Model Basics

Background to the Modeling Approach and Parameters

Assumptions-I

- The model used for the CIB depends on several assumptions (of varying importance):
  - The “population size”, N_t is the total number of beluga in the population at the time of the annual census survey.
  - All individuals in the population are the same (model does not account for different ages or sexes for births, deaths or harvest).
  - The population is closed [i.e. no (or extremely limited) immigration and emigration].
  - The impact of temporal variations in the environment are not accounted for.
  - There is no population size below which the birth rate collapses.

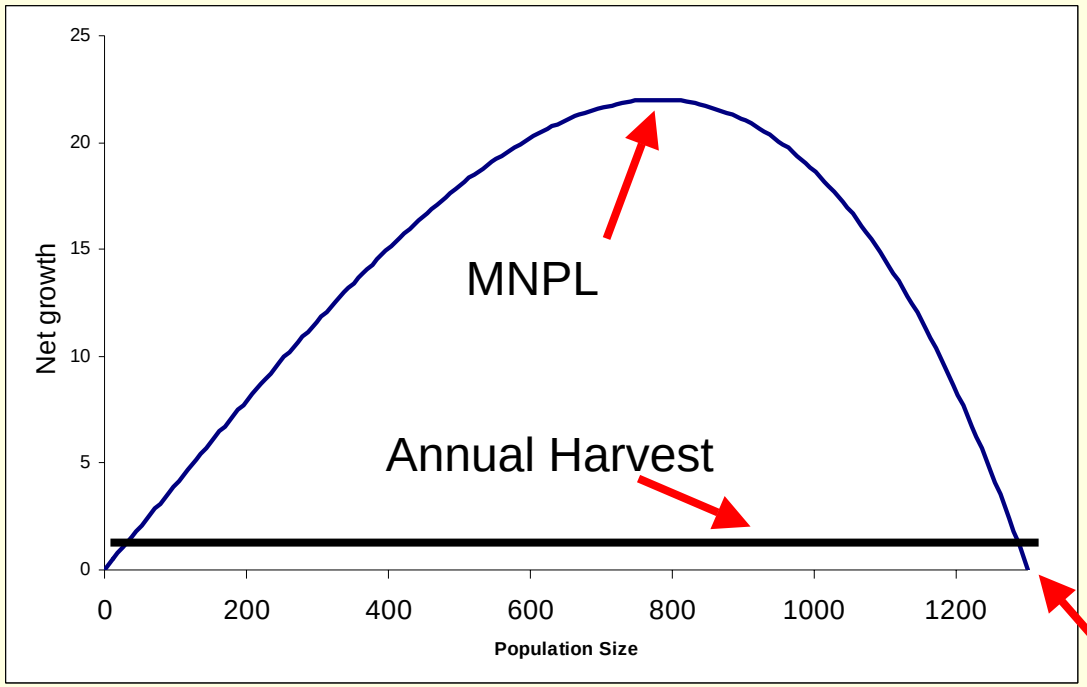
Assumptions-II

- More assumptions:
  - The net annual growth of the population:
    - depends on the size of the population, N_t;
    - depends on R_{max} (maximum per capita growth rate) which occurs when N_t is small.
    - is at a maximum at MNPL.
    - goes to zero when the population reaches "carrying capacity", K.
    - is not affected by variations in the environment or population structure.

Conceptual Basis

Population Size (next year)=

Population Size (this year) + Net Growth (this year) – Harvest (this year)



Carrying Capacity K

Mathematical Details

$$N_{t+1} = N_t + R_{\max} N_t (1 - (N_t / K)^z) - H_t$$

N_t – population size at the start of year t,

$R_{\max}$ – maximum per capita growth rate,

K – carrying capacity,

H_t – harvest during year t,and

z – skewness parameter.

Parameters

- During the ALJ hearing reasonable ranges where chosen for the model parameters.
- R_{max} (Maximum growth rate) was set at between 0.02-0.06.
- K (Carrying Capacity) was set between 1000 and 1600.
- z was set at 2.4 which results in an MNPL (Maximum Net Productivity Level) at 60 % K.

R_{max}

- In a typical beluga population there is roughly half females and half of these are sexually mature.
- On average sexually mature females produce a calf every 3 years so births/year are about 1/12 or 8% of N.
- If mortality is estimated between 2% and 6% per year then the growth rate (births – deaths) will be in the range of 2% to 6%.
- Little data is available to estimate these rates directly for Cook Inlet. NMFS has begun a project to estimate calving rates.

K

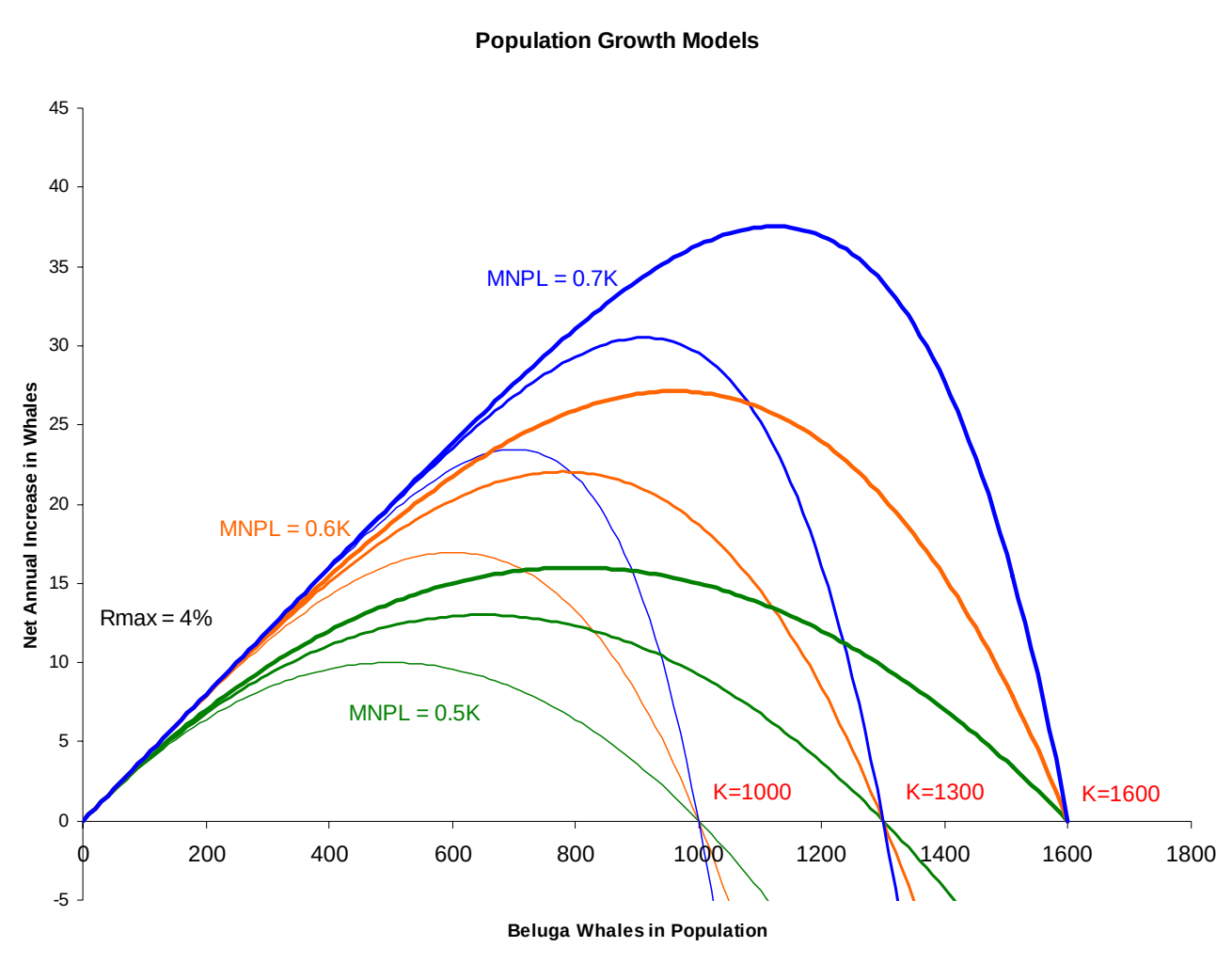
- The estimate of Cook Inlet carrying capacity, 1300 beluga, is based on a survey from the late 1970's and a correction factor considered reasonable for that survey.
- We assume that carrying capacity has not changed but given the uncertainty in the survey results and correction factor have assigned a range of 1000-1600.

Interaction between R_{max} and K

z

- The shape parameter z determines how close MNPL is to K and the range over which the growth is close to R_{max}
- The choice z = 2.4 corresponds to MNPL = 60% K. This value is considered reasonable for cetaceans.
- For a population well below MNPL, there is little difference in the growth of the population between MNPL = 60% K and 70% K until the population is significantly larger that the current size.

Interaction between z and K



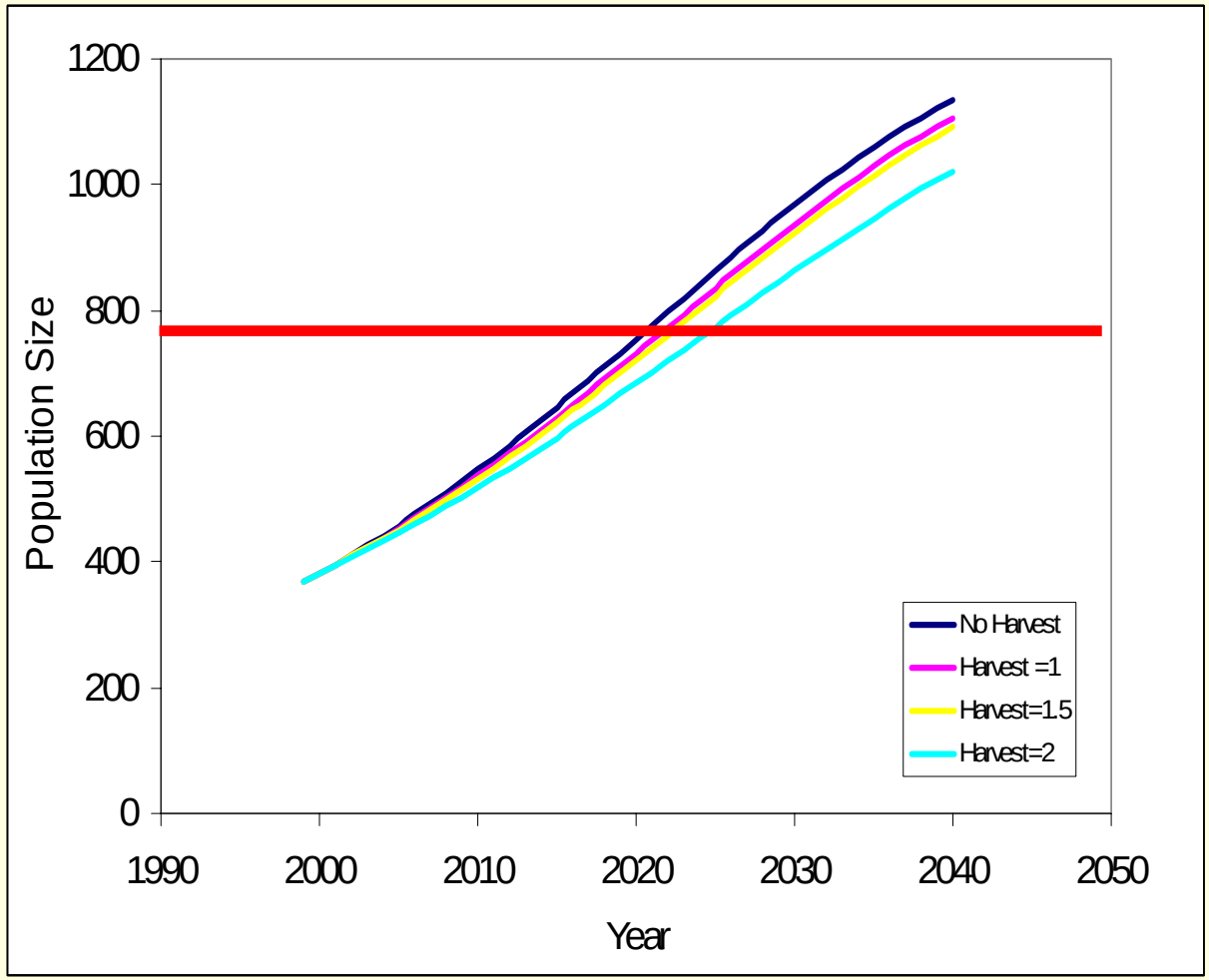
Evaluating Alternative Management Policies

Projections; Multiple Simulations

Projecting the Consequences of Alternative Harvest Sequences

- The model forms the basis for this evaluation.
- Consider a case in which the parameters of the model are known (i.e. R_{max} =4%, K=1300, N_{1999} =350):
  1) Calculate the net change in the population size between 1999 and 2000 using the model.
  2) Remove the harvest during 1999.
  3) Repeat steps 2) and 3) for 2000, 2001, etc.

Population Projections



Delays:

Option 1: 4%; 1 years

Option 2: 9%; 2 years

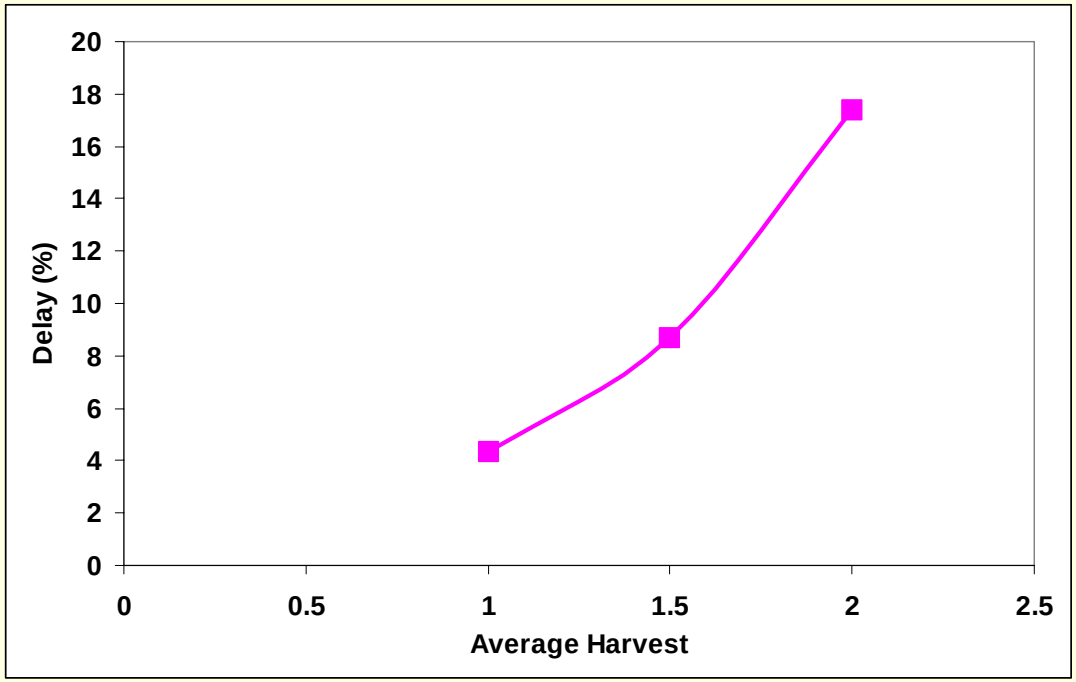
Option 3: 17%; 4 years

Making a Decision-I

- We then base a decision on the harvest policy in terms of which harvest policy increases the recovery time by no more than y%.
- Note that the choice of y is a policy decision and not a quantity that can be determined from research / science.

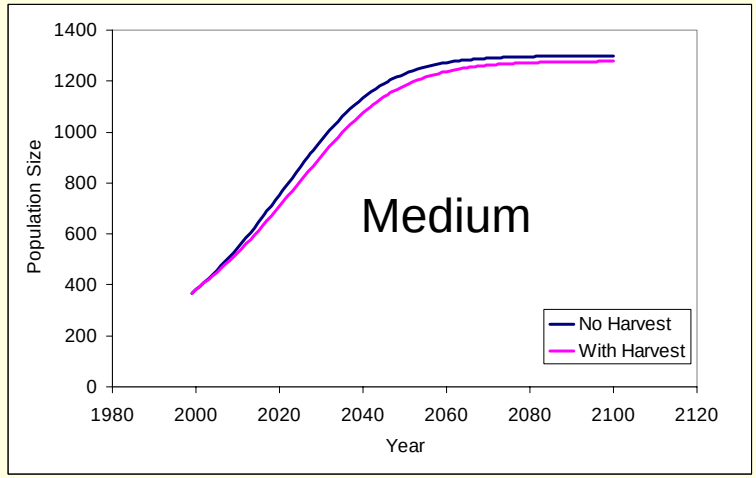
Making a Decision-II

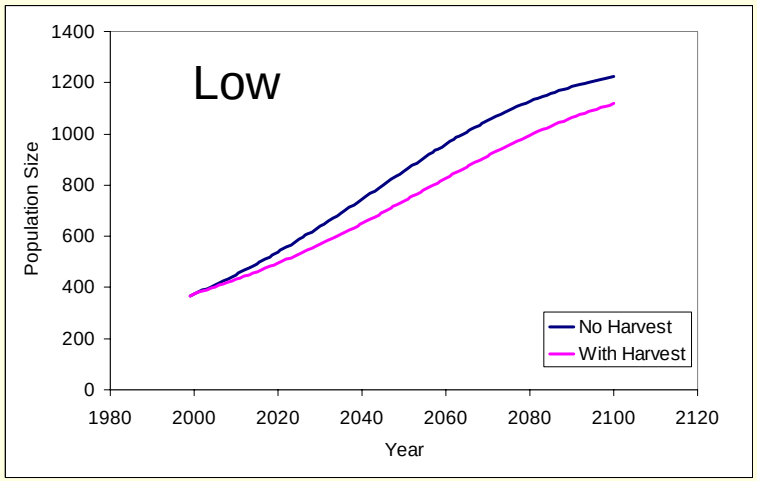
- The results for different harvest polices can be represented in terms of the trade-off between risk (delay) and reward (average harvest).

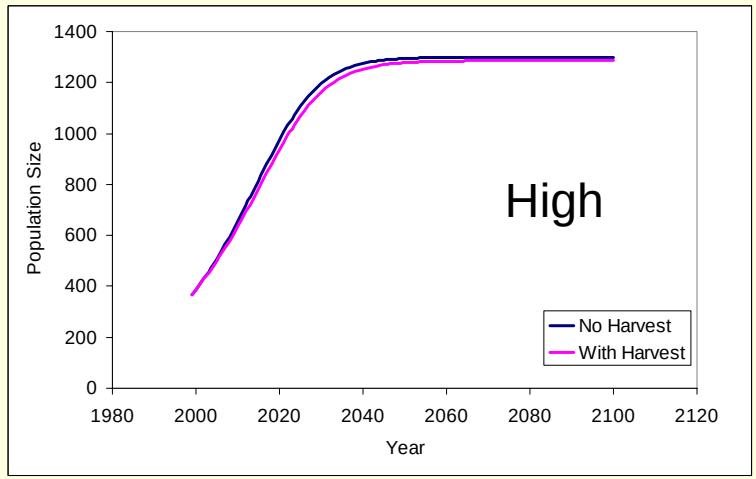


Sensitivity to Uncertainty-I

- The values R_{max} , K, and N_{1999} are not known exactly. When R_{max} is lower the percent delay in recovery is also greater.







Low, medium and high productivity

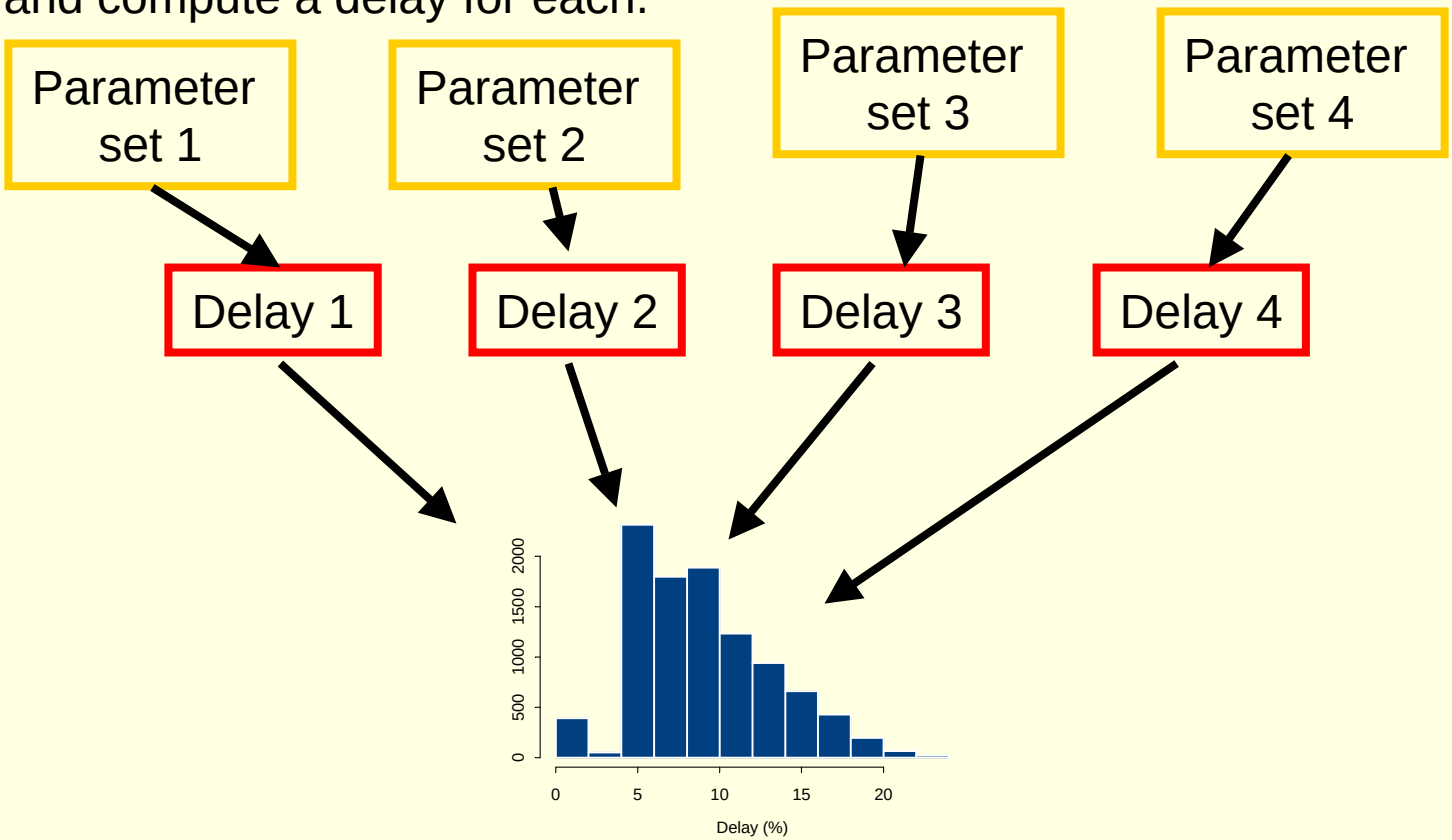
Sensitivity to Uncertainty-II

- Our decision will differ depending on the values assumed for these parameters:

R_{max}	No harvest	With harvest	# years	% delay
2%	2044	2055	11	24
4%	2022	2024	2	9
6%	2014	2015	1	7

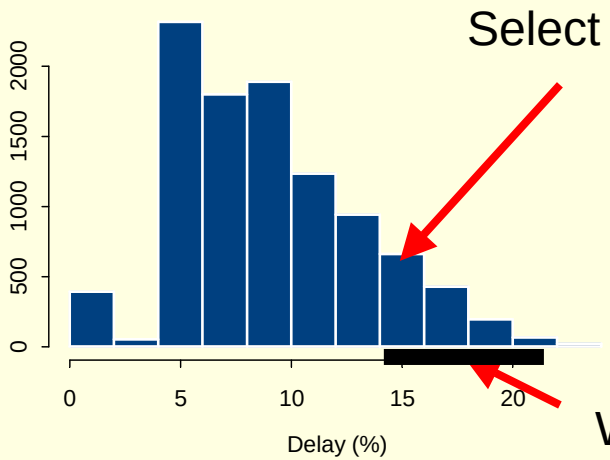
Sensitivity to Uncertainty-III

- For a given harvest policy we choose values for R_{max} , K, and N_{1999} from the stipulated ranges. We take 10,000 sets of parameters and compute a delay for each.



Sensitivity to Uncertainty-IV

- The decision now involves two factors:
  - What delay are we willing to tolerate?
  - What is the probability that the delay will not be as long as this?

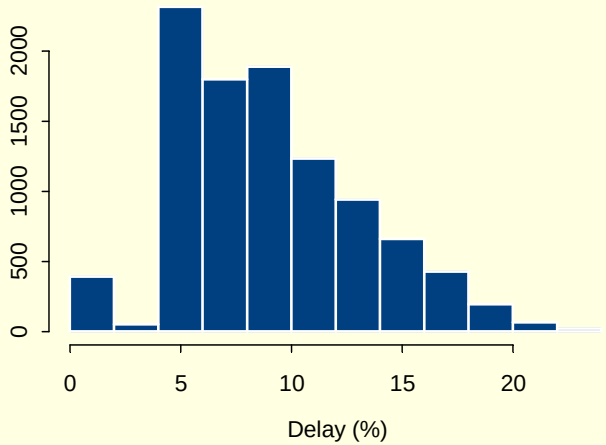


We can count how many of the delays are at least 15%

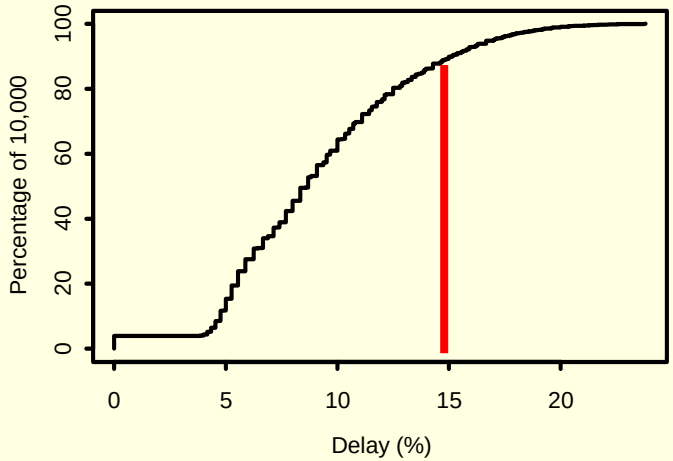
Different harvest policies will lead to different histograms.

Sensitivity to Uncertainty-V

The histogram of delays can be represented as a cumulative distribution by summing the the number of parameter sets that lead to delays less than a range of values (1%, 2%, 3%).

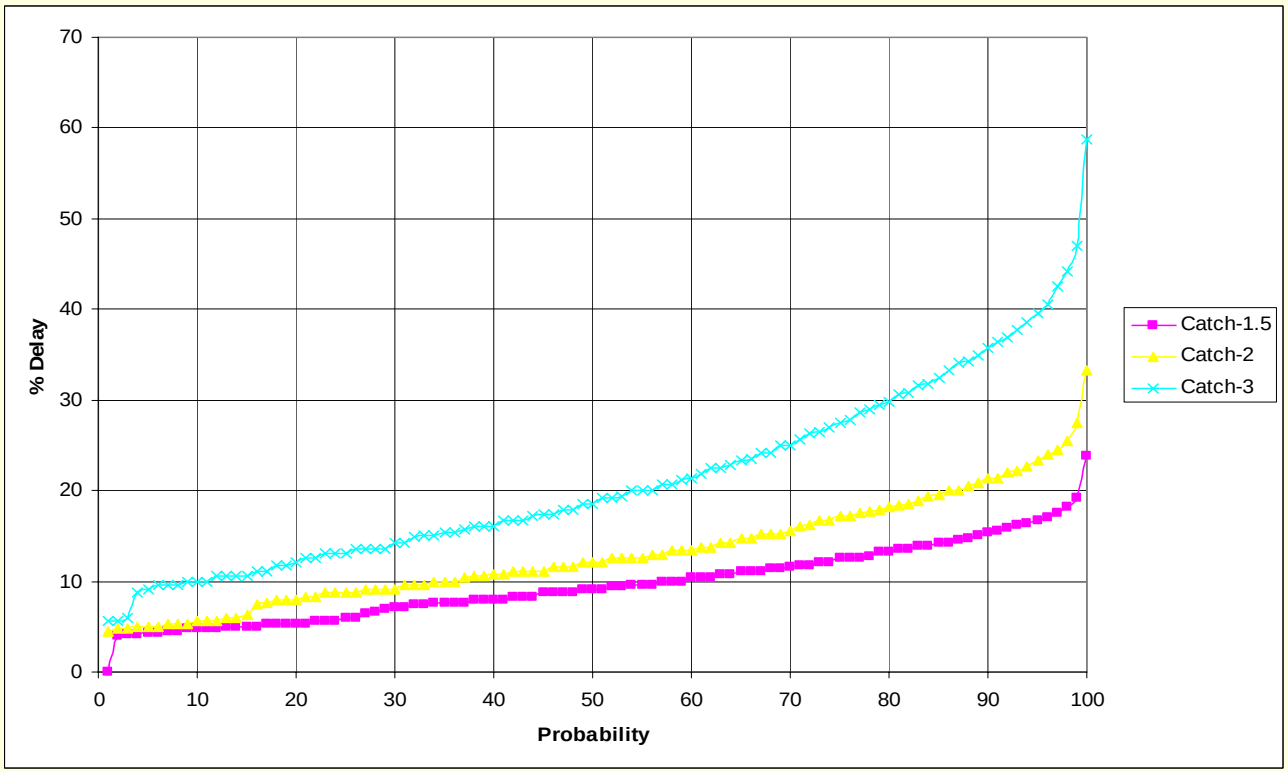


Using the cumulative distribution, we can compute the probability that the delay will be at least as large as any particular value (here 15%)



Sensitivity to Uncertainty-VI

- A variety of harvest policies can be compared on a single plot.

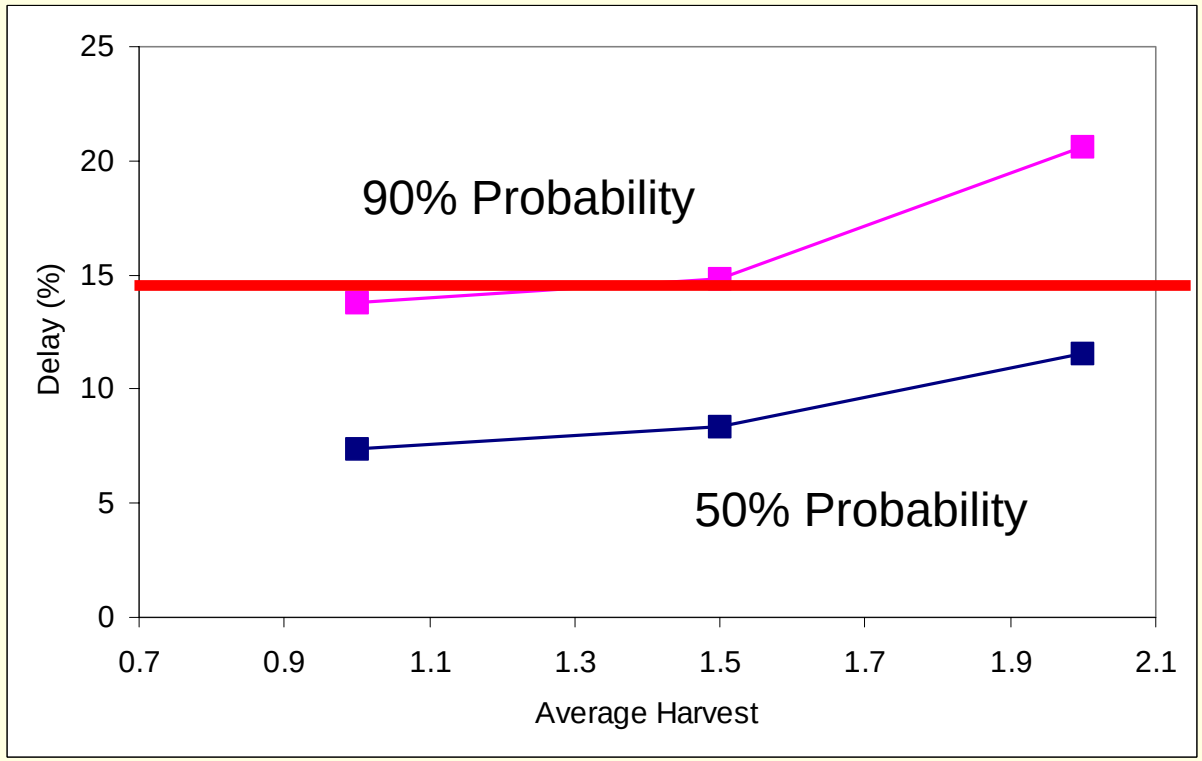


Sensitivity to Uncertainty-VII

- Including uncertainty implies that the policy choice depends not only the length of the delay but also on the probability that the delay is not as long as the selected delay. Both of these choices are policy calls. Note:
  - A choice of 50% for the probability would be considered “risk neutral”.
  - Any value for this probability greater than 50% would be considered “precautionary”.
  - Any value for this probability less than 50% would be considered “risk tolerant” (and would seem inconsistent with the concept of “recovery”).

Sensitivity to Uncertainty-VIII

We will select a 15% delay and see how the results change with the chosen probability



The choice of an “acceptable” policy (from a risk perspective) depends in this case on the choice of a probability. For a 50% probability all three policies are “acceptable”; for a 90% probability only the lowest harvest level is “acceptable”.