Age Class	Male survival rates	Female survival rates	Birth rates (females born to females)
1	0.60	0.60	0
2	0.80	0.90	0.35
3	0.95	0.95	0.45
4	1.00	0.97	0.45
5	1.00	0.97	0.45
6	1.00	0.95	0.45
7	1.00	0.95	0.45
8	0.75	0.95	0.45
9	0.34	0.70	0.45
10	0	0.80	0.45
11			0.45

TABLE 3.10 Birth and Survival Rates for Impala Age Classes.

Note: The initial population size and distribution were made up. All other parameters including the numbers associated with different types of hunting and predation were taken from the article by Ginsberg and Milner-Gulland entitled *Sex-Biased Harvesting and Population Dynamics in Ungulates: Implications for Conservation and Sustainable Use* [21] and is reprinted by permission of Blackwell Science Inc.

Project 3.10. Barren Ground Caribou

Modelers and biologists from the Canadian Wildlife Service held a workshop to develop a model of barren-ground caribou population dynamics which resulted in the paper [71]. This project constructs a simplified version of this model. Assume you are part of a biological modeling team hired by the Canadian Wildlife Service to address the following questions. 1) What is expected from an unmanaged caribou population under normal circumstances? 2) What is the effect of harsh springs and winters? 3) What is the effect of the current hunting strategy under normal circumstances and with weather effects? 4) What is the effect of a revised hunting plan under both normal and weather effects? The parts below isolate and give details on these issues. Your report should address all these points, but you are in no way constrained by the organization presented here.

1. Baseline model. Using the demographic data in Table 3.11, construct a model for the caribou. Assume calves (fawns) are equally likely to be male as female. Further assume that the male population is always sufficient for siring purposes. Although caribou occasionally live more than 10 years, there is one class for caribou of age 10 and over. You should experiment and use your judgment to determine the number of years to run your model.

2. Weather Effects. Bad winters slightly affect the adult survival rate. With high snowfalls, the caribou are slowed and more susceptible to wolf attacks. Winters are rated on an index ranging from 0 to 1 with 0 being mild and 1 being the most severe. Figure 3.17 shows the change in survival rate for one adult class. Assume the others

Age	Number of male	Number of female	Mortality rate	Percentage of females calving
1	4,500	4,500	0.60	0.00
2	4,000	4,000	0.03	1.8
3	3,500	3,800	0.03	48.0
4	3,100	3,600	0.03	82.0
5	2,700	3,400	0.03	92.0
6	2,400	3,200	0.03	92.0
7	2,100	3,000	0.02	92.0
8	1,900	2,900	0.02	90.0
9	1,700	2,700	0.02	90.0
10+	2,700	5,000	0.50	90.0

TABLE 3.11 Starting Population Size and Normal Rate Values for Caribou Simulation. Reprinted from Ecological Modelling, *Computer Simulation of Barren-Ground Caribou Dynamics* by C.J. Walters, R. Hilborn and R. Peterman,1975, with permission from Elsevier Science.

are shifted so that the mild winters match the survival rates shown in Table 3.11. (In other words the third age class ranges from 0.97 to 0.94, with the transition points at 0.25 and 0.5.) Bad springs severely affect the survival of fawns, and can result in the death of the entire cohort of offspring (the transition point is at 0.85). The fawn survival rate as a function of a spring index is shown in Figure 3.18. Assume the winter and spring indices are random variables following a uniform distribution. Further assume that the severities of winters and springs are independent of each other (i.e., use separate random numbers for winter and spring). Add this stochasticity to your model and run an appropriate number of simulations.

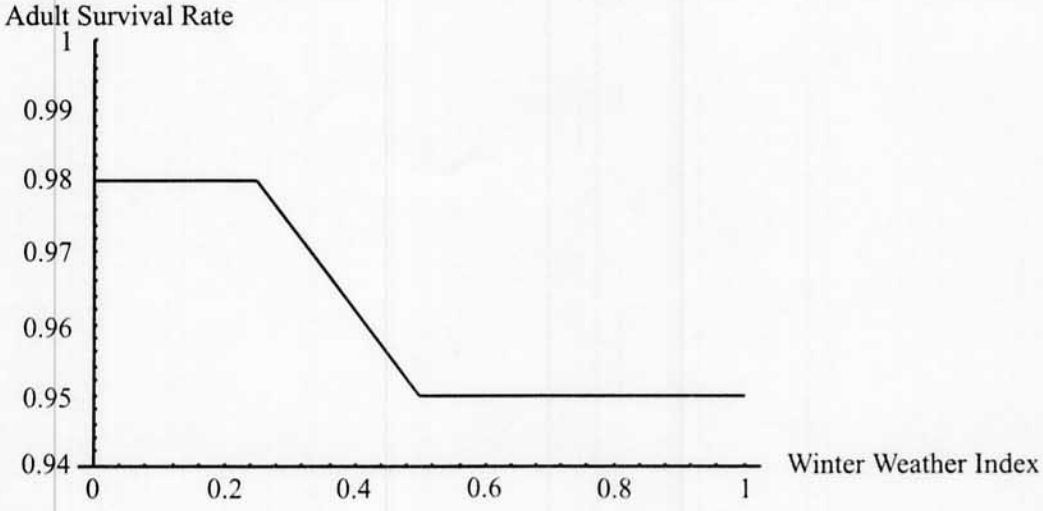

FIGURE 3.17 Effects of Winters on Adult Survival. Index Is Inches of Snow Divided by 100.

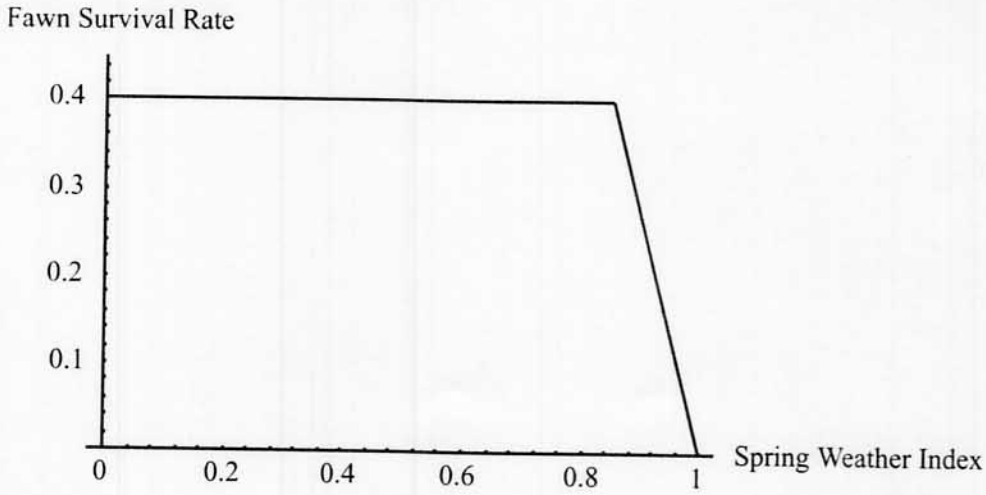

FIGURE 3.18 Fawn Survival Rate is 40% Unless Spring is Extremely Severe.

3. Hunting. There are two hunting seasons for caribou: summer and winter. Hunting rates for the various sexes, age classes, and seasons are shown in Table 3.12. Re-do the models from parts **1** and **2** to include hunting.

4. Hunting Redux. A new management plan proposes doubling the male harvest and halving the female harvest. Consider the effects of this both with and without weather effects.

Age	Summer Male	Summer Female	Winter Male	Winter Female
1	0.005	0.005	0.005	0.005
2	0.0285	0.016	0.06655	0.012
3	0.0285	0.016	0.06655	0.012
4	0.0285	0.016	0.06655	0.012
5	0.0285	0.016	0.06655	0.012
6	0.0285	0.016	0.06655	0.012
7	0.0285	0.016	0.06655	0.012
8	0.0285	0.016	0.06655	0.012
9	0.0285	0.016	0.06655	0.012
10+	0.0285	0.016	0.06655	0.012

TABLE 3.12 Hunting Rates for Various Ages, Sexes, and Seasons. Reprinted from Ecological Modelling, *Computer Simulation of Barren-Ground Caribou Dynamics* by C.J. Walters, R. Hilborn and R. Peterman,1975, with permission from Elsevier Science.