An analysis of a recreational hunter's red deer tallies in the Tararua Ranges, North Island, New Zealand

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Abstract: We examined the jaw size, age and sex distribution of 324 red deer constituting a comprehensive record of all recreational hunting kills made by a single hunter of the Tararua ranges of North Island New Zealand over a period 20 years (1976-1996). The proportion of stags shot at times other than the rut (March - April) was not significantly different to that in a sample of deer obtained by commercial helicopter hunting and did not change significantly after the first three years of hunting regardless of any effect of helicopter hunting. Conversely, significantly greater numbers of males were shot during the months of the rut and this proportion increased significantly after the first three years of hunting presumably as a result of increased selectivity and or skill. The recreational hunter harvested significantly greater numbers of older animals than did helicopter hunters. The proportion of older animals shot during, and at times other than the rut, increased significantly after the first three years of hunting. Analysis of jaw length versus age showed a significant increase in the jaw size of age cohorts born after 1976 i. e. after an increase in culling effort and was indicative of a general decline in population density during the period of the study.

Keywords: Red deer; *Cervus elaphus*; hunting tallies; jaw length index; cementum age; sex ratio; Tararua Ranges; New Zealand.

Introduction

The red deer introduced into New Zealand from 1850 to 1940 (Wodzicki, 1950) are regarded as a threat to conservation values (King, 1990) by their effect in modifying forest composition and structure (Veblen and Stewart, 1982; Wardle, 1984) but they are also valued as a sporting asset (Cole, 1998). Whilst recreational hunting may be ineffective in controlling deer populations in extensive remote areas with high deer densities (Smith, 1974; Nugent *et al*, 1987) it has been shown to be effective in controlling deer numbers in small recreational hunting areas that are close to urban areas (Nugent, 1988). Managers seeking to maintain acceptable deer population densities with a combination of recreational hunting and commercial helicopter recovery operations require specific information regarding the demographic impact of the two hunting regimes as well as any tendency for this to vary with population density and level of hunter experience.

The breeding capacity and annual productivity of deer herds may be modified by manipulation of the ratio of hinds to stags in the annual harvest (McCulloch, 1984; Buckland *et al.,* 1996). New Zealand hunters have long been aware of the effectiveness of a strategy of refraining from shooting hinds in enhancing the survival potential of herds (Henderson, 1971) but the extent to which such practices influence general hunting patterns is unknown. Short term voluntary restriction by hunters in the hunting of hinds in response to a known decline in a local herd has been recorded in the USA (McCulloch, 1984). Conversely, it has been suggested (Nelson, 1969) that a significant number of hunters are satisfied with harvesting any kind of deer particularly when trophy heads are not a prospect (Mohler and Toweill, 1982). Long term trends of the extent to which a hunter elects to shoot mainly stags in a period when there is a sustained significant reduction of population numbers (Nugent and Fraser, 1993) have not been studied.

A comprehensive hunting record and collection of lower jaws from all deer killed by a single hunter over a twenty year period was used to search for demographic trends that may be of importance in the long term management of deer populations. We compared sex, age and sex ratios with those obtained in commercial helicopter based hunting operations and by recreational hunters in adjacent and other areas. We also investigated long term trends in nutritional status as indicated by jaw length.

Methods

Description of site and hunting history

The Tararua Forest Park comprises an area of 116,535 ha of very rugged terrain extending from sea level to an altitude of 1571 m with areas of lowland tawa and kamahi forest, upland mixed podocarp/beech forest, subalpine beech forest and alpine tussock grasslands. The area has been administered as a Forest Park since 1954 (Department of Conservation, 1996).

Red deer were liberated at various locations in the early 1900s (Wodzicki, 1950). Owing to concern about the effect of deer numbers on vegetation and erosion within the Park (Kelton, 1983) the New Zealand Forest Service commenced restricted culling operations in 1930. Annual culling effort as judged by cull returns steadily increased, peaking in 1976 (P. Brady, Department of Conservation, Wellington, N.Z., *pers. comm.*), the year immediately prior to the commencement of extensive commercial helicopter venison recovery operations within the park (Kelton, 1983).

Description of recreational hunting record

The hunting record commenced in late 1976 when the hunter was aged 17 and continued until 1996. The hunting style was exploratory with infrequent visits to the same area. Hunting effort was thus distributed over large areas of the western and the eastern ranges. Hunting was both for trophies and for venison. During the rut there was emphasis on stag hunting but at other times any animal encountered was harvested. Larger bodied animals were favoured when quarry were encountered in groups. Hunting trips took place mainly during weekends. Hunting effort was consistent throughout the year averaging one trip per 3-4 weeks with a total of 313 trips.

Decription of commercial hunting

No recent sex ratio or age class data were available for commercial helicopter recovery operations in the Tararua ranges during times when no live capture operations were being undertaken. Consequently we compared sex ratios and age classes in the hunter's record with data obtained from commercial red deer helicopter recovery operations that were conducted in the adjacent Ruahine Forest Park during 1990 -1992 (Figures kindly provided by Department of Conservation Regional Office, Napier, N. Z.), and in Puroera Conservation Park during 1989-1993 (Fraser 1996) (Tables 1, 4 and 6). Commercial operations took place in spring in the Pureora Conservation park and in winter in the Ruahine Forest Park. The Ruahine ranges are of similar elevation to the Tararuas, contain areas of lowland tawa-kamahi forest, upland montaine podocarp-beech, subalpine beech and alpine tussock grasslands and abut the northern edge of the Tararuas at the Manawatu gorge. The Pureora Forest Park ranges from 300-1165m in altitude and is mainly podocarp hardwood forest with pepperwood at higher altitudes (Nugent *et al.,* 1997).

Jaw length and aging

Jawbones were cleaned of flesh and air dried before measurement. The 'tip to hinge' distance from the anterior limit of the alveolus of the first lower incisor to the rear limit of the hinge was measured (± 0.5 mm) using the technique described by Fraser and Sweetapple (1993). The first and second molar teeth were then extracted from the air-dried jaws with pliers, sectioned, and aged by cementum line analysis (Fraser and Sweetapple, 1993). When animals were less than six months old and the first molar absent, age was estimated from tooth eruption sequence (Fraser and Sweetapple, 1993).

Statistics

Cohort year was calculated as year of death minus age, and two cohort groups were classified as prior to or during and after 1976 , the year of maximal goverment culling effort and year preceeding the commencement of commercial helicopter recovery operations. Animals were also classified according to whether they were shot prior to or following 1980 i.e. after the hunter had been hunting for more than or less than three years. Animals shot during March and April were classified as shot during the rut. Animals were also classified according to site where shot i.e. east or west of the main divide.

Mann-Whitney U tests for the effect of cohort year and for the differences after the first three years of hunting were conducted on pooled proportional residuals from animals of both sexes of selected age in SYSTAT (Wilkinson, 1990).

Chi-square tests were carried out for the effect of 'rut' on the sex of animal recovered and for the effect of 'first three years of hunting' i. e. 1976-1980 versus 1981-1996, on gender, size, age class and rut in SYSTAT (Wilkinson, 1990). . Animals were classified into age groups < 1, 1, 2-4 and >4 yrs. for the purposes of comparing the age distributions of the hunter's kills with those obtained in helicopter culls. Chi-square and related tests were also carried out for the effect of 'type of hunting' i.e. commercial versus recreational hunting, on gender and age in SYSTAT (Wilkinson, 1990).

There was insufficient data to enable fitting of reparametrised Richards curves (White and Brisbin, 1980; Brisbin *et al*., 1987). We therefore fitted a variety of empirical non-linear models (Frampton and Nugent, 1992). Plots of age versus jaw length were smoothed using the LOWESS non parametric method (Cleveland, 1981) and the age at which the curve intersected with a straight line (the asymptote) was determined. Exponential curves were fitted independently to data from animals of each sex and of age less than that at the asymptote using NLIN in SYSTAT (Wilkinson, 1990). Proportional residuals (observed/expected) were calculated from the residuals of the best fitting exponential models using the method of Frampton and Nugent (1992). Plots of the proportional residuals against age were then assessed for uniformity by eye and by use of the LOWESS smoothing function (Cleveland, 1981).

Results

During the period 1976-1996 the hunter shot a total of 324 deer of which 94 (29 %) were shot during the rut.

Sex ratio of hunter harvest

The overall proportion of stags in the recreational hunter's harvest was 55.8 %. The overall percentage of stags harvested during the rut (64.9 %) was significantly higher (Pearson Chi-square = 5.3, d.f. = 1, P = 0.021) than the proportion of stags harvested at other times (50.9 %) (Table 1). Results of comparisons of the overall sex ratio in the hunter's harvest with that of the Pureora red deer study (Fraser, 1996) and that of a recent study of recreational sika deer hunters in the Kaimanawas (Fraser and Speedy, 1997) are shown in Table 2. Whilst the total number of animals shot decreased in successive decades, the overall proportion of stags that were killed was significantly higher in the 1981-1996 than in the 1976-1980 period (Table 3). Moreover, separate analyses of animals killed during the rut and those killed at other times (Table 3) showed that this was due to a very significant increase in the proportion of stags harvested during the rut in the 1981-1996 period, with no significant difference in the proportion of stags harvested in the non-rutting period

Table 1. The effect of the rut on the proportion of sex of deer recovered (row percentages)[1].

	Female	Male	Total	N
non-rut	49.1	50.9	100	230
rut	35.1	64.9	100	94
Total	45.1	54.9		
N	146	178		324

[1]Pearson Chi-square = 5.30, d.f. = 1, P = 0. 021

Table 2. Comparison of overall hunter's harvest with that of other recent studies (row percentages)[1].

	Female	Male	Total	N
This study	45.0	54.9	100	324
Pureora study[2]	44.3	55.7	100	4867
Kaimanawa study[3]	45.4	54.6	100	1937
N	3184	3944		7128

[1]Pearson Chi-square = 0.69, d.f. = 2, P = 0.708
[2]Fraser (1996)
[3]Fraser and Speedy (1997)

Table 3. The effect of the first three years of hunting on proportion of sex of deer recovered (row percentages)[1].

Data	Experience	Female	Male	Total	N
Overall[2]	<3 yr	50.8	49.2	100	191
	>3 yr	28.2	71.8	100	133
	Total	45.1	54.9		
	N	146	178		324
Non-rut[3]	<3 yr	51.4	48.6	100	144
	>3 yr	33.3	66.7	100	86
	Total	47.1	50.9		
	N	113	117		230
Rut[4]	<3 yr	48.9	51.1	100	47
	>3 yr	21.3	78.7	100	47
	Total	35.1	64.9		
	N	33	61		94

[1]Comparison between rut and non rut: Mantel Haenzel Chi-square = 7.89 P = 0.005.
[2]Pearson Chi-square = 6.15, d.f. = 1, P = 0.013.
[3]Pearson Chi-square = 0.786, d.f. = 1, P = 0.375.
[4]Pearson Chi-square = 7.89, d.f. = 1, P = 0.005.

in the 1981-1996 period. Thus the rut had a very significant influence (Mantel Haensel Chi-square = 7.89, P = 0.005) on the relative proportions of males harvested in the two time periods.

The sex ratio of animals harvested at times other than the rut was not significantly different from commercial operations in the Ruahine Forest Park (Pearson Chi-square = 1.36, d.f. = 1, P = 0.244) (Table 4) and in the Pureora Conservation Park (Fraser, 1996) (Pearson Chi-square = 0.072, d.f. = 1, P = 0.788) (Table 4).

Table 4. Effect of recreational versus helicopter hunting on sex ratio of deer recovered excluding animals obtained during the rut (row percentages)[1].

Comparison	Site	Female	Male	Total	N
Ruahine vs. Tararua[2]	Ruahine	54.2	45.8	100	310
	Tararua	49.1	50.9	100	230
	Total	52.0	48.0		
	N	281	259		540
Pureora vs. Tararua[3]	Ruahine	50.2	49.8	100	514
	Tararua	49.1	50.9	100	230
	Total	49.9	50.1		
	N	371	373		744

[1]Ruahine Forest Park helicopter recovery is for the period 1990-1992 and Pureora Conservation Park helicopter recovery data is as for Fraser (1996).
[2]Comparison with Ruahine commercial figures. Pearson Chi-square = 1.36, d.f. = 1, P = 0,224.
[3]Comparison with Pureora commercial figures. Pearson Chi-square = 0.072, d.f. = 1, P = 0.788.

Table 5. The effect of the first three years of hunting on age classes of deer recovered (row percentages).

Data	Experience	<2 yr old	2-4 yr old	>4 yr old	Total	N
Overall[1]	<3 yr	39.3	12.0	48.7	100	191
	>3 yr	25.6	24.0	50.4	100	133
	Total	33.6	17.0	49.4		
	N	109	55	160		324
Non-rut[2]	<3 yr	39.6	13.2	47.2	100	144
	>3 yr	31.4	27.9	40.7	100	86
	Total	36.5	18.7	40.7		
	N	84	43	103		230
Rut[3]	<3 yr	38.3	61.7		100	47
	>3 yr	14.9	85.1		100	47
	Total	26.6	73.4			
	N	25	69			94

[1]Pearson Chi-square = 11.09, d.f. = 2, P = 0.004.
[2]Pearson Chi-square = 7.73, d.f. = 2, P = 0.021.
[3]Pearson Chi-square = 6.59, d.f. = 1, P = 0.01.

Age distribution of hunter harvest

The percentage of adults was significantly higher in the 1981-1996 than the 1976-1980 period (Chi square = 11.09, d.f. = 2, P = 0.004)(Table 5). The proportion of older animals that were killed during the rut was similarly significantly different between the two periods (Chi square = 6.59, d.f. = 1, P = 0.01) as was the proportion of older animals that were killed at times other than the rut during the two periods (Chi square = 6.59, d.f. = 2, P = 0.01) (Table 5).

Comparison of the age class distribution of the overall Ruahine helicopter cull with that of the recreational hunter's data set by Chi-square analysis showed no significant differences between the three younger age classes (Chi square = 1.051, d.f. = 1, P = 0.591) (Table 6) but highly significant differences when animals older than four yrs were included (Chi square = 47.4, d.f. = 1, P < 0.0001). This difference persisted when animals taken in the rut were excluded, (Table 6) (Chi square = 31.8, 1 *d.f.* P <0.0001), but was not significant when the comparison was limited to the three youngest age classes (Chi square = 1.181, d.f. = 1, P = 0.554).

Jaw measurements

Smoothing of jaw measurement curves gave distinctive curves for stags and for hinds with both curves reaching an asymptote at about 8 years of age (Fig 1). The best fit for jaw length curves of either sex was obtained with a cubic polynomial of log transformed age (Table 7) that included only animals aged less than 8.2 yrs. Plots of proportional residuals versus age for deer of both sexes aged between one years and seven years showed a random scatter of data points about the mean of 1.0 and a LOWESS function that was close to horizontal (Fig 2).

Table 6. Comparison of age classes of red deer recovered by recreational hunter[1] and by commercial helicopter recovery[2].

Animals	Site	<1 yr	1 yr	2-3 yr	4 yr and over	Total	N
All[3]	Ruahines	84	80	80	58	100	302
	Tararuas	49	60	55	160	100	324
	N	133	140	135	193		626
Excluding rut[4]	Ruahines	84	80	80	58	100	302
	Tararuas	37	47	43	103	100	230
	N	121	127	123	161		532

[1]Animals shot by a single hunter in the Tararua Ranges during the period 1976-1996.
[2]Animals shot by commercial helicopter in the Ruahine Ranges during the period.1990-1992 (data kindly supplied by Department of Conservation, Hawkes Bay Regional Office).
[3]All age classes. Pearson Chi-square = 63.7, d.f. = 3, P<0.001.
[4]Excluding animals shot during the rut. Pearson Chi-square = 41.6, d.f. = 3, P<0.001.

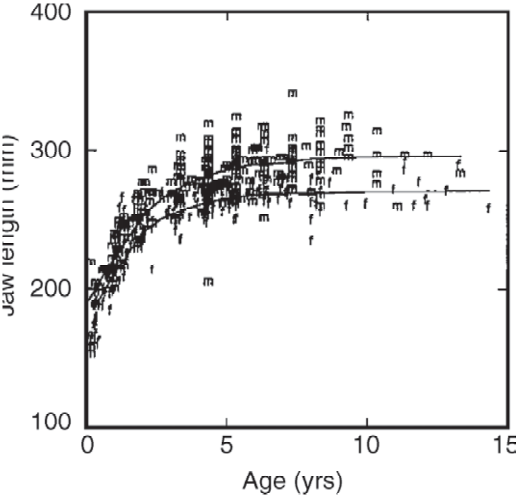

Figure 1. Plots obtained by LOWESS smoothing of male (upper curve) and of female (lower curve) Tararua red deer heel to hinge jaw lengths versus age determined by cementum line analysis. m = male; f = female.

Table 7. Determinants of polynomial regression of jaw length as a dependant variable of a cubic polynomial on log converted age (in years) with age restricted to below 8.2 years.

Gender	Expression	R^2
Female	$y = 217.149 + 2.184 (\log_e age) + 4.260 (\log_e age)^2 + 6.335 (\log_e age)^3$	0.850
Stags	$y = 227.473 + 2.511 (\log_e age) + 4.683 (\log_e age)^2 + 7.125 (\log_e age)^3$	0.874

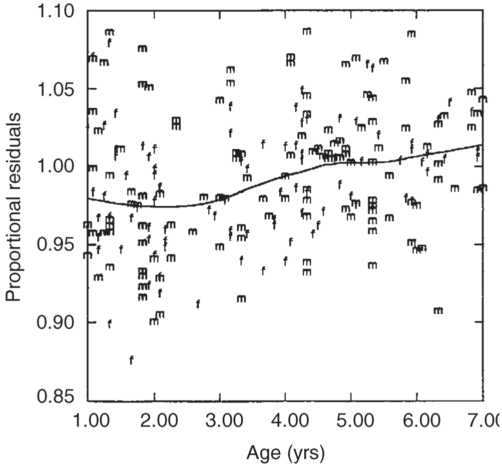

Figure 2. Proportional residuals from growth curve estimates plotted against age as determined by cementum line of red deer shot by a recreational hunter in the Tararua ranges during the period 1976-1996 showing the line obtained by LOWESS smoothing of the data points. m = male; f = female.

Table 8. Analysis of Variance for effect of year of birth on standard residuals from cubic polynomial curve fitting of the lengths of lower jaws of red deer[1] shot in the Tararua Ranges of North Island New Zealand in the period 1976 –1996[2].

Source	d.f.	F-ratio	*P*
Peak cull (C)[3]	1,221	15.751	<0.0001
Gender (G)	1,221	3.235	0.073
Site (S)[4]	1,221	0.435	0.510
C x G	1,221	1.279	0.259
C x S	1,221	0.000	0.989
S x G	1,221	1.793	0.182
C x S x G	1,221	0.001	0.970

[1]Curve fitted to jaw lengths of animals aged less than eight years and analysis restricted to deer aged between one and seven years.
[2]Lillifors test for normality of residuals P = 0.291.
[3]P = year of birth prior to 1976, the year of peak N.Z.F.S. culling effort.
[4]S = site where shot, east or west of the main divide.

Table 9. Comparison of sex ratios of harvests obtained in recent recreational and in commercial (helicopter) hunting studies.

	Stags	Hinds
This study (overall)	178	146
This study (excluding rut)	117	113
Ruahine commercial (excludes rut)[1]	168	142
Pureora (overall recreational)[2]	1122	882
Pureora commercial (Spring)	258	256

[1]Ruahine 1992 figures kindly provided by Department of Conservation Regional Office;
[2]Pureora figures from Fraser (1996).

An ANOVA (Table 8) of the bulked proportional residuals from deer of both sexes aged between one and seven years for the effect of 'cohort group' showed a significant overall increase in jaw size (F= 15.75, d.f. = 1,221, P = <0.0001) in cohorts born during or after 1976, a gender effect of borderline significance (F = 3.2, d.f. = 1,221, P = 0.073) indicating that the effect of gender was not completely eliminated by the choice of curves, and no significant effect of site where shot (F = 0.43, d.f. = 1,221, P = 0.510), or any interaction terms. Residuals from this analysis were normally distributed (Lillifors test P = 0.138).

Discussion

The sex ratios in adult Scottish deer herds are heavily biased toward females (Clutton-Brock and Albon, 1989) such that there are commonly two females to one male (Darling, 1937). Clutton Brock *et al.* (1982) found that whilst the sex ratios at birth of the red deer population on the Isle of Rhum were consistently biased against hinds, mortality rates were significantly higher in one to two year old males than in similar aged females because of their greater nutritional requirements and consequent greater susceptibility to food shortages. The sex ratio of deer that were recovered by the hunter in this longitudinal study along with those obtained in a number of helicopter operations (Table 9) indicates that currently there are relatively low overall proportions of hinds in populations of a number of species of deer that were liberated in New Zealand. Even allowing for the fact that hinds in good body condition may produce greater numbers of male offspring (Trivers and Willard, 1973; Maynard-Smith, 1973; Clutton Brock *et al.,* 1982) the figures indicate that age and sex specific mortality are more evenly distributed in New Zealand than in Scottish red deer herds.

The fact that the sex ratio for the deer killed by the recreational hunter at times other than the rut was not significantly different from the limited season helicopter kill figures from the Ruahine Ranges and the spring helicopter kill figures for the Pureora Ranges (Fraser, 1996) suggests that, at times other than the rut, the hunter was equally non selective and killed any deer that he encountered. Further, that the hunter's overall bias to stags (54.9%), which was not significantly different to that of recreational hunter's in the Pureora red deer study (Fraser, 1996) (56.0% stags) or that of a recent study of sika deer in the Kaimanawas (Fraser and Speedy, 1997) (54.6% stags) (Table 9), resulted largely from the significantly greater proportions of stags killed during the rut. Such increases are likely to result from seasonal increases in activity and mobility of the quarry along with shifts in hunting strategy. Similar shifts in hunting strategy according to hunting situation have been recorded in overseas studies e.g. non restricted harvests during the limited elk hunting season in Idaho from 1959-1974 averaged 60% bulls in September, 53% in October and 47% in November (Mohler and Toweill, 1982) indicating an increasing tendency of hunter's choosing to expend their permit in the shooting of a female as the season neared its close.

Whilst the greater mobility of red deer stags during the rut may contribute to the significant increase in the overall proportion of stags that are shot at this time (Lentle and Saxton, 1991) the significant difference in the sex ratio of the harvest after the first three yrs of hunting may be indicative of either a shift in population demographics (see below), or a significant influence of experience i.e. that an element of hunter skill and choice influenced the numbers of stags that were killed during the rut.

The significantly greater proportion of older animals harvested by the hunter in comparison to those recovered in the Ruahine Ranges by the commercial helicopter, viewed in the light of the greater mean age of the recreational hunting harvest (3.8 yrs) than the commercial hunting harvest (2.6 yrs) demonstrated in the Pureora study (Fraser, 1996), indicate that there may be differences in the overall demographic impacts of recreational hunting and commercial helicopter recovery operations on deer herds. As was postulated by Fraser (1996) this finding may in part result from the timing of commercial hunting effort in spring when younger, more mobile, and less experienced animals are more likely to be encountered. However, the analyses of age class distributions in the recreational hunter's harvest indicates a significant increase in mean age of animals harvested three years after the commencement of hunting both during and excluding the rut. This suggests again either that with increase in experience the hunter was able to approach older and more wary animals more successfully, or that a demographic bias in commercial helicopter operations had significantly influenced the mean relative age of the remaining population. The latter phenomenon has been reported previously in New Zealand red deer populations (Challies, 1978; 1985).

The results from the analyses of proportional residuals for the effect of 'cohort year' show a significant increase in jaw size from 1976 which we presume is evidence of a general increase in nutritional status that may result from a decline in overall population density leading to increased quantity or quality of food available to survivors (Langvatn *et al.*, 1996). This hypothesis fits in with a similar but statistically unsubstantiated conclusion in the Tararua survey conducted by Kelton (1983) and the steady decline in numbers of deer culled by NZFS hunters following the peak in 1976 (Phil Brady, Dept. of Conservation, Wellington, N.Z., *pers. comm.*). An alternative hypothesis is that the increase in nutritional status results from a change in the type of locations that were hunted in the advent of helicopter hunting in combination with nutritional differences according to habitat (Nugent and Frampton, 1994). Whilst such differences may have contributed to the outcome, the failure of the analysis of residuals from jaw length curves to demonstrate any significance differences between the wetter western (seaward) and colder eastern (landward) Tararua ranges (Department of Conservation 1996), indicates that such differences are likely to be of smaller magnitude than those arising from other effects.

The results of this study add weight to evidence from a Pureora Conservation Forest study (Fraser, 1997) that there may be differences in the mean age and overall sex ratio of helicopter and recreational hunting harvest. Further, that the demographic impact of ground based hunting may change either with increase in hunter experience or in relation to changes in population density brought about by commercial helicopter recovery operations. Such differences are likely to have important implications for the management of residual populations of a species in which the effective breeding life of females can be as long as twelve years (Clutton-Brock *et al.,* 1982).

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