

# *Science Project*

## *Kermode Bear Populations: Computer Simulation*

According to the Tsimshian creation legend, before there was life, the earth was a barren land of ice and snow. The legend continues to say that the raven creator Moksgm'ol made the earth as green as it is now. Moksgm'ol wanted something to remind himself of when the earth was white, so he went among the black bears of the Queen Charlotte Islands and made every tenth one white so he could look upon the bears and remember how the world had been. These white bears are called spirit bears or Kermode bears. People have begun to study these rare Kermode bears. They have discovered that cause of the bears' white coats is a single nucleotide mutation in the Mc1r receptor gene which controls coat color. The change is a single Adenine to Guanine mutation. These bears are not albino. They have black eyes and nose, and some Kermode bears have a few darker hairs. Although they are white, they are not polar bears.

Since I am interested in bears, for my science project, I chose to create a computer simulation to predict "How many Kermode bears will there be in 300 years with a certain starting population?"

My hypothesis is that Kermode bears will steadily comprise 10% of the population, purebred black bears 50% and carriers 40% of the entire population.

The materials I used for this project include our Windows 2000 computer, a computer programming language and compiler called Eiffel 5.3 and the spreadsheet program Excel. I obtained research information from the sources in my bibliography.

My science project simulation consists of two classes: BEAR and KERMODE\_SIMULATION (see source code in Appendix A and B). BEAR includes attributes for genotype, phenotype, age, and gender. The attribute `is_eligible` tells the simulation that the bear is eligible for mating. Another set of attributes define important model variables related to BEAR. These include the age at which bears can mate, the ratio of males to females at birth, and how many years a mother doesn't breed after having cubs. Functions in BEAR include `increment_age` (ages the bear one year), `conceive` (creates new cubs given a mother and father), and `make_from_scratch` (creates a new bear given set attributes).

KERMODE\_SIMULATION is where the actual simulation takes place. Important attributes in this class include `population` (a list of bears currently alive in the simulation), and the two data structures used for recording model information. Other attributes define variables related to the simulation. These include `number_of_runs` (the number of times the model is run), `number_of_years` (the number of years in each run), `average_litter_size` (the size of a females litter), `target_population_size` (the model adjusts the mortality rate to maintain a population this size), `file_location` (the computer directory where out files are stored), and `mortality_table` (shows the probability of bears at any given age will die.)

The following is a general outline of how the program runs.

1. Create data structures to hold model output.

2. Run simulation the number of times indicated by number\_of\_runs (100).

For each run:

    Create the same starting population each time. This starting population is  
    30 Kermode bears, 60 carriers and 210 purebred black bear

    For each year (300 per run):

        Record population information

        Cull population

        Identify bears eligible for mating

        Mate bears and create cubs

3. Write results to specified file.

In deciding mortality and mating success, I used a random\_number\_sequence which was compared to the probabilities defined by the mortality table and model assumptions. The assumptions that I made were very important to the outcome of the model. These include:

- A male bear can reproduce until it dies
- Males and Females can reproduce after/at the age of 6
- Females spend exactly 2 years with cubs and don't breed during that time.
- 25% of Eligible couples will have cubs in year.
- Every eligible male has one chance to mate with a randomly selected eligible female
- Every litter has two cubs
- Cubs have a 50% chance of dying within their first 3 years.
- Every surviving bear dies at the age of 20.

- Mortality goes up with increasing population.
- The beginning population is always 300 bears
  - 30 Kermode
  - 60 Carriers
  - 210 Purebred
- Starting age and gender distribution is the same for each genotype.
- 50% of cubs are male/ 50% of cubs are female.
- Mortality is the same for males and females
- Mortality and breeding success is the same for all genotypes

The results of the simulation are written to two files. The first file is called end\_of\_year information. This includes average populations for the end of each year. The second file is called end\_of\_run. The end of run information has the exact end of run information for each of the 100 runs.

The results of the model were written to two files, as stated earlier. These data are presented in Appendix D, Table 1 and 2. The first thing I noticed about my total\_by\_year information is that the numbers of all genotype populations go down, then stabilize. (Appendix A, Figure A) This suggests that the starting population that I chose for my model is unstable. My question/problem for this science project was, ‘How many Kermode bears will there be in 300 years with a certain starting population.’ My results show that there is no way of answering that with a single number. The ending number of Kermode bears ranged from 0-83. Using my end\_of\_run table (Appendix D, Table 2) I calculated in what percentage of the runs the Kermode bear population declined from the starting population of 30 bears, went extinct, or increased. (Appendix C, Figure C) I realized that the Kermode bear population decreased in

79% of all runs. Using the same end\_of\_run table, (Appendix D, Table 2) I noticed that in the majority of the runs, the Kermode bear population ended with between 5 and 15 bears. (Appendix C, Figure B) This implies between a 50% to 84% decrease in Kermode populations. So, not only did the population decrease in 79% of the runs, but it decreased significantly.

My expectation for the results was a constant population throughout the various years and runs. My actual data showed far from that. In fact, my results showed vast variation. The whole range of ending Kermode bear populations throughout the runs was 0-83 bears. Thus, my model indicates that because its population is so small, the frequency of the Kermode bear genotype can vary widely depending on the survival and breeding success of the few individual bears of the Kermode genotype. However, my simulation suggests that if all the assumptions are valid, the Kermode bear population is likely to decline from its original population, but will most likely not go extinct.

After looking over the results, I concluded that my hypothesis was incorrect. My hypothesis stated that the Kermode population would always comprise around 10% of the population, the carriers of the Kermode gene would always stay around 40% and purebred black bear populations would stay close to 50%. My results show that the percentage of the population of any certain genotype varies from run to run. The population of Kermode bears in the wild is relatively stable, and higher than my model predicted. This may suggest that

Kermode bears have a breeding or survival advantage over black bears. The reason that this may be true is because the simulation, which assumes there is no advantage for Kermode bears, predicts a significant decrease in population of the Kermode genotype. The 'survival advantage' may simply be that the spirit bears have never been hunted by native peoples and almost never hunted by game hunters, where as the black bears have. If people care about the fate of the beautiful Kermode bear, than the results of my simulation justify active conservation of the spirit bears.



Table 1 Average Population Totals (by year)				
Year	Kermode	Carrier	Purebred	Total
0	29.7	59.4	207.9	297
1	27.4	65.2	212.26	304.86
2	24.81	68.06	205.37	298.24
3	22.13	68.58	198.18	288.89
4	20.96	70.08	195.98	287.02
5	19.39	72.43	193.89	285.71
6	17.28	72.18	188.03	277.49
7	15.69	72.95	185.28	273.92
8	14.65	74.5	181.08	270.23
9	13.78	76.28	180.78	270.84
10	12.96	77.16	179.07	269.19
11	12.21	80.43	182.14	274.78
12	12.21	83.39	187.84	283.44
13	12.03	85.66	191.95	289.64
14	11.86	88.84	195.1	295.8
15	11.82	91.28	201.5	304.6
16	11.65	92.47	202.38	306.5
17	11.16	92.86	202.67	306.69
18	10.84	93.67	203.6	308.11
19	10.91	94.26	203.45	308.62
20	10.66	95.45	204.64	310.75
21	10.74	96.92	204.1	311.76
22	10.72	97.03	204.14	311.89
23	10.66	96.13	206.48	313.27
24	10.72	96.62	207.48	314.82
25	10.84	96.79	207.96	315.59
26	10.93	97.78	209.08	317.79
27	11.21	98.14	208.73	318.08
28	11.47	97.84	210.35	319.66
29	11.23	98.77	210.55	320.55
30	11.35	99.17	211.61	322.13
31	11.27	98.8	211.54	321.61
32	11.7	98.69	211.27	321.66
33	11.57	98.29	211.86	321.72
34	11.51	98.03	211.96	321.5
35	11.29	98.54	212.5	322.33
36	11.25	98.15	211.87	321.27
37	11.41	97.94	212.09	321.44
38	11.64	96.95	211.43	320.02
39	11.61	96.79	211.51	319.91
40	11.4	95.84	211.77	319.01
41	11.43	96.58	211.39	319.4

Year	Kermode	Carrier	Purebred	Total
42	11.64	96.67	212.21	320.52
43	11.5	96.63	212.3	320.43
44	11.54	97.21	212.23	320.98
45	11.71	96.88	210.4	318.99
46	11.62	96.13	211.34	319.09
47	11.9	97.14	211.86	320.9
48	12.05	97.18	211.88	321.11
49	12.2	96.78	212.24	321.22
50	12.15	96.11	212.01	320.27
51	12.41	96.39	211.6	320.4
52	12.29	96.51	213.19	321.99
53	12.2	96.39	213.75	322.34
54	12.1	95.35	214.31	321.76
55	12.13	96.11	213.54	321.78
56	12.05	96.28	212.73	321.06
57	12.14	95.53	211.91	319.58
58	12.12	95.69	212.09	319.9
59	11.85	95.3	212.49	319.64
60	12	95.49	213.74	321.23
61	12.14	96.1	214.13	322.37
62	12.25	95.59	216.13	323.97
63	12.3	95.37	216.66	324.33
64	12.04	94.52	216.4	322.96
65	12.12	95.03	215.56	322.71
66	12.12	94.58	214.15	320.85
67	12.22	95.01	213.85	321.08
68	12.17	95.68	213.51	321.36
69	12.1	95.13	213.35	320.58
70	12.34	96.09	214.97	323.4
71	12.12	95.77	213.83	321.72
72	12	95.82	213.32	321.14
73	11.92	95.91	211.92	319.75
74	12.01	95.77	213.26	321.04
75	11.96	95.72	212.38	320.06
76	12.33	96.64	213.84	322.81
77	12.49	96.46	213.59	322.54
78	12.27	97.14	214.75	324.16
79	12.26	97.4	213.97	323.63
80	12.38	98.24	212.06	322.68
81	12.26	98.19	211.69	322.14
82	12.08	96.97	212.52	321.57
83	12.06	98.01	214.03	324.1
84	12.29	97.78	213.8	323.87
85	12.61	96.74	214.49	323.84

Year	Kermode	Carrier	Purebred	Total
86	12.7	97.31	214.18	324.19
87	12.89	97.02	213.48	323.39
88	12.55	97.5	213.67	323.72
89	12.72	97.67	213.77	324.16
90	12.57	97.26	213.83	323.66
91	12.6	96.86	213.57	323.03
92	12.49	97.33	214.37	324.19
93	12.61	96.93	213.32	322.86
94	12.77	96.23	212.46	321.46
95	12.77	95.53	212.18	320.48
96	12.71	94.98	210.96	318.65
97	12.53	95.28	211.91	319.72
98	12.56	96	210.88	319.44
99	12.68	94.2	211.55	318.43
100	12.58	94.66	211.19	318.43
101	12.19	94.87	212.15	319.21
102	12.51	95.96	212.31	320.78
103	12.52	96.53	210.97	320.02
104	12.77	96.42	210.78	319.97
105	12.69	96.49	209.92	319.1
106	13.09	97.47	209.21	319.77
107	12.93	97.07	209.58	319.58
108	13	97.35	209.57	319.92
109	12.83	97.98	208.26	319.07
110	12.84	97.58	210.14	320.56
111	12.72	97.51	209.9	320.13
112	12.88	97.31	210.33	320.52
113	13.28	97.89	209.73	320.9
114	13.39	97.6	210.22	321.21
115	13.61	97.21	209.11	319.93
116	13.54	97.56	209.64	320.74
117	13.32	97.88	209.37	320.57
118	13.25	97.59	208.31	319.15
119	13.47	98.31	208.37	320.15
120	13.58	98.63	207.72	319.93
121	13.41	98.33	207.08	318.82
122	13.6	97.59	207.59	318.78
123	13.84	97.61	208.09	319.54
124	13.36	96.97	207.84	318.17
125	13.54	97.82	207.07	318.43
126	13.49	97.89	206.54	317.92
127	13.52	97.63	207.49	318.64
128	13.72	98.5	207.78	320
129	13.69	98.73	207.95	320.37

Year	Kermode	Carrier	Purebred	Total
130	13.81	98.62	207.43	319.86
131	13.74	99.08	209.15	321.97
132	13.77	99.31	206.98	320.06
133	14.16	99.58	207.53	321.27
134	14.29	99.81	206.63	320.73
135	14.15	99.3	207.68	321.13
136	14.27	98.88	209.49	322.64
137	14.48	97.75	210.2	322.43
138	14.07	96.44	209.98	320.49
139	13.87	96.57	209.07	319.51
140	14.19	97.48	209.84	321.51
141	14.17	98.1	209.98	322.25
142	14.41	98.33	209.7	322.44
143	14.41	97.6	210.56	322.57
144	14.06	96.67	209.49	320.22
145	14.51	95.74	209.71	319.96
146	14.02	95.03	208.94	317.99
147	13.74	94.97	210.13	318.84
148	13.86	94.16	210.3	318.32
149	13.94	95.42	211.29	320.65
150	13.88	95.38	212.65	321.91
151	14.02	95.31	211.27	320.6
152	13.97	95.57	210.74	320.28
153	13.98	95.25	211.82	321.05
154	13.76	95.43	214.03	323.22
155	14.26	95.81	213.63	323.7
156	13.78	95.51	213.35	322.64
157	14.12	95.51	213.39	323.02
158	14.02	95.56	213.59	323.17
159	14	95.88	214.41	324.29
160	13.77	96.43	215.93	326.13
161	13.97	95.67	215.87	325.51
162	13.69	95.22	215.52	324.43
163	13.62	94.63	214.03	322.28
164	14.02	94.26	215.18	323.46
165	14.18	94.75	214.26	323.19
166	14	94.5	214.5	323
167	14.01	93.8	214.63	322.44
168	14.03	94.69	214.08	322.8
169	13.81	94.22	214.59	322.62
170	13.64	94.52	214.58	322.74
171	13.85	94.87	215.01	323.73
172	13.48	93.68	213.75	320.91
173	13.7	93.67	212.89	320.26

Year	Kermode	Carrier	Purebred	Total
174	13.7	93.92	210.93	318.55
175	14.46	94.46	212.25	321.17
176	14.13	94	212.32	320.45
177	14.14	94.07	212.43	320.64
178	14.08	94.23	212.22	320.53
179	14.09	94.24	213.43	321.76
180	13.68	94.56	212.71	320.95
181	13.98	94.9	212.13	321.01
182	13.83	94.64	212.16	320.63
183	14.08	95.52	212.11	321.71
184	14.08	96.29	211.78	322.15
185	14.44	96.72	212.79	323.95
186	14.28	96.41	212.14	322.83
187	14.17	96.26	212.17	322.6
188	14.42	96.78	211.67	322.87
189	14.5	96.93	211.86	323.29
190	14.16	96.82	210.78	321.76
191	14.43	96.1	211.52	322.05
192	14.33	97.37	212.06	323.76
193	14.44	96.28	212.81	323.53
194	14.69	95.28	211.62	321.59
195	14.6	94.59	211.46	320.65
196	15.06	94.41	211.53	321
197	15.3	94.58	209.84	319.72
198	15.27	94.85	210.03	320.15
199	15.23	95.32	211.69	322.24
200	14.76	94.11	210.24	319.11
201	14.91	94.37	212.87	322.15
202	15.02	94.06	212.04	321.12
203	14.92	93.58	211.84	320.34
204	15.04	93.15	209.91	318.1
205	14.97	92.85	210.89	318.71
206	14.95	93.01	211.06	319.02
207	15.06	93.92	210.94	319.92
208	14.86	94.42	212.1	321.38
209	14.96	94.52	212.3	321.78
210	14.68	94.63	211.5	320.81
211	14.94	94.61	211.15	320.7
212	14.7	94.23	210.69	319.62
213	15.04	95.83	212.41	323.28
214	14.82	96.8	212.02	323.64
215	15.25	96.88	211.66	323.79
216	14.92	96.92	212.64	324.48
217	14.79	98.06	211.81	324.66

Table 1 Average Population Totals (by year)				
Year	Kermode	Carrier	Purebred	Total
218	14.93	98.27	209.52	322.72
219	14.93	97.9	208.77	321.6
220	14.83	98.06	208.87	321.76
221	14.62	97.84	209.01	321.47
222	14.71	97.92	210.37	323
223	14.49	98.46	210.04	322.99
224	14.61	97.5	210.02	322.13
225	14.96	98.38	209.61	322.95
226	14.85	98.36	209.93	323.14
227	14.84	98.37	210.3	323.51
228	14.95	98.68	210.26	323.89
229	15.02	98.54	209.33	322.89
230	15.29	98.39	210.61	324.29
231	15.16	97.07	210.22	322.45
232	15.21	96.97	210.3	322.48
233	15.31	96.17	209.6	321.08
234	15.18	96.61	209.55	321.34
235	15.18	96.08	209.91	321.17
236	15.07	96.07	210.7	321.84
237	15.35	95.17	209.52	320.04
238	15.53	95.85	210.5	321.88
239	15.41	94.82	210.63	320.86
240	15.81	95.18	208.76	319.75
241	16.13	94.71	209.97	320.81
242	16.04	94.17	210.02	320.23
243	15.91	94.78	210.51	321.2
244	15.87	94.6	211.01	321.48
245	15.39	94.28	210.84	320.51
246	15.56	93.67	209.67	318.9
247	15.54	92.55	211.85	319.94
248	15.58	92.6	211.69	319.87
249	15.52	92.86	211.03	319.41
250	15.39	93.41	209.41	318.21
251	15.77	92.79	209.89	318.45
252	15.8	93.52	208.94	318.26
253	16.13	93.68	209.63	319.44
254	16.21	93.48	209.86	319.55
255	16.05	93.71	210.97	320.73
256	16.38	94.28	211.06	321.72
257	16.62	93.75	211.46	321.83
258	16.91	93.03	210.54	320.48
259	16.89	93.5	210.16	320.55
260	16.98	94.08	212.07	323.13
261	16.56	93.54	210.73	320.83

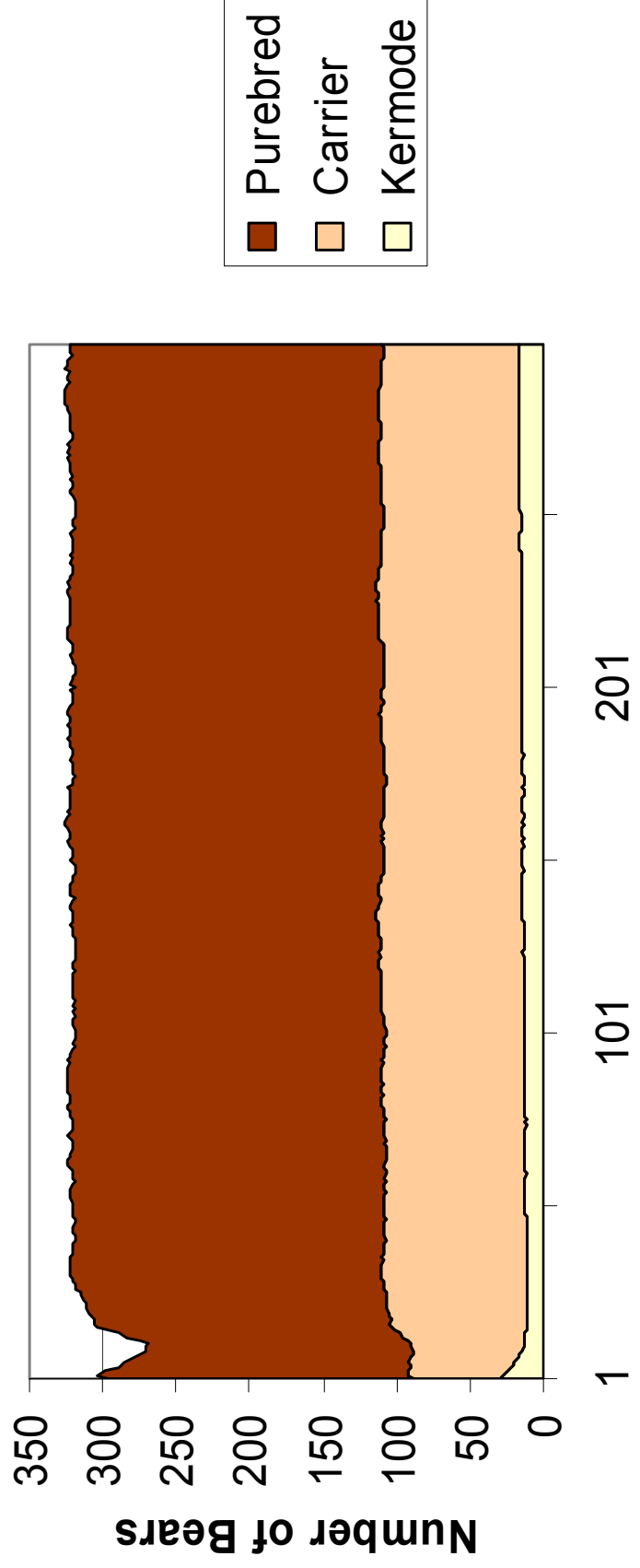
Year	Kermode	Carrier	Purebred	Total
262	16.47	94.12	210.89	321.48
263	16.39	94.98	211.81	323.18
264	16.4	94.8	211.31	322.51
265	16.24	95.4	210.74	322.38
266	16.41	95.45	211.57	323.43
267	16.51	95.26	210.87	322.64
268	16.3	95.77	212.11	324.18
269	16.43	95.43	210.97	322.83
270	16.65	95.31	211.73	323.69
271	16.61	95.82	210.56	322.99
272	16.41	94.75	209.53	320.69
273	16.57	94.11	210.28	320.96
274	16.85	94.53	211.78	323.16
275	16.65	94.48	211.76	322.89
276	16.69	94.23	211.28	322.2
277	16.76	95.15	211.14	323.05
278	16.72	95.49	210.5	322.71
279	16.79	94.84	211.08	322.71
280	16.92	95.15	211.86	323.93
281	16.62	95.42	211.88	323.92
282	16.64	95.99	212.8	325.43
283	16.58	96.02	212.95	325.55
284	16.53	95.53	213.37	325.43
285	16.76	95.66	214.29	326.71
286	16.66	94.88	213.63	325.17
287	16.74	94.48	212.96	324.18
288	16.2	94.23	212.84	323.27
289	16.46	93.99	213.91	324.36
290	16.16	94.38	214.08	324.62
291	16.31	93.49	212.85	322.65
292	16.7	94.71	213.92	325.33
293	16.43	94.6	212.74	323.77
294	16.3	94.3	213.65	324.25
295	15.93	93.03	212.71	321.67
296	16.13	93	212.28	321.41
297	15.82	93.66	213.3	322.78
298	15.95	93.26	213.46	322.67
299	16.34	94.26	211.54	322.14

Table 2 End of Run Population				
Run	Kermode	Carrier	Purebred	Total
1	57	173	91	321
2	15	138	148	301
3	22	116	195	333
4	50	176	121	347
5	10	98	257	365
6	2	33	277	312
7	4	49	253	306
8	33	126	163	322
9	1	29	286	316
10	8	80	232	320
11	29	136	155	320
12	5	71	235	311
13	1	40	281	322
14	19	153	190	362
15	5	47	293	345
16	4	87	266	357
17	6	86	255	347
18	47	149	152	348
19	14	114	206	334
20	27	138	191	356
21	41	137	170	348
22	28	132	191	351
23	2	52	248	302
24	20	145	161	326
25	21	111	172	304
26	54	152	121	327
27	83	162	81	326
28	7	80	250	337
29	4	46	232	282
30	0	8	325	333
31	30	101	153	284
32	15	113	178	306
33	15	115	190	320
34	26	144	164	334
35	5	64	240	309
36	3	66	232	301
37	54	166	101	321
38	9	131	201	341
39	24	122	156	302
40	2	102	236	340
41	9	102	220	331
42	7	71	246	324
43	2	64	246	312
44	11	87	214	312

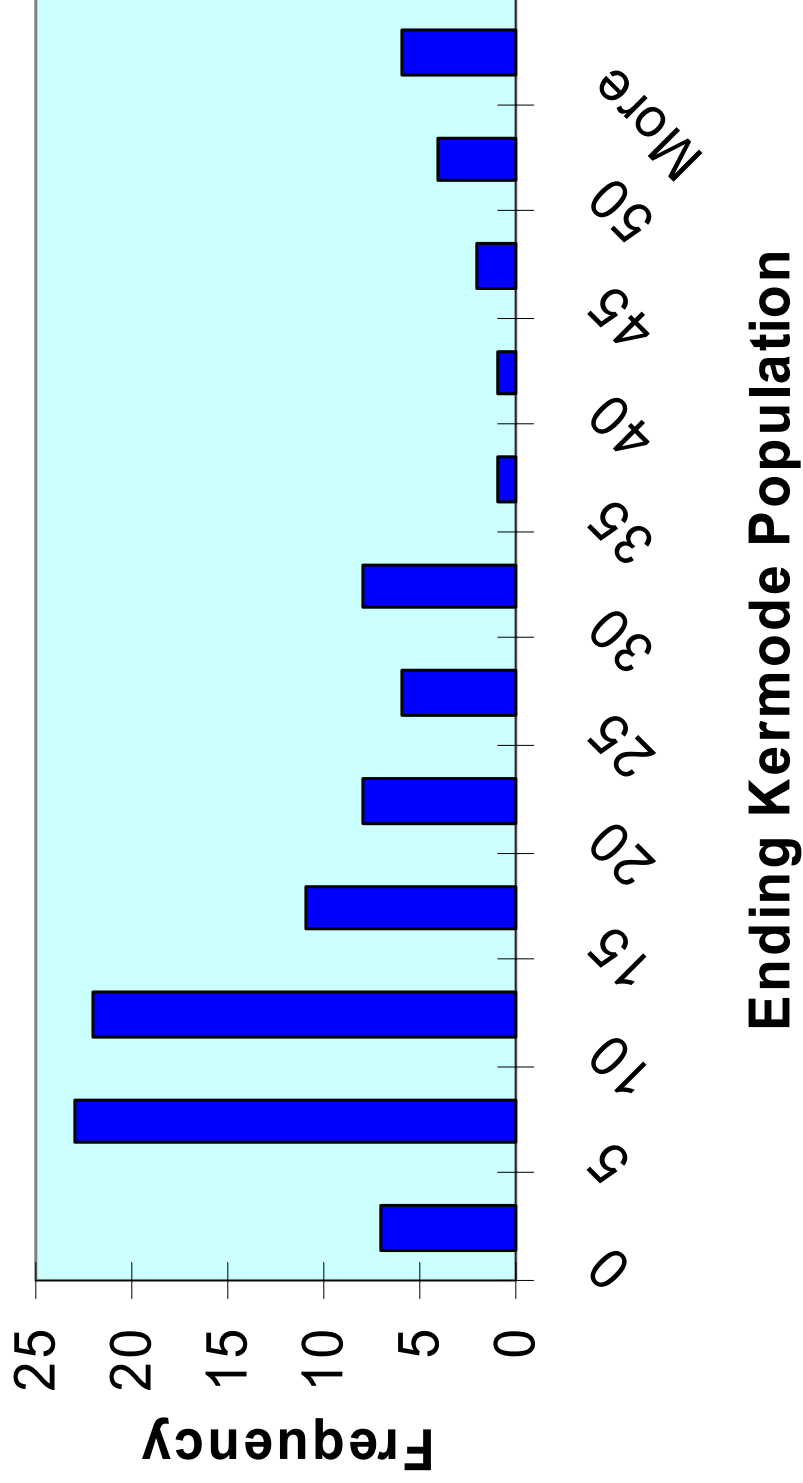
Table 2 End of Run Population				
Run	Kermode	Carrier	Purebred	Total
45	7	62	242	311
46	12	80	221	313
47	1	40	296	337
48	10	77	231	318
49	36	132	191	359
50	17	103	166	286
51	7	82	247	336
52	27	152	142	321
53	0	0	319	319
54	8	104	240	352
55	81	170	89	340
56	14	104	190	308
57	9	59	256	324
58	0	26	329	355
59	3	83	231	317
60	24	155	147	326
61	9	88	234	331
62	0	27	301	328
63	46	149	112	307
64	5	65	250	320
65	9	96	224	329
66	13	101	220	334
67	23	114	195	332
68	7	92	265	364
69	22	106	236	364
70	9	74	221	304
71	3	39	289	331
72	16	120	172	308
73	16	135	209	360
74	6	66	249	321
75	28	157	153	338
76	17	120	189	326
77	1	47	291	339
78	0	17	269	286
79	4	53	265	322
80	6	71	266	343
81	16	121	160	297
82	8	65	276	349
83	43	140	129	312
84	11	81	223	315
85	17	103	174	294
86	13	137	171	321
87	9	67	222	298
88	76	172	93	341

Table 2 End of Run Population				
Run	Kermode	Carrier	Purebred	Total
89	3	74	231	308
90	47	141	148	336
91	1	32	283	316
92	0	28	286	314
93	0	24	303	327
94	11	99	210	320
95	9	97	208	314
96	7	71	237	315
97	30	148	159	337
98	5	87	244	336
99	1	61	275	337

**Figure A**  
**Population Average for All Runs**



**Figure B**  
**Histogram of Ending Kermode Populations**



**Figure C**  
**Predicted Kermode Population**

