

**DEVELOPMENT OF A PRELIMINARY POPULATION MODEL FOR
THE WESTERN ARCTIC CARIBOU HERD**

FINAL REPORT

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EXECUTIVE SUMMARY

- We developed an age-specific stochastic population model for the Western Arctic Caribou Herd. This model was calibrated to herd size during the period 1986–2008 and the resulting model fit the data relatively well.
- Adult survival was the demographic parameter with the largest impact on population size, even a 3 % increase in adult survival was inadequate to stop a population decline if herd demographics remain at their 2008 levels.
- Harvest levels and percentage of cows harvested can greatly impact population trajectory.
- Future modeling efforts would be improved if the following WAH-specific parameters were determined: age-specific survival rates of bulls and cows, harvest rates, and age-specific parturition patterns.

INTRODUCTION

The Western Arctic Herd (WAH) is currently the largest caribou herd in Alaska. The herd calves in the Utukok uplands of the western Brooks Range, moves into the western Brooks Range during the insect season, and migrates south to winter on the Seward Peninsula and in western Alaska. The WAH declined to an estimated size of 75,000 in 1976 and then increased to a peak count of 490,000 in July 2003 before declining 23% to an estimated 377,000 in the most recent photocensus in July 2007 (Dau 2007). Results of a 2009 photocensus are not yet available.

The WAH is important for subsistence hunters in western Alaska and a potential continued decline in herd size is a major concern for rural communities. In order to better understand the current decline in the WAH and model potential scenarios for changes in population size I developed a stochastic model of population size using existing estimates of various demographic parameters.

RESULTS AND DISCUSSION

Our model of herd growth for the years 1986-2008 was relatively close to the actual herd size estimates (Figure 1) given the large variance in estimates of demographic parameters and population estimates. The pattern is consistent with an increasing population, a general leveling out followed by a gradual decline although the increase and decrease phases in the modeled population were more gradual than the actual population changes estimated from photocensus data.

Scenario B (historic average) predicts a gradual increase in herd growth over the next 20 years while the other 2 scenarios predict declines (Figure 2). Scenario B (historic average) is probably overly optimistic as adult survival appears to be declining and is unlikely to revert to the 1986–2008 average in the near future. Scenario C (continuing trend) is probably overly pessimistic as demographic parameters are unlikely to keep declining for the next 20 years. These two scenarios should therefore be viewed as the best and worst case scenarios. Scenario A (2008 parameters) is likely the most accurate predictor of future herd growth. Altering the size of the harvest and the proportion of females in the harvest can substantially alter population size (Table 2; Figure 3).

I also looked at the sensitivity of the population predictions based on changes in average demographic parameters. Using scenario A (2008 parameters), I estimated the average population estimate after adding and subtracting 3% to the parturition rate, calf survival, and adult survival. As expected a 3% change in adult survival had the largest impact on population size, calf survival was second and parturition rates was third (Figure 4). Even a 3% increase in adult survival was inadequate to stop a population decline under scenario A (2008 parameters).

The estimated harvest of the WAH has been remarkable stable during 1999–2006 (Dau 2007) although this stability may be partially a result of the model used to estimate harvest (Sutherland 2005). This model does not incorporate changes in herd size and has only a subjective three-category caribou availability variable. Thus the parameterization of the model may not adequately capture yearly variation in harvest levels and changes in herd level as a result in caribou population declines. How herd harvest will change in a declining population remains an unanswered question. New estimates of village harvest based on survey data should be

compared to the theoretical harvest model (Sutherland 2005) to determine if the model needs to be reparameterized or altered to incorporate herd size.

The model indicated that the survival rate of collared female caribou was too low to account for the observed changes in herd size from 1986–2008. Haskell and Ballard (2007) also found that survival rates from collared caribou were too low and concluded that the weight of collars decreased caribou survival. This contention is certainly plausible and is supported by research on zebra that concluded that movement rates were lower in zebras with heavier telemetry collars (Brooks et al. 2007). My modeling also suggests that the collaring schedule used for the WAH may have underestimated adult female survival rates because the collared sample oversamples older females relative to the age structure of the population (unpublished data). This bias may act in conjunction with the potential negative impact of the collar on survival.

This model provides a number of population projections based on harvest strategies and various potential changes in herd demographics. This provide some useful guidance on what level of herd changes are possible but still lack definitive information on how demographic parameters will change in the future. Accurately predicting how the population will change requires information on the causes in changes in survival and parturition. The current decline in the WAH appears to be caused primarily by a gradual decline in survival rates in adults and probably calves. Parturition rates were low in the late 1990's but have increased since 2000.

The gradual decline in survival rates coupled with stable parturition rates, no discernible decline in body condition (Dau 2007), and apparently stable harvest levels suggests that the current decline in herd size is due to either a change in weather or predation levels. There have been documented declines in lichen biomass on the winter range (Joly et al. 2007) but this is apparently not currently reflected in body condition.

Based on these simulations, it looks likely that the WAH will continue to decline in the near future. This herd had a precipitous decline in the late 1970's that was attributed to harvest and predation (Davis et al. 1980). Lowering the harvest and decreasing the proportion of females in the harvest will increase herd size relative to the status quo but is unlikely to halt the decline in herd size.

METHODS

I used estimates of adult female survival, parturition rates, caribou harvest, and calf survival (calculated based on parturition rate and short yearling counts) calculated from annual research conducted by the Alaska Department of Fish and Game (ADFG; Dau 2007) as well as additional assumptions of important parameters to develop a stochastic age- and sex-specific population model in an Microsoft Excel spreadsheet. I first developed a model based on ADFG data collected 1986–2008 that approximated the population trajectory of the WAH during that period. Not all necessary parameters were studied for the WAH (e.g. adult male survival and calf survival) and none of the demographic parameters had age-specific estimates, these parameters were estimated based on existing literature. I used the average parameter values from the first 5 years to simulate a population with a stable age structure and used this age structure in the model as a starting age structure.

Because a model with estimated demographic parameters did not adequately describe the population trajectory of the WAH over this period, parameters were modified using the best available information on potential variance and biases in the data until it roughly matched the population trajectory. In this way we developed age- and sex-specific estimates of the necessary demographic parameters for the 1986–2008 period (Table 1). Some skepticism of the original demographic parameters was justified because most were estimated based on a small sample size of caribou relative to the size of the WAH (Dau 2007). Other researchers have concluded that there are inherent biases in telemetry data possibly as a result of the weight of collars (Haskell and Ballard 2007, Brooks et al. 2008), and the age structure of animals with telemetry collars is unlikely to be representative of the age structure of the population as a whole and may oversample senescent animals (Eberhardt 2002, unpublished model). Survival of females was estimated to remain high throughout most of the lifespan of females and then decline rapidly near senescence (Thomas and Barry 1990, Messier et al. 1988) possibly as a result of increased tooth wear in older females (Kojola et al. 1998). This could lead to underestimates of adult survival and overestimates of parturition rate.

Adult male survival rates used in the model were similar to estimates reported for the WAH (Davis and Valkenburg 1985) and higher than estimated from the nearby Teshekpuk Herd that

has higher rates of hunting mortality (Carroll 2007). Calf survival rates were set at levels similar to the CAH (Arthur and Del Vecchio 2007).

These modified estimates were used to predict future herd growth over the next 20 years based on three potential scenarios:

- Scenario A (2008 parameters): If demographic parameters remained at their 2008 level (as determined by regressions of parameters vs. year); or
- Scenario B (historic average): If demographic parameters remained at their average value over the 1986–2008 period; or
- Scenario C (continuing trend): If demographic parameters start at their 2008 level and continue to change according to the trajectories observed during 1986–2008.

Each demographic parameter was allowed to vary according to the expected variance in the estimate to capture the stochasticity inherent in the forecast. For each scenario the model was run 1000 times and the mean and 95% confidence intervals were calculated. We also ran each model using different levels of caribou harvest and different sex ratios of harvested animals.

ASSUMPTIONS

Every model is only as good as the data used to create it and the accuracy of the assumptions underlying the model. In the case of an age- and sex-specific caribou population model there are many parameters that have to be estimated based on varying level of effort of data collected with varying levels of precision. Although the WAH has been subject to routine, relatively intensive monitoring spanning decades, some parameters still had to be estimated based on the literature from other herds. The following assumptions were made for the 1986-2007 model:

1. Age and sex-specific survival rates were a constant proportion of the estimated annual survival rates based on collar data.
2. I assumed that adult survival estimates from telemetry collar data were underestimates of true adult survival because of negative effects of collars (Haskell and Ballard 2007) and differences in age-structure of the collared sample (unpublished analysis). The pattern in age-specific female survival rates were based

on an average of estimates for the George River and Beverly herds (Thomas and Barry 1990, Messier et al. 1988, Taylor 1991).

3. Age-specific survival rates for adult males were not available so we estimated these parameters as a constant proportion of adult female survival rates based on the observed bull:cow ratios, estimates of total adult male mortality for collared WAH males (L. Parrett pers. comm.), and the fact that male survival declines rapidly for males of rutting age.
4. Calf survival rates over the first year were estimated based on observed short yearling counts and parturition rates and adjusted for potential biases. These estimates were compared to estimates for the CAH (Arthur and Del Vecchio 2007). Male and female calves were assumed to have identical survival probabilities and 50 percent of calves were assumed to be males.
5. Parturition rates were based on estimates from telemetry data and adjusted for potential biases caused by an unrepresentative age-distributions among collared females. The pattern of age-specific parturition patterns were taken from Adams and Dale (1998).
6. Harvest rates were assumed to be approximately 15,000 a year and independent of herd size (Sutherland 2005, Dau 2007; with a maximum harvest rate of 10% of the herd) and 40% of the harvest was females. Harvest mortality and mortality by other causes were assumed to be additive. Age-specific harvest of yearlings and older were assumed to be proportionate to their relative proportion in the population.
7. Harvest and the percent of harvest comprised of female caribou remained constant. Calves only comprise a low (2%) proportion of the harvest. Mortality due to wounding loss was not included in the model.

Because multiple parameters have to be estimated and adjusted, there are a large number of possible combinations of parameters that could approximate the observed population growth. Defining a single “best” model to use will require professional judgment of the precision and accuracy of the various parameters. The results presented here represent just one possible

combination of parameters and the model should be adjusted as necessary based on new information.

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Table 1. The demographic parameters used in a population model of the Western Arctic herd
1986–2008.

Year	From Dau (2007)			Adjusted or Estimated Parameters			
	Prop. Short Yearlings	Parturition Rate	Adult Female Survival	Calf Survival	Adult Female Survival	Adult Male Survival	Parturition
1986	0.23	0.86*	0.88	0.70	0.92	0.80	0.82
1987	0.23	0.74	0.88	0.69	0.92	0.80	0.71
1988	0.22	0.81	0.91	0.89	0.92	0.80	0.77
1989	0.32	0.78	0.85	0.73	0.89	0.77	0.75
1990	0.24	0.72	0.85	0.63	0.89	0.78	0.69
1991	0.19	0.80*	0.86	0.61	0.90	0.79	0.76
1992	0.22	0.86	0.85	0.49	0.89	0.77	0.82
1993	0.19	0.52	0.8	0.71	0.84	0.72	0.51
1994	0.19	0.71	0.84	0.49	0.87	0.75	0.69
1995	0.17	0.59	0.87	0.73	0.90	0.78	0.58
1996	0.22	0.61	0.82	0.81	0.85	0.72	0.60
1997	0.26	0.58	0.85	0.75	0.88	0.76	0.57
1998	0.21	0.53	0.92	0.61	0.91	0.80	0.52
1999	0.15	0.58	0.83	0.59	0.86	0.75	0.57
2000	0.18	0.69	0.78	0.49	0.80	0.69	0.67
2001	0.19	0.66	0.82	0.44	0.84	0.73	0.64
2002	0.15	0.78	0.85	0.47	0.87	0.76	0.76
2003	0.19	0.68	0.81	0.58	0.83	0.71	0.66
2004	0.22	0.59	0.85	0.41	0.87	0.76	0.58
2005	0.12	0.69	0.78	0.50	0.80	0.70	0.67
2006	0.20	0.65	0.72	0.60	0.74	0.62	0.63
2007	0.25	0.73	0.86	0.33	0.88	0.78	0.71
2008	0.11	0.70	0.78*	0.48	0.80	0.70	0.68
Average	0.202	.690	0.837	0.596	0.864	0.750	0.669

* Not reported in Dau (2007), estimated based on simulation model and previous and subsequent values.

Table 2. The predicted population size and 95% confidence intervals of the Western Arctic caribou herd under 3 different scenarios with varying levels of human harvest and sex ratios of harvested animals. The population was assumed to start at 377,000 with annual harvest of 15,000 caribou of which 40% were females.

Scenario	Harvest Level	% females	10-years		20-years	
			Population	95% C.I.	Population	95% C.I.
Scenario B (historic average)	10,000	40	507,710	382,176-650,374	677,117	446,093-928,625
	15,000	20	506,913	390,183-641,660	705,331	489,874-974,063
	15,000	40	462,645	350,607-586,763	587,266	393,533-831,151
	15,000	60	404,811	301,746-525,775	437,274	270,468-635,316
	20,000	40	414,149	303,219-537,519	474,902	305,306-685,186
Scenario A (2008 levels)	10,000	40	280,188	205,894-363,357	216,652	143,518-310,376
	15,000	20	284,041	207,774-372,074	227,341	147,984-312,749
	15,000	40	246,017	176,152-332,162	161,005	98,208-239,025
	15,000	60	205,145	141,388-278,085	93,335	51,085-149,258
	20,000	40	211,053	151,270-284,121	128,763	82,022-185,925
Scenario C (Continuing trend)	10,000	40	193,091	140,695-254,794	32,521	17,340-55,456
	15,000	20	193,048	138,102-254,894	41,960	22,484-65,082
	15,000	40	166,677	113,886-223,445	25,647	14,224-41,662
	15,000	60	133,593	88,928-188,475	12,913	6,249-21,837
	20,000	40	140,275	99,196-187,033	22,052	12,149-35,133

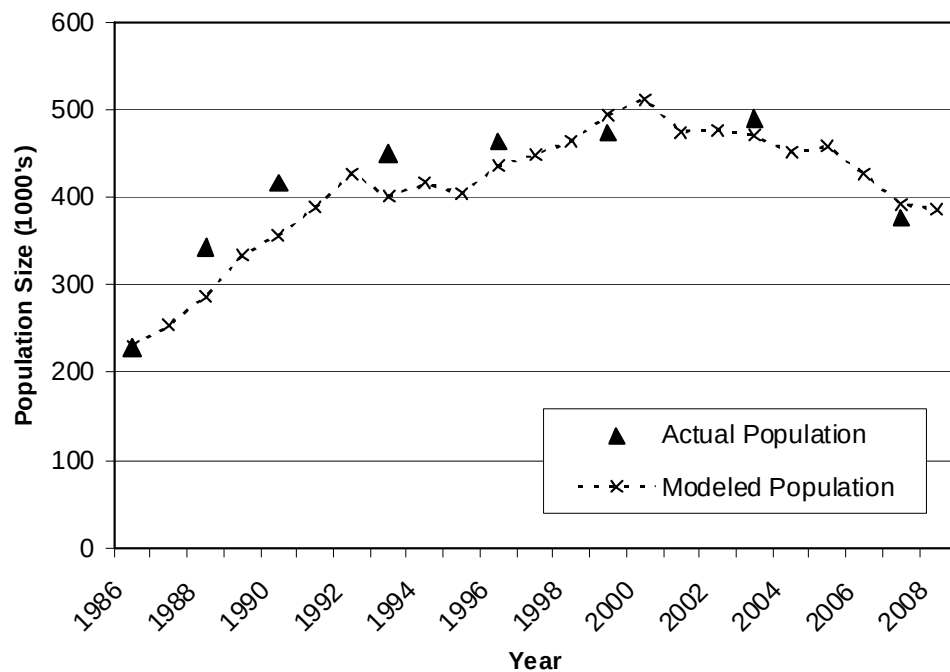


Figure 1. The actual and modeled population size of the Western Arctic caribou herd 1986–2008. Actual population size based on photocensuses conducted by Alaska Department of Fish and Game (Dau 2007).

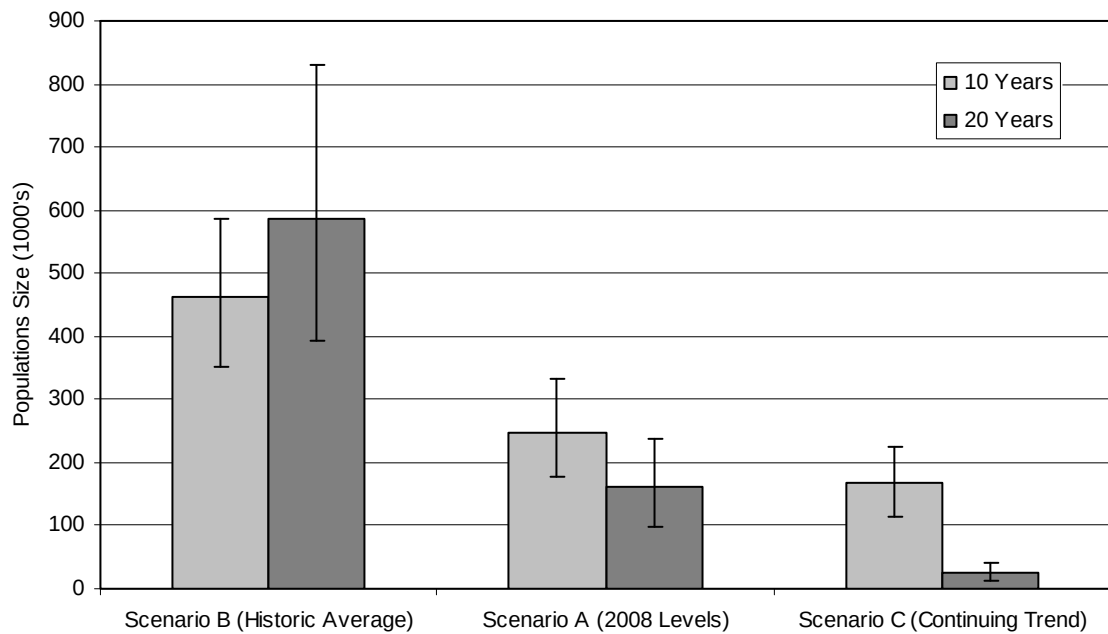


Figure 2. The predicted changes in population after 10 and 20 years (and 95% confidence interval) based on three different scenarios of changes in demographic scenarios. The population was assumed to be 377,000 in year zero.

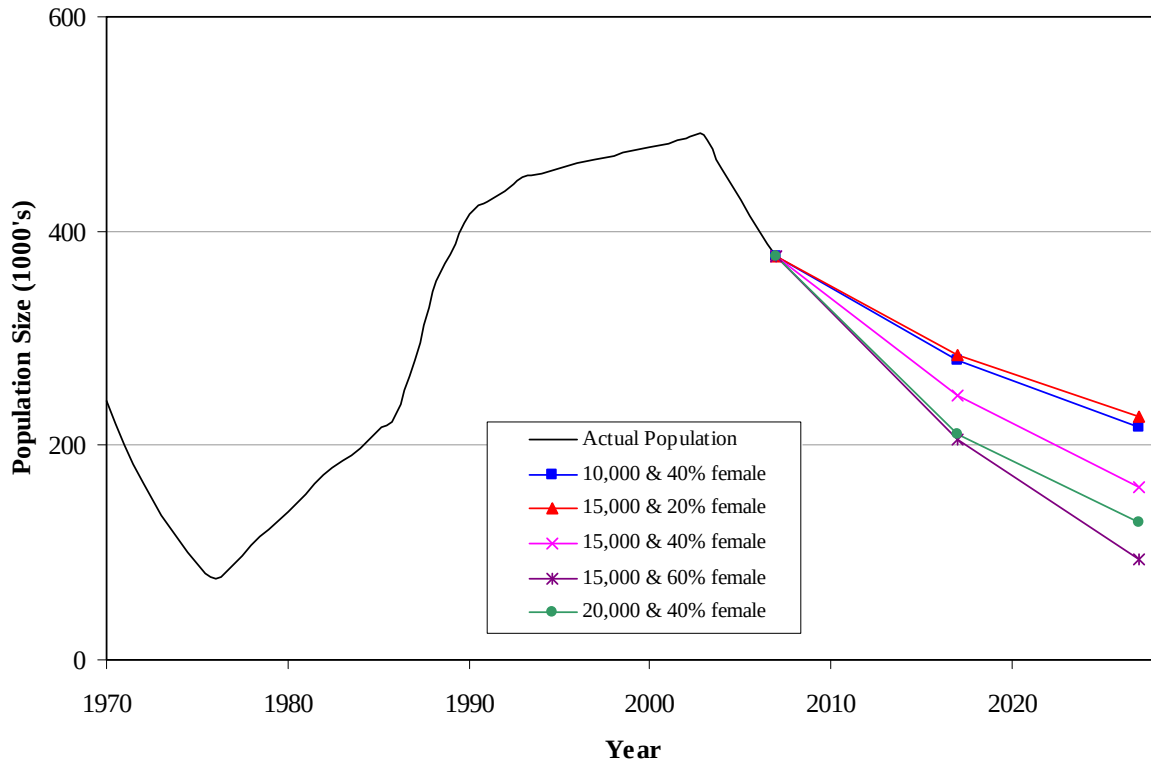


Figure 3. The predicted changes in population after 10 and 20 years (95% confidence interval) for scenario A (2008 levels) under various levels of total annual harvest and various proportion of harvested caribou that are female.

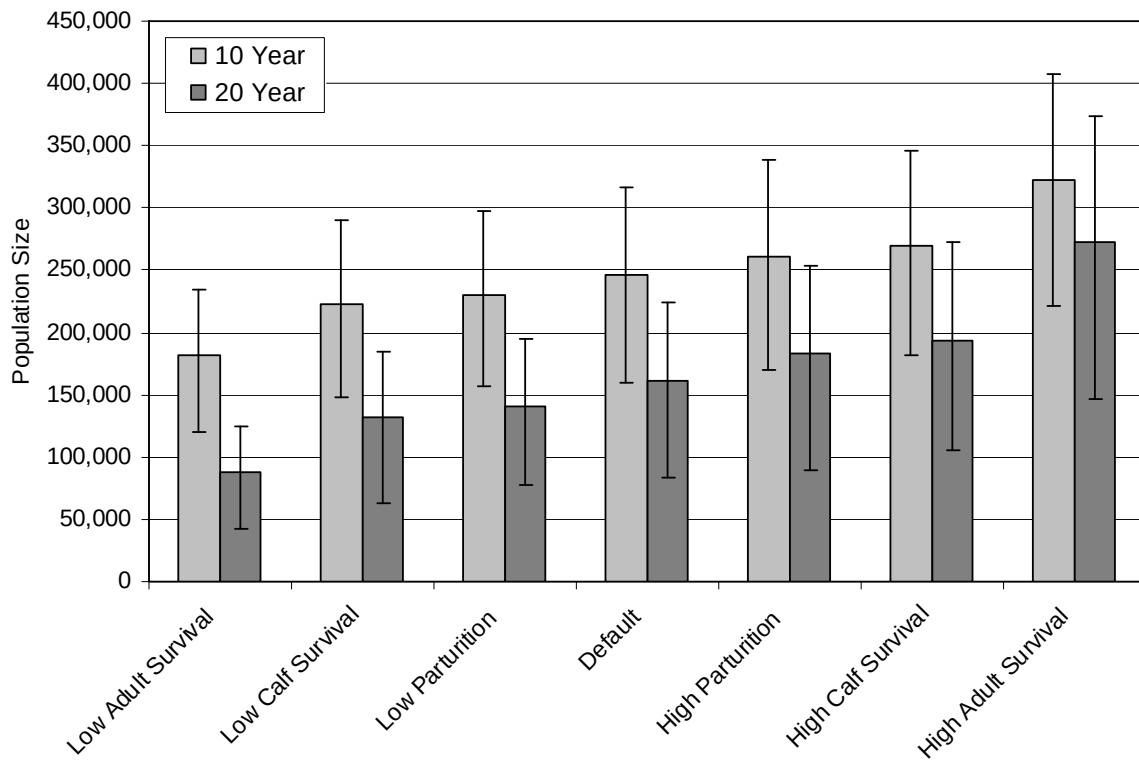


Figure 4. The predicted population sizes after 10 and 20 years (95% confidence interval) for scenario A (2008 levels) when parturition, calf survival, and adult survival were increased and decreased by 3%.