7. (Invasion of white pine)

We will examine data that indicates the prevalence of white pine (*Pinus strobus*) in the vicinity of the Lake of the Clouds, a lake in the Boundary Waters Canoe Area of northeastern Minnesota.

The lake is deep (31 meters), calm, sheltered from wind, and devoid of inflowing streams. Consequently, the lake's bottom is covered with layers of annual sedimentary deposits. Each layer contains a sampling of pollen, and by counting the pollen belonging to each species of tree and herb, it is possible to estimate the ratio of one plant species to another.

White pine became extinct in northern Minnesota during the last period of glaciation, although it remained in southern climates such as Virginia. Once the glaciers began to retreat, the white pine began to expand northward again; it reappeared in northern Minnesota about 9400 years ago (H. E. Wright, "The roles of pine and spruce in the forest history of Minnesota and adjacent areas," *Ecology*, **49**, 937-55, 1968).

A. J. Craig (*Absolute pollen analysis of laminated sediments: a pollen diagram from northeastern Minnesota*, M.S. thesis, University of Minnesota, 1970) counted pollen in a phenomenal 9400 sedimentary laminæ from a core at Lake of the Clouds. According to his data, as white pine invaded the region surrounding the lake, it competed with entrenched populations of jack pine (*Pinus banksiana*) and red pine (*Pinus resinosa*), which occupy essentially the same coarse, sandy soil as *P. strobus*. The combined pine tree pollen accounted for about 60-70% of the pollen during the period of interest; other plant species remained essentially constant during the time period (with the exception of spruce (*Picea*) which decreased).

Craig's data is condensed and analyzed by W. A. Watts ("Rates of change and stability in vegetation in the perspective of long periods of time," *Quaternary Plant Ecology*, H.J.B. Birks and R.G. West, eds, Blackwell Scientific, 1973), and we have reproduced portions of this data below. Note that in the second column, time is measured in units of thousands of years.

Years Ago	Years since 9131 (Thousands)	*P.bank/P.resin* percentage	*P.strobus* percentage
9131	0.0	53.4	3.2
8872	0.259	65.5	0.0
8491	0.640	61.8	3.7
8121	1.010	55.2	3.4
7721	1.410	60.4	1.7
7362	1.769	59.4	1.8
7005	2.126	50.6	10.6
6699	2.432	51.6	7.0
6444	2.687	40.0	21.2
5983	3.148	29.7	34.2
5513	3.618	25.0	40.4

5022	4.109	32.5	29.8
4518	4.613	22.7	46.2
4102	5.029	31.6	33.0
3624	5.507	32.5	37.6
3168	5.963	27.1	39.5

Percentages of pollen for red/jack pine and white pine for sedimentary layers at Lake of the Clouds, MN.

By scanning the data, it is clear that percentages of red and jack pine decreased during the time period indicated, whereas white pine pollen increased. If we assume that these pollen counts are representative of the relative populations of these species, then we have a basis for examining the population growth of *P. strobus* and the simultaneous decline of *P. banksiana* and *P. resinosa*.

a) Enter the *P. strobus* data set and plot the data to model the growth of the white pine population near Lake of the Clouds. In particular,

- Find and record an initial population, a net birth rate, and a coefficient of overcrowding that qualitatively matches the growth curve for this species of pine.
- Identify the three phases of logistic growth for this species of pine (if applicable). How long was the expansion phase?
- Estimate the equilibrium value for this species.

b) Repeat the above analysis for the *P. banksiana* and *P. resinosa* data set (green data points). Again, identify phases of growth, if applicable.

c) Using log-linear plots find equations for the growth and decline of these species of pines.