Management of Mountain Sheep in the Yukon: An evaluation of several approaches

prepared for
Department of Renewable Resources
Yukon Territorial Government
March 1997

by
Michael Dehn
Feet on the Ground Communications
403-667-7890
Box 4967
Whitehorse, YT

Table of Contents

Management of Mountain Sheep in the Yukon:
An evaluation of several approaches

Michael Dehn

1. Background, Objective, and Approach

The purpose of this report is to evaluate a number of ideas for managing mountain sheep, some of which have been in place for several years and some of which are currently under active consideration. Concern for funding the relatively expensive census techniques combined with the fact that not all populations can be censused on a regular basis has led to a discussion of a number of means which might be used to obtain useful management information more cheaply.

The work described below incorporates a simple population model, briefly described in the first section and provided on disk along with this report, to evaluate some of the techniques. The techniques evaluated include measurement of yearling numbers and yearling/ewe ratios to calculate population trends, use of average age of harvest to measure a) relative harvest intensity over time, and b) sudden changes in harvest pressure. In considering the average age of harvest, the simple model is expanded to include a harvest component and consideration is given to the effect of harvest rate on age distribution.

Finally, consideration is given to the question as to whether census data obtained in one area can be extrapolated to another area, which contains either another part of the same population or a separate, but similar population.

2. Life Table Model

A basic model was developed in which each cohort enters the population as a lamb crop and survives according to a fixed survivorship schedule. Unlike a standard Leslie-Matrix model, the number of lambs in this model is an input rather than a function of the (unknown) fecundity schedule. This approach incorporates data which has been collected over the years on the size of lamb crops and also has the capability to incorporate environmental variability into the model as reflected in the varying size of yearly lamb crops.

Data used for the model was taken from the Ruby Range sheep population (subzones 5-31, 5-34, 5-36). The initial population was taken from 1974 counts, and data on lamb counts in each year for which data exists was used to drive the model.

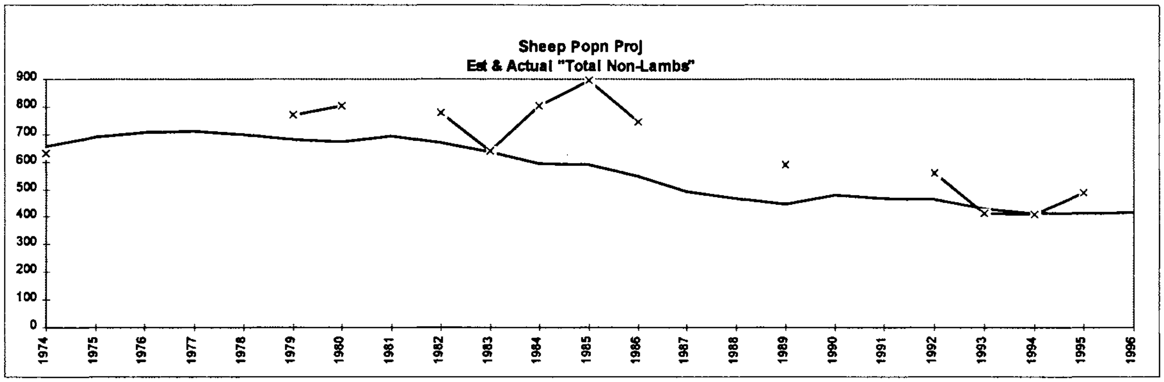
The model is presented as an Excel workbook, Ruby.xls (see below). As each cohort ages, it moves horizontally across the spreadsheet so that the number of lambs born in, for example, 1982 (76, cell J35) and surviving to their first birthday (50) is shown immediately to the right in cell K35, and those surviving to their second birthday (48, cell L35) to the right of that, etc. The survivorship schedule is presented in cells I7 to T7 schedule (for supporting data on a nearby population see Hoefs, M & IT Cowan, 1979. Ecological investigation of a population of Dall sheep (Ovis dalli dalli Nelson). Syesis 12: 1-81.).

As the model is presented it contains actual data for the number of lambs where known (lambs, row 11) and uses the average number of lambs in years when no data is available. It also has provision for easily modifying the number of lambs in order to facilitate examination of the effect of various fluctuations in natural circumstances – for example a series of good or bad lamb years. Modifications to the number of lambs can be made without altering the model by inserting the desired lamb numbers into row 9, the 'whatif' row.

Basic Population Model

When lamb number is missing, the average number counted between 1974 and the current year is used.																								
lx							1000	660	634	609	585	550	523	465	400	304	186	82	11					
lx/lx-1								0.66	0.96	0.96	0.96	0.94	0.95	0.89	0.86	0.76	0.61	0.44	0.13					
whatif		140	140	140	140			153						105	105		111	111						
lambs	144					140	175		76	59	126	68	49			162			35	62	82	86	#N/A	89
clambs	144	140	140	140	140	140	175	153	76	59	126	68	49	105	105	162	111	111	35	62	82	86	#N/A	89
Birth Year \ Year	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
1962																								
1963	3	0																						
1964	3	1	0																					
1965	16	10	4	1																				
1966	34	28	16	7	1																			
1967	65	56	42	26	11	2																		
1968	122	108	93	71	43	19	3																	
1969	118	112	100	86	65	40	18	2																
1970	94	88	84	75	64	49	30	13	2															
1971	78	75	70	67	60	51	39	24	11	1														
1972	60	58	55	52	49	44	38	29	18	8	1													
1973	64	61	59	57	53	51	45	39	29	18	8	1												
1974	144	95	91	88	84	79	75	67	58	44	27	12	2											
1975		140	92	89	85	82	77	73	65	56	43	26	11	2										
1976			140	92	89	85	82	77	73	65	56	43	26	11	2									
1977				140	92	89	85	82	77	73	65	56	43	26	11	2								
1978					140	92	89	85	82	77	73	65	56	43	26	11	2							
1979						140	92	89	85	82	77	73	65	56	43	26	11	2						
1980							175	116	111	107	102	96	92	81	70	53	33	14	2					
1981								153	101	97	93	90	84	80	71	61	47	28	13	2				
1982									76	50	48	46	44	42	40	35	30	23	14	6	1			
1983										59	39	37	36	35	32	31	27	24	18	11	5	1		
1984											126	83	80	77	74	69	66	59	50	38	23	10	1	
1985												68	45	43	41	40	37	36	32	27	21	13	6	1
1986													49	32	31	30	29	27	26	23	20	15	9	4
1987														105	69	67	64	61	58	55	49	42	32	20
1988															105	69	67	64	61	58	55	49	42	32
1989																162	107	103	99	95	89	85	75	65
1990																	111	73	70	68	65	61	58	52
1991																		111	73	70	68	65	61	58
1992																			35	23	22	21	20	19
1993																				62	41	39	38	36
1994																					82	54	52	50
1995																						86	57	55
1996																							#N/A	#N/A
1997																								89
Year	**1974**	**1975**	**1976**	**1977**	**1978**	**1979**	**1980**	**1981**	**1982**	**1983**	**1984**	**1985**	**1986**	**1987**	**1988**	**1989**	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**
ESTIMATED:																								
Whatif Adults	593	596	616	617	606	590	580	580	610	628	593	545	539	495	441	425	412	440	442	453	417	401	395	391
Whatif Tot Non-L	657	691	708	710	698	683	673	696	711	678	632	628	584	528	510	494	519	513	516	476	458	455	451	#N/A
Whatif Total	801	831	848	850	838	823	848	849	787	737	758	696	633	633	615	656	630	624	551	538	540	541	#N/A	#N/A
Adults	593	596	616	617	606	590	580	580	610	587	554	508	504	462	411	389	373	409	405	407	375	362	360	
Tot Non-Lambs	657	691	709	710	698	683	673	696	669	637	593	591	548	494	470	448	480	468	464	430	416	416	417	
Total	801	831	849	850	838	823	848	785	745	696	719	659	597	583	559	610	569	557	499	492	498	502	#N/A	
ACTUAL:																								
Tot Non-Lambs	633					769	805		778	641	802	895	746			592			562	415	410	489		

As the model stands, it provides a reasonable approximation to the actual population trend observed in aerial census counts as indicated by the graph below comparing the model's projections (solid line) and the actual data (X's).



The model as shown above appears to provide a reasonable reflection of population trends over a 23-year period using only the number of lambs as its input. However, obtaining data on the number of lambs is expensive and felt by some to be disruptive of the sheep, so consideration was given to other means of obtaining management information. In the discussion which follows, reference will be made to this model and possible modifications of the model. The first modification considered is the use of the number of yearlings or of the yearling/ewe ratio as an input to the model rather than the number of lambs.

3. Yearling/Ewe Ratio

3.1 Rationale

Because survival is most variable during the first year of life, it is thought that the number of yearlings may provide a better input into subsequent population dynamics than the number of lambs. In addition, if the ratio of yearlings to ewes rather than the absolute number of yearlings can be made to suffice, surveys could be conducted before lambing, possibly reducing the effect of the survey-related disturbance on the population while at the same time making the logistics of helicopter flying easier by avoiding the fire season when machines tend to be busy or on-call. Unfortunately it is not possible to conduct a count of yearlings later in the summer (July or August) because determining group composition from the air is too difficult.

3.2 Evaluation

A complete evaluation of this approach is not possible at this time because the data are insufficient; however, it is possible to combine the life table model based on the number of lambs with the information which is available on yearlings to determine if the yearling approach improves the estimate of population size.

Sheep census data taken between 1974-1996 for subzones 5-31, 5-34, and 5-36 were examined to determine which censuses provided sufficient classifications of nursery groups into yearlings and ewes to provide a reasonable estimate of the proportion of yearlings. In general, when compositions were reported in more than a minimal number of observations (which were ignored for these purposes) the number of animals classified is around 20% of the Total Nursery Sheep counted, and there was very little difficulty or ambiguity in selecting years for inclusion in this analysis. Unfortunately only 6 censuses provided sufficient information on yearlings to incorporate into the modified life table model (Shown in boxes in the life table below.)

If this approach were actually implemented, the only information available for construction of the life table would be yearly yearling/ewe ratios and occasional population counts. However for the purposes of this exercise the available yearling data was incorporated into the existing life table model by using the counts of Total Nursery Sheep which exist for each census:

yearlings/(ewes+yearlings) x Total Nursery Sheep

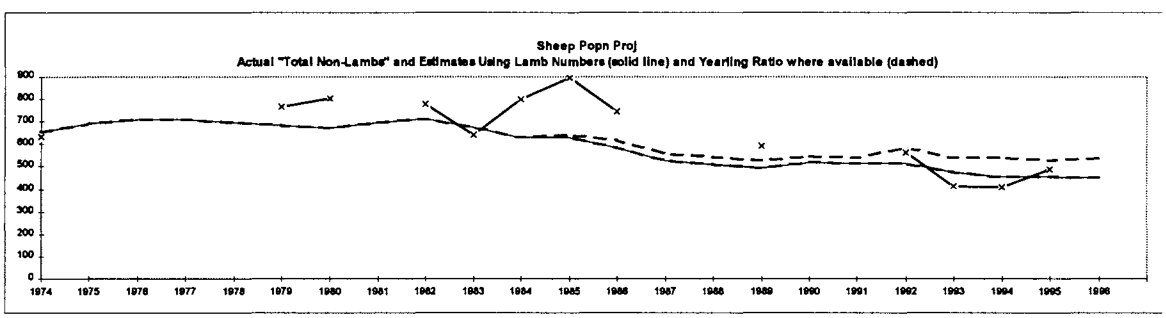
In field work the first of these factors would be known from census data based on a sample of nursery groups, but Total Nursery Sheep would not be known, assuming the survey was done in March or April, and it would have to be estimated from the model or estimated in the field at another time of the year. Thus the calculations presented below may be more accurate than the actual technique would be when applied. However, given the lack of available data, it seems that either method would likely give similar results at this point. As the accompanying table and graph indicate, the yearling approach gives nearly identical results to the lamb approach. Thus it is worth considering more fully.

3.3 Conclusion

It is recommended that a complete study design be developed which incorporates this approach. Evaluation of the use of yearling data would require three or four years of data collection at an appropriate time of the year to obtain yearling/ewe ratios as well as total counts taken in the same years after lambing. The yearling counts or yearling/ewe ratios should be incorporated into a model such as the one presented in this report if an understanding of the dynamics of sheep populations is desired.

Sheep Population Model Using Estimated Yearling Numbers (boxed) Rather Than Lamb Numbers

Where the ratio yearlings/TNS is available, it is used rather than lamb numbers (indicated by box)																								
When lamb number is missing, the average number counted between 1974 and the current year is used.																								
lx							1000	660	634	609	585	550	523	465	400	304	186	82	11					
lx/lx-1								0.66	0.96	0.96	0.96	0.94	0.95	0.89	0.88	0.76	0.61	0.44	0.13					
whatif		140	140	140	140			153						105	105		111	111						
lambs	144					140	175		76	59	126	68	49			162			35	62	82	86	#N/A	89
clambs	144	140	140	140	140	140	175	153	76	59	126	68	49	105	105	162	111	111	35	62	82	86	#N/A	89
Birth Year \ Year	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
1962																								
1963	3	0																						
1964	3	1	1	0																				
1965	16	10	4	1																				
1966	34	26	16	7	1																			
1967	65	56	42	26	11	2																		
1968	122	108	93	71	43	19	3																	
1969	118	112	100	86	65	40	18	2																
1970	94	88	84	75	64	49	30	13	2															
1971	78	75	70	67	60	51	39	24	11	1														
1972	60	58	55	52	49	44	38	29	18	8	1													
1973	64	61	59	57	53	51	45	39	29	18	8	1												
1974	144	95	91	88	84	79	75	67	58	44	27	12	2											
1975		140	92	89	85	82	77	73	65	56	43	26	11	2										
1976			140	92	89	85	82	77	73	65	56	43	26	11	2									
1977				140	92	89	85	82	77	73	65	56	43	26	11	2								
1978					140	92	89	85	82	77	73	65	56	43	26	11	2							
1979						140	92	89	85	82	77	73	65	56	43	26	11	2						
1980							175	116	111	107	102	96	92	81	70	53	33	14	2					
1981								153	101	97	93	90	84	80	71	61	47	28	13	2				
1982									76	50	48	46	44	42	40	35	30	23	14	6	1			
1983										59	39	37	36	35	32	31	27	24	18	11	5	1		
1984											126	96	92	89	85	80	76	68	58	44	27	12	2	
1985												68	68	65	63	60	57	54	48	41	31	19	8	1
1986													49	32	31	30	29	27	26	23	20	15	9	4
1987														105	69	67	64	61	58	55	49	42	32	20
1988															105	69	67	64	61	58	55	49	42	32
1989																162	107	103	99	95	89	85	75	65
1990																	111	73	70	68	65	61	58	52
1991																		111	120	115	111	106	100	95
1992																			35	21	20	19	19	18
1993																				62	66	63	61	59
1994																					82	54	52	50
1995																						86	82	79
1996																							#N/A	#N/A
1997																								89
Year	**1974**	**1975**	**1976**	**1977**	**1978**	**1979**	**1980**	**1981**	**1982**	**1983**	**1984**	**1985**	**1986**	**1987**	**1988**	**1989**	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**
ESTIMATED:																								
Whatif Adults	593	596	616	617	606	590	580	580	610	628	593	545	551	529	474	456	442	468	466	517	472	472	458	473
Whatif Tot Non-Lambs	657	691	709	710	698	683	673	696	711	678	632	641	619	562	543	526	549	541	586	538	538	526	540	#N/A
Whatif Total	801	831	849	850	838	823	848	849	787	737	758	709	668	667	648	688	630	624	551	600	620	612	#N/A	#N/A
Adults	593	596	616	617	606	590	580	580	610	587	554	508	504	462	411	389	373	409	405	407	375	362	360	
Tot Non-Lambs	657	691	709	710	698	683	673	696	669	637	593	591	548	494	470	448	480	468	464	430	416	416	417	
Total	801	831	849	850	838	823	848	785	745	696	719	659	597	583	559	610	569	557	499	492	498	502	#N/A	
ACTUAL:																								
Tot Non-Lambs	633					769	805		778	641	802	895	746			592			562	415	410	489		



4. Average age of harvest

4.1 Rationale

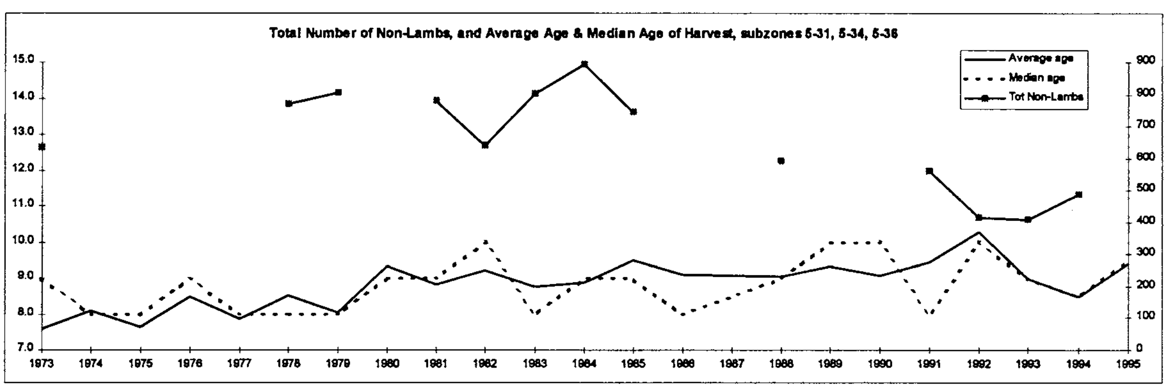
Data collected from compulsory submissions of mountain sheep kills provides a large and relatively complete data base of the age of rams harvested since 1980. The rationale behind this collection effort has been the belief that the average age of harvest in each year provides indications of such potential problems as over-harvest through increased effort or increased number of hunters, or of a decline in local sheep populations. It has been expected that either of these situations would be reflected in a trend toward a lower average age of harvest over several years.

4.2 Evaluation

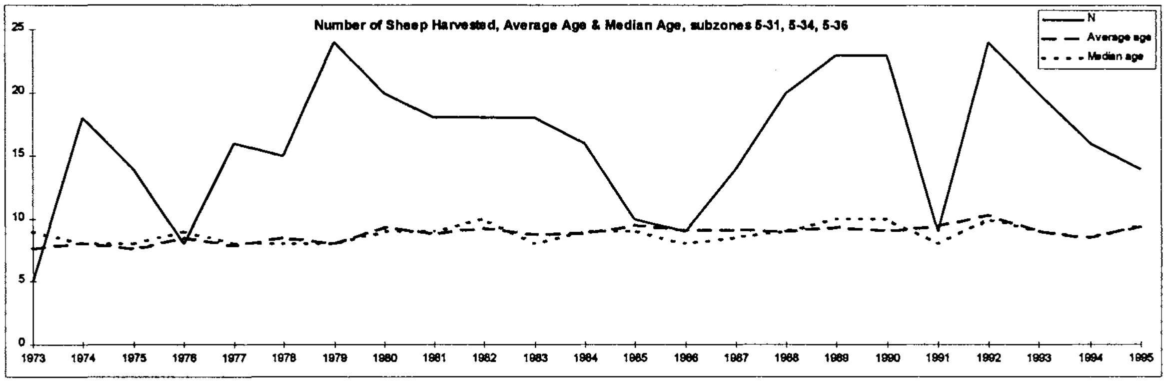
The validity of the average age of harvest was evaluated using two approaches. Data from subzones 5-31, 5-34, and 5-36 were examined to determine whether a known population decline from 1984 to 1992 was reflected in the age of harvest data, and secondly, the approach was examined from a theoretical standpoint.

4.3 Field data approach

The population trend within the three subzones is shown below, along with the average and median age of rams shot. It is evident from the figure that the age of harvest provides no indication of the declining population throughout the period under consideration. Specifically the obvious population decline between 1984 and 1992 is not reflected in either measure of the age of harvest, which remained fairly stable in spite of annual fluctuations.



If the average age of the harvest remains relatively stable during a population decline it might be expected that the number of animals harvested would decline. But the number of sheep harvested (below) shows no relationship to the decline in population numbers either.



4.4 Theoretical Approach

The observed data discussed above would lead one to inquire as to whether it is even theoretically possible to use age of harvest as an index of population status or harvest exploitation level. Just what trend would one expect to see in average age of harvest as the intensity of the harvest varied?

4.4.1 Model

In order to address this question, some modifications were developed for the life table model as presented below. Each of several changes to the original model is shown on a separate tab (or worksheet) on the Excel workbook "Exploitation Analysis.xls" and also in Appendix 1.

The first tab (entitled "Naïve-no hunting") presents a basic model similar to that presented above For the purposes of this exercise, however, it was important to exclude environmental variability for the first stage of the analysis and therefore all lamb crops after 1981 were set to a constant number of lambs, 76, for reasons which are explained in the next section.

The second tab (Male Population Only) is identical to the first, except that the numbers of animals have been reduced by 50% to account for the fact that only male sheep are hunted by residents and non-residents.

The third tab (Male Population with Hunting) presents the population in each age category remaining after hunting has occurred. The hunting rate may be varied between 0.0 and 1.0 by changing the number in cell I1, and such a change will result in a change in the numbers and graphs presented on this tab and on the succeeding tab. The hunting rate is the only number which should be changed in this set of tables unless one wishes to change basic assumptions of the model.

Finally the fourth tab (Harvest) shows the conclusions of the analysis for the harvest rate specified on the previous tab. The results shown include the number of males of each age harvested for each year, and charts showing the male population over time, the number of males harvested by year, and the age distribution of the male population (all ages) and of the harvest (age 8 and up).

4.4.2 Assumptions

As described above, the annual lamb crop after 1981 was set to a constant 76 animals which was taken to be a reasonable average for a population of this size. The decision to hold the lamb crop constant was taken in order to enable one to disentangle the effect of environmental variation, which is reflected in lamb crops, from the effect of harvest rate. Although it was originally thought that it would be useful to compare the results from this "constant-lamb-crop" approach to those obtained using actual lamb numbers, this turned out to be unnecessary since the conclusions expressed below are robust to environmental variation. This assumption does not dramatically affect the overall population trend projected by the model while at the same time it allows conclusions to be drawn with respect to hunting intensity only.

Although it is known that some male sheep reach full curl at an earlier age than others, the vast majority are full curl by 8 years of age. In order to simplify the analysis the assumption was made that all males age 8 and older are full curl and that no animal becomes full curl before age 8. This assumption should not effect the conclusions which result from the analysis.

It was also necessary to make some assumptions about the way in which hunters select a ram. If hunters preferentially select older rams from the available full curl rams, then older rams would be killed preferentially, and other factors being equal, age of harvest might reflect the level of exploitation.

However, in discussions taken before the analysis was done it was realized that although some hunters may prefer older rams, others are known to prefer younger animals, and on balance the preferences of hunters may more closely approximate a random selection of full curl rams. The decision was taken to assume that on the whole hunting represents a random selection of the available full-curl animals. This dramatically limits the interpretation which may be placed on average age of harvest, as the discussion below will make clear.

In the discussion which follows, the term 'harvest rate' is defined as the proportion of full curl rams taken each year, not as the proportion of the population.

4.4.3 Analysis

In order to determine the effect of harvest rate on various aspects of sheep population characteristics, including population size and the average age of the harvest over time, the model was used to produce outputs for four levels of harvest rate (0.01, 0.10, 0.25, and 0.75) and the results were compared.

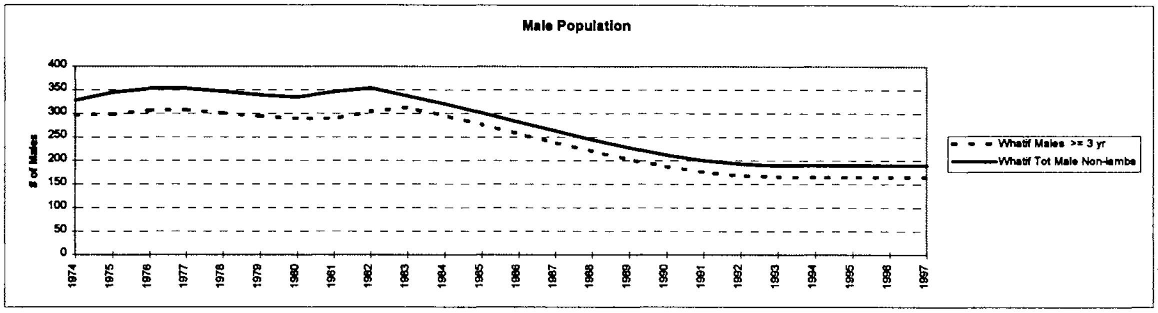
4.4.3.1 Population size

The projected changes in male population size over time are shown below (Male Population) for each of the harvest levels for both adult males (≥3 yr) and for males older than lambs. A number of features are immediately apparent from these graphs. Each graph shows a similar trend over time which represents a stabilizing as the original age distribution works its way through the model until the effect of constant lamb crops comes into play. Much larger lamb crops occurred (in the field and in the model) in the earlier years and resulted in a bulge in the age distribution which is probably responsible for much of the phenomena observed in the Ruby Range population. As this bulge works its way through the model and eventually dies out, the population size decreases to a lower level.

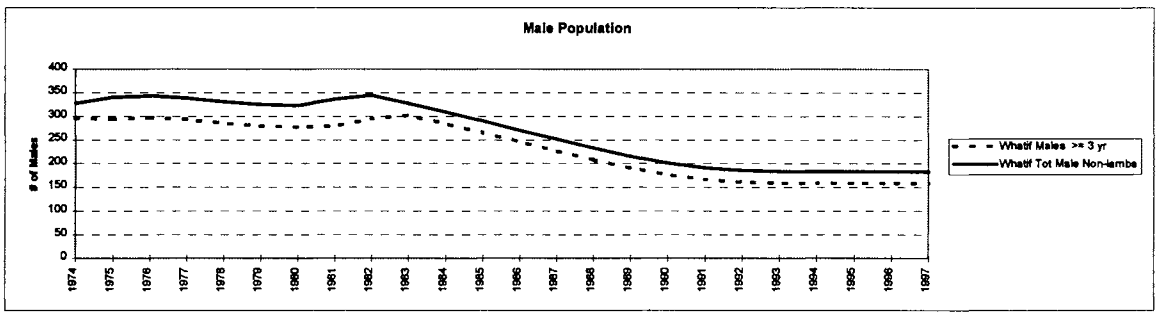
In constructing this model an attempt was made to strike a reasonable balance between including so many details that the major conclusions would be too tentative and on the other hand excluding so much that the model would be unrealistic. A comparison of the population projections below with actual census data presented earlier (see Total Number of Non-Lambs, page 5) indicates that the output from the model reasonably mirrors the actual changes in the population.

It is evident from the graphs below that even a high harvest rate does not have a large impact on the size of the male population. This is because there are relatively few full curl males in a sheep population so that even removing 75% of them does not have a dramatic effect on the total number of males. This is not to say that the population is not affected by a high level of harvest, of course, because the age distribution will change as a result of harvest level (see next section).

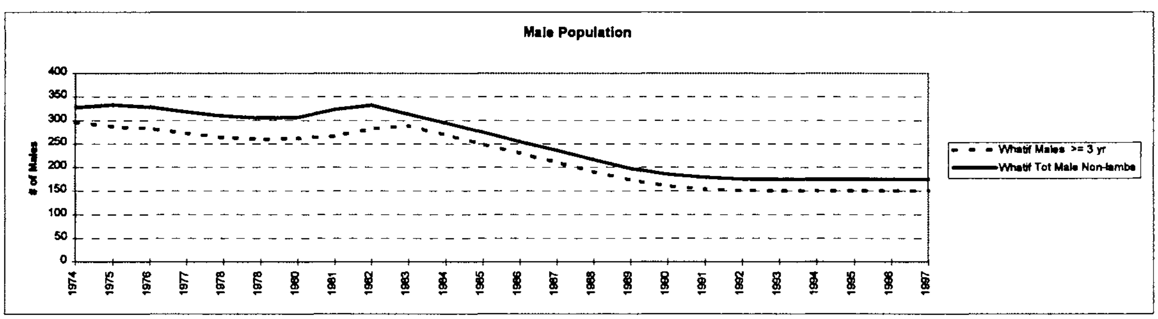
Harvest Rate = 0.01



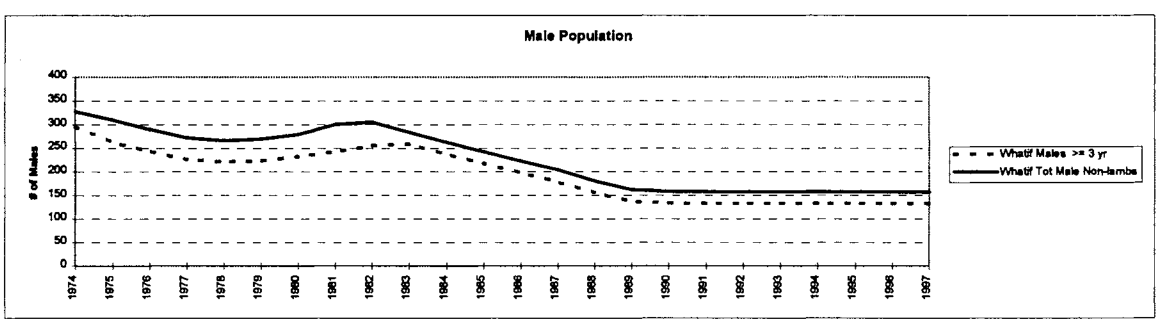
Harvest Rate = 0.10



Harvest Rate = 0.25



Harvest Rate = 0.75



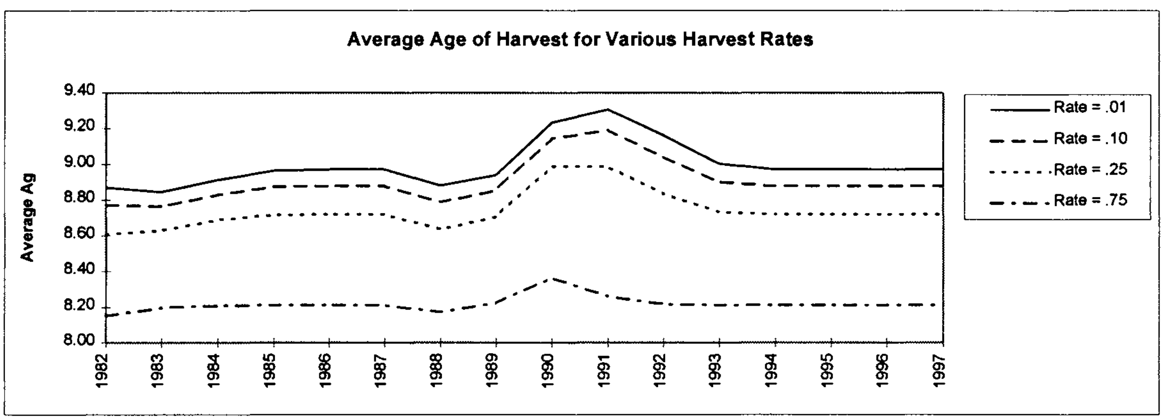
4.4.3.2 Average age of harvest over time

The average age of harvested rams predicted by the model is shown below for each of four harvest rates. Although there is a difference in the average ages of harvest (on the order of 0.25 to 0.8 years), the natural fluctuation in average age of harvest (e.g. the 1989-1993 “hump”) (approx 0.4 years) will swamp such differences for any reasonable fluctuation in actual harvest rate. Thus one must conclude that changes in average age of harvest due to the effects of harvest rate are not distinguishable from age fluctuations in the harvest due to natural events.

Note that even in the post-1993 period, when the effect of the constant-lamb-crop assumption makes itself felt in harvestable age classes the difference due to exploitation rate is small enough to be of questionable usefulness as a management tool. In the real world, fluctuations in average age of harvest due merely to sampling error would make the small differences in average age useless in determining harvest rate (for example, see the actual average age of harvest shown on page 6).

Average age of Harvest

	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
Rate = .01	8.87	8.85	8.91	8.97	8.97	8.97	8.88	8.94	9.23	9.31	9.16	9.01	8.97	8.97	8.97	8.97
Rate = .10	8.77	8.77	8.83	8.87	8.88	8.88	8.79	8.85	9.15	9.19	9.04	8.90	8.88	8.88	8.88	8.88
Rate = .25	8.61	8.63	8.69	8.72	8.72	8.72	8.64	8.71	8.99	8.99	8.84	8.74	8.72	8.72	8.72	8.72
Rate = .75	8.15	8.20	8.21	8.21	8.21	8.21	8.18	8.22	8.37	8.26	8.22	8.21	8.21	8.21	8.21	8.21



Worse yet from the standpoint of using age of harvest as an indicator of harvest rate, the average age of harvest in this model remained approximately constant (within 0.1 year) from 1982 to 1988 while the adult male population declined steadily. In addition the average age of harvest actually increased from 1988-1991 while the male population continued its dramatic decrease.

Thus although the model population maintained a steady decline from 1982 to 1992 the average age of harvest did not reflect this decade-long trend – instead it first remained constant, then increased, then decreased. It is clear that average age of harvest provides no information on population trends or status under the assumptions used in this model and that even a constant average age of harvest cannot be taken as assurance that the population is not in trouble.

4.4.4 Detecting dramatic changes in the harvest rate

As shown in the preceding section, the average age of harvest does not reflect changes harvest rate when plotted over time. Might it never-the-less serve as a warning flag if a sudden increase in hunting pressure occurred, perhaps due to a change in hunting patterns or to a sudden decline in the sheep population?

As long as the overall pattern of animals killed in the a population resembles a random selection of full curl animals the answer is "no." Calculations shown in Appendix 2 illustrate that different potential harvest rates applied to the same population in a given year result in the same average age of harvest. That is, the average age of harvest will give no indication of a dramatic increase in harvest intensity.

4.5 Conclusion regarding average age of harvest

The important conclusion of this section should not be lost in the details: Both the actual data and the model indicate the same conclusions: If the harvest represents a more or less random selection of huntable animals, the average age of harvest is not a reliable index of hunting pressure. Thus if the manager is using average age of harvest to serve as a warning sign of a population being overhunted, it is entirely possible to miss the fact that hunting pressure is increasing, either because more animals are being taken (a fact which would most likely be noted) or because the same number of animals are being killed but the huntable population is declining. This conclusion applies equally to both long-term and short-term changes in harvest intensity.

5. Further applications of the model in understanding the effect of harvest rate

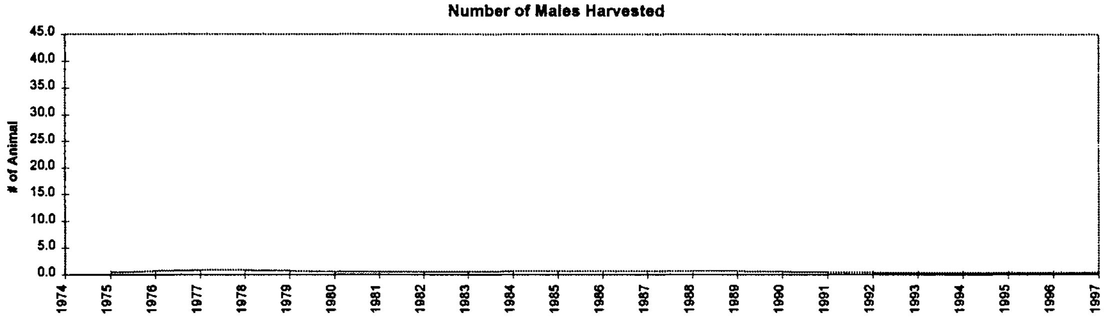
Four detailed outputs from the harvest model are shown below, one for each of the harvest levels (0.01, 0.10, 0.25, 0.75), and additional outputs for other harvest levels can be generated easily as described above. These outputs can aid in understanding the effect of the harvest level on a sheep population. For example, the number of males harvested is shown in the top graph on each page, and it is clear that the higher the harvest rate, the more animals are taken (note: this conclusion is not entirely obvious and would not be true for harvests which included females). This effect is particularly noticeable in the years before the model population stabilizes (approximately 1983) because there was a higher proportion of older animals in those years, but even after that point more animals are taken when the harvest rate is higher.

Secondly, age distributions for the entire male population are presented for several different years. In all cases the age distribution is somewhat ragged and changing in the earlier years, but settles down to a more stable shape by the mid-1980's. The effect of a population bulge moving through the age classes is evident when one compares the age distributions with the chart showing the number of animals harvested immediately above.

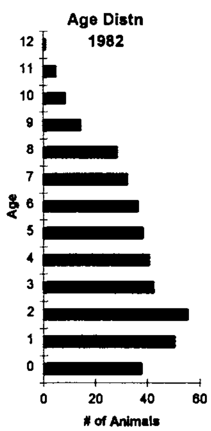
Finally, the age distribution of the harvest is shown for the same years. It is evident that a higher rate of harvest results in a sharper decline in the population distribution across the years when males are exposed to harvest (age 8+). It is this sharper drop-off with age that is responsible for the somewhat lower average age of harvest at high harvest rates noted above, and it reflects a change in the age distribution of the population resulting from higher harvest rates. Unfortunately as stated above, the results of this modeling exercise indicate that the slight lowering of average age is too small to be reliably detected and is subject to various types of confounding, such as change in age distribution due to natural causes.

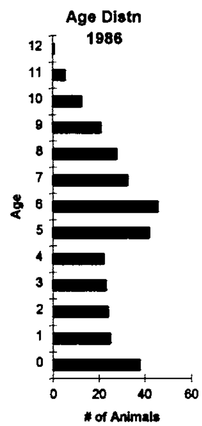
The greatest utility of this section of the model is likely to be in actually manipulating the harvest rate in the spreadsheet itself and observing changes in the outputs of the model.

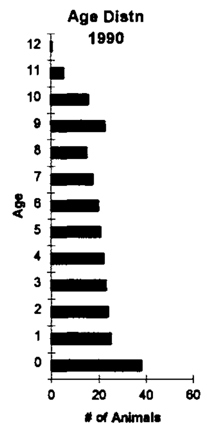
Harvest Rate = 0.01

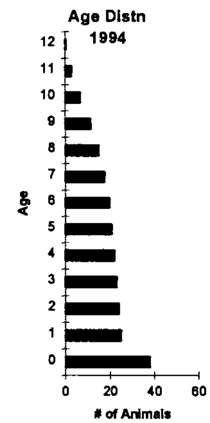


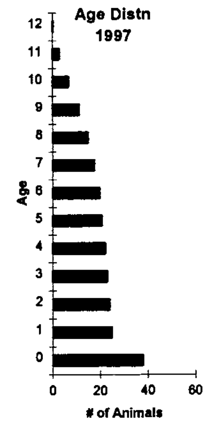
Age Distribution of Male Segment of Population



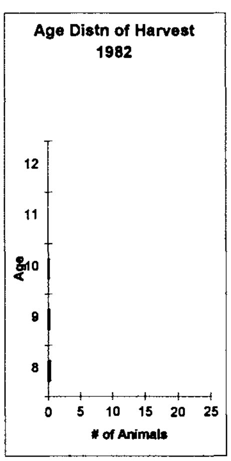


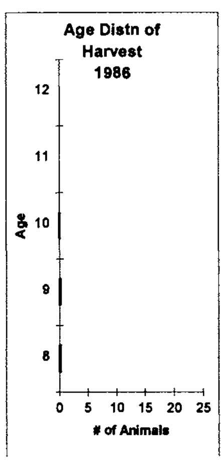


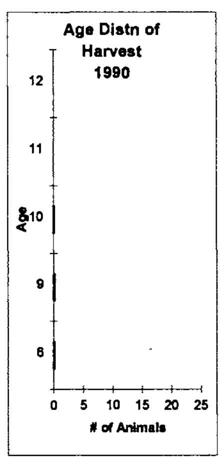


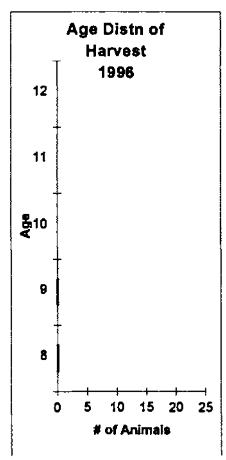


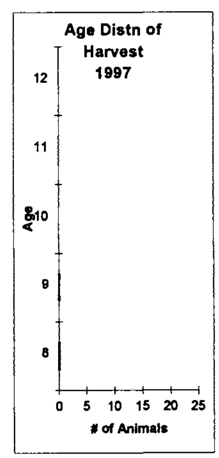
Age Distribution of the Harvest



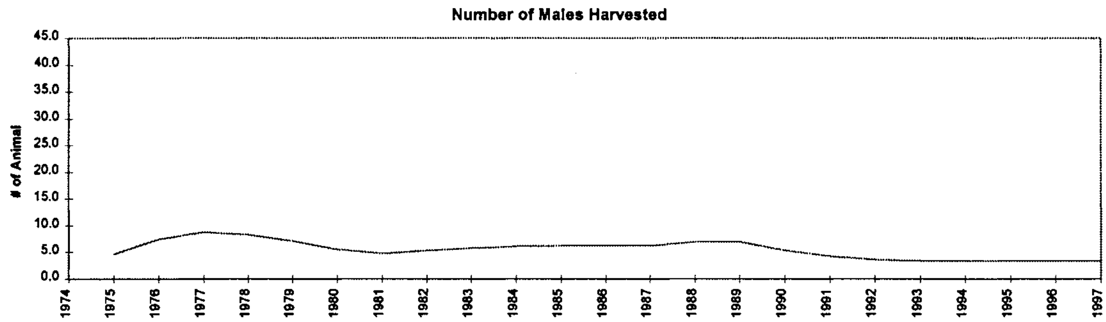




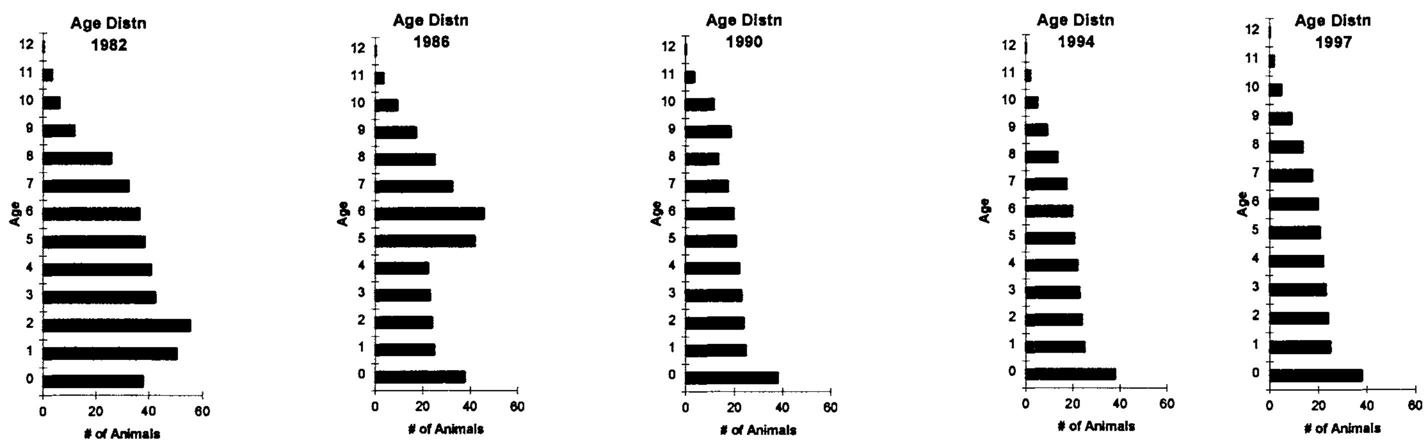




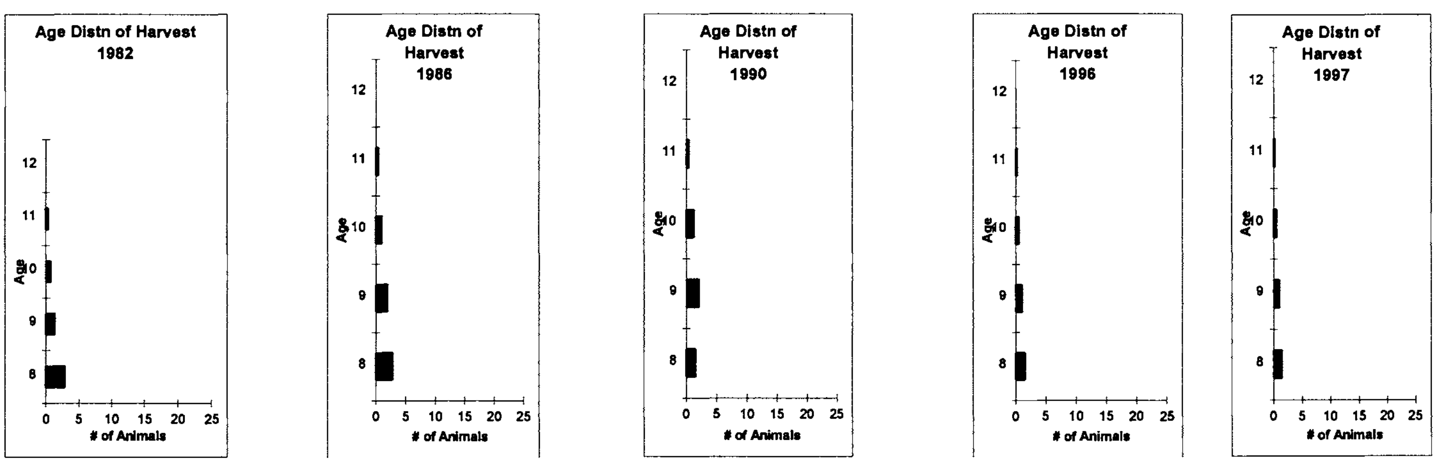
Harvest Rate = 0.10



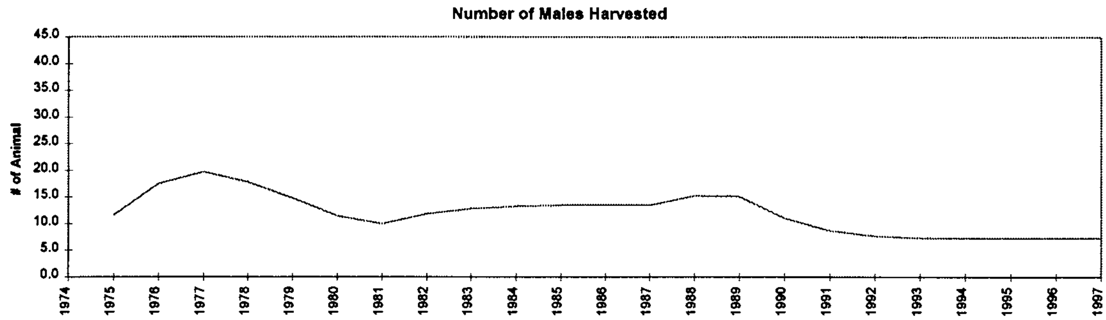
Age Distribution of Male Segment of Population



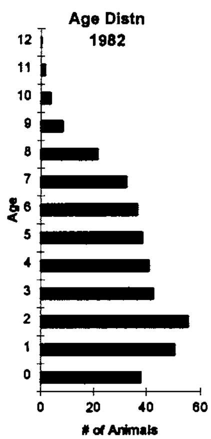
Age Distribution of the Harvest

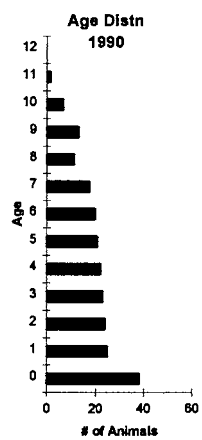


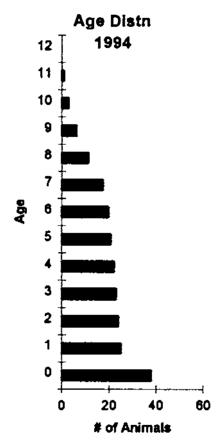
Harvest Rate = 0.25



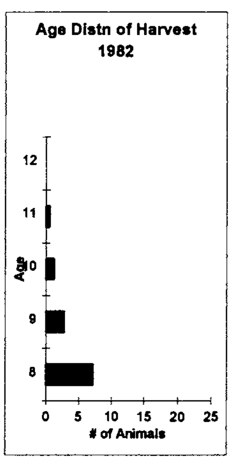
Age Distribution of Male Segment of Population

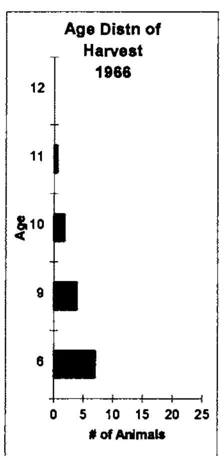


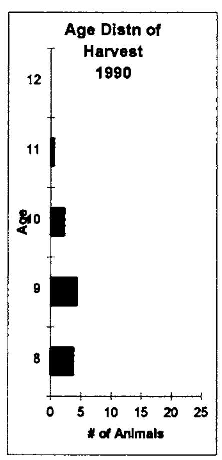


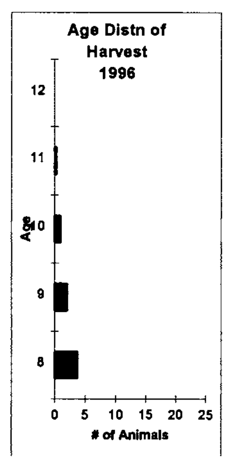


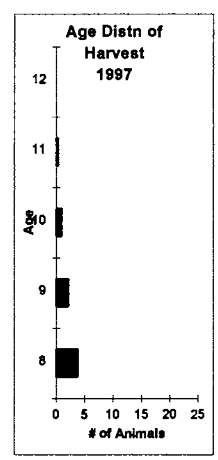
Age Distribution of the Harvest



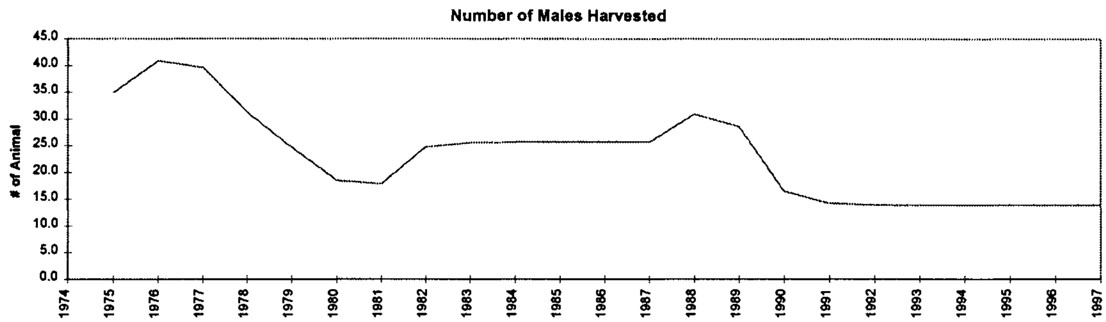




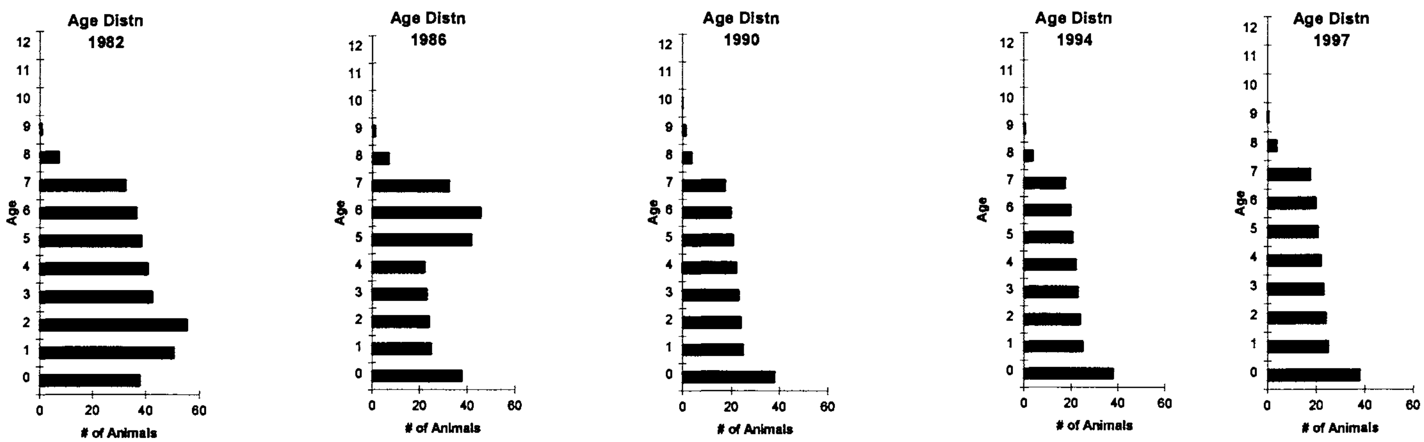




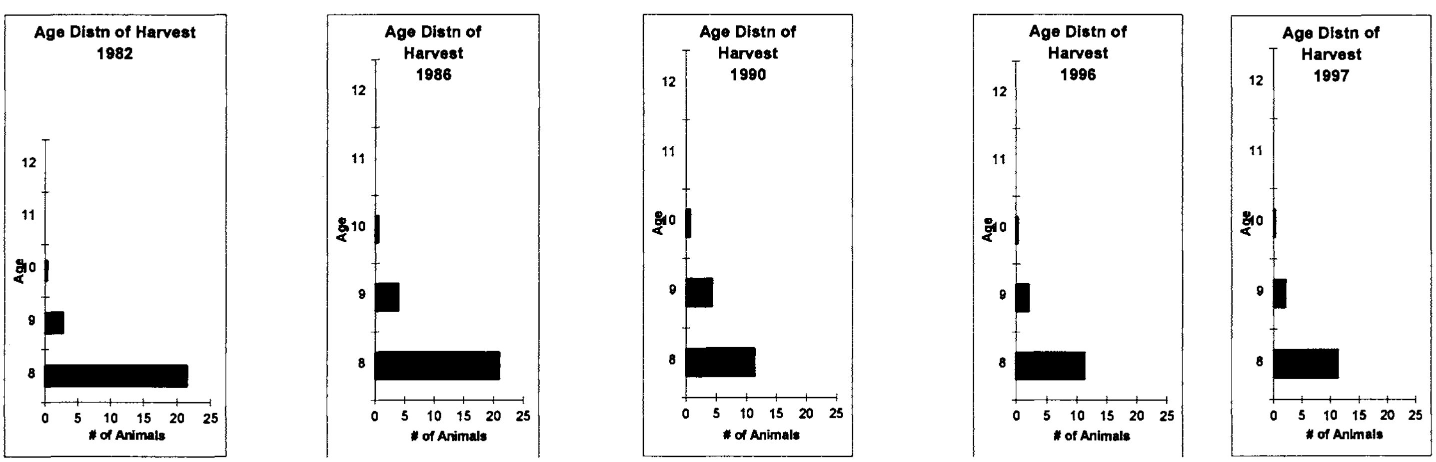
Harvest Rate = 0.75



Age Distribution of Male Segment of Population



Age Distribution of the Harvest



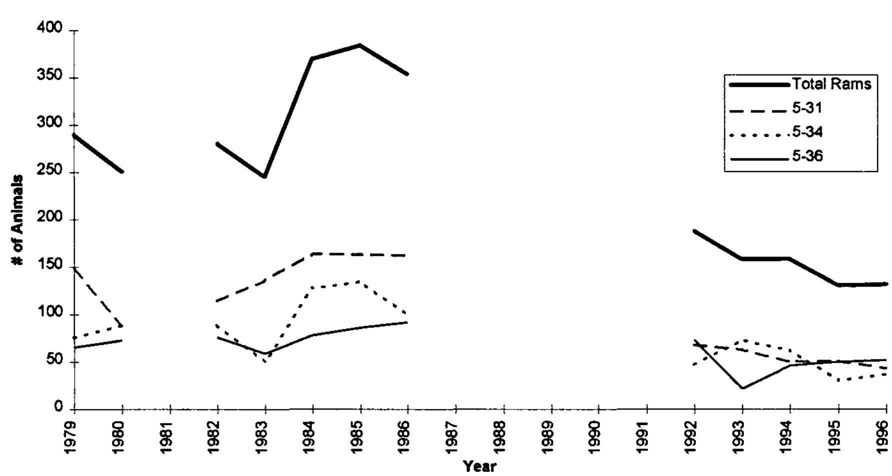
6. Can survey counts and classifications obtained in one area be used to estimate the population in other nearby areas?

If potential indices which might be used for estimating the status of populations (such as lamb/ewe ratio or average age of harvest) are not useful, it would be helpful if one could establish other 'shortcuts' which might be used to estimate the relative status of a population. Two possibilities are considered below. The first is to census part of a sheep population and extrapolate to the remaining population. The second is to census an entire population and assume that any trends in the population also apply to other nearby, similar populations. Data pertaining to each of these possibilities is considered below.

6.1 Comparison from one subzone to nearby subzones

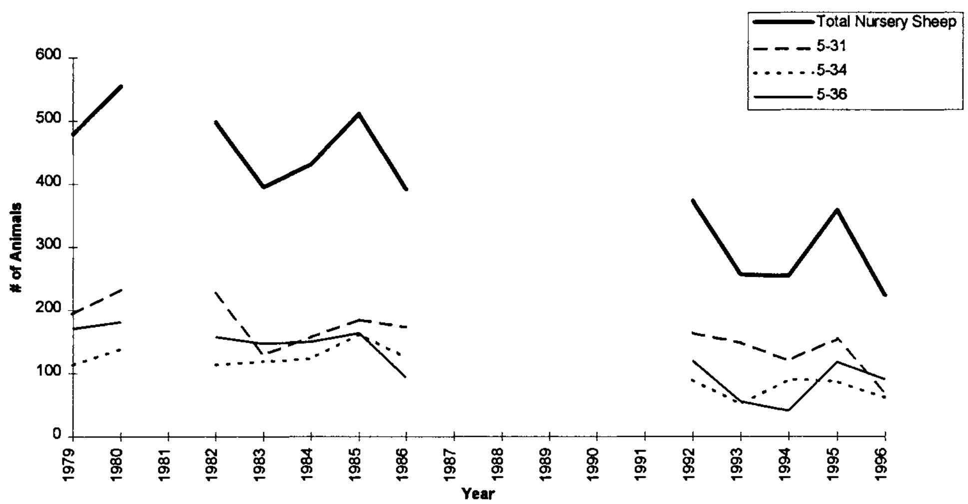
A reasonably complete data series exists from 1979 to the present for three subzones in the Ruby Range which contain what is believed to be an entire population. These data are shown below for rams and for total nursery sheep separately. One appropriate question to ask of the data is whether one would have identified the dramatic decline which occurred between 1984 and 1996 using only data from any one of the subzones shown below. For the ram data it seems unlikely, as data for two of the three subzones (5-34, 5-36) show little change between data taken in 1986 and in 1992. Dramatic changes occurred only in subzone 5-31.

Total Rams Counted on Surveys in each of subzones 5-31, 5-34, & 5-36



The data for total nursery sheep (below) show a different pattern, but never-the-less, one which would make it difficult to discern the overall pattern by looking only one of the subzones. Note that when all of the subzone data is seen portrayed on the same graph, the general trend is clearly the same as the total for all three subzones because there is not as much variability between subzones as there is In the ram data above. However when the data for each subzone is examined separately, it is not as evident that a decline would be identified. In particular, none of the subzones shows much change between 1986 and 1992, a period when the population is known to have declined. In fact, depending on which subzone had been sampled, one might have concluded that the population was actually increasing for a time.

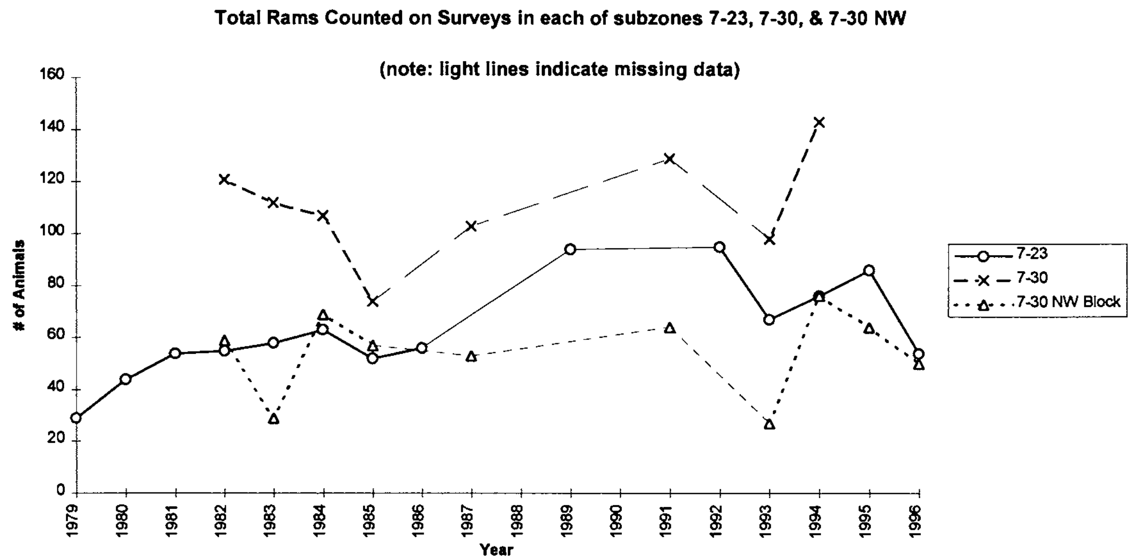
Total Nursery Sheep Counted on Surveys in each of subzones 5-31, 5-34, & 5-36

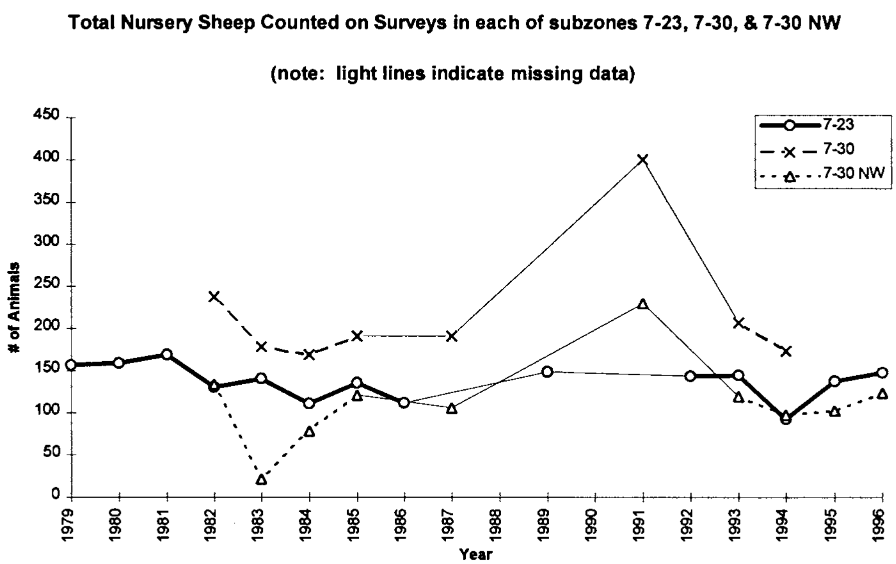


The final, and perhaps most conclusive argument against sampling part of a population by selecting a subzone or, in fact any limited geographical area, is that the results are unlikely to lead to any management action or conclusions. For example if one subzone is found to contain less sheep over a two or three year period, one could never tell if the population might be just concentrated on the remaining range or whether in fact the population had declined. Another way of stating this point is that for sampling to be effective, it must be done in a manner which establishes a statistical basis for extrapolating to the population. It is unlikely that such an approach would be economical for mountain sheep in the Yukon because census counts can be conducted with little more than it would cost to take an effective sample.

6.2 Comparisons of nearby populations

Little data is available to determine whether counts of one sheep population can reasonably be applied to other populations. The one comparison for which enough data exists is the comparison of counts in subzone 7-23 with those in 7-30, which contains a different population or with those in the northwest block of 7-30 which contains most of the 7-30 population and which has been censused an additional time. These data are shown for rams and for total nursery sheep below.





It is evident from examining the two charts above that data from the population in subzone 7-23 gives at most a very general impression of the population trends occurring in 7-30 or 7-30NW. Because of the erratic pattern of the 7-30 / 7-30NW data around the 7-23 data it is unrealistic to expect any reasonable management decisions to result from extrapolation of 7-23 data to the nearby 7-30 population. In some cases such an extrapolation would be reasonably accurate, but in other years the results would be extremely misleading.

6.3 Conclusion

Survey counts obtained from one area cannot be applied to other nearby areas with any degree of reliability, no matter whether the other areas are additional ranges of the same population or are additional ranges of other similar, nearby populations.

7. Overall Conclusions

The work conducted in this report leads to several conclusions. In the first place, none of the 'short-hand' methods for obtaining management information which were evaluated appear to give acceptable results. Thus sub-sampling a population on the basis of a subzone or even extrapolating from one population to another are entirely unreliable methods of obtaining population information. In addition, the traditional method used as a safeguard for sheep populations, namely tracking the average age of harvest, has no validity under the conditions assumed in this analysis.

On the other hand, it does appear that accurate data gathered on the number of yearlings would be useful in tracking a population and might be considered as an alternative to lamb counts. Depending on the time of year, this data may need to be used in conjunction with population counts or estimates from a model to track a population through time. One advantage of using yearling/ewe ratio data is that it could be obtained at a time of the year when counting, logistics, and disturbance to the animals are all optimized, although it must be remembered that if ratios are used it will also be necessary to obtain census counts anyway once every two to four years. This approach should be pursued with a careful study design and a plan to evaluate the results over a period of three or four years. If successful, the yearling/ewe ratio approach, combined with the modeling approach used in this report will give accurate information at a lower cost than the current counts while at the same time satisfying some of the concerns about sheep disturbance while the lambs are young.

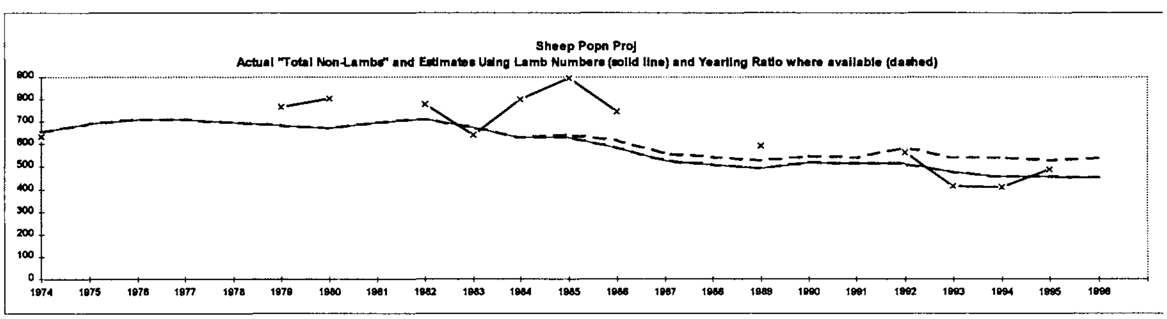
It would appear that there is no short-cut method for obtaining useful management data if population trends are considered a necessary component of proper management. If population information is desired, it will be necessary to invest the required resources into obtaining accurate information as none of the other short-cut methods provide useful or reliable information on population status. The method recommended above will provide sufficient information at a reduced cost, but if sufficient resources cannot be devoted to properly evaluate the approach, the resources which are available would be better put to studying other aspects of mountain sheep management.

8. Appendix 1: Harvest Exploitation Model

Tab 1: Naïve (no hunting)

When lamb number is missing, the average number counted between 1974 and the current year is used.
From 1983 on the number of lambs is held at 76 for this analysis

lx							1000	660	634	609	585	550	523	465	400	304	186	82	11					
lx/lx-1								0.66	0.961	0.961	0.961	0.94	0.951	0.889	0.86	0.76	0.612	0.441	0.134					
whatif		140	140	140	140			153		76	76	76	76	76	76	76	76	76	76	76	76	76	76	76
lambs	144					140	175		76	59	126	68	49			162			35	62	82	86	#N/A	89
clambs	144	140	140	140	140	140	175	153	76	76	76	76	76	76	76	76	76	76	76	76	76	76	76	76
Birth Year \ Year	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
1962	0																							
1963	3	0																						
1964	3	1	0																					
1965	16	10	4	1																				
1966	34	26	16	7	1																			
1967	65	56	42	26	11	2																		
1968	122	108	93	71	43	19	3																	
1969	118	112	100	86	65	40	18	2																
1970	94	88	84	75	64	49	30	13	2															
1971	78	75	70	67	60	51	39	24	11	1														
1972	60	58	55	52	49	44	38	29	18	8	1													
1973	64	61	59	57	53	51	45	39	29	18	8	1												
1974	144	95	91	88	84	79	75	67	58	44	27	12	2											
1975		140	92	89	85	82	77	73	65	56	43	26	11	2										
1976			140	92	89	85	82	77	73	65	56	43	26	11	2									
1977				140	92	89	85	82	77	73	65	56	43	26	11	2								
1978					140	92	89	85	82	77	73	65	56	43	26	11	2							
1979						140	92	89	85	82	77	73	65	56	43	26	11	2						
1980							175	116	111	107	102	96	92	81	70	53	33	14	2					
1981								153	101	97	93	90	84	80	71	61	47	28	13	2				
1982									76	50	48	46	44	42	40	35	30	23	14	6	1			
1983										76	50	48	46	44	42	40	35	30	23	14	6	1		
1984											76	50	48	46	44	42	40	35	30	23	14	6	1	
1985												76	50	48	46	44	42	40	35	30	23	14	6	1
1986													76	50	48	46	44	42	40	35	30	23	14	6
1987														76	50	48	46	44	42	40	35	30	23	14
1988															76	50	48	46	44	42	40	35	30	23
1989																76	50	48	46	44	42	40	35	30
1990																	76	50	48	46	44	42	40	35
1991																		76	50	48	46	44	42	40
1992																			76	50	48	46	44	42
1993																				76	50	48	46	44
1994																					76	50	48	46
1995																						76	50	48
1996																							76	50
1997																								76
Year	**1974**	**1975**	**1976**	**1977**	**1978**	**1979**	**1980**	**1981**	**1982**	**1983**	**1984**	**1985**	**1986**	**1987**	**1988**	**1989**	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**
ESTIMATED:																								
WhatIf Adults	593	596	616	617	606	590	580	560	610	628	593	556	517	480	443	409	378	354	338	331	331	331	331	331
WhatIf Tot Non-L	657	691	708	710	698	683	673	696	711	678	644	606	568	530	493	459	428	404	388	382	381	381	381	381
WhatIf Total	801	831	848	850	838	823	848	849	787	754	720	682	644	606	569	535	504	480	464	458	457	457	457	457
Adults	593	596	616	617	606	590	580	580	610	587	554	508	504	462	411	389	373	409	405	407	375	362	360	
Tot Non-Lambs	657	691	709	710	698	683	673	696	669	637	593	591	548	494	470	448	480	468	464	430	416	416	417	
Total	801	831	849	850	838	823	848	785	745	696	719	659	597	583	559	610	569	557	499	492	498	502	#N/A	
ACTUAL:																								
Tot Non-Lambs	633					769	805		778	641	802	895	746			592			562	415	410	489		



Tab 2: Male Population Only

When lamb number is missing, the average number counted between 1974 and the current year is used.
From 1983 on the number of lambs is held at 76 for this analysis

whatif		140	140	140	140			153		76	76	76	76	76	76	76	76	76	76	76	76	76
lambs	144					140	175		76	59	126	68	49			162			35	62	82	86
clambs	144	140	140	140	140	140	175	153	76	76	76	76	76	76	76	76	76	76	76	76	76	76
Birth Year \ Year	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995
1962	0																					
1963	2	0																				
1964	2	1	0																			
1965	8	5	2	0																		
1966	17	13	8	3	0																	
1967	33	28	21	13	6	1																
1968	61	54	47	35	22	10	1															
1969	59	56	50	43	33	20	9	1														
1970	47	44	42	37	32	24	15	7	1													
1971	39	37	35	33	30	26	19	12	5	1												
1972	30	29	28	26	25	22	19	14	9	4	1											
1973	32	31	30	28	27	25	23	19	15	9	4	1										
1974	72	48	46	44	42	40	38	33	29	22	13	6	1									
1975		70	46	44	43	41	39	37	33	28	21	13	6	1								
1976			70	46	44	43	41	39	37	33	28	21	13	6	1							
1977				70	46	44	43	41	39	37	33	28	21	13	6	1						
1978					70	46	44	43	41	39	37	33	28	21	13	6	1					
1979						70	46	44	43	41	39	37	33	28	21	13	6	1				
1980							88	58	55	53	51	48	46	41	35	27	16	7	1			
1981								77	50	49	47	45	42	40	36	31	23	14	6	1		
1982									38	25	24	23	22	21	20	18	15	12	7	3	0	
1983										38	25	24	23	22	21	20	18	15	12	7	3	0
1984											38	25	24	23	22	21	20	18	15	12	7	3
1985												38	25	24	23	22	21	20	18	15	12	7
1986													38	25	24	23	22	21	20	18	15	12
1987														38	25	24	23	22	21	20	18	15
1988															38	25	24	23	22	21	20	18
1989																38	25	24	23	22	21	20
1990																	38	25	24	23	22	21
1991																		38	25	24	23	22
1992																			38	25	24	23
1993																				38	25	24
1994																					38	25
1995																						38
1996																						
1997																						
Year	**1974**	**1975**	**1976**	**1977**	**1978**	**1979**	**1980**	**1981**	**1982**	**1983**	**1984**	**1985**	**1986**	**1987**	**1988**	**1989**	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**
ESTIMATED:																						
Whatif Adults	297	298	308	309	303	295	290	290	305	314	297	278	259	240	222	205	189	177	169	166	165	165
Whatif Tot Non-Lamb	329	346	354	355	349	341	336	348	356	339	322	303	284	265	247	230	214	202	194	191	190	190
Whatif Total	401	416	424	425	419	411	424	424	394	377	360	341	322	303	285	268	252	240	232	229	228	228

Tab 3: Male Population with Hunting

Male Population Only -- Hunted at the following proportion: 0.250 and leaving the following proportion unhunted: 0.750
Boxes around number of huntable males remaining alive at year-end
When lamb number is missing, the average number counted between 1974 and the current year is used.
From 1983 on the number of lambs is held at 76 for this analysis (number of male lambs = 38)

lx							1000	660	634	609	585	550	523	465	400	304	186	82	11			
lx/lx-1								0.66	0.961	0.961	0.961	0.94	0.951	0.889	0.86	0.76	0.6118	0.441	0.134			
whatif		140	140	140	140			153		76	76	76	76	76	76	76	76	76	76	76	76	76
M & F lambs	144					140	175		76	59	126	68	49			162			35	62	82	86
M & F lambs (safe-keeping)	144					140	175		76	59	126	68	49			162			35	62	82	86
male clambs	72	70	70	70	70	70	88	77	38	38	38	38	38	38	38	38	38	38	38	38	38	38
Birth Year \ Year	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995
1962	0																					
1963	2	0																				
1964	2	0	0																			
1965	8	4	1	0																		
1966	17	10	4	1	0																	
1967	33	21	12	5	2	0																
1968	61	54	35	20	9	3	0															
1969	59	56	50	32	18	8	3	0														
1970	47	44	42	37	24	14	6	2	0													
1971	39	37	35	33	30	19	11	5	2	0												
1972	30	29	28	26	25	22	14	8	4	1	0											
1973	32	31	30	28	27	25	23	15	8	4	1	0										
1974	72	48	46	44	42	40	38	33	22	12	6	2	0									
1975		70	46	44	43	41	39	37	33	21	12	5	2	0								
1976			70	46	44	43	41	39	37	33	21	12	5	2	0							
1977				70	46	44	43	41	39	37	33	21	12	5	2	0						
1978					70	46	44	43	41	39	37	33	21	12	5	2	0					
1979						70	46	44	43	41	39	37	33	21	12	5	2	0				
1980							88	58	55	53	51	48	46	41	26	15	7	2	0			
1981								77	50	49	47	45	42	40	36	23	13	6	2	0		
1982									38	25	24	23	22	21	20	18	11	6	3	1	0	
1983										38	25	24	23	22	21	20	18	11	6	3	1	0
1984											38	25	24	23	22	21	20	18	11	6	3	1
1985												38	25	24	23	22	21	20	18	11	6	3
1986													38	25	24	23	22	21	20	18	11	6
1987														38	25	24	23	22	21	20	18	11
1988															38	25	24	23	22	21	20	18
1989																38	25	24	23	22	21	20
1990																	38	25	24	23	22	21
1991																		38	25	24	23	22
1992																			38	25	24	23
1993																				38	25	24
1994																					38	25
1995																						38
1996																						
1997																						
Year	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995
ESTIMATED with hunting:																						
Whatif Males >= 3 yr	297	287	283	273	264	259	261	267	282	289	270	250	230	212	192	173	161	154	151	150	150	150
Whatif Tot Male Non-lambs	329	334	329	319	310	306	307	324	333	314	295	275	255	237	217	198	186	179	176	175	175	175
Whatif Total Males	401	404	399	389	380	376	395	401	371	352	333	313	293	275	255	236	224	217	214	213	213	213
Total Adults (M & F) w/o Hunting:																						
Adults	593	596	616	617	606	590	580	580	610	587	554	508	504	462	411	389	373	409	405	407	375	362
Tot Non-Lambs	657	691	709	710	698	683	673	696	669	637	593	591	548	494	470	448	480	468	464	430	416	416
Total	801	831	849	850	838	823	848	785	745	696	719	659	597	583	559	610	569	557	499	492	498	502
ACTUAL:																						
Tot Non-Lambs	633					769	805		778	641	802	895	746			592			562	415	410	489

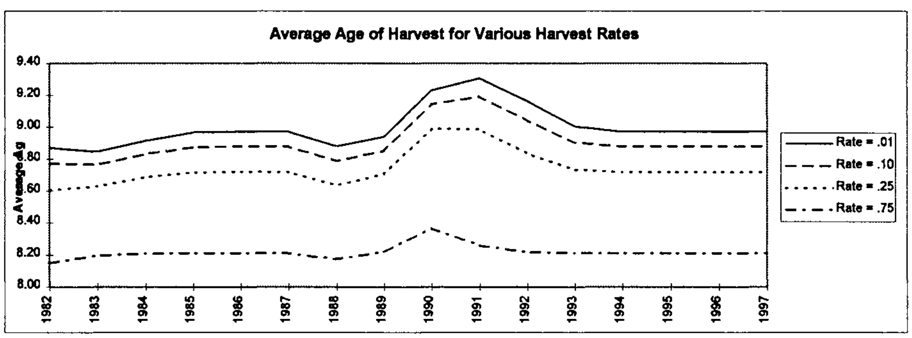
Tab 4: Harvest

NUMBER OF ANIMALS HARVESTED (IN BOXES) FOR HARVEST RATE OF: 0.25

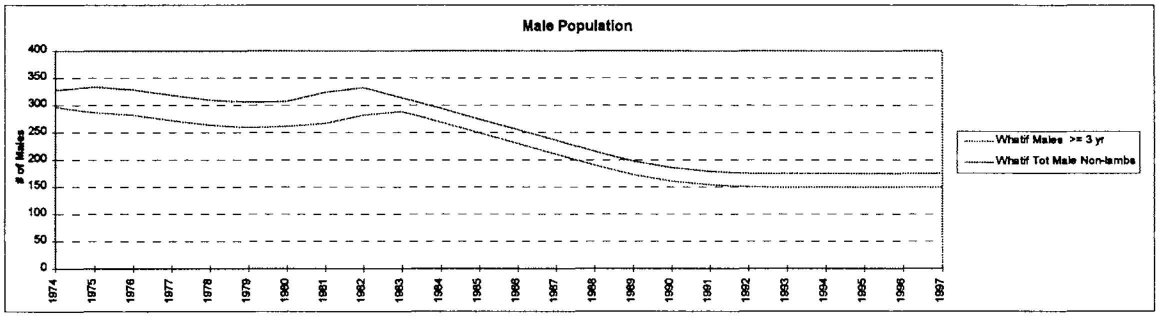
Birth Year \ Year	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
1962	0																							
1963	2	0.1																						
1964	2	0.2	0.0																					
1965	8	1.2	0.4	0.0																				
1966	17	3.2	1.5	0.5	0.0																			
1967		7.0	4.0	1.8	0.6	0.1																		
1968			11.7	6.6	3.1	1.0	0.1																	
1969				10.7	6.1	2.8	0.9	0.1																
1970					8.0	4.6	2.1	0.7	0.1															
1971						6.4	3.7	1.7	0.6	0.1														
1972							4.7	2.7	1.2	0.4	0.0													
1973								4.8	2.8	1.3	0.4	0.0												
1974									7.2	4.1	1.9	0.6	0.1											
1975										7.0	4.0	1.8	0.6	0.1										
1976											7.0	4.0	1.8	0.6	0.1									
1977												7.0	4.0	1.8	0.6	0.1								
1978													7.0	4.0	1.8	0.6	0.1							
1979														7.0	4.0	1.8	0.6	0.1						
1980															8.8	5.0	2.3	0.8	0.1					
1981																7.7	4.4	2.0	0.7	0.1				
1982																	3.8	2.2	1.0	0.3	0.0			
1983																		3.8	2.2	1.0	0.3	0.0		
1984																			3.8	2.2	1.0	0.3	0.0	
1985																				3.8	2.2	1.0	0.3	0.0
1986																					3.8	2.2	1.0	0.3
1987																						3.8	2.2	1.0
1988																							3.8	2.2
1989																								3.8
1990																								
1991																								
1992																								
1993																								
1994																								
1995																								
1996																								
1997																								
Year	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
Total Harvest		12	18	20	18	15	12	10	12	13	13	13	13	13	15	15	11	9	8	7	7	7	7	7
Average age of Harvest (current)									8.61	8.63	8.69	8.72	8.72	8.72	8.64	8.71	8.99	6.99	8.84	8.74	8.72	8.72	8.72	8.72

Average age of Harvest

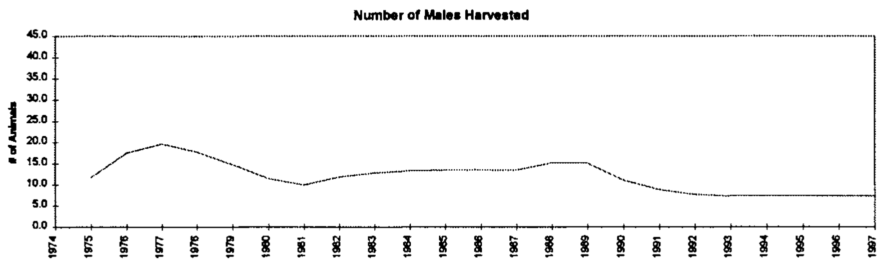
	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
Rate = .01	8.87	8.85	8.91	8.97	8.97	8.97	8.88	8.94	9.23	9.31	9.16	9.01	8.97	8.97	8.97	8.97
Rate = .10	8.77	8.77	8.83	8.87	8.88	8.88	8.79	8.85	9.15	9.19	9.04	8.90	8.88	8.88	8.88	8.88
Rate = .25	8.61	8.63	8.69	8.72	8.72	8.72	8.64	8.71	8.99	8.99	8.84	8.74	8.72	8.72	8.72	8.72
Rate = .75	8.15	8.20	8.21	8.21	8.21	8.21	8.18	8.22	8.37	8.26	8.22	8.21	8.21	8.21	8.21	8.21



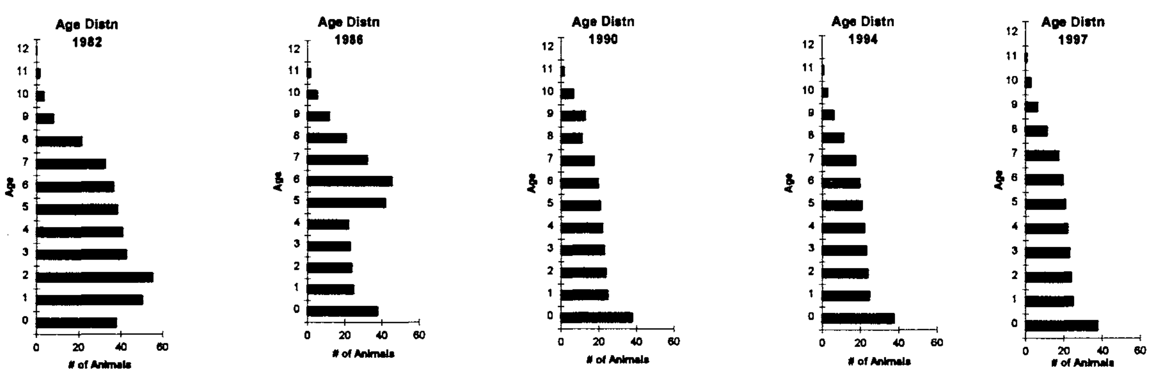
Harvest Rate = 0.25



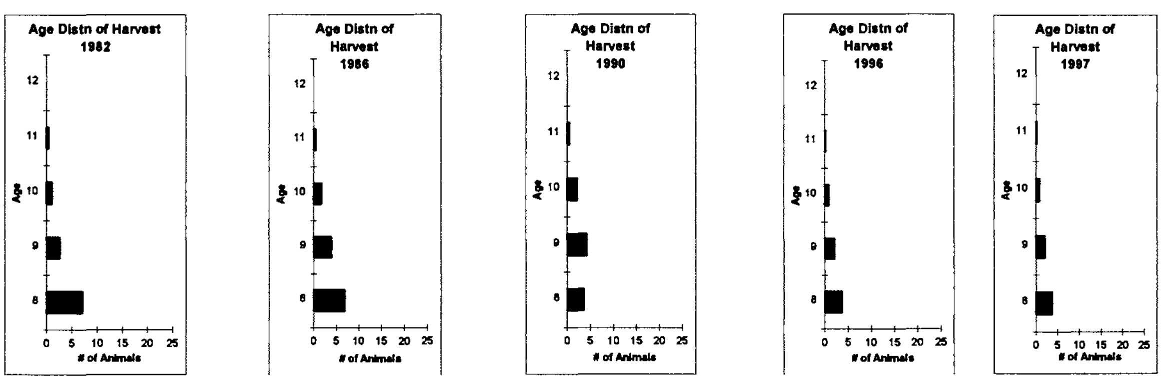
Harvest Rate = 0.25



Male Population Age Distributions for Harvest Rate = 0.25



Age Distribution of the Harvest



9. Appendix 2: Calculation of expected average age of harvest for fixed age distribution

9.1 Introduction

The calculations below illustrate that the expected average age of harvest for a given population in a given year does not vary with hunting pressure, as long as hunters randomly select full curl animals. Thus the average age of harvest cannot be used to identify even dramatic year-to-year changes in hunting pressure.

Unlike the model presented in the text in which hunting is allowed to affect the age structure of the population over time, the calculations below assume a constant age distribution and calculate the average age of harvest which would result from two different harvest rates. Such a calculation is appropriate, for instance, when one wishes to determine the effect of several potential harvest rates for a given year. These calculations illustrate that the average age of harvest is identical for different harvest rates – the results do not depend on the specific numbers chosen, rather they illustrate that average age of harvest reflects the age distribution of the population, not the level of exploitation.

9.2 Details

The calculations assume a small population with a specified age distribution. The average age of harvest is calculated for two different rates of exploitation. The calculations show every way to harvest the specified number of animals (either 2 or 3 depending on the example) and the probability associated with each combination. The average age of harvest is calculated in the last column by summing over the product of the probabilities times the number of ways each combination can be achieved. In both cases it is equal to the average age of the huntable population (8.5 years), as it will be in all cases where the same assumptions are applied, no matter what level of hunting pressure is selected.

CALCULATION OF EXPECTED AVERAGE AGE OF HARVEST FOR TWO EXPLOITATION RATES

Assume 10 animals with following age distn: age 8, 6; age 9, 3; age 10, 1 (ie. 60%, 30%, 10%)
Note: Average of all full curl rams in pop'n is 8.5
Let h=harvest rate, H=number of animals harvested
p = probability of individual harvest = # in rams in age class / # in full curl rams in popn
# of ways = the number of ways in which animals of specified ages can be obtained
x-bar = average age of specified harvest
P = probability of specified harvest = product of p's

h=.2, H=2, Average age of all full curl rams = 8.5
possibilities

age	p	age	p	# of ways	x-bar	P	(P)(# ways)	(x-bar)(P)(# ways)
10	0.100	9	0.333	2	9.50	0.033	0.067	0.633
10	0.100	8	0.667	2	9.00	0.067	0.133	1.200
9	0.300	9	0.222	1	9.00	0.067	0.067	0.600
9	0.300	8	0.667	2	8.50	0.200	0.400	3.400
8	0.600	8	0.556	1	8.00	0.333	0.333	2.667
						sum	1.000	**8.500 Avg Age of Harvest**

h=.3 H=3 Average age of all full curl rams = 8.5
possibilities

age	p	age	p	age	p	# of ways	x-bar	P	(P)(# ways)	(x-bar)(P)(# ways)
10	0.100	9	0.333	9	0.250	3	9.33	0.008	0.025	0.233
10	0.100	9	0.333	8	0.750	6	9.00	0.025	0.150	1.350
10	0.100	8	0.667	8	0.625	3	8.67	0.042	0.125	1.083
9	0.300	9	0.222	9	0.125	1	9.00	0.008	0.008	0.075
9	0.300	9	0.222	8	0.750	3	8.67	0.050	0.150	1.300
9	0.300	8	0.667	8	0.625	3	8.33	0.125	0.375	3.125
8	0.600	8	0.556	8	0.500	1	8.00	0.167	0.167	1.333
								sum	1.000	**8.500 Avg Age of Harvest**