associated *P. clandestinum* pastures. The winter pastures were not present on the estate, the visibility in the pine plantations was too poor for the census techniques to be tested, and low woody cover was too intermittent to be considered as a separate habitat type.

Table 4. HABITAT TYPES FOR USE IN STRATIFICATION OF CENSUS AREAS ON FORESTRY LANDS

Habitat types	
Included	**Excluded**
1. Low woody cover*	1. Pine plantation (>2 years)
2. Wetland/riparian areas*	2. Flat open terrain
3. Grassland corridors*	3. Eucalyptus plantation
4. Firebreak	4. Areas around human development
5. Areas with *P. clandestinum* pastures	5. Harvested areas
6. Pine plantation (0-2 years)	6. Steep terrain & wooded areas

*Primary reedbuck habitat

6.3.2 Social organisation

Jungius (1971a) found reedbuck social behaviour to be strictly territorial and this was partly supported by the findings of Howard (1983) who stated that reedbuck were at least temporarily territorial. Venter (1979), however, concluded that reedbuck were organised according to a dominance hierarchical system. Howard (1983) asked whether this territoriality could regulate population density and have a function in population regulation, and found that when culling mortality was raised from zero to 20% population size remained constant, thus indicating that social behavioural losses (i.e. through territorial disputes and the forcing of reedbuck into marginal habitats) were reduced in a compensatory manner. Social behaviour is an important limiting factor in reedbuck populations (especially for males). Basically, a finite amount of cover and grazing on the forestry estate is monopolised by a few territorial males, with the result that an upper limit is set to the male population size (Howard, 1983). From this it can be inferred that a harvesting quota of 20% on a stable or increasing population would not influence the status of the population. In a context of reduced availability of land and the formation of discontinuities in the landscape due to development, agriculture and forestry, the harvesting of reedbuck (where translocation is not feasible) is advised to reduce social behavioural losses. Basically, both hunting and translocation implemented correctly reduce intraspecific competition and function to support stable or increasing populations, whereby within a limited area a lower male: female sex ratio can be engineered. This is feasible in that male trophy and sub-adults reedbuck can be focussed on in culling operations. Census techniques that provide the sex ratio of the population are essential, and thus this study aims to test census techniques that evaluate this ratio.

Venter (1979) found that reedbuck the most frequently recorded group size was one, followed by a group size of two. Venter (1979) also found that group size was affected by activity, with animals grazing in larger groups and resting in smaller groups. Howard (1983) found that reedbuck congregate on planted annual pastures or irrigated winter pastures at night in the winter months in the Drakensberg/KwaZulu-Natal Midlands.

For the purposes of the line transect counts, whereby the population density of reedbuck is sampled and applied to the total area of reedbuck habitat, it is important that reedbuck are territorial or organised according to a dominance hierarchical system. This means that reedbuck maintain a relatively constant seasonal population density dependent on forage availability, breeding activities, population losses, cover and external disturbances (e.g. forest management practices).

6.3.3 Spatial distribution

For the scope of this study it had to be determined whether home territories or ranges were more applicable to the objectives of the study. A home range is an "area over which an animal normally moves in pursuit of its routine activities" (Jewell (1966) *ex* Venter, 1979). Jungius (1971a) defined a home territory or core area as "a certain part within a home range which is defended by the male, and sometimes by the female, against intruding males or females of the same species". It is clear that the extent of the home range or lifetime range (as put forward by Howard (1983)) has more applicability to the objectives of this study as it illustrates the potential extent of a reedbuck's movement through its lifetime, thus indicating the distance a reedbuck would travel from a forestry estate in order to obtain forage (especially winter forage) and the distance over which dispersion may occur. The core area or home territory is assumed to be an indicator of the residency of a reedbuck on an estate, and thus all reedbuck counted on an estate are assumed to have their core areas on the Mount Shannon estate.

Howard (1986) found that in winter strict territories were abandoned, and the reedbuck generally spend the daytime within a radius of about 1.5 km of pastures on which they feed at night, with the compromise minimising the distance between preferred daytime habitat and pastures.

An analysis of the extent of home ranges and the spatial dispersion of reedbuck is essential in the development of a framework for the coordination of reedbuck management at a local level, in that it examines the extent of movement between forestry lands and the adjacent agricultural lands. The extent of home ranges and the movement of reedbuck both have an effect on legal and administrative protection, and harvesting strategies. Noting the seasonality of reedbuck territoriality put forward by Howard (1983), it was necessary to test the repeatability and effectiveness of census techniques before and after the first significant frosts in May. The first significant frosts in May were chosen as the interface between summer and winter conditions, and thus seasonal reedbuck behaviour. In the past, the period after the first frosts in May was preferred due to the fact that reedbuck are harvested during this period of the year.

The relevant findings into the extent of home territories and the spatial dispersion of reedbuck include the following:

(a) Howard (1983) found that reedbuck movements are restricted to well-defined home territories or core areas, with seasonal ranges being smaller than lifetime ranges, thus indicating a certain degree of dispersion through the lifetime. Howard (1983) found the smallest lifetime range to be those of adult males (74 hectares) and the largest to those of sub-adult males (210 hectares). Howard (1983) also found that there was a considerable degree of overlap between male and female home territories. Howard (1983) recognised that dispersal affected both sub-adult males and females, and to some extent adult males (excluding adult females). Further, Howard (1983) found that approximately 90% of sub-adult females were lost to an area before the age of two years, while 50% of males were lost to an area before the age of three years. These losses were seen as predominantly being the result of dispersal. Howard (1983) used farms in the Polela Valley in the Underberg District as his intensive study area.

(b) Howard (1986) developed the pasture catchment theory based on the findings of Howard (1983) whereby it was found that in winter reedbuck generally spend the daytime within a radius of about 1.5 km of the planted pasture on which they feed at night, and generally feed on the closest food source to their preferred daytime habitat. This in conjunction with the potential home range could be used in the development of a coordination framework. Once again, these findings are based on data from the Polela Valley in the Underberg District.

(c) Venter (1979) found that the home range size for adult male reedbuck was 5.04 hectares and 6.33 hectares for adult female reedbuck. Venter (1979) also found a large degree of overlap between male and female home ranges. Venter (1979) used the Eastern Shores of Lake St Lucia for his study.

(d) Jungius (1971a) found that the mean territory size was 44.3 hectares in winter and 54.0 hectares in summer, thus indicating a much larger home range according to the above definition. Jungius (1971a) used the Kruger National Park as his study area.

All these results show significant variation, and thus indicate that reedbuck home ranges and territories could be site specific. Venter (1979) explained the vast difference between his results and those of Jungius (1971a) to be as a result of differences in the habitat quality. If these inferences are valid, then the results obtained by Howard (1983) are the most applicable to this study, as his study was done in the Polela valley closely associated with the Boston area.

Howard (1983) found that the reedbuck population density that an area can sustain is closely related to the habitat suitability, and consequently the population densities throughout their distribution vary accordingly. Howard (1983) found that in the Underberg district a population density of 7.6 reedbuck per km^2 or 0.076 reedbuck per ha was recognised. This was based on the entire area of the case study site, and not on the area of suitable reedbuck habitat. This study aims to estimate the population density observed within suitable reedbuck habitat on the Mount Shannon, and thus the Boston area.

6.4 <u>Physiological condition</u>

Howard (1984a) investigated the physiological condition of reedbuck under different environmental conditions in the Natal Drakensberg. The Natal highlands offer only marginal habitat for reedbuck, with the end of winter being a time of severe nutritional stress and animals are in poor condition (Howard, 1984a). Reedbuck in these areas were found to have improved physiological condition when closely associated with winter pastures, thus providing some explanation for the demographic success of reedbuck in the region (Howard, 1984a). The Mount Shannon estate provides habitat quality similar to that observed in the Natal highlands. The Mount Shannon estate has winter pastures some distance away on the north-western boundary, however, according to the pasture catchment theory (Howard, 1986) these winter pastures are too far distant to be utilised by the Mount Shannon population. Research into the winter physiological condition of reedbuck on the Mount Shannon estate would provide valuable insight into possible future management practices to alleviate pressure exerted by reedbuck on the productivity of winter pastures, and the relationship between reedbuck ecology and the forestry landscape (e.g. how well the conditions at Mount Shannon are suited to increasing reedbuck populations?). If the reedbuck population on the Mount Shannon estate is found to have suitable physiological condition and are independent of commercial winter pastures, then these conditions could be replicated on other forestry estates in the region or other similar areas.

6.5 Reedbuck management on privately-owned farmland

The importance of wildlife management on private farmland is illustrated in the fact that all of the nineteen naturally occurring antelope species in KwaZulu-Natal are represented on privately-owned farmland. Of these antelope species, ten (bushbuck *Tragelaphus scriptus*, grey duiker *Sylvicapra grimmia*, grey rhebuck *Pelea capreolus*, southern reedbuck *Redunca arundinum*, mountain reedbuck *Redunca fulvorufula*, blesbok *Damaliscus dorcas*, impala *Aepyceros melampus*, oribi *Ourebia ourebia*, steenbok *Raphicerus campestris*, and suni *Neotragus moschatus*) are more abundant on privately-owned farmland than within designated protected areas (Collinson, *pers. comm. in* Howard, 1983). Initiatives such as the Natural Heritage Site Programme (Department of Environmental Affairs and Tourism (DEAT)), the inauguration of a network of conservancies (EKZN Wildlife), and the proliferation of organisations such as the KwaZulu-Natal Hunting and Conservation Association and the KwaZulu-Natal Game Ranchers' Association, are indicative of the realisation by administrative bodies and private landowners that coordinated conservation outside of protected areas is essential. Another manifestation of this realisation by private landowners is the inauguration of numerous working groups committed to the conservation and monitoring of red data species outside of protected areas (e.g. The Wattle Crane Foundation and the Blue Swallow and Oribi Working Groups).

Wildlife in South Africa have the legal status of *res nullius*, and thus belong to nobody, but may be owned by anybody who takes possession of it in terms of the Nature Conservation Ordinance of 1974 (Ord. 15 of 1974). Reedbuck are known to move on and off different properties and each property may have different management policies as regards reedbuck, thus highlighting the necessity for the coordination of reedbuck management to ensure the maintenance of viable populations.

There are several strategic issues related to reedbuck management on private farmland in the Drakensberg/Midlands area, and these include the following:

6.5.1 Mondi Forests landholdings

As the largest individual private landholder in the Drakensberg/KwaZulu-Natal Midlands Mondi Forests have a responsibility to provide an example as regards the sustainable management of natural resources and the conservation of endangered species (e.g. oribi, wattle crane and blue swallow) on forestry lands. The sustainable management of reedbuck populations on Mondi Forests estates forms an integral part of this responsibility, as without effective management and coordination with neighbouring landowners this resource could be exploited and depleted.

6.5.2 Conservancies

The Mount Shannon estate forms part of the Boston conservancy. Due to their extent, the technical support provided by Ezemvelo-KZN Wildlife and farm security, conservancies have become the cornerstone of wildlife conservation and management outside of protected areas in KwaZulu-Natal. The Natal Parks Board defined a conservancy as the voluntary, co-operative management of an area by the local community and its user groups. The proposed formal definition for inclusion in the Nature Conservation Ordinance of 1974 (Ord. 15 of 1974) is "any lawfully owned land inhabitated by any single persons where co-operative conservation effort is practiced and in respect of which registration has been granted by the Natal Parks Board" (Markham, 1988). By 1993, there were 1.3 million hectares under conservancies, thus equivalent to approximately 20% of KwaZulu-Natal (Davies, 1993). By 1999, 227 conservancies with 3392 members employing 771 conservancy guards to protect 1576566 ha had been established (Markham *pers. comm.*, 2002). One of the primary functions of conservancies is the combating of illegal snaring and poaching of wildlife on forestry and agricultural estates, thus functioning to protect reedbuck populations in these areas. This system of conservancies provides an ideal platform from which the coordination of reedbuck management and harvesting at a local level in KwaZulu-Natal can be launched. The conservancy system has degraded in recent years, and become more focussed in its farm security function as opposed to biodiversity conservation (Markham *pers. comm.*, 2002).

In the past it was the conservancy system that maintained the constant flow of census data from different areas, but this was never coordinated or collected. The analysis of the historical game count records illustrates the inadequacies of the historical census techniques and the management systems supporting them (Section 5).

6.5.3 <u>Crop damage due to increased population</u>

Reedbuck populations in the Drakensberg/KwaZulu-Natal Midlands have increased to levels above the natural carrying capacity due to the increase in the winter carrying capacity through the provision of winter pastures (e.g. *Lolium spp.*). As can be seen in the Gamequest survey done by Howard (1983) reedbuck populations in the Drakensberg/KwaZulu-Natal Midlands were increasing, and thus these populations were considered to be a potential threat to agricultural productivity. This was 20 years ago, and thus efforts must be made to collect census data and develop a reedbuck management database, so that the current status of reedbuck populations can be ascertained. This study could form the precursor to the compilation of this information, providing species and site-specific census techniques.

6.5.4 <u>Increased harvesting</u>

Reedbuck harvesting includes both the translocation and hunting of resident reedbuck populations. It is assumed that translocations do not occur onto the forestry estates and adjacent lands as matter of administrative policy. Live reedbuck have a high market price at present (De Jager *pers. comm.*), and thus there is increased pressure to utilise this resource.

6.5.5 Increased poaching

The poaching of reedbuck includes the practice of hunting with dogs, snaring and unlicensed or unauthorised shooting. In recent years, there has been an increase in the incidence of poaching on forestry properties and the adjacent agricultural lands (Pott *pers comm.*, 2003). For the purposes of this study the influence of poaching on reedbuck populations is considered to be constant over time, and thus does not influence the repeatability of any census techniques implemented.

6.5.6 Lack of standardised census technique

Different census techniques generate different population estimates on a given site, and thus cannot be reliably compared with one another to obtain relative abundance or make inferences as regards management prescriptions. At present night pasture counts and total counts are used to census reedbuck on agricultural and forestry land, thus allowing for at least some degree of repeatability, but no standardised census technique (i.e. all the aspects of the census technique used are documented and repeated in subsequent censes) is being applied. The derivation of confidence intervals for these census techniques would allow for comparison, but this is not feasible due to the amount of site-specific research required. The implementation and application of a standardised census technique as part of the EKZN Wildlife permit and licencing system, would allow for a higher repeatability and the development of useful comparisons between estates through the development of a game count database. This would also allow for the accumulation of valuable data into a central database for application in research as regards reedbuck ecology (e.g. carrying capacity and habitat preferences) and the application of management prescriptions (e.g. the planting of irrigated winter pastures and burning regimes). The primary objective of this study is the development of a reedbuck census technique for forestry estates through the testing of four different reedbuck census techniques.

6.5.7 Insufficient coordinated reedbuck population management at a local level

At present reedbuck population management through hunting and translocation occurs without sufficient coordination between the forestry estates and adjacent landowners, whereby game counts are rendered obsolete due to the assumption that the reedbuck resident on forestry estates are not harvested when congregating on winter pastures after the first frosts in May. The requirement for private landowners to develop management plans for wildlife resources on their property (as put forward in the proposed Biodiversity Bill) would go a long way towards the coordination and management of privately-owned land.

7. LITERATURE REVIEW PERTAINING TO METHODOLOGY

7.1 Sequence of decisions for the selection of census techniques developed by Caughley (1977)

Caughley (1977) developed a sequence of decisions for the selection of census techniques, whereby the selection process was governed by estimation, utilisation, infrastructural and density considerations. This sequence of decisions thus ignored factors such as the characteristics of the census area, the characteristics of the animal, and the specific objectives of the census. As a result of these shortcomings, the framework for selecting wildlife census techniques developed by Collinson (1982) was chosen for in depth analysis and application to the objectives of this study, the characteristics of the case study site, and reedbuck behaviour and ecology.

7.2 Framework for selecting wildlife census techniques developed by Collinson (1982)

A framework for selecting wildlife census techniques developed by Collinson (1982) was related to census techniques used and/or evaluated by Melton (1978), Venter (1979), Howard (1983), Southwell & Weaver (1993), Peel & Bothma (1995), Bothma *et. al.* (1990), Knott & Venter (1990), Beavers & Ramsey (1998), and Reilly &

Haskins (1999) to identify census techniques applicable to the requirements of this study. The basic requirement of this study was to provide a census technique(s) that must be simple, have high repeatability (over time), be cost effective and time efficient.

Collinson (1982) identified five criteria for the selection of census techniques: the objectives and goals; the characteristics of the census area; the characteristics of the animal; the cost/time considerations; and the skills and attitudes of user groups.

7.2.1 Objectives and goals

The initial step in the selection of an appropriate census technique involves the consideration of the research or management objectives for which information on population density is required (Caughley & Sinclair, 1994). The objective of this study is the derivation of reedbuck census techniques that can be used over time to support management prescriptions such as harvesting quotas and the alteration of land management practices to support viable reedbuck populations. Collinson (1982) identified three basic parameters that must be considered to fulfil the objectives of the research or management objectives, and these included the minimum amount of accuracy, precision and/or repeatability. Basically, in the absence of well-stated research or management objectives there is no basis for deciding on the goals of the census.

This study determines to test census techniques that must be simple, have high repeatability (over time), be cost effective and time efficient. The census techniques are required for the derivation of harvesting quotas and the assessment of the influence of reedbuck management prescriptions on forestry and adjoining agricultural lands. These research and management objectives can be related to the management objective of "sustained yield harvesting or conservation" put forward by Collinson (1982), whereby an absolute estimate is required, with at least moderate accuracy initially, precision that is dependent on time/cost considerations and must have a high repeatability over time.

7.2.2 Characteristics of census area

The second step in the selection of a census technique is the evaluation of the characteristics of the census area in terms of the following criteria (Collinson, 1985):

(a) The consideration of the size of the census area is important in choosing between a ground and an air-based operation, using a sampling or a non-sampling strategy, and whether to operate from a vehicle or on foot. Based on time and cost saving criteria a ground operation and non-sampling strategy are suitable for small areas, whereas aerial operations and a sampling strategy are suitable for large areas (Caughley, 1977; Venter, 1979; Collinson (1982); Cauglhey & Sinclair, 1994; Lancia, Nichols & Pollock, 1996). Caughley (1977) stated that non-sampling total counts of animals was only feasible when the area is small and the animals are conspicuous.

The Mount Shannon estate has a total area of 2226 hectares (with 1057 hectares unplanted), thus advocating a ground operation and non-sampling strategy. But as with most factors in the assessment of wildlife populations, size is not absolute, and it is very difficult to determine what is small and what is large, and thus a sampling strategy was tested. Both ground and vehicle operations were also tested.

(b) Landform characteristics such as hilly, mountainous or uneven terrain can complicate the survey design of the census technique, as if the land forms of the census area are highly variable it may be necessary to apply a stratified survey design, whereby the census area is divided into zones or strata within which animal density is homogenous (Caughley, 1977) or the observer's range of visibility is homogenous (Burnham *et al.* (1980) *ex.* Collinson, 1982). Landform characteristics influenced the mean visibility index utilized during the line transect counts.

The landform characteristics on the Mount Shannon estate are characterised by flat wetland areas, hilly grassland areas, and mountain areas with grassland plateaus. This heterogeneous landscape requires a stratified sampling design for the line transect count method.

(c) Vegetation characteristics (e.g. height and density) influence the visibility, and thus the probability of sighting an animal (Collinson, 1982). Factors that need to be considered include the physiognomy, and the potential long-term changes in the vegetation (e.g. bush encroachment) that might influence the repeatability of the census technique implemented (Collinson, 1982). In cases where long-term changes in the vegetation physiognomy are expected, the application of a techniques such as a line transect methods that are robust to such changes is advised by Collinson (1982). The physiognomy of the vegetation at the time of the census influences the choice between the use of a sampling or a non-sampling strategy (e.g. densely wooded vegetation would increase the probability of missing animals in a sampling strategy, thus making a non-sampling strategy more applicable) and the application of a stratified or a non-stratified survey (e.g. homogeneous vegetation physiognomy would negate the applicability of a stratified sampling survey) (Collinson, 1982).

There are no perceived long-term changes to the vegetation physiognomy on the Mount Shannon estate, as can be seen in the fact that the physiognomy is largely governed by the fire and veld management practices, the standards set by Mondi Forests and the Forest Stewardship Council (FSC), the forestry industry as regards wetland and riparian conservation (including the removal of alien invasive species), and the core business of plantation forestry. Sustainable forestry requires the planting of an equivalent area of trees as that which is harvested, and thus certain areas on these estates may be planted and harvested on a schedule, thus maintaining a relatively constant mosaic of homogenous vegetation types (e.g. pine plantation (at different ages), wetland areas and open grassland) within a heterogeneous mosaic. The influence of harvesting operations on reedbuck populations through disturbance and the removal of cover is unknown, but reedbuck were observed to avoid recently harvested areas on the Mondi Forests Goodhope and Linwood estates in the region. Because the impact is unknown, for the purposes of this study the influence of harvesting on the repeatability of a reedbuck census technique is assumed to be insignificant or constant. On the Mount Shannon estate harvesting has not yet occurred.

The forestry landscape on the Mount Shannon estate constitutes homogeneous vegetation types within a heterogeneous mosaic, thus advocating the testing of a stratified sampling design for the line transect counts.

Forestry estates have large tracts of land under plantation forestry (predominantly pine in the Drakensberg area), and thus reedbuck that are flushed by the movements and activities of observers may move into plantations and may be omitted from a specific census. This influenced both the sampling and non-sampling census strategies, and proved impossible to overcome beyond understanding that reedbuck counted in non-sampling census strategies represented the minimum population size for the estate. Research into a correction factor for census results accounting for reedbuck that are hiding within plantations would serve to reinforce harvesting quotas. Howard (1983) estimated that a single count at night gives an estimate of 67-100% of the reedbuck present within a census area. This relationship was used in this study due to the absence of any other conversion factor and the scope of this study.

(d) Man-made features (e.g. roads, fences, firebreaks and plantations) are important in choosing between operating on foot or from a vehicle. Fencing is important as most techniques can be biased by animals moving out of the study area (Collinson, 1982).

The road network on the Mount Shannon estate is extensive and follows the edges of plantation compartments, providing sufficient viewing opportunities for the application of vehicle-based night and dawn counts, however, these roads do not pass directly through reedbuck habitat (e.g. wetland and grassland areas), and thus operating on foot was essential as part of the non-sampling dawn flush counts. The Mount Shannon estate has a total road area of 55 hectares (i.e. approximately 183km of road), thus constituting 2.5% of the total area.

7.2.3 Characteristics of animals

The inter-relationship of the characteristics of the animals and the vegetation physiognomy together influence the probability of sighting animals during a visual search (Collinson, 1982).

Collinson (1982) identified four main animal characteristics that influence the choice of census technique relative to the vegetation physiognomy, and these include the following:

(a) The size, colour and/or posture in conjunction with the vegetation affect the visibility of animals (Caughley & Sinclair, 1994). These factors influence the choice of census technique between operating from the ground and the air (i.e. the location of a suitable proportion of animals from the air is not feasible when the animals are small and/or well camouflaged), and sampling and non-sampling strategies (i.e. the bias from omitting small and/or well camouflaged animals is decreased when a sampling strategy is used). Animals that tend to hide or lie down at certain times of the day (e.g. reedbuck) also tend to reduce the repeatability of the census technique, if the time of census is not standardised. Venter (1979) noted that this problem could be avoided by conducting the census at a time of day when this behaviour is not apparent, and thus due to the crepuscular activity of reedbuck censes were tested at both dawn and dusk.

Reedbuck are a "hider" species and are dependent on cover as a habitat requirement, and thus aerial counts were not feasible, and a sampling strategy (e.g. the line transect counts) seemed more applicable in order to reduce the bias of omitting animals from non-sampling counts (e.g. dawn flush count and night habitat counts).

(b) Animal movement or mobility is the primary source of bias in census estimates (Collinson, 1982), as due to its movements an individual could be counted on more than one occasion, and individuals could be omitted all together due to a response to the approaching observer. Animal movement influences the choice between sampling and non-sampling strategies (i.e. the risk of double-counting is normally reduced when a sampling strategy is implemented), and modified strip transects or line transect methods (i.e. modified strip transect methods are less sensitive to bias from animal movement than line transect methods) (Collinson, 1982). The repeatability of census techniques is also influenced by the possibility of the population altering its response behaviour and/or habitat preference over time. This can be overcome through the application of a stratified survey design, which would reduce the bias resulting from such changes.

Reedbuck are known to be territorial (Jungius, 1971a; Howard, 1983) and are a "hider" species that remain under cover until the observer is very close, and thus may be omitted from the dawn flush counts. The influence of animal mobility can be avoided through the application of measures such as dividing the census area into blocks and conducting the counts simultaneously, continually referring to a map of the area to note the movement of animals into adjacent counting blocks to be removed from adjacent counts, and the recognition of physical characteristics to avoid double-counting. From site inspections, reedbuck movements on the Mount Shannon Goodhope and Linwood estates was influenced by the presence of livestock in the area, any hunting activity, forest management operations (e.g. pruning, thinning and harvesting), autumn burns and fire management, and the seasonal dormancy of the indigenous grasses. These factors are common for most forestry estates in the Drakensberg/KwaZulu-Natal Midlands. Further research into the interrelationship between reedbuck and these external factors through mark-recapture experiments would serve to allow census techniques to be modified accordingly. To avoid the use of several observers, the census area was not divided into counting blocks, however, if the size of the study site is too large to be covered within three hours then division into counting blocks becomes necessary.

(c) The influence of the social behaviour of animals on the selection of census techniques centres on whether the animal is solitary or gregarious (and whether it forms many small or few large herds) (Collinson, 1982). The size of home ranges and the territoriality of animals are also important. These considerations are important when choosing between a sampling and non-sampling strategy (i.e. the use of a sampling strategy when animals form few large herds requires substantial sampling effort to obtain an estimate with an acceptable degree of precision) (Collinson, 1982). The fluctuation of home ranges and herd size seasonally is important, as the repeatability could be reduced if the sampling or non-sampling strategy is not conducted at the same time each year (i.e. standardisation).

Reedbuck are territorial and predominantly solitary (Jungius, 1971a; Venter, 1979; Howard, 1983). Venter (1979) found reedbuck were organised according to a dominance hierarchical system and the most frequently recorded group size was one, followed by a group size of two. Venter (1979) also found that group size was affected by activity, with animals grazing in larger groups and resting in smaller groups. Howard (1983) found that reedbuck congregate on planted annual pastures or irrigated winter pastures at night in the winter months in the Drakensberg/KwaZulu-Natal Midlands, with the number of reedbuck feeding on the relatively nutritious pasture grasses increasing to more than twice that recorded in summer. This meant that the testing of night habitat counts before and after the first significant frosts in May was necessary. The application and testing of the line transect counts is viable as reedbuck are predominantly solitary, and thus less sampling effort is required to obtain results with a suitable degree of precision. As noted reedbuck are territorial or seasonally territorial (Jungius, 1971a; Howard, 1983) with the population organised according to a dominance hierarchy (Venter, 1979), and thus should exist at relatively constant population densities within different habitat types or strata. These assumptions serve to further justify the testing of line transect or modified transect methods.

(d) It is important to note that the amount of sampling effort required for a given level of precision is inversely proportional to population density (Collinson, 1983). The population density is an important consideration when choosing between a sampling and a non-sampling strategy, as when the population density is particularly low, the sampling effort required to obtain an acceptable estimate may not justify the application of a sampling strategy.

Population density is relative and influenced by numerous factors (e.g. seasonal behaviour, forage availalbility, breeding and disturbance), and thus the testing of a sampling strategy (i.e. line transect method) was necessary.

7.2.4 Cost/Time considerations

The concepts of time and cost are inter-related in that within a management framework time has a monetary value, and thus these two factors will be dealt with together. Any census study has time and cost constraints, and matching these to the most appropriate census technique is essential.

This study determines to test and refine a reedbuck census technique that can be used by Mondi Forests (and other forestry landowners) and private landowners to more effectively manage reedbuck populations on their lands. Reedbuck management falls outside of their core business, and thus census techniques must be cost effective and time efficient. The only income derived from reedbuck management on these lands is that obtained from harvesting (i.e. live sales and hunting). As a result of these constraints the census techniques tested in this study are restricted to vehicle and ground operations with a low investment of man-hours and personnel.

7.2.5 Skills and attitudes of the users

Any census technique has to be conducted by human agents, and thus the level of technical training and commitment to the census process influences the outcome and the validity of the results (Caughley & Sinclair, 1994). Reedbuck management is not the core business of Mondi Forests and other forestry landowners, and thus consideration must be given to managers who do not have the time or skills to effectively implement comprehensive or technical analyses.

Most census techniques required the assistance of unqualified observers, and often are repeated without the supervision of a qualified researcher as part of a management system, and thus Collinson (1982) made the following recommendations:

- The requirement for observers to make too many subjective decisions when making observations or in data analysis must be avoided (e.g. Kelker's method);
- Excessive human exertion must be avoided (e.g. operation from a vehicle involves less physical exertion than operating on foot); and
- Long sessions of repetitive observation should be avoided.

This study determines to test a reedbuck census technique that can be repeated over time with a high repeatability by unsupervised forest managers and private landowners (who are not qualified researchers), and thus the census techniques must be as simple as possible. Through standardisation the census technique implemented become less personality driven and have increased repeatability. The census techniques chosen for evaluation in this study were chosen as a result of their simplicity, previous application to reedbuck populations and adherence to the criteria for the selection framework for census techniques put forward by Collinson (1982).

7.3 Additional literature pertaining to methodology

The following observations pertinent to the primary objectives of the study can be drawn from the literature:

(a) Reilly & Haskins (1999) conducted a study examining the comparative efficiency of aerial and ground counting techniques as applied to the Suikerbosrand Nature Reserve. The study concluded that aerial counts provided a very good point data set with valuable distribution data concurrently, while the ground counts were easier to organise and apply on a regular basis and were also less susceptible to budgetary constraints. The variance values in this study highlighted possible problems with regards to long-term repeatability, but replicating the measure of variance allowed confidence intervals to be determined. The study found that the ground method if replicated and applied vigorously would be able to measure the achievement of management objectives for most species of large ungulate.

This study highlighted the suitability of ground-based census techniques when related to the size of the study area, the research/management objectives, the budgetary constraints and reedbuck behaviour.

(b) Knott & Venter (1990) implemented a field test on the accuracy and repeatability of a line transect method, and provided comment on the applicability of this method. Knott & Venter (1990) cited Burnham *et al.*(1980) indicating that a minimum of 40 observations are needed for a specific species to be able to estimate population size.

Knott & Venter (1990) put forward three main assumptions relative to line transect sampling, and these include:

- That all animals directly on the transect line will never be missed;
- That all animals are fixed at the first point of sighting and do not move before being detected; and
- That all measurements are recorded accurately.

Knott & Venter (1990) also cited the main problems encountered in line transect sampling in line with Burnham *et al.* (1980), and these included:

- Defining the straight line of travel;
- Obtaining accurate measurements of sighting distance and angles; and
- Ensuring that all animals on or close to the transect line are seen with certainty.

Basically, the results of this study highlight the problems associated with the counting of the more mobile ungulate species, and backed up the choice in this study to test line transect methods.

(c) Bothma *et al.* (1990) evaluated the accuracy of some commonly used census techniques, including a drive count, an aerial count (both helicopter and fixed-wing aircraft), a 24-hour waterhole count, and line transect counts.

The study found that line transect counts using a fixed strip width based on the visibility of game in that type of vegetation involved (i.e. mean visibility index) could be an economical, user-friendly and cost-effective census technique. Bothma *et al.* (1990) also made the observation that the line transects could be conducted on foot or from a vehicle.

Based on this study and the work done by Peel & Bothma (1995), Bothma *et al* (1990), Howard (1983) and Venter (1979) the line transect method used in this study was developed. This method was designed to be relatively accurate and have a high repeatability over time, while at the same time being time efficient, user-friendly and cost-effective.

(d) Peel & Bothma (1995) compared the accuracy (i.e. how close a game count is to the actual number) of four census techniques for impala *Aepyceros melampus*. These census techniques included a helicopter count, fixed-wing aircraft count, a high-wing aircraft count, and line transect counts. Peel & Bothma (1995) found that line transect (although relatively inaccurate in their study) provided an accurate estimate of the impala populations.

For the purposes of this study the findings of Peel & Bothma (1995) further justify the testing of the line transect method as a sampling strategy to be applied to reedbuck on forestry areas in the Drakensberg/ Natal Midlands.

7.4 Advantages, disadvantages and assumptions of line transect method

According to Burnham *et al.* (1980) *in* Collinson (1982), line transect methods are superior to modified strip transect methods. The line transect method used in this study is based on the method used by Peel & Bothma (1995) and tested by Bothma, Peel, Pettit and Grossman (1990) to census impala *Aepyceros melampus*. These included modified transect methods using mean sighting distance (King's method) and mean perpendicular sighting distance, and fixed strip transects. Modified transect methods do not include all the area censured, and thus was expected to over-estimate the reedbuck population. The fixed strip transects were expected to perform better due to the fixed sample area and the assumption that the majority of reedbuck within the fixed strip width are flushed.

For a line transect sampling to yield unbiased estimates of the population (apart from survey design and sample size considerations) the following assumptions must hold true (Collinson, 1982): reedbuck on the transect line will never be missed; no reedbuck are disturbed and move out of the transect due to the activities of the observer; no reedbuck are counted on more than one occasion; and reedbuck are randomly distributed within a specific habitat type or stratum, and have no habitat preferences within a specific stratum.

The disadvantages of using line transect methods are that the equations used are based on a statistically invalid models (Collinson, 1982) and that line transects ignore areas outside the transect strip width (Davis & Winstead, 1980). This error is only reduced as the sample size tends towards the total area of reedbuck habitat. Equations using mean perpendicular and radial sighting distances both determine the strip width according to the mean sighting distance of sighted animals. Reedbuck are a hider species, and therefore, not all animals present are visible and over 75m away often do not flush, thus resulting in a deflated sample area. This study determines to test whether fixed strip width, mean perpendicular sighting distance or mean radial sighting distance equations best suit reedbuck ecology and the forestry landscape and obtain the most accurate and repeatable results.

The advantages of using a line transect method are that the larger the sampling area the higher the precision of the census becomes, and that execution and analysis are relatively simple (Collinson, 1982).

8. METHODOLOGY

To understand the rationale behind these census techniques the following assumptions are summarized below:

- Long-term changes in vegetation structure and characteristics will not influence the repeatability of the census techniques.
- Reedbuck distribution and climatic conditions are constant over the identified time period from year to year.
- Reedbuck are predominantly crepuscular or nocturnal (Howard, 1983; Howard, 1986; Venter, 1979; Junguis, 1971a), and thus are most visible at dawn for flush counts and line transect counts, and at dusk for night habitat counts.
- Howard (1986) found that habitat preferences were seasonal, whereby reedbuck occupied vleis and natural grassland on uneven terrain (providing adequate cover) during summer, and agricultural land (i.e. planted pastures) and adjacent woody cover during winter.
- The first significant frosts in May were assumed to be the transition between summer and winter, and the point after which the indigenous grasses become dormant.
- Reedbuck are a typical "hider" species (i.e. first means of defence is to avoid detection) (Jungius, 1971a), and thus require sufficient cover in their habitat and spend most of each day "lying up" in herbaceous cover (e.g. in wetlands).
- Reedbuck are strictly territorial (Jungius, 1971a) or seasonally territorial (Howard, 1983), with home ranges ranging from 74 ha to 210 ha (Howard, 1983).
- Reedbuck exhibit a dominance hierarchy (Venter, 1979), whereby intraspecific competition causes increased mortality (especially in males).
- Poaching and hunting with dogs will not be considered as factors influencing reedbuck populations on forestry estates, as a result of the lack of data and the apparent reduced occurrence of poaching on the estates.
- Factors such as adult and juvenile mortality, disease, predation, natality and disturbance by long-term management practices and other external factors are assumed to be constant over time, and thus not influence the repeatability of the census techniques.

- The influence of future timber harvesting and forestry operations on the repeatability of the census techniques will be considered to be constant for this exercise. Research into this relationship is encouraged.
- The census techniques were designed for application by private landowners and Mondi Forests, and thus must be simple, have high repeatability (over space and time), be cost effective and time efficient.
- The census results are an estimate, which through standardization can be used over time to indicate trends in the population dynamic of reedbuck populations in forestry areas and adjacent agricultural lands.
- Results obtained from the non-sampling dawn flush counts and night habitat counts were considered to reflect the minimum population size on the estate, excluding reedbuck not flushed and those moving through or hiding in plantations.

For the purposes of ungulate management the most important properties of a census technique are its repeatability and accuracy (Howard, 1983; Collinson, 1982), and thus the underlying objective of these census techniques is repeatability so as to enable landowners to determine population trends relative to management and harvesting practices.

Four census techniques were tested on the Mount Shannon Estate: Dawn Flush Counts (DFC); Night Habitat Counts (before frost) (NHCa); Night Habitat Counts (after frost) (NHCb); and Line Transect Counts (LTC).

8.1 Timing

The hunting season is over the winter months, and thus census techniques were tested prior to the hunting season in April and May with the first significant frosts marking the transition point between seasons. Further, Howard (1986) observed seasonal differences in reedbuck behaviour before and after the first autumn frosts. The Dawn Flush Counts (DFC), Line transect counts (LTC) and Night Habitat Counts (before frost) (NHCa) were conducted in April, while the Night Habitat Counts (after frost) (NHCb) and LTC were conducted in May after the first significant frosts. The first significant frosts were recorded on the 2/05/2003.

8.2 Visibility

Although not an assessment factor in the study, visibility has a significant influence on the number of reedbuck counted in a census (Caughley, 1977; Venter, 1979; Howard, 1983; Caughley & Sinclair, 1994). Visibility is governed by the weather conditions, landform and vegetation characteristics, and management operations (e.g. burning). For the purposes of this study, the influence of the landform and vegetation characteristics was accounted for in the LTC using the mean visibility index (discussed in 8.6), and the weather and atmospheric conditions were compared using the sighting distance index (Table 5). The sighting distance index (SDI) was used for all the counts, and gave an indication of the influence of fog, low cloud, smoke, dust, etc. The maximum sighting distance was measured as the distance at which a person dressed in khaki cannot be sighted. The SDI was developed for incorporation into the recording sheets to provide (if necessary) explanation for outlier census results (e.g. results that were very low). The SDI was primarily part of the recording process.

Table 5. SIGHTING DISTANCE INDEX

Maximum sighting distance at which a person in khaki cannot be seen.

Visibility	**Dawn**	**Night**
Very poor	0-25	0-25
Poor	26-100	26-50
Moderate	101-500	51-250
Good	501-2500	251-1000
Excellent	>2500	>1000

8.3 Dawn Flush Counts (DFC)

The objective of the DFC was to test a count on foot conducted before the first significant frosts along a standardized route using flushing to increase coverage and disturbance. The DFC were conducted on six consecutive days between 1/04/2003 and 6/04/2003. The following method was used in the DFC:

(a) Assessment of the road network on site and using a land-use map of the Mount Shannon estate. A standardized census route that allows for the maximum coverage of identified reedbuck habitat was plotted.

(b) Each 3-hour DFC was conducted at sunrise.

(c) The same vehicle, driver and observer were used for each count, and the vehicle moved at 20km/h.

(d) Where the area counted was >100m away from the vehicle, the observer flushed reedbuck from these areas on foot.

(e) Vantage points not accessible with the vehicle within 100m of the road that allowed for increased coverage were walked to on foot.

(f) Deviations from the road were included in the standardized census route.

(g) The observer used 10 x 42 binoculars for all the counts.

(h) The observer did not make unnecessary noise, recorded quickly so as to keep moving, and moved at a constant speed stopping only briefly.

(i) Appendix 1 is an example of the DFC recording sheet.

8.4 Night Habitat Counts (before frost) (NHCa)

The objective of the NHCa were to test a count conducted from a vehicle at night before the first significant frosts along a standardized route. The NHCa were conducted on six consecutive days between 1/04/2003 and 6/04/2003. The following method was used in the NHCa:

(a) The standardized census route was used.

(b) Each 3-hour NHCa was conducted from sunset.

(c) The same vehicle, driver, observer and recorder were used for each count, and the vehicle moved at 20km/h.

(d) A 200 000 candlepower spotlight and 10 x 42 binoculars were used for each count.

(e) The vehicle stopped briefly at designated pastures – these stops were standardized for all the counts.

(f) Appendix 2 is an example of the NHCa recording sheet.

8.5 Night Habitat Counts after frost (NHCb)

The objective of the NHCb were to test a count conducted at night after the first significant frosts along a standardized route. The NHCb were conducted on six consecutive days between 4/05/2003 to 9/05/2003. The method used for the NHCb was the same as that for the NHCa.

Non-sampling census technique outputs:
- DFC census results
- NHCa census results
- NHCb census results
- NHC_{TOTAL} results
- All recording sheet data (e.g. sighting distance index)

8.6 Line transect counts (LTC)

The objective of the LTC were to test a sampling strategy at dawn before and after the first significant frosts using line and modified transect methods. The LTC were conducted on consecutive days before and after the first significant frosts from 22/04/2003 and 25/04/2003 and 6/05/2003 to 9/05/2003.

The following method was used in the LTC:

(a) A stratified survey design was used.

(b) The reedbuck habitat areas identified for use as strata on the Mount Shannon Estate include the following: wetland/riparian areas; young pine plantations (i.e. less than 2 years since planting); areas with associated *P. clandestinum* pastures; firebreaks; and grassland corridors. The young pine plantations were not included due to the low visibility index in these areas.

(c) A land-use map of the Mount Shannon Estate and a site inspection were used to map the different reedbuck habitat types to be included in the LTC process, and an estimate of the area of each reedbuck habitat type was obtained using ArcView 3.2.

(d) Areas of primary reedbuck habitat were assigned three 1km transects due to the higher probability of sighting reedbuck in these areas, while other areas (i.e. areas with associated *Pennisetum* clandestinum pastures and firebreaks) were assigned one 1km transect each. Thus, eight 1km transects were required for Mount Shannon Estate.

(e) The breakdown of the eight transects conducted within the LTC process is as follows: three wetland/riparian areas (primary reedbuck habitat on forestry estates); three grassland (primary reedbuck habitat on forestry estates); one corridor *P. clandestinum* pastures; and one corridors and firebreaks (used for forage in winter).

(f) The three wetland/riparian transects were conducted in different wetland/riparian areas on the Mount Shannon estate.

(g) The three grassland transects were conducted in different grassland areas on the Mount Shannon estate.

(h) Most of the unplanted areas are linear, and thus transects were orientated diagonally across these corridors so as to get a suitable transect length traversing the area.

(i) In instances where the area was large enough for a transverse transect a East-West direction was walked, so as to keep the rising sun behind the observer and to optimize the visibility on either side of the transect line.

(j) The transect length was limited to 1km due to the time constraint of 3 hours, and in areas where transects of 1km were impossible two transects of 500m were conducted. The length and orientation was regulated using a Garmin GPS 12.

(k) For each of the counts the location and orientation of the transects were kept constant.

(l) The LTC were conducted from dawn for three hours, thus allowing 25 minutes for each transect (including movement between transects).

(m) The same observers were used. Optics not used.

(n) Two observers were used, each conducting transects simultaneously.

(o) The observer did not make unnecessary noise, recorded quickly so as to keep moving, and moved at a constant speed stopping only briefly.

(p) The fixed strip width/2 or maximum perpendicular sighting distance of the transect line was determined using the mean visibility index, with 75m as the maximum. A maximum of 75m was used for all strata, because reedbuck are predominantly flushed within a maximum of 50 - 75m.

(q) The mean visibility index (MVI) for the vegetation was calculated as the mean distance (done three times) at which a person on foot (wearing khaki clothes) first disappears from view along a transect line in a given stratum

(Bothma *et al.*, 1995). The mean visibility index was predominantly governed by the edges of the pine plantations, tall grass, woody cover and hilly terrain, and was determined for each stratum prior to the first LTC (Table 6).

Table 6. FIXED STRIP WIDTH AND MEAN VISIBILITY INDICES FOR EACH STRATUM

Stratum	MVI (m)	Max. perp. sighting distance	Fixed strip width (m)
Wetland/riparian areas	72	72	144
With associated *Pennisetum clandestinum* pastures	78	75	150
Firebreaks	53	53	106
Grassland corridors	81	75	150

(r) Reedbuck were counted where they were first seen, and the radial distance from the observer to the animal was measured using a rangefinder.

(s) The angle (α) of the observation relative to the direction of the transect was measured with a compass model.

(t) Eight counts were done. Four before the frost and four after the frost.

(u) Appendix 3 is an example of the LTC recording sheet.

(v) Three methods of counting were used within the framework of the LTC (adapted from Bothma *et al.*, 1990):

- Method A: All reedbuck sightings $\leq$ maximum perpendicular sighting distance (strip width/2 from the transect line) were counted (with $\hat{Y}$ = fixed strip width/2);
- Method B: Only reedbuck sightings $\leq$ maximum perpendicular sighting distance from the transect line were counted (with $\hat{Y}$ = mean of actual sighting distances of reedbuck from the transect line); and
- Method C: All reedbuck sightings along the transect line were counted regardless of maximum perpendicular sighting distance (with $\hat{Y}$ = fixed strip width/2).

(w) Two methods of calculation were used, and these included population estimates based on radial sighting distance (King's method)/Modified strip transect) and mean perpendicular distance from the transect line.

(x) Modified Strip Transect (MST)

The following equation was used to estimate reedbuck population based on radial sighting distance (adapted from Bothma *et al.*, 1990):

$$\mathbf{N_1 = AZ/2X\check{D}}$$

Where, N_1 = population estimate

A = total area of reedbuck habitat (m^2)

Z = total number of animals counted

X = total transect length (m)

$\check{D}$ = the mean radial distance (m)

The mean radial distance is based on individual distances D being measured from the observer directly to the reedbuck sighted. Group size is taken into account when calculating $\check{D}$ (i.e. $\check{D} = \sum(D_i$ x group size)/Total number sighted).

(y) Mean perpendicular distance (MPD)

The following equation was used to estimate reedbuck population based on mean perpendicular distance from the transect line (adapted from Bothma *et al.*, 1990):

$$\mathbf{N_2 = AZ/2X\hat{Y}}$$

Where, N_1 = population estimate

A = total area of reedbuck habitat (m^2)

Z = total number of animals counted

X = total transect length (m)

Y = mean perpendicular distance from the transect line (m)

The individual perpendicular distance from the transect line were derived from the radial distance and the sighting angle (α). Group size was accounted for in the same manner as in King's method.

Sampling census techniques outputs:

- Results for counting method A using perpendicular sighting distance (PDA) before and after the first significant frosts.
- Results for counting method B using perpendicular sighting distance (PDB) before and after the first significant frosts.
- Results for counting method C using perpendicular sighting distance (PDC) before and after the first significant frosts.
- Results for counting method A using radial sighting distance (King's method) (KMA) before and after the first significant frosts.
- Results for counting method B using radial sighting distance (King's method) (KMB) before and after the first significant frosts.
- Results for counting method C using radial sighting distance (King's method) (KMC) before and after the first significant frosts.
- Results for all counting and calculation methods using stratified and unstratified design.
- Reedbuck population densities for each stratum.
- Sex ratios for the line transect method.

8.7 Age Determination

Age determination with large enough sample size provides an indication of the population age structure and status at a specific point in time, and was done using the field classification charts modified from Howard (1983). These methods were based on the horn length relative to ear length for males, and shoulder height relative to adult female shoulder height for females. In this study, an adult female reedbuck was any animal over the age of 12 months, while a socially mature adult male reedbuck was over the age of 36 months (Venter 1979; Howard 1983). Howard (1983) estimated reedbuck life expectancy at birth for male reedbuck to be between 3.94 and 4.28, and 3.95 and 5.29 for female reedbuck.

The age classes used in the census process were juvenile (J), sub-adult (SA), and adult (A). The positioning of a reedbuck into an age class was subjective. This aspect of the census process may not be included in the census technique prescribed for the forestry estates, as it requires the observer to make too many subjective decisions, and thus will have a high variance between samples. Age determination as part of the census technique was nonetheless tested.

Any solitary reedbuck were considered to be a sub-adult or adult. Through estimating the average height of the vegetation in an area, the observer was able to estimate the shoulder height of an observed reedbuck. An adult male was taken as having a shoulder height of 90cm, while an adult female was taken as having a shoulder height of 80cm (Skinner & Smithers 1990). Figure 5 was used to position female reedbuck into age classes, noting that adult male reedbuck are larger. A male reedbuck with a horn length greater than 150% the length of its ears was considered to be an adult (Howard 1983) (Figure 6).

Figure 5 illustrates the field age classification chart that was used in the age classification of female reedbuck based on the shoulder height relative to adult shoulder height (Howard, 1983).

Figure 5. FIELD AGE CLASSIFICATION CHART FOR FEMALE REEDBUCK (Howard, 1983)

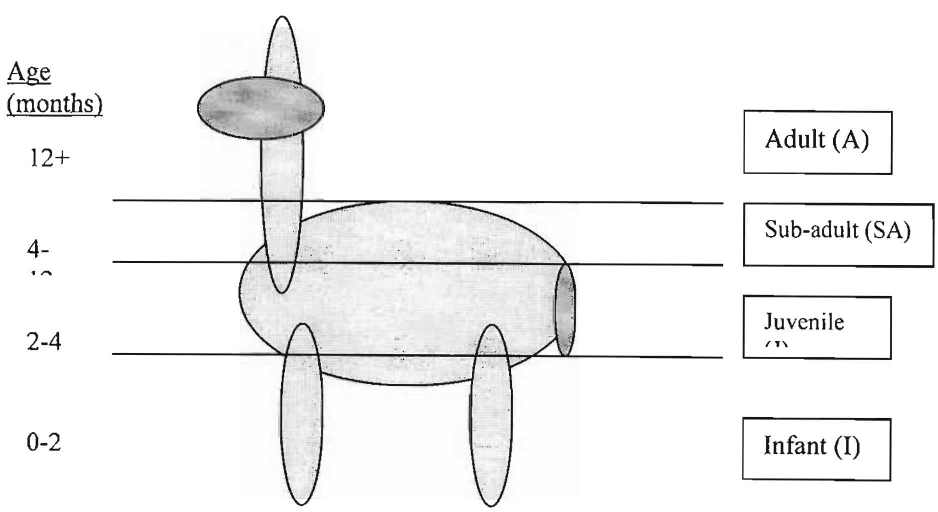
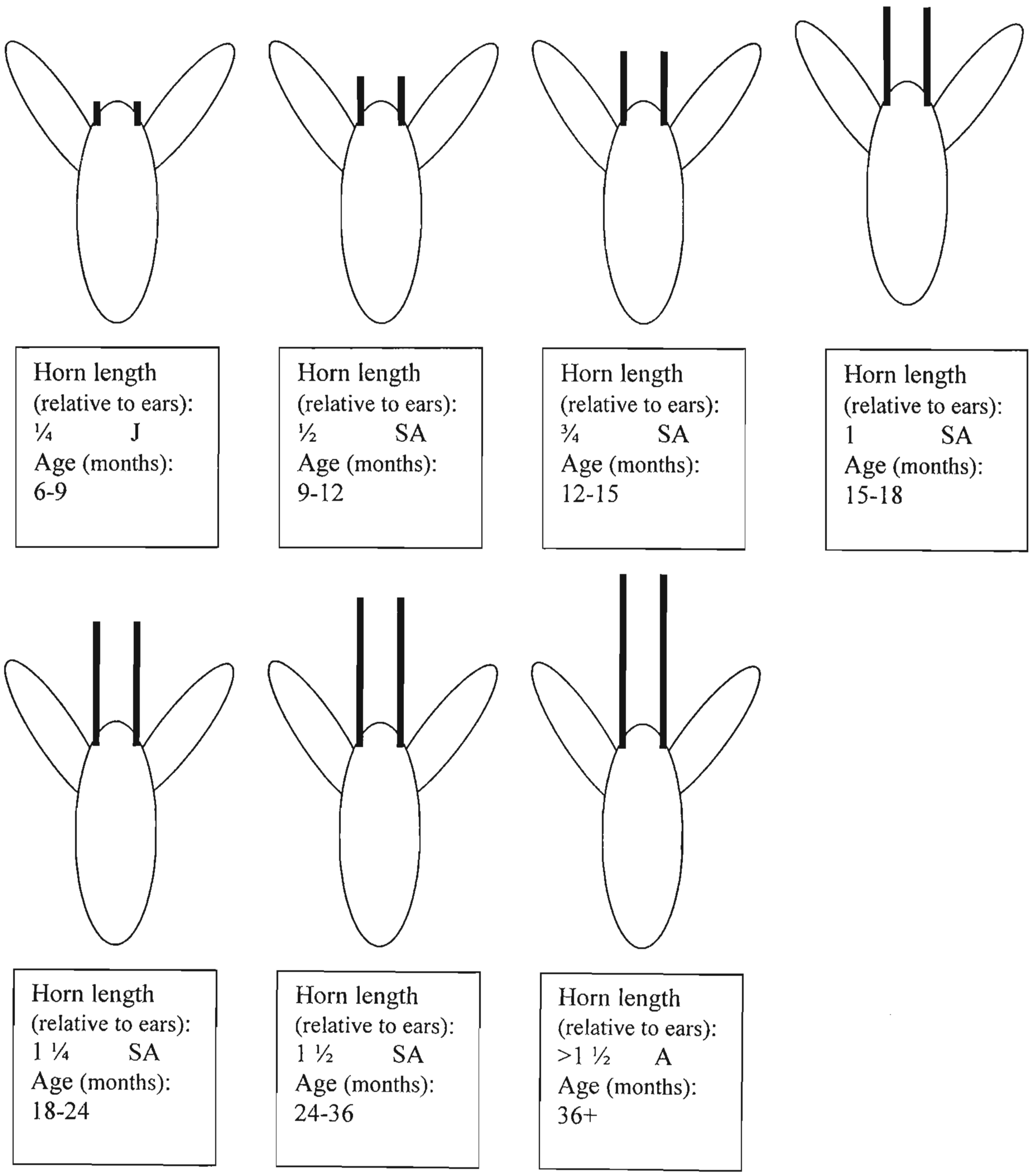


Figure 6 illustrates the field age classification chart that was used in the age classification of male reedbuck based on the length of the horn relative to the ears (Howard, 1983).

Figure 6. FIELD AGE CLASSIFICATION CHART FOR MALE REEDBUCK (Howard, 1983)



8.8 Sex Determination

Junguis (1971) reported that horned females have not been observed in southern reedbuck, and thus sex determination will be done purely on the basis of the presence or absence of horns. Howard (1983) and Venter (1979) reported that horns become visible after 5 - 6 months, and thus on the recording sheets infants and juveniles were not sexed.

8.9 Methodology process diagram

The methodology process diagram illustrates the relative timing and the interrelationship of the research components, also highlighting the opportunities for triangulation (Figure 7).

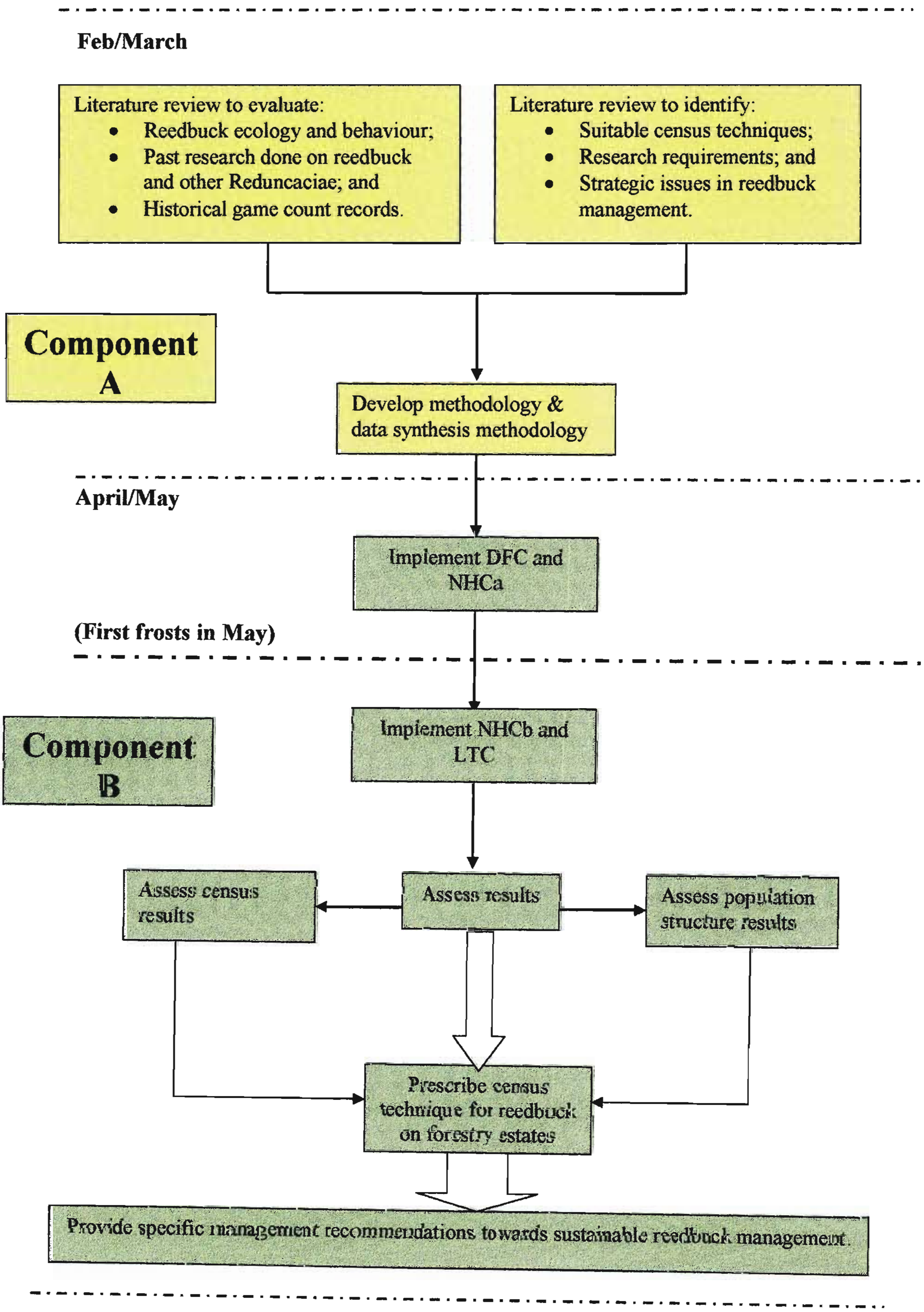


Figure 7. METHODOLOGY PROCESS DIAGRAM

9. DATA SYNTHESIS AND ANALYSIS

The primary objective of this study is the identification of a census technique(s) to be used by private landowners and incorporated into a census database to yield meaningful data on reedbuck abundance. This census technique(s) must function within a coordination framework ensuring sustainable management of reedbuck populations.

The data collected for critical evaluation during the course of this study include the following: historical game count records for the Mount Shannon estate; census results from the Dawn Flush Counts (DFC); census results from the Night Habitat Counts (NHC) (before and after the first significant frosts in May); population estimates from the Line Transect Counts (LTC); population structure data from the DFC, NHCa, and NHCb; sex ratio data from DFC, NHCa, NHCb, and LTC; and additional notes on recording sheets (e.g. presence of livestock in area, burning and reedbuck activity).

For management and conservation applications the primary factor that was evaluated for each census technique was the repeatability and accuracy. Repeatability is "a measure of how constant the magnitude and direction of bias in a census estimate remains from census to census" (Norton-Griffith (1978) *ex.* Collinson, 1984). Repeatability and accuracy are influenced by the bias in each census. With regards to census techniques bias cannot simply refer to sample error only, and must include inaccuracies that arise from factors such as observer error, instrument error and animal behaviour or vegetation condition violating the underlying assumptions of a census technique (Collinson, 1985). Ideally, the bias should be close to zero and remains constant from census to census, and in this study was minimised through the strict standardisation of methods. Within the scope of this study, repeatability was not considered to be an exclusively statistical concept, and thus the concept applied equally to estimates obtained from sampling and non-sampling census techniques.

Repeated measures ANOVA was used to determine whether there was a significant difference between the population estimates and sex ratios obtained from the different census techniques. Posthoc Scheffè tests were used to determine which dependent variables differed significantly from each other. Box plots using standard error were used to illustrate the repeatability of the census results for the different census techniques. For the LTC, stratification and the different counting and calculation methods were assessed separately.

Figure 8 is the methodology process diagram for the data analysis component of this study.

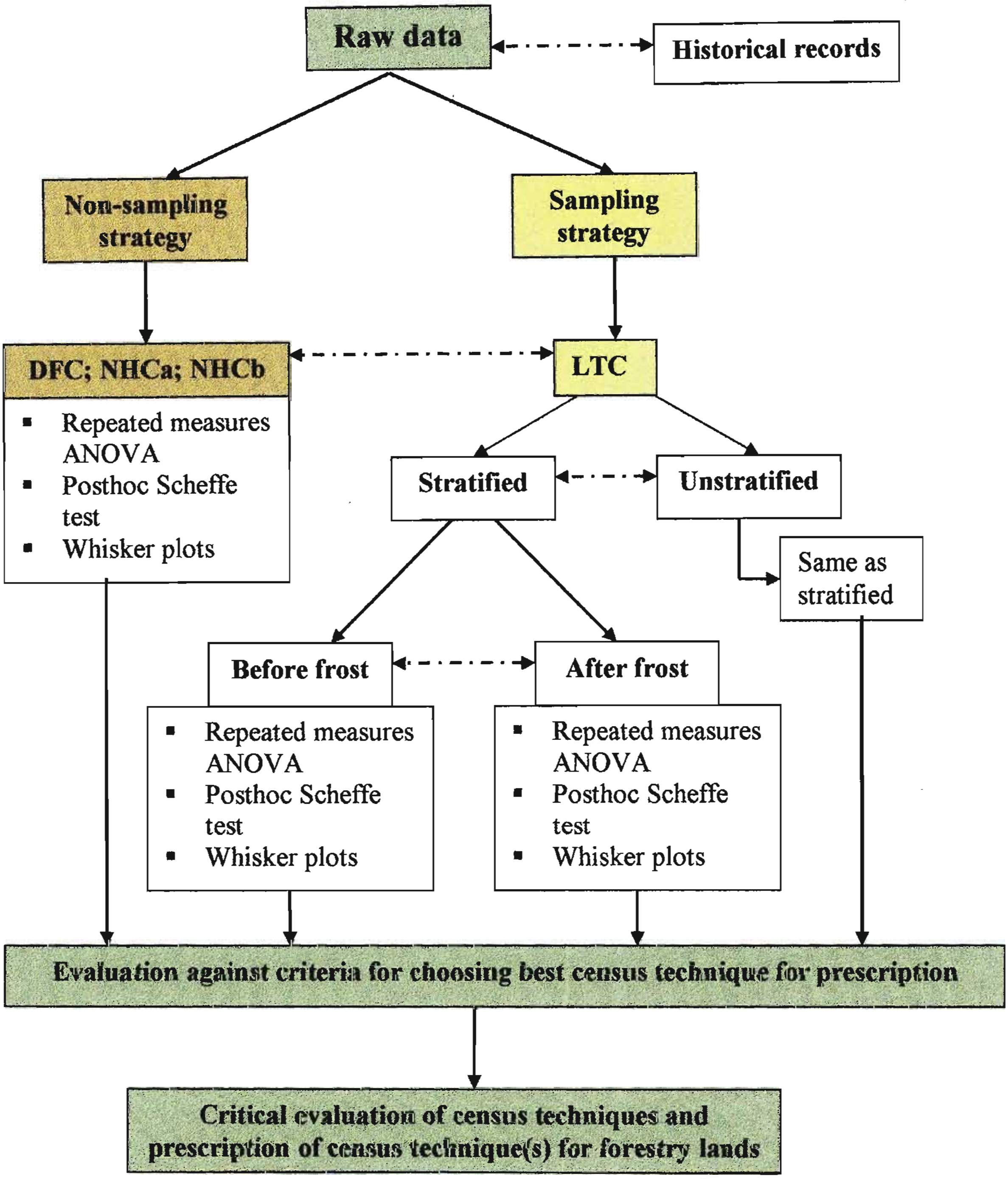


Figure 8. DATA ANALYSIS PROCESS DIAGRAM

9.1 Historical game count records

The historical game count records obtained from Mondi Forests were used for comparison with the results obtained in this study. These results were used an indication of previous population size and were not considered to be an absolute estimate of the population due to the lack of standardisation and apparent poor repeatability.

9.2 Population estimates from DFC and NHC

The results from these non-sampling census techniques were used to give an indication of the minimum reedbuck population on the Mount Shannon estate, as these constitute sightings of as many reedbuck as possible along a standardised census route. These results were used for comparison with those obtained from the LTC sampling census technique.

Factors that may have influenced the effectiveness and repeatability of these results include the following:

- Weather conditions impacted on visibility and reedbuck behaviour.
- The phase of the moon may have influenced the NHC results, even though Venter (1979) found that moon phase did not impact on the repeatability and precision.
- Forest management practices on the estate (e.g. autumn burns and silvicultural prescriptions) impacted on reedbuck distribution and to some extent visibility (i.e. smoke and dust in the air).
- Reedbuck moving through or hiding in the 1114 ha of pine plantation were omitted from these counts.
- Reedbuck that were not flushed in the DFC were omitted.
- These were vehicle operations, and thus the disturbance caused by the vehicle may have flushed reedbuck or caused them to hide, thus excluding them from the count.
- Not all areas of reedbuck habitat could be included in the DFC and NHC due to the time constraints, inaccessibility with a vehicle, and the range of the spotlight.

NHC are the census technique adopted by Mondi Forests at present, and thus these were tested both before and after the first significant frosts in May.

For the non-sampling census techniques the following criteria were used in selecting the optimum method:

- The individual count that yielded the highest census result was considered to represent the minimum reedbuck population on the estate.
- The technique that yielded the highest mean census result was considered to be the most effective.
- The technique that yielded the lowest variance and standard error was considered to have the highest repeatability.

9.3 Population estimates from the LTC

The LTC were used to test a sampling strategy, and were related to results obtained from the DFC and NHC. Howard (1983) estimated that a single count at night gave an estimate between 68-100% of all the reedbuck resident in a given area. This was used to develop a control range. LTC population estimates that fell within this range were considered to be accurate.

Factors that may have influenced the effectiveness and repeatability of these results include the following:

- Weather conditions impacted on visibility and reedbuck behaviour.
- Undulating terrain with broken veld may have resulted in reedbuck being omitted from the count due the animals being flushed prior to sighting.
- As each count progressed from dawn the reedbuck became more and more difficult to flush and sight, thus impacting on the transects conducted at the end of each census.
- The random distribution of reedbuck within each stratum may have been disturbed by forest management practices, the presence of livestock and the presence of other vehicles on the estate.
- The determination of the total area of each stratum was subjective, and thus over or under estimation may have occurred.

For the non-sampling census techniques the following criteria were used in selecting the optimum method:

- The combination of counting and calculation method that yielded the lowest variance and standard error was considered to have the highest repeatability.
- The stratified and unstratified sampling designs were compared with regards to the repeatability and precision.
- If there is no significant difference between two counting or calculation methods then the simpler technique was selected. This was also based on accuracy and practicality.
- The comparison of the population densities within each stratum was used to determine whether stratification was in fact necessary. Close similarities between the densities would indicate that stratification was not necessary.

9.4 Population density estimates from the LTC

Howard (1983) found that the reedbuck population density that an area can sustain is closely related to the habitat suitability, and consequently the population densities throughout their distribution vary accordingly. Howard (1983) found that in the Underberg district a population density of 7.6 reedbuck per km^2 or 0.076 reedbuck per ha was recognised. This was based on the entire intensive study area, and not on the area of suitable reedbuck habitat. Howard (1983) investigated the population density of a complex of semi-intensive farms in the Underberg district (10500 ha), and thus reedbuck population densities would be much higher if determined exclusively for suitable reedbuck habitat. This study aims to estimate the population density observed within suitable reedbuck habitat on the Mount Shannon, and thus the Boston area.

9.5 Population structure data from the DFC, NHCa, and NHCb

The population structure provides information on the age and sex ratios. Juvenile/Adult ratios are a measure of the natality and rearing success of the population (Downing, 1980). The relative size of each age class of females is required to interpret age-specific reproductive rates, which is necessary as older females have a higher rearing success (Downing, 1980).

For the purposes of this study the repeatability and accuracy of the population structures developed from the DFC, NHCa, and NHCb was tested. Venter (1979) found a foetal sex-ratio of 12 males : 13 females, which does not differ significantly from the expected 1 : 1 ratio. The results obtained by Venter (1979) from field sex classification were significantly different from a 1 : 1 sex ratio (P<0.001). This study also determined whether the population structures were biased to any age or sex classes.

The juvenile age class was impossible to sex, and the sub-adult age class required a high proportion of subjective decisions to be made, either based on shoulder height or horn relative to ear length. Basically, a high proportion of juvenile animals to the adult population is indicative of a healthy reedbuck population (Venter, (1979).

This study made use of 100% stacked bar graphs representing the proportion of each age/sex class for each the non-sampling counts. From each graph the repeatability and precision of the census technique can be ascertained. Population structure was not an output of the LTC process.

For example, Figure 9 shows a poor repeatability as can be seen in the fluctuations in the proportions of each age/sex class in each census, while Figure 10 exhibits a higher repeatability with more consistent age/sex classes from count to count.

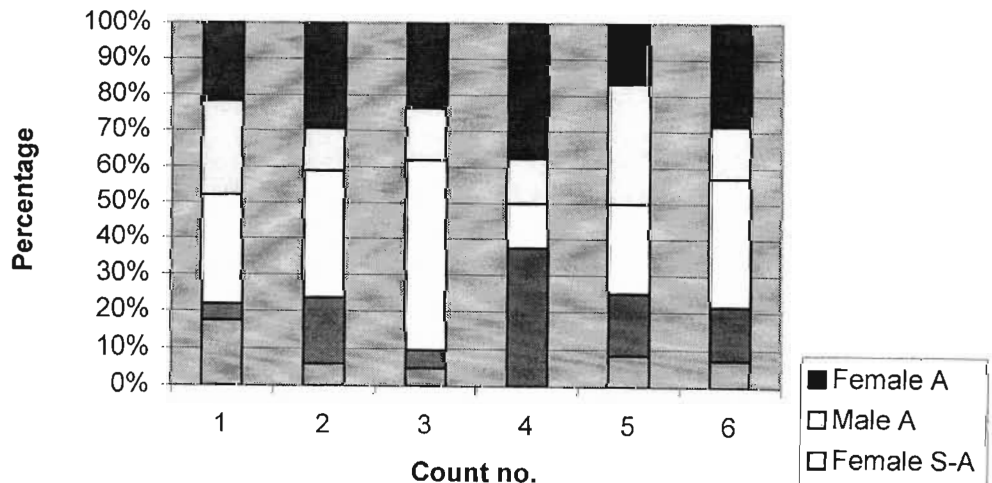


Figure 9. 100% Stacked chart comparing the population structure of each of the DFC

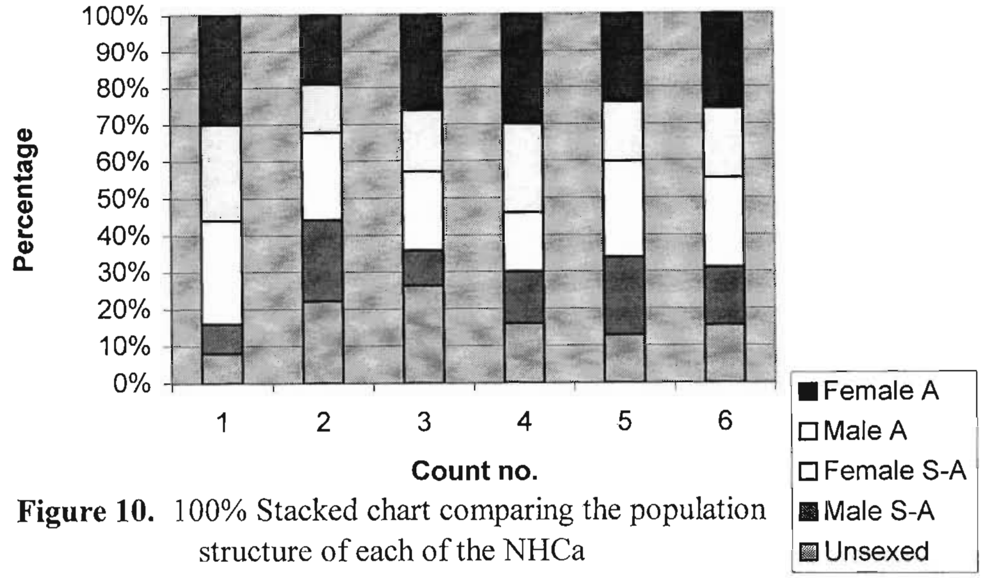


Figure 10. 100% Stacked chart comparing the population structure of each of the NHCa

9.6 Sex ratio data from DFC, NHCa, NHCb, and LTC

Sex ratios require periodic assessment to determine whether it falls within the range needed for normal reproductive performance. The sex ratio was expressed as the ratio of males per female (Caughley, 1977), and gives an indication of the ability of the population to increase in optimal conditions.

Within the scope of this study the repeatability and precision of the sex ratios obtained from the DFC, NHCa, NHCb, and LTC was assessed, and it was determined whether the sex ratios were biased towards any sex.

9.7Additional notes on recording sheets

Additional notes on the recording sheets were used to explain any anomalies observed within the data (e.g. outlier results).

10. REEDBUCK MANAGEMENT AT A LOCAL LEVEL

One of the primary factors undermining the sustainable management of reedbuck at a local level is the lack of coordination between neighbouring landowners, resulting in unsustainable harvesting of reedbuck populations in order to protect agricultural productivity. This is critical on forestry estates in the Drakensberg/KwaZulu-Natal Midlands as can be seen in the movement of reedbuck onto irrigated winter pastures in winter for forage, thus bringing the reedbuck into conflict with commercial farmers. These commercial farmers tend to hunt or translocate these reedbuck off their land, thus rendering any reedbuck census on forestry lands obsolete, and any resultant harvesting quotas unsustainable.

Questionnaire-based qualitative research is required to develop a framework for the coordination of reedbuck management at a local level. This coordination framework should determines to enable a forestry estate to:

(a) Determine which neighbouring landowners should be included in a coordination framework. Howard (1983) found that in winter reedbuck feeding each night on planted pastures generally spend the daytime within a radius of about 1.5 km of that food source, and generally feed at the closest food source to their preferred daytime habitat (i.e. forestry corridors, wetland areas and firebreaks). These observations led Howard (1983) to the derivation of the "pasture catchment" concept, whereby each pasture has an associated "catchment" from which reedbuck are "drawn". The pasture catchment concept allows for relevant neighbouring landowners to forestry lands to be identified, and thus included in the coordination framework. The size of the catchment associated with any particular property depends on winter food sources (e.g. planted or relict pastures) both on the property and on the neighbouring farms (i.e. at a local level), and thus farms with the same area and same area of pastures may have different pasture catchment areas (Howard, 1983).

(b) Provide guidelines for the inauguration of a coordinated reedbuck census and harvesting programme, whereby communication between landowners at critical times (e.g. after the first frosts in May and during the hunting season) will ensure reliable census records and sustainable management.

(c) Make recommendations towards the inclusion of the assessment of the coordination of reedbuck management at a local level into the EKZN Wildlife hunting licensing and hunting permit system, thus ensuring that the correct number of animals is harvested.

(d) Ensure that misconceptions as regards reedbuck populations (e.g. the misconception by commercial farmers that the reedbuck observed at night on their irrigated pastures are resident on their lands, and thus can be harvested) in the Midlands/Drakensberg area are combated through increased public awareness by means of workshops and the setting up of coordination committees.

11. APPLICATION

This study determines to provide a census technique that is simple, cost effective, time efficient, accurate and has a high repeatability over time. Initially, these results will be applied to the Mondi Forests estates in the Drakensberg/KwaZulu-Natal Midlands as part of their multiple resource utilization programme, and depending on the results could be incorporated into a local coordination framework involving other landowners.

12. ACKNOWLEDGEMENTS

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Appendix 1: Recording Sheet for DFC

RECORDING SHEET FOR THE DAWN FLUSH COUNT #1

Date & Time: 2/04/2003 @5:56am
Observer: Stephen Boyes
Weather conditions: Clear with early mist
Visibility: Good

Sighting	Age Class					Notes	Total
	J	M_{SA}	F_{SA}	M_A	F_A		
1				1		Tall grass. Moved into young pine plantation	1
2			1			Feeding	1
3				2	1	Feeding on short *Pennisetum clandestinum*	3
4			1	1	1	Hiding adjacent to *Pennisetum clandestinum* pasture	3
5	1				2	Feeding	3
6			2			Feeding	2
7				1		Feeding on short *Pennisetum clandestinum*	1
8			2				2
9	2				1	On edge of young pine plantation	3
10	1			1			2
11		1	1			Feeding	2
12							
13							
14							
15							
16							
17							
18							
19							
20							
21							

22							
23							
24							
25							
26							
27							
28							
29							
30							
Total	4	1	7	6	5		23

Other sightings:
2 x oribi
1 x common duiker
3 x long-crested eagle
2 x wattle crane
2 x black crow

Where,
MA = Male adult
FA = Female adult
MSA = Male sub-adult
FSA = Female sub-adult
J = Juvenile

Visibility (m): Distance at which a person in khaki cannot be seen.
Very poor: 0 -25 Dawn(D) & Night(N)
Poor: 26 - 100 (D) & 26 - 50 (N)
Moderate: 101 - 500 (D) & 51 - 250 (N)
Good: 501 - 2500 (D) & 251 - 1000 (N)
Excellent: 2500+ (D) & 1000 (N)

Comments:
Few reedbuck were sighted, with the majority of the sightings before 7am (thus biasing the results to those areas censused before 7am) . Most sightings were of reedbuck flushed from hiding places by bthe movement of the observer. Weather and conditions did not influence visibility or coverage.

Appendix 2: Recording Sheet for NHC

RECORDING SHEET FOR THE NIGHT HABITAT COUNTS (AFTER FROST) #1

Date & Time: 04/05/2003 @5.58pm
Observer: Stephen Boyes
Weather conditions: Cold
Visibility: Moderate to Good

Sighting	Age Class					Notes	Total
	Unsexed	M_{SA}	F_{SA}	M_A	F_A		
1					1	Moving through low woody cover in valley	1
2		1	2			Moving through low woody cover in valley	3
3	3					At a distance (could not ID the horns or male feactures (e.g. square nose)	3
4	1		1		1	Juvenile	3
5				2		Feeding	2
6	1					At a distance (could not ID the horns or male feactures (e.g. square nose)	1
7				1	1		2
8			1			Moving through wetland area	1
9		2				Wetland/riparian area	2
10					1		1
11	1					At a distance (could not ID the horns or male feactures (e.g. square nose)	1
12	1					At a distance (could not ID the horns or male feactures (e.g. square nose)	1
13		1			1	Feeding	2
14		1				Exposed in low-open grassland	1
15				1			1
16					1	Feeding	1
17	2		1	2	1	Feeding on *Pennisetum clandestinum* pastures on high-lying area	6
18				1			1
19		1	1			On edge of young pine plantation	2
20	1					Hiding adjacent to *Pennisetum clandestinum* pasture	1
21					2	Wetland/riparian area	2

22	1					At a distance (could not ID the horns or male feactures (e.g. square nose)	1
23	2					At a distance (could not ID the horns or male feactures (e.g. square nose)	2
24				1	1	Feeding	2
25	1					At a distance (could not ID the horns or male feactures (e.g. square nose)	1
26					1		1
27		2	1				3
28	3					At a distance (could not ID the horns or male feactures (e.g. square nose)	3
29					2	On edge of young pine plantation	2
30							
Total	17	8	7	8	13		53

Other sightings:
2 x spotted eagle owl
1 x serval
2 x black-backed jackal

Where,
MA = Male adult
FA = Female adult
MSA = Male sub-adult
FSA = Female sub-adult
J = Juvenile

Visibility (m): Distance at which a person in khaki cannot be seen.
Very poor: 0 -25 Dawn(D) & Night(N)
Poor: 26 - 100 (D) & 26 - 50 (N)
Moderate: 101 - 500 (D) & 51 - 250 (N)
Good: 501 - 2500 (D) & 251 - 1000 (N)
Excellent: 2500+ (D) & 1000 (N)

Comments:
New moon may have influenced count, however, Venter (1979) found that moon phase did not influence the repeatability of night drive counts on the Eastern shores of Lake St. Lucia. Reedbuck congrgated in the wetalnd/riparian areas, and avoided the *Pennisetum clandestinum* pastures that had been impacted by the first frosts.

Appendix 3: Recording Sheet for LTC

RECORDING SHEET FOR THE LINE TRANSECT METHOD #1

Date & Time: 22/04/2003@6.04am
Observer: Stephen Boyes
Weather conditions: Overcast & clear
Visibility: Good

Transect no.: 1 **Stratum: Wetland/riparian**

Visibility index = 72m **Maximum perpendicular sighting distance = 72m**
Strip width = 144m

Sighting	Sex			Radial distance (D) (m)	Sighting angle (α)	Notes	Total
	Male	Female	Unsexed				
1	1	2		62	40	Flushed	3
2		1		95	60	Flushed	1
3		1		30	0	Flushed	1
4	1			87	32	Flushed	1
5							
6							
7							
Total	2	4					6

Comments:
Evidence of trampling by cattle and overgrazing. Horses also observed along the transect. These factors may have bias the results.

Transect no.: 2 **Stratum: Grassland corridor**

Visibility index = 81m **Maximum perpendicular sighting distance = 75m**
Strip width = 150m

Sighting	Sex			Radial distance (D) (m)	Sighting angle (α)	Notes	Total
	Male	Female	Unsexed				
1		2		84	25	Flushed	2
2		1		42	56	Flushed	1
3		1		111	65	Feeding	1
4	1	1		47	29	Flushed	2
5							
6							
7							
Total	1	5					6

Comments:
Very wet under foot and difficult to move rapidly.

Transect no.: 3 **Stratum: Wetland/riparian**

Visibility index = 72m **Maximum perpendicular sighting distance = 72m**
Strip width = 144m

Sighting	Sex			Radial distance (D) (m)	Sighting angle (α)	Notes	Total
	Male	Female	Unsexed				
1	1			76	12	Lying down	1
2		1		45	34	Flushed	1
3							
4							
5							
6							
7							
Total	1	1					2

Comments:
Area closely associated with road, and as a result of movement through the area earlier, the reedbuck may have moved away.

Transect no.: 4 **Stratum: Areas with associated*Pennisetum clandestinum* pastures**

Visibility index = 78m **Maximum perpendicular sighting distance = 75m**
Strip width = 150m

Sighting	Sex			Radial distance (D) (m)	Sighting angle (α)	Notes	Total
	Male	Female	Unsexed				
1		1	1	43	82	Flushed	2
2	1			45	34	Lying down	1
3		1		106	52	Feeding	1
4		1		67	22	Flushed	1
5							
6							
7							
Total	1	3					5

Comments:
Pennisetum clandestinum pastures do not provide adequate cover (although reedbuck do hide in them), and thus are not as popular in the daytime.

Transect no.: 5 **Stratum: Grassland corridor**

Visibility index = 81m **Maximum perpendicular sighting distance = 75m**
Strip width = 150m

Sighting	Sex			Radial distance (D) (m)	Sighting angle (α)	Notes	Total
	Male	Female	Unsexed				
1	1	1		76	32	Flushed	2
2		1		85	47	Flushed	1
3		1		32	35	Feeding	1
4							
5							
6							
7							
Total	1	3					4

Comments:
The terrain was undulating, and often the visibility was poor.

Transect no.: 6 **Stratum: Wetland/riparian**

Visibility index = 72m **Maximum perpendicular sighting distance = 72m**
Strip width = 144m

Sighting	Sex			Radial distance (D) (m)	Sighting angle (α)	Notes	Total
	Male	Female	Unsexed				
1		2		121	34	Flushed	2
2	1			65	81	Flushed	1
3							
4							
5							
6							
7							
Total	1	2					3

Comments:
Vlei adjacent to Dam 2 does not provide adequate cover for reedbuck.

Transect no.: 7 **Stratum: Grassland corridor**

Visibility index = 81m **Maximum perpendicular sighting distance = 75m**
Strip width = 150m

Sighting	Sex			Radial distance (D) (m)	Sighting angle (α)	Notes	Total
	Male	Female	Unsexed				
1		1		102	43	Flushed	1
2	2			67	12	Flushed	1
3							
4							
5							
6							
7							
Total	2	1					2

Comments:
Open grassland with no low woody cover and patches in which cover is minimal.

Transect no.: 8 **Stratum: Firebreak**

Visibility index = 53m **Maximum perpendicular sighting distance = 53m**
Strip width = 106m

Sighting	Sex			Radial distance (D) (m)	Sighting angle (α)	Notes	Total
	Male	Female	Unsexed				
1							
2							
3							
4							
5							
6							
7							
Total	0	0	0				0

Comments:
Insufficient cover and closely adjacent plantation meant that no animals were sighted in these areas.

CENSUS TECHNIQUES FOR SOUTHERN REEDBUCK *Redunca arundinum* ON FORESTRY LANDS IN THE DRAKENSBERG/NATAL MIDLANDS

Component B: RESEARCH PAPER

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CENSUS TECHNIQUES FOR SOUTHERN REEDBUCK *Redunca arundinum* ON FORESTRY LANDS IN THE DRAKENSBERG/KWAZULU-NATAL MIDLANDS

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Census techniques developed for southern reedbuck *Redunca arundinum* were tested on a forestry estate in the Drakensberg/KwaZulu-Natal Midlands. Both sampling and non-sampling strategies were tested. The census techniques also gathered data on sex ratios, population structure, and reedbuck behaviour. Non-sampling dawn flush counts and night habitat counts (before and after the first significant frosts) were used to estimate minimum population size and the control range. Repeated measures ANOVA, standard error box plots and Posthoc Scheffè tests were used to assess the comparative repeatability of the census techniques. Dawn flush counts yielded very low estimates. Night habitat counts before the first significant frosts performed best of the non-sampling strategies, obtaining the highest repeatability and minimum population estimate. For the line transect counts three counting and two calculation methods, including both modified and fixed strip width transects, were tested. Line transect counts consistently over-estimated population size, but were relatively accurate and repeatable when the application of fixed strip width (determined using the mean visibility index) was tested. This method was thus selected as the line transect count most suitable for monitoring reedbuck abundance on forestry lands in the Drakensberg/KwaZulu-Natal Midlands. There was no significant difference between the results obtained before and after the first significant frosts. The sex ratios obtained were significantly below the expected ratio of 1: 1, showing a bias to female reedbuck. Population structures exhibited poor repeatability.

Keywords: Census technique, southern reedbuck *Redunca arundinum*, repeatability, population estimate, forestry estate, line transect

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Introduction

Conservation outside of protected areas through sustainable management and value addition is essential in modern biodiversity conservation strategies. Due to the provision of baseline data for comparison monitoring forms an integral part of the sustainable management of natural resources, and species and area specific census techniques form the foundation upon which sustainable management practices can be developed. A good census technique includes details of population structure, sex ratio, age structure, habitat preference, as well as status and abundance of a given species in a given area (Davis & Winstead 1980). This study tests census techniques developed specifically for southern reedbuck *Redunca arundinum* on forestry lands in the Drakensberg/KwaZulu-Natal Midlands. For conservation or sustainable management, a census technique with high repeatability provides the data required to monitor population status, prescribe sustainable harvesting quotas, and monitor the influence of management systems (Collinson 1982). In this study, management constraints restricted the census techniques to those that had high repeatability (over space and time), were simple, cost-effective, and time efficient.

Reedbuck populations in the Drakensberg area have been limited historically by the low winter carrying capacity of seasonally inundated wetlands (Howard 1983). Over the past 50 years, the landscape of these areas has changed through commercial afforestation, the planting of winter pastures (e.g. *Lolium spp.*), the delineation and conservation of wetland and riparian areas on forestry lands, and the burning and maintenance of grassland corridors and firebreaks within the forestry landscape (Howard 1983; Howard 1986). This land-use mosaic has been able to support increasing reedbuck populations in the Drakensberg/KwaZulu-Natal Midlands through the provision of reedbuck habitat and winter forage (Howard 1986). As a result, cohesive behaviour of reedbuck has become more seasonal, with reedbuck congregating on irrigated winter pastures after the first significant frosts when the indigenous grasses have become dormant (Howard 1986).

The primary parameter in the assessment of the census techniques for sustainable management is precision or repeatability, whereby a small standard error is indicative of high repeatability (Bothma *et al.* 1990; Caughley & Sinclair 1977). Repeatability is a measure of how constant the magnitude and direction of bias in a census estimate remains from census to census (Norton-Griffith 1978 *in* Collinson 1982). High repeatability allows for inferences to be made concerning population status, even though a census technique with a high repeatability may yield results that do not nearly approach the true or inferred size of the population. An integral part of the repeatability of a census technique is the bias in each census (Collinson 1985). Bias does not simply refer to sample error only, and includes inaccuracies that arise from factors such as observer error and bias, instrument error, weather and visibility, animal behaviour and vegetation characteristics that violate the underlying assumptions of the census technique (Collinson 1982). Ideally, the bias should be constant from census to census, and in this study this was achieved through the strict standardisation of census techniques. Repeatability was not considered to be an exclusively statistical concept, and was evaluated for both sampling and non-sampling census techniques.

A secondary parameter in the assessment of the census techniques for conservation and sustainable management is accuracy. Accuracy is a measure of how close a game count is to the actual population size (Collinson 1982). Accurate census estimates are required for the calculation of stocking rates (animal standing biomass) and harvesting quotas (Bothma *et al.* 1990). Reedbuck are harvested on forestry lands, and thus sustainable harvesting quotas from accurate census estimates are a necessity. A prerequisite for evaluating the accuracy of a census technique is known population size (Collinson 1985). In this study the control was the minimum population estimate and control range obtained from the non-sampling counts.

Our census allowed for data collection on population structure, sex ratios and animal behaviour. The repeatability and accuracy of these results were evaluated in much the same way as the population estimates.

The census techniques tested in this study comprised: Dawn Flush Counts (DFC); Night Habitat Counts (before the first significant frosts) (NHCa); Night Habitat Counts (after the first significant frosts) (NHCb); and Line Transect Counts (LTC). The first significant frosts in May were chosen as the interface between seasons, thus allowing for the evaluation of any changes in reedbuck distribution and behaviour at these times. Howard (1983) also used the first significant frosts in May as a marker in the census techniques prescribed within his integrated approach to the management of reedbuck on farmland in Natal. Historical game count records were reviewed as part of the study. At present reedbuck are counted on forestry lands using non-sampling night drive counts.

Long-term changes in vegetation physiognomy are expected on forestry lands, due to harvesting and planting operations, and Collinson (1982) stated that line transect methods were robust to these changes. Bothma and Peel (1995) found that line transect methods, although inaccurate, provided population estimates with high repeatability for impala *Aepyceros melampus*. Bothma, Peel, Pettit and Grossman (1990) concluded that line transect methods could provide useful crude estimates of impala population size for private landowners given the simple calculations required.

This study determined to test these conclusions relative to reedbuck on forestry lands in the Drakensberg/KwaZulu-Natal Midlands.

Study site

The study site was the Mount Shannon estate in the Boston conservancy (South 29°39' to 29°43'; East 29°54' to 29°57'). The total area of the estate is 2226 ha, with a planted area of 1114 hectares, a conservation area of 1057 ha, and a road area of 55 ha. The estate was registered as Natural Heritage Site (no. 269) in 1996, and as a Site of Conservation Significance (no. 95 and 96) in 1995. The Mount Shannon estate is representative of the region (i.e. good example of veld type 45 (Natal Mistbelt)) and the forestry landscape, and has a comparatively large reedbuck population that is hunted annually (Table 1), and thus was chosen as the study site for testing reedbuck census techniques in the Drakensberg/KwaZulu-Natal Midlands. Timber harvesting operations were not active on the estate over the period, meaning census results were not biased by these activities. Due to time constraints in this study the influence of winter pastures were excluded. Winter pastures are not part of the forestry landscape, and thus would not affect reedbuck movements or cohesive behaviour on forestry estates. On the Mount Shannon there were no immediately adjacent winter pastures, thus making this estate ideal for this study.

Methods

Several assumptions were necessary as a precursor for testing census techniques for reedbuck on forestry lands. Reedbuck are predominantly crepuscular or nocturnal

(Howard 1983; Howard 1986; Venter 1979; Junguis, 1971), and Howard (1986) found that habitat preferences were seasonal, whereby reedbuck occupied vleis and natural grassland on uneven terrain during summer, and agricultural land and adjacent woody cover during winter. Grassland corridors, wetland/riparian areas, low woody cover and pine plantation (0-2 years), areas with associated *Pennisetum clandestinum* pastures, and firebreaks were identified as potential reedbuck habitat types on forestry lands in the Drakensberg/KwaZulu-Natal Midlands (Table 2). The four habitat types identified as reedbuck habitat for the census techniques and strata of the LTC on the Mount Shannon estate were grassland corridors, wetland/riparian areas, areas with associated *P. clandestinum* pastures, and firebreaks. The young pine plantations were not included due to the low visibility in these areas. Reedbuck are a typical hider species (i.e. first means of defence is to avoid detection) (Jungius 1971), spending the majority of the daylight hours lying up in herbaceous cover (e.g. in wetlands). Reedbuck are strictly territorial (Jungius 1971) or seasonally territorial (Howard 1983). Reedbuck exhibit a dominance hierarchy (Venter 1979), whereby intraspecific competition causes increased male mortality. Poaching and hunting with dogs will not be considered as factors influencing reedbuck populations on forestry estates, as a result of the lack of data and the apparent reduced occurrence of poaching on the forestry estates in the Drakensberg/KwaZulu-Natal Midlands (R.McC. Pott *pers comm.* 2003)[1]. It was assumed that reedbuck distribution and climatic conditions are constant over the identified time period from year to year. Factors such as adult and juvenile mortality, disease, predation, natality and disturbance by long-term management practices and other external factors (e.g. drought) are assumed to be constant over time, and thus not influence the repeatability of the census techniques.

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Census techniques were tested prior to the hunting season. Howard (1986) observed seasonal differences in reedbuck cohesive behaviour before and after the first significant frosts. These findings were tested in this study, using the first significant frosts as the transition point. DFC, LTC (before frost) and NHCa were conducted in April, while NHCb and LTC (after frost) were conducted in May after the first significant frosts. The first significant frosts were recorded on the 2/05/2003.

Dawn Flush Counts (DFC)

The objective of the DFC was to test a non-sampling census technique conducted at dawn, before the first significant frosts, along a standardized census route using flushing (on foot to increase coverage and flushing disturbance). DFC were conducted on six consecutive days between 1/04/2003 and 6/04/2003.

The road network was assessed using a site inspection and land-use map of the Mount Shannon estate. A standardized census route that allows for the maximum coverage of identified reedbuck habitat was plotted. Each of the 3-hour DFC were conducted at sunrise. The same vehicle, driver and observer were used for each count, and the vehicle moved at 20km/h. The observer used 10 x 42 binoculars for all counts. In instances where the area counted was >100m away from the vehicle, the observer flushed reedbuck from these areas on foot. Any important vantage points not accessible with the vehicle were walked to on foot, and deviations from the standardized census route were adjusted. Sex/age class, group size and additional information on reedbuck behaviour were recorded. The sex/age classes used in the DFC were juvenile, male sub-adult, female sub-adult, male adult and female adult.

The date, time of day, other sightings, weather conditions, visibility and additional notes were also recorded for each DFC.

Night Habitat Counts (before frost) (NHCa)

The objective of the NHCa was to test a non-sampling census technique conducted at night, before the first significant frosts, along a standardized census route. The NHCa were conducted on six consecutive days between 1/04/2003 and 6/04/2003.

The standardized census route was used. Each of the 3-hour NHCa were conducted from sunset. The same vehicle, driver, observer and recorder were used for each count, and the vehicle moved at 20km/h. A 200 000 candlepower spotlight and 10 x 42 binoculars were used for each count. The vehicle stopped briefly at designated pastures – these stops were standardized for all the counts. Sex/age class, group size and additional notes on reedbuck behaviour were recorded. The same sex/age classes as the DFC were used, but juvenile reedbuck (along with sightings that could not be sexed) were included as unsexed. The date, time of day, other sightings, weather conditions, visibility and comments were also recorded for each NHCa.

Night Habitat Counts (after frost) (NHCb)

The objective of the NHCb was to test a census technique conducted at night, after the first significant frosts, along a standardized census route. The NHCb were conducted on six consecutive days between 4/05/2003 and 9/05/2003. The method used for the NHCb was the same as that for the NHCa.

Line Transect Counts (LTC)

The objective of the LTC was to test a sampling strategy at dawn before and after the first significant frosts using line and modified transect methods. The LTC were conducted on consecutive days from 22/04/2003 to 25/04/2003 and 6/05/2003 to 9/05/2003.

A stratified survey design was tested. A site inspection and land-use map of the Mount Shannon Estate were used to map the different reedbuck habitat types for use as strata in the LTC process. An estimate of the area of each stratum of reedbuck habitat was obtained using ArcView 3.2. Primary reedbuck habitat (Table 2) was assigned three 1km transects, while other areas were assigned only one. The eight transects conducted in LTC process comprised: three wetland/riparian area transects; three grassland corridor transects; one area with associated *P. clandestinum* pastures transect; and one firebreak transect. The three wetland/riparian and grassland transects were conducted on distant sites on the Mount Shannon estate. The transect length was limited to 1km due to time constraints, and in areas where transects of 1km were impossible two transects of 500m were conducted. The length and orientation was regulated using a Garmin GPS 12. For each of the counts the location and orientation of the transects were standardised.

Most unplanted areas are linear, and thus transect lines were orientated diagonally across these corridors so as to get a suitable transect length. Where the area was large enough for a transverse transect, an East-West direction was walked, so as to keep the rising sun behind the observer to optimize the visibility on either side of the transect line. The LTC were conducted from dawn for three hours, thus allowing 45 minutes for each transect (including movement between transects).

Optics were not used. Two observers were used, each conducting transects simultaneously. The observers were given the following guidelines: do not make unnecessary noise; record quickly so as to keep moving; and move at a constant speed stopping only briefly.

The fixed strip width/2 or maximum perpendicular sighting distance of the transect line was determined using the mean visibility index with 75m as the maximum. A maximum of 75m was assumed for all strata, as generally due to their hiding behaviour only flushed reedbuck within 50 - 75m are counted. The mean visibility index (variable according to the stratum) for the vegetation was calculated as the mean distance ($n = 3$) at which a person on foot (wearing khaki clothes) first disappears from view along a transect line in a given stratum (Bothma *et al.* 1990). The mean visibility index was determined for each stratum prior to the first LTC. Reedbuck were counted where they were first seen, and the radial distance from the observer to the animal was measured with a rangefinder. The sighting angle (α) of the reedbuck relative to the transect line was measured with a compass model. The recording sheet recorded the sex, group size and additional notes on reedbuck behaviour. The date, time of day, other sightings, weather conditions, visibility and comments were also recorded for each LTC.

Three counting methods were used within the framework of the LTC (adapted from Bothma *et al.* 1990): Method A: All reedbuck sightings $\leq$ maximum perpendicular sighting distance (strip width/2 from the transect line) were counted (with $\hat{Y}$ = fixed strip width/2); Method B: Only reedbuck sightings $\leq$ maximum perpendicular sighting distance from the transect line were counted (with $\hat{Y}$ = mean of actual sighting distances of reedbuck from the transect line); and Method C: All reedbuck sightings along the transect line were counted regardless of maximum perpendicular sighting distance (with $\hat{Y}$ = fixed strip width/2).

Two calculation methods were used, including population estimates based on radial sighting distance (King's method/Modified strip transect) and mean perpendicular distance from the transect line. The following equation was used for the modified strip transects to estimate reedbuck population based on radial sighting distance (King's method): $N_1 = AZ/2X\check{D}$ (adapted from Bothma *et al.* 1990). Where: N_1 = population estimate; A = total area of reedbuck habitat (m^2); Z = total number of animals counted; X = total transect length (m); and $\check{D}$ = the mean radial distance (m). The mean radial distance was based on individual distances D being measured from the observer directly to the reedbuck sighted. Group size was taken into account when calculating $\check{D}$ (i.e. $\check{D} = \sum(D_i$ x group size)/total number sighted). The following equation was used to estimate reedbuck population abundance on mean perpendicular distance from the transect line: $N_2 = AZ/2X\hat{Y}$ (adapted from Bothma *et al.* 1990). Where: Y = mean perpendicular distance from the transect line (m). The individual perpendicular distance from the transect line were derived from the radial distance and the sighting angle (α). Group size was accounted for in the same manner as for the King's method.

As can be seen in the recording sheets, transects were separated into strata and recorded as such. For the assessment of an unstratified design, all of the sightings were grouped together regardless of the strata and assessed according to the counting and calculation methods.

Age Determination

Age determination with large enough sample size provides an indication of the population age structure and status at a specific point in time, and was done using the field classification charts modified from Howard (1983). These methods were based on the horn length relative to ear length for males, and shoulder height relative to adult female shoulder height for females. In this study, an adult female reedbuck was any animal over the age of 12 months, while a socially mature adult male reedbuck was over the age of 36 months (Venter 1979; Howard 1983). The age classes used in the census process were juvenile (J), sub-adult (SA), and adult (A). The positioning of a reedbuck into an age class was subjective. Any solitary reedbuck were considered to be a sub-adult or adult. Through estimating the average height of the vegetation in an area, the observer was able to estimate the shoulder height of an observed reedbuck. An adult male was taken as having a shoulder height of 90cm, while an adult female was taken as having a shoulder height of 80cm (Skinner & Smithers 1990). Figure 1 was used to position female reedbuck into age classes, noting that adult male reedbuck are larger. A male reedbuck with a horn length greater than 150% the length of its ears was considered to be an adult (Howard 1983) (Figure 2).

Sex Determination

Junguis (1971) reported that horned females have not been observed in southern reedbuck, and thus sex determination was done on the basis of the presence of horns.

Howard (1983) and Venter (1979) reported that horns become visible after 5 - 6 months, and thus juveniles were not sexed.

Results

The two parameters of primary importance were the repeatability and the accuracy of census techniques. Repeatability was assessed using standard error box plots, repeated measures ANOVA and Posthoc Scheffe tests. Basically, a significantly lower standard error was indicative of higher repeatability. For the evaluation of the accuracy of LTC, the highest number of reedbuck counted in the non-sampling census techniques was regarded as the minimum population. This population estimate excluded reedbuck that were within the plantations (50% of the area), flushed before being sighted, lying down or hidden, in areas that could not be viewed from the standardized census route, and missed due to observer error. Howard (1983) estimated that a single count at night gave an estimate of 67-100% of all the reedbuck resident in a study area. Population estimates from the LTC that fell within this control range were considered to be accurate. Further research is required to establish a conversion factor that can be used to correct the population estimate to account for these excluded animals.

Non-sampling census techniques

DFC yielded the lowest minimum population estimate (23) and NHCa yielded the highest (68). NHCa also yielded the highest mean population estimate (57) (Table3; Figure 3). DFC and NHCb yielded the lowest standard deviation (5.64), and therefore, the relative variability of these two counts was less than the NHCa (8.67). The variability of the non-sampling census techniques could have been influenced by the sample size, with the night counts having larger minimum population estimates, and thus a lesser ability to generate variability. There was no significant difference between NHCa and NHCb (RMANOVA, $F(1,5) = 3.42$, $p = 0.124$), however, there was a significant difference between all three non-sampling census techniques (RMANOVA, $F(2,10) = 67.27$, $p < 0.05$). A Posthoc Scheffe test confirmed that the DFC was significantly different from the night counts, but there was no significant difference between the two night counts before and after the first significant frosts. Figure 3 shows that NHCb had a lower standard error and narrower confidence interval than NHCa. NHCb had a higher repeatability, but was not significantly different to NHCa.

The control range based on the minimum population estimate from NHCa was 68 –102 reedbuck. Accurate line transect results would be taken as falling within this range.

DFC yielded the lowest total sex ratio (0.526 males: female), while NHCa and NHCb yielded the same total sex ratio (0.71 males: female). The DFC total sex ratios were based on 28-30% of the number of reedbuck censured in the NHCa and NHCb (Table 4). DFC yielded a maximum sex ratio of 1: 1, while NHCa and NHCb yielded maximum sex ratios of 0.826 males: female and 0.947 males: female respectively (Table 4). NHCa yielded a lower standard deviation (11.77) than the NHCb (22.05), however, there was no significant difference between the sex ratios obtained in the night counts (RMANOVA, $F(1,5) = 0.020$, $p = 0.892$). There was also no significant difference between the sex ratios obtained from all three non-sampling census techniques (RMANOVA, $F(2,10) = 0.768$, $p = 0.927$).

DFC yielded a low proportion of juveniles ranging from 0-18% of the sampled population, exhibiting a bias towards sub-adult females and a poor repeatability in the population structure. NHCa and NHCb yielded population structures with a higher repeatability, but there was a high proportion of unsexed reedbuck in the NHCb (32-44%) (Figure 6).

Sampling census technique: Line Transect Counts (LTC)

The LTC process produced five sets of results based on the three counting and two calculation methods. Stratified and unstratified sampling designs were also tested. Earlier transects consistently obtained higher population density estimates, and thus transects should be walked simultaneously by numerous observers.

Only the wetland/riparian area and firebreak strata yielded maximum perpendicular sighting distances <75m, 72m and 53m respectively (Table 5). No reedbuck were sighted in the firebreak stratum, thus only one stratum had a maximum sighting distance <75m.

The wetland/riparian areas and grassland corridors yielded corresponding population density estimates, while the population density estimates for the areas with associated *P. clandestinum* pastures were approximately half that of the other two strata in which reedbuck were sighted (Table 6). Repeated measures ANOVA and Posthoc Scheffe tests demonstrated significant differences between the population density estimates for the three different strata.

Using the stratified design, only counting method A after the frost using King's method (KMA) and fixed strip width (PDA) yielded population estimates within the control range. Counting method B using mean perpendicular distance (PDB) yielded population estimates between 72 –113 reedbuck above the control range (Table 7; Figure 7). There was a significant difference between the population estimates obtained from the LTC using mean perpendicular sighting distance (PDB) and fixed strip width (PDA and PDC) (RMANOVA, $F(2,14) = 48.84$, $p < 0.05$). Posthoc Scheffe test confirmed the significant difference, except between the two methods using fixed strip width. There was no significant difference in population estimate caused by frost: counting method A using King's method (KMA) (RMANOVA, $F(1,6) = 1.993$, $p = 0.208$), counting method A using fixed strip width (PDA) (RMANOVA, $F(1,6) = 0.527$, $p = 0.495$), counting method B using mean perpendicular distance (PDB) (RMANOVA, $F(1,6) = 2.85$, $p = 0.142$), counting method C using King's method (KMC) (RMANOVA, $F(1,6) = 2.36$, $p = 0.175$), and counting method C with fixed strip width (PDC) (RMANOVA, $F(1,6) = 1.70$, $p = 0.239$). Because of no significant difference in population estimates due to frost only the counting and calculation methods were assessed. Counting methods A and C using fixed strip width yielded the lowest standard deviation, 13.18 and 10.45 respectively (Table 7). Basically, PDC yielded the lowest standard error and narrowest confidence interval, followed by PDA, KMC, and KMA (Figure 7).

A significant difference was found between the results obtained with the stratified and unstratified sampling design, with a significant difference found between all the counting and calculation methods, except counting method B using mean perpendicular distance (PDB) (RMANOVA, $F(1,7) = 1.65$, $p = 0.239411$) and counting method C with a fixed strip width (PDC) (RMANOVA, $F(1,7) = 3.13$, $p = 0.119975$). All of the population estimates using the unstratified design were outside of the control range (Table 8). The standard deviations were consistently lower than those obtained using the stratified design (Table 8). Similar relationships were obtained from repeated measures ANOVA and Posthoc Scheffè tests for the stratified and unstratified LTC population estimates.

The mean sex ratio obtained for the LTC (0.618 males: female) was lower than that obtained in the night counts (0.711 males: female). The standard deviation for the LTC was similar to that obtained in the night counts, and the maximum sex ratio for LTC (0.917 males: female) was similar to that obtained in the night counts (0.947 males: female) (Table 4). There was no significant difference between sex ratios obtained from LTC and the DFC (RMANOVA, $F(1,5) = 0.293$, $p = 0.871$), NHCa (RMANOVA, $F(1,5) = 0.860$, $p = 0.396$) and NHCb (RMANOVA, $F(1,5) = 1.154$, $p = 0.331$).

The population density estimates obtained by the LTC were much higher than those obtained by Howard (1983) due to being based on identified reedbuck habitat and not the entire area (Table 9). Howard (1983) estimated a population density of 0.076 reedbuck/ha for the entire area of a 10500 ha complex of semi-intensive farms in the Underberg district. When related to the entire area of Mount Shannon the mean population density was 0.01387 reedbuck/ha.

Discussion

Historical game count records (Table 1) are not a reflection of the population size or status, because of the lack of standardization, poor repeatability and the dated nature of the data. At present, reedbuck on forestry lands are counted using non-sampling night drive counts between the 21st of May and the 17th of July. The lack of standardization of census techniques, observers, time of year, census route and the absence of a census database, contributed to the poor performance of historical game counts. The historical game counts did, however, produce similar results to those obtained in this study.

Dawn counts performed very poorly with very few reedbuck being sighted. Reedbuck are crepuscular (Junguis 1971; Venter 1979; Howard 1983), and thus should be active at dawn. Factors such as vehicle disturbance, seasonal changes in reedbuck behaviour, site-specific reedbuck behaviour, weather and visibility, the close proximity of cover provided by plantations, and/or management practices (e.g. livestock grazing) may have influenced the DFC population estimates. It was observed during the DFC and LTC that reedbuck avoided areas in which livestock were grazing or moving through. If the above factors were insignificant, this study would indicate that reedbuck on forestry lands in the Drakensberg/KwaZulu-Natal Midlands are more nocturnal than crepuscular over this period. Weather conditions influenced the population estimates obtained from the DFC, in that cold conditions with poor visibility (caused by low mist) resulted in fewer sightings. The DFC proved to have little value for future application to reedbuck populations at this time of year in the Drakensberg/KwaZulu-Natal Midlands.

Night counts were influenced by weather conditions and visibility, large sighting distances, vehicle disturbance, and management practices that altered spatial distribution (e.g. autumn burns). The non-sampling counts had the objective of finding a method and conditions (e.g. morning or evening) whereby the highest number of reedbuck could be sighted without repetition. Repetition was avoided as far as possible, but the probability of it happening in all the counts was equal. Regardless of constant error or bias, NHCa yielded the highest total of sighted reedbuck. Basically, NHCa performed the best as there was no significant difference due to frost and the NHCa obtained the highest mean population estimate. However, the NHCb had a lower standard deviation than the NHCa , and thus had a higher repeatability. Due to the high repeatability and ease of application, night counts prior to the hunting season (regardless of the first frosts) provide a useful estimate of minimum population size and control range for monitoring reedbuck abundance on forestry lands in the Drakensberg/KwaZulu-Natal Midlands. Howard (1983) noticed a change in spatial distribution after the first significant frosts because of an increased dependence on winter pastures on agricultural lands. Possibly due to the absence of winter pastures on forestry lands (unlike on agricultural lands), this study found that spatial distribution and cohesive behaviour was not influenced by the first significant frosts in May. These findings were supported by those obtained from the LTC.

Our study did not assess the repeatability of the actual number of reedbuck counted in each transect, but rather the repeatability of the different line transect counting and calculating methods. Therefore, this study was an exercise in matching reedbuck ecology, site characteristics, cohesive behaviour, etc. to the appropriate counting and calculation methods at the optimum time.

Stratification was necessary as the population density estimates from the three LTC strata were significantly different. The firebreak stratum is no longer considered as reedbuck habitat for LTC, because of no sightings in this stratum, lack of cover, and the close proximity of the plantations to the transect line. Only the grassland strata had a maximum perpendicular sighting distance of >75m, and thus the maximum perpendicular sighting distance should be standardized to 75m (regardless of the mean visibility index for each stratum) (Table 5). The results from the LTC confirmed the significant inherent variability of strip counts when based on small sample sizes and narrow and variable strip widths (Bothma *et al.* 1990). All of the LTC obtained Z <40, thus reducing the accuracy of the census results due to the sample being too small (Anderson, Laake, Crain & Burnham 1979; Knott & Venter 1990). Anderson *et al.* (1979) and Knott & Venter (1990) found that in line transects the accuracy was reduced when the total number of animals sampled in transects is below 40. With larger estates this problem can be avoided, but can be considered to be significant as forestry estates irrespective of size have variable reedbuck habitat, habitat quality and reedbuck population densities, and thus a larger estate may not necessarily have a larger reedbuck population and avoid this problem.

The unstratified LTC results over-estimated the population due to the over-estimation of the population density in the areas with associated *P. clandestinum* pastures. The advantages of stratification (e.g. robust to changes in vegetation physiognomy) far exceed the relative simplicity of the unstratified design.

The main problems encountered in LTC included defining the straight line of travel, obtaining accurate measurements of sighting distance and angles, ensuring that all animals on or close to the transect line are seen with certainty, and minimising the difference in time between first and last census with two observers. The use of a Garmin GPS12, compass model and rangefinder minimised the first two problems, but reedbuck hiding and lying down behaviour meant that some reedbuck might not have been sighted.

There were no significant differences caused by frost observed in the stratified LTC, and thus only the combinations of the three counting and two calculations methods were assessed. Counting method A, using fixed strip width (PDA), performed best, yielding the only population estimate within the control range and the second lowest standard error (Figure 7). Counting method A involved counting only reedbuck within the fixed strip width, and thus the population estimate was calculated to include the entire sampled area within the fixed strip. All reedbuck within 75m of the observer are expected to be flushed, thus (in the absence of sampling error) giving an accurate estimate of the population density in that stratum. Modified strip transects based on King's method and mean perpendicular sighting distance under-estimated the sample area, and thus over-estimated population density. Calculated with the mean perpendicular sighting distance the modified strip became too narrow, resulting in a mean population estimate 92 reedbuck above the control range. Counting method C involved counting all reedbuck sighted (ignoring the fixed strip width), and thus calculations based on fixed strip width were over-estimated. Basically, modified strip transects are based on models that are statistically invalid (Collinson 1982). As a result of these inadequacies, and reedbuck hiding behaviour, the LTC exclusively counting reedbuck within a fixed strip width and calculated using the fixed strip width (PDA) performed the best. This LTC is most suited to monitor reedbuck abundance on forestry estates in the Drakensberg/KwaZulu-Natal Midlands. PDA would still require the measurement of sighting distance and angle, and thus observer and instrument error will not be reduced, but its influence on the repeatability of the calculations will be minimised.

According to the population structure, the DFC failed to census juvenile reedbuck effectively or there were no juvenile reedbuck present. Juveniles are difficult to census because of hiding behaviour, and there was a bias to sub-adult females. Bias to sub-adult females could have been due to the difficulty in differentiating between adult and sub-adult female reedbuck. Poor repeatability of the DFC was due to the comparatively small sample sizes. NHCa performed the best with the lowest relative variability and an acceptable proportion of unsexed animals. The NHCb yielded a high proportion of unsexed animals (32-44%), due to poor visibility and weather conditions, long sighting distances and increased incidence of reedbuck lying down. The positioning of reedbuck into age/sex classes did not hinder the non-sampling census process, and thus should be included in night counts. The LTC did include population structure as an output due to the low number of reedbuck counted in each census.

The sex ratio was assumed to approximate 1: 1. Venter (1979) found a foetal sex ratio of 12 males: 13 females (0.92 males: female), which did not differ significantly from the expected 1: 1 ratio. However, the field age and sex classifications were significantly different from a 1: 1 sex ratio ($P<0.001$) (Venter 1979). The sex ratios obtained from all the census techniques exhibited a bias to females, with the number of males in the DFC only accounting for 34% (Table 4). Sexing reedbuck within the LTC had the least expected observer error (due to short sighting distances) and inaccuracies that arise from factors such as weather and visibility, animal behaviour and vegetation condition. Night counts, however, obtained the highest mean sex ratios, lowest standard error, and highest sex ratio (0.947 males/female). The night counts may have performed better due to reduced sampling error, in that the night count estimates were based on more sightings. LTC and night counts had sex ratio estimates close to the expected ratio with high repeatability, and thus the sexing of reedbuck should be included in these census techniques.

The low proportion of male reedbuck may have been due to bias to female reedbuck (not likely as males are more conspicuous), hunting off-take impacting negatively on the male population (e.g. excessive trophy hunting), high male mortality (i.e. sex specific mortality) due to intraspecific competition, observer bias, sampling error, and/or weather conditions and visibility.

Population density estimates within a broken landscape (e.g. forestry and agricultural lands), unless based on line transect data, are not useful for comparison owing to the difficulty of defining the sample area. This is apparent in the differences observed in the population density estimates obtained from LTC (unstratified), those adjusted to the entire study site, and results obtained by Howard (1983). LTC yielded repeatable population density estimates for identified reedbuck habitat, providing data that can be used to monitor reedbuck population dynamics on and between forestry lands, agricultural lands, protected areas and other land uses.

This study was inconclusive as regards the timing of the prescribed census techniques. First significant frosts had no significant impact on the population estimates and sex ratios. Although, assessing the standard error and relative variability of the census techniques indicated that night counts before the first significant frost and LTC after the first significant frosts performed the best on forestry lands in the Drakensberg/KwaZulu-Natal Midlands. Therefore, for the purposes of standardisation April should be prescribed for night counts, and May after the first significant frosts for LTC.

Conclusion

Despite the preliminary nature of this study, night counts before the first significant frosts (NHCa) counted the most reedbuck with good repeatability and yielded the best population structure, and LTC after the first significant frosts including only animals within the fixed strip width using fixed strip width obtained the most accurate and repeatable population estimates. This study prescribes LTC after the first significant frosts using a fixed strip width of 75m for forestry lands in the Drakensberg/KwaZulu-Natal Midlands, as this method obtained population estimates close to the inferred population size with a comparatively high repeatability. LTC yield population density estimates based on known sample area, and thus through regional application could develop reedbuck habitat standards on forestry lands. The strict standardisation of each census is essential from year to year.

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Table 1. Mount Shannon historical reedbuck count records

Year	Game count result
1989	71
1990	74
1991	74
1992	72
1993	41
1994	39
1995	48

Table 2. Habitat types identified for stratification of census areas on forestry lands

Habitat types	
Included	Excluded
1. Low woody cover*	1. Pine plantation (>2 years)
2. Wetland/riparian areas*	2. Flat open terrain
3. Grassland corridors*	3. Eucalyptus plantation
4. Firebreak	4. Areas around human development
5. Areas with *Pennisetum clandestinum* pastures	5. Harvested areas
6. Pine plantation (0-2 years)	6. Steep terrain & wooded areas

* Primary reedbuck habitat

Table 3. Analysis of population estimates for non-sampling census techniques

Census technique	n	s^2	s	x	Max
DFC	6	31.77	5.64	15.83	23
NHCa	6	75.2	8.67	57	68
NHCb	6	31.77	5.64	52.17	61
NHC_{TOTAL}	12	54.99	7.42	54.58	68

Table 4. Analysis of sex ratios for non-sampling census techniques

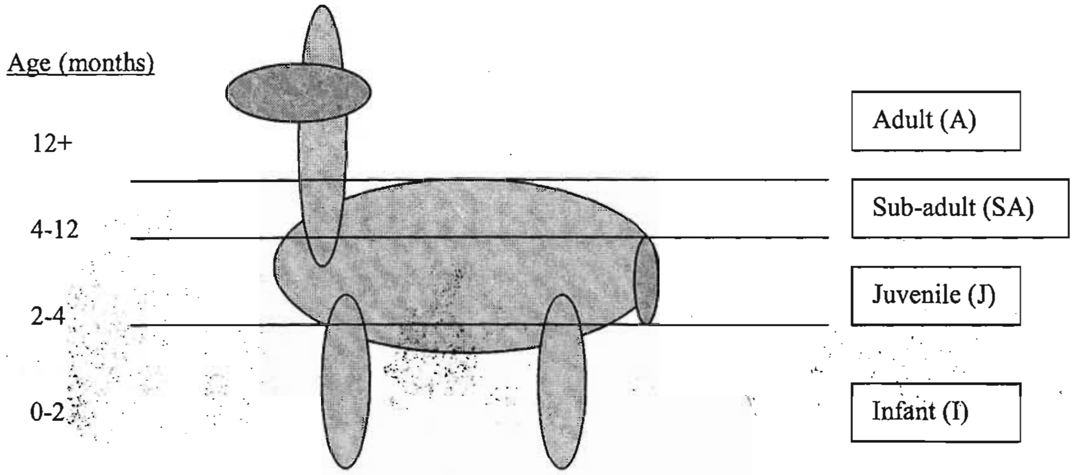
Census technique	n	Max	s	x	Total Sex Ratio	Total Sampled
		(males/100 females)			(males/100 females)	
LTC	8	91.66	18.24	61.88	61.11	247
DFC	6	100	36.45	66.42	52.6	95
NHCa	6	82.6	11.77	70.34	70.9	342
NHCb	6	94.74	22.05	71.95	70.8	313
NHC_{TOTAL}	12	94.74	16.87	71.14	70.9	655

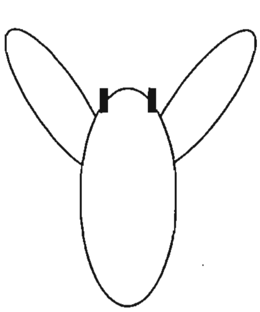
Table 5. Fixed strip width and mean visibility indices (MVI) for each stratum

Stratum	MVI (m)	Max. perp. sighting distance	Fixed strip width (m)
Wetland/riparian areas	72	72	144
With associated *Pennisetum clandestinum* pastures	78	75	150
Firebreaks	53	53	106
Grassland corridors	81	75	150

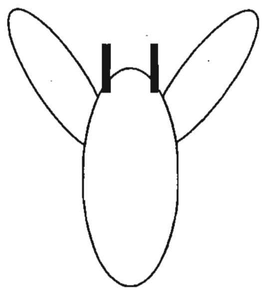
Table 6. Population density estimates for each stratum in LTC

Stratum	Method	n	Calculation method	
			King's method (animals/hectare)	Perpendicular distance (animals/hectare)
Wetland/riparian areas	A	8	0.245	0.226
	B	8	-	0.405
	C	8	0.246	0.275
Grassland corridor	A	8	0.278	0.250
	B	8	-	0.526
	C	8	0.300	0.297
Areas with associated kikuju Pastures	A	8	0.114	0.117
	B	8	-	0.205
	C	8	0.117	0.125
Firebreaks	A	8	0	0
	B	8	-	0
	C	8	0	0

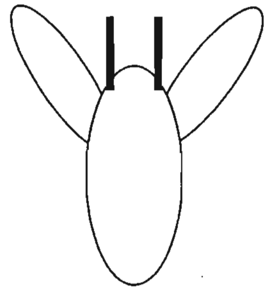

Age (months)
12+
4-12
2-4
0-2
Adult (A)
Sub-adult (SA)
Juvenile (J)
Infant (I)



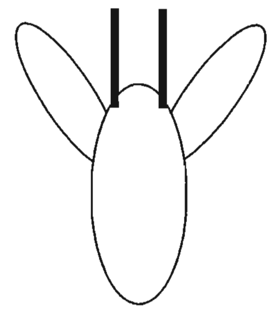
Horn length
(relative to ears):
¼ J
Age (months):
6-9



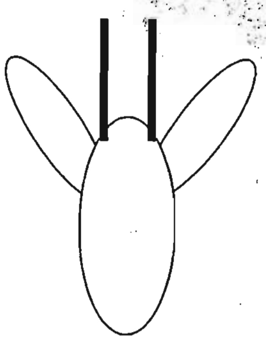
Horn length
(relative to ears):
½ SA
Age (months):
9-12



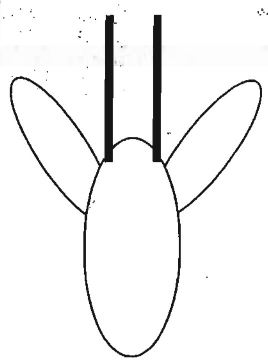
Horn length
(relative to ears):
¾ SA
Age (months):
12-15



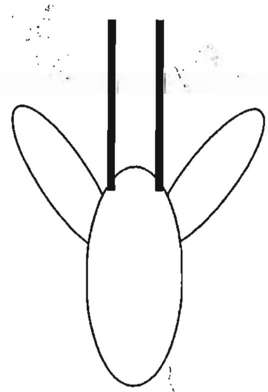
Horn length
(relative to ears):
1 SA
Age (months):
15-18



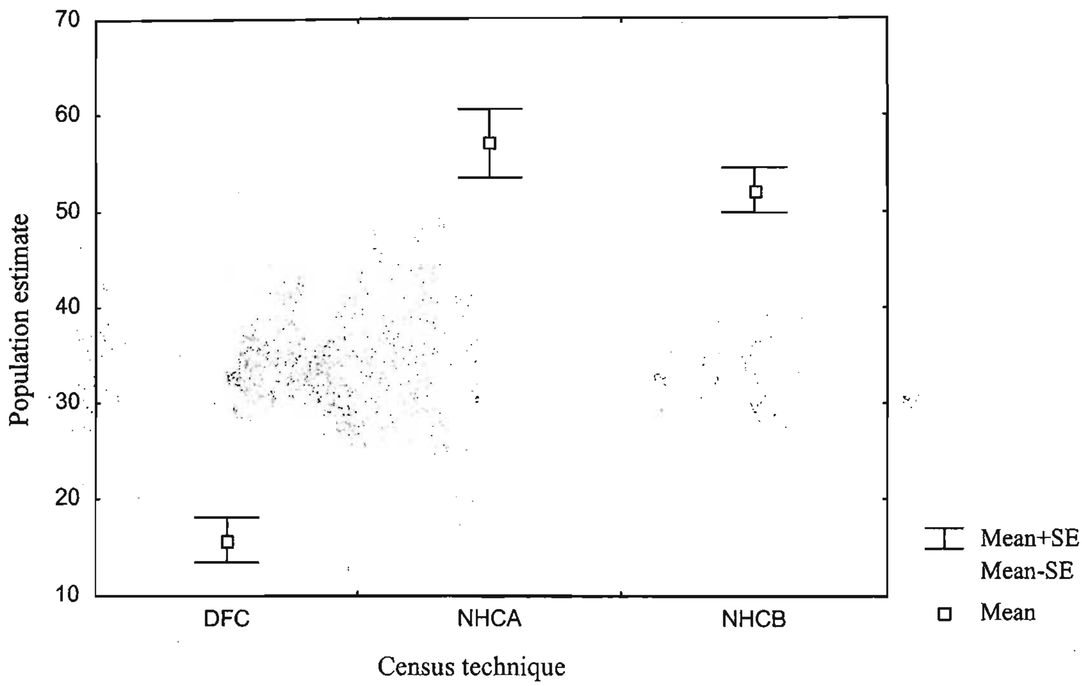
Horn length
(relative to ears):
1 ¼ SA
Age (months):
18-24

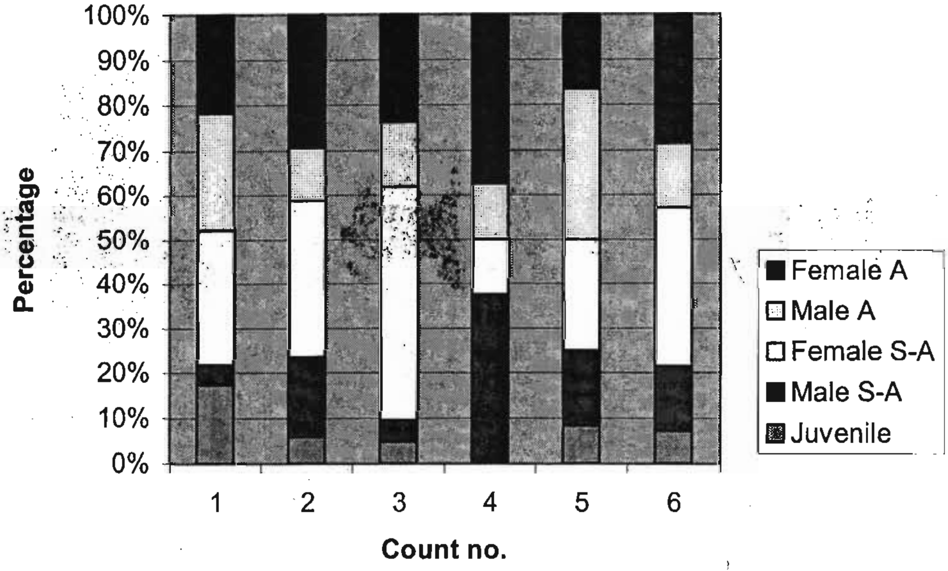


Horn length
(relative to ears):
1 ½ SA
Age (months):
24-36

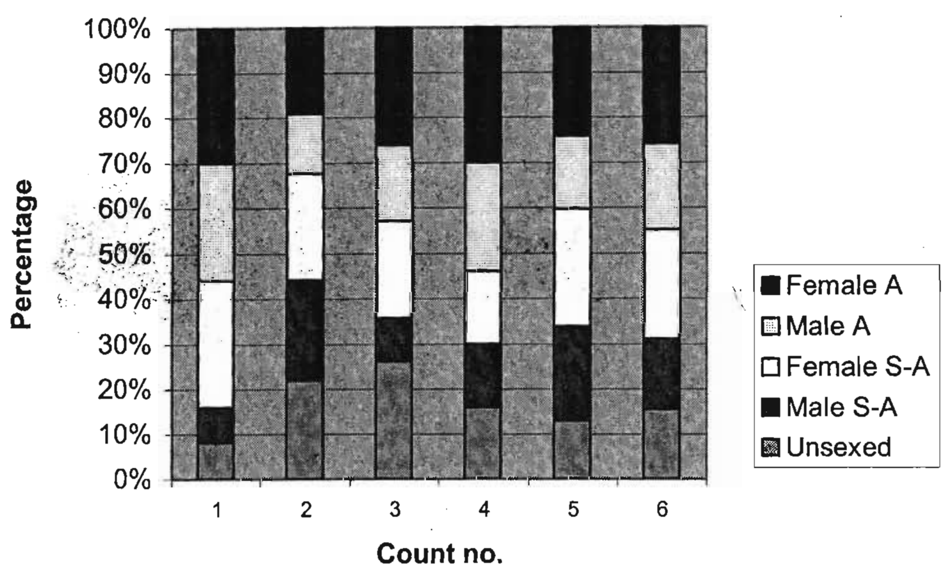


Horn length
(relative to ears):
>1 ½ A
Age (months):
36+


70
60
50
40
30
20
10
Population estimate
DFC
NHCA
NHCB
Census technique
Mean+SE
Mean-SE
Mean



100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Percentage
1
2
3
4
5
6
Count no.
Female A
Male A
Female S-A
Male S-A
Juvenile


100%
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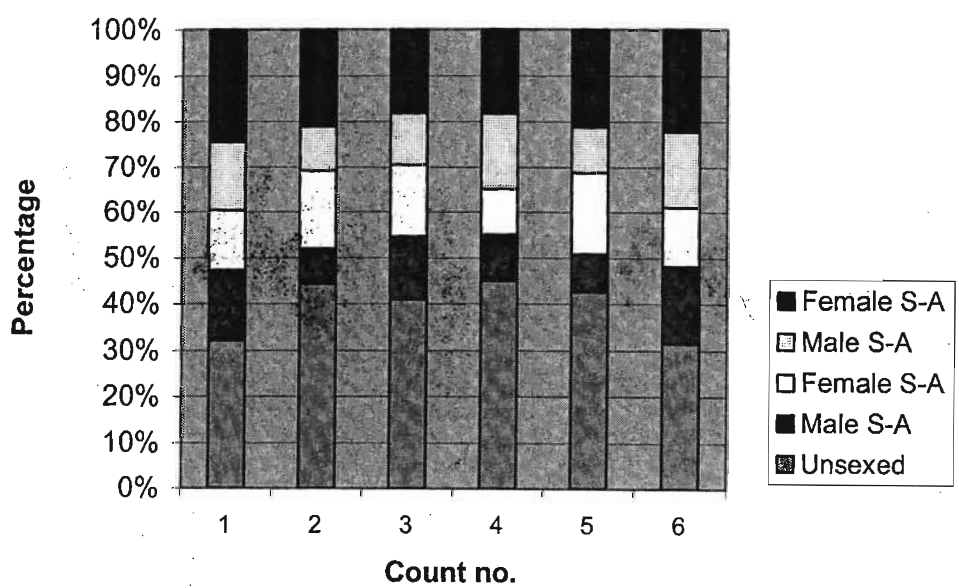
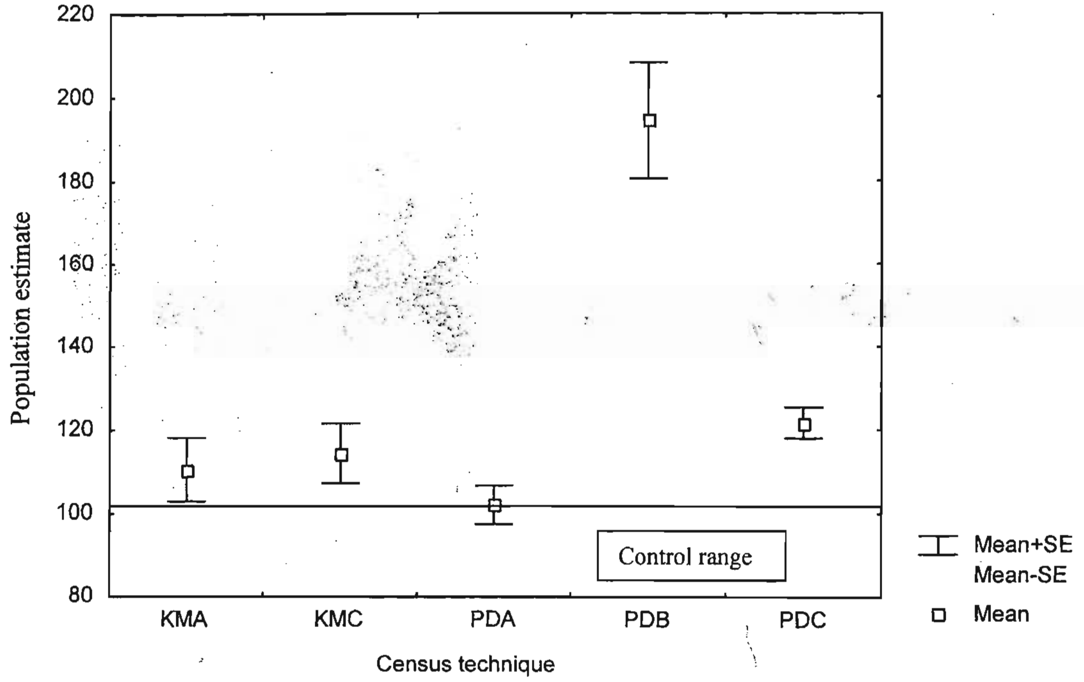
20%
10%
0%
Percentage
1
2
3
4
5
6
Count no.
Female A
Male A
Female S-A
Male S-A
Unsexed



100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Percentage
1
2
3
4
5
6
Count no.
Female S-A
Male S-A
Female S-A
Male S-A
Unsexed


220
200
180
160
140
120
100
80
Population estimate
KMA
KMC
PDA
PDB
PDC
Census technique
Control range
Mean+SE
Mean-SE
Mean

Figures

KMA = King's method (Method A); KMC = King's method (Method C);

PDA = Fixed strip width (Method A); PDB = Mean perpendicular distance (Method B); PDC = Fixed strip width (Method C).