Development of Life-Stage Specific Population Dynamics Models for Lost River and Shortnose Suckers in the Upper Klamath Basin

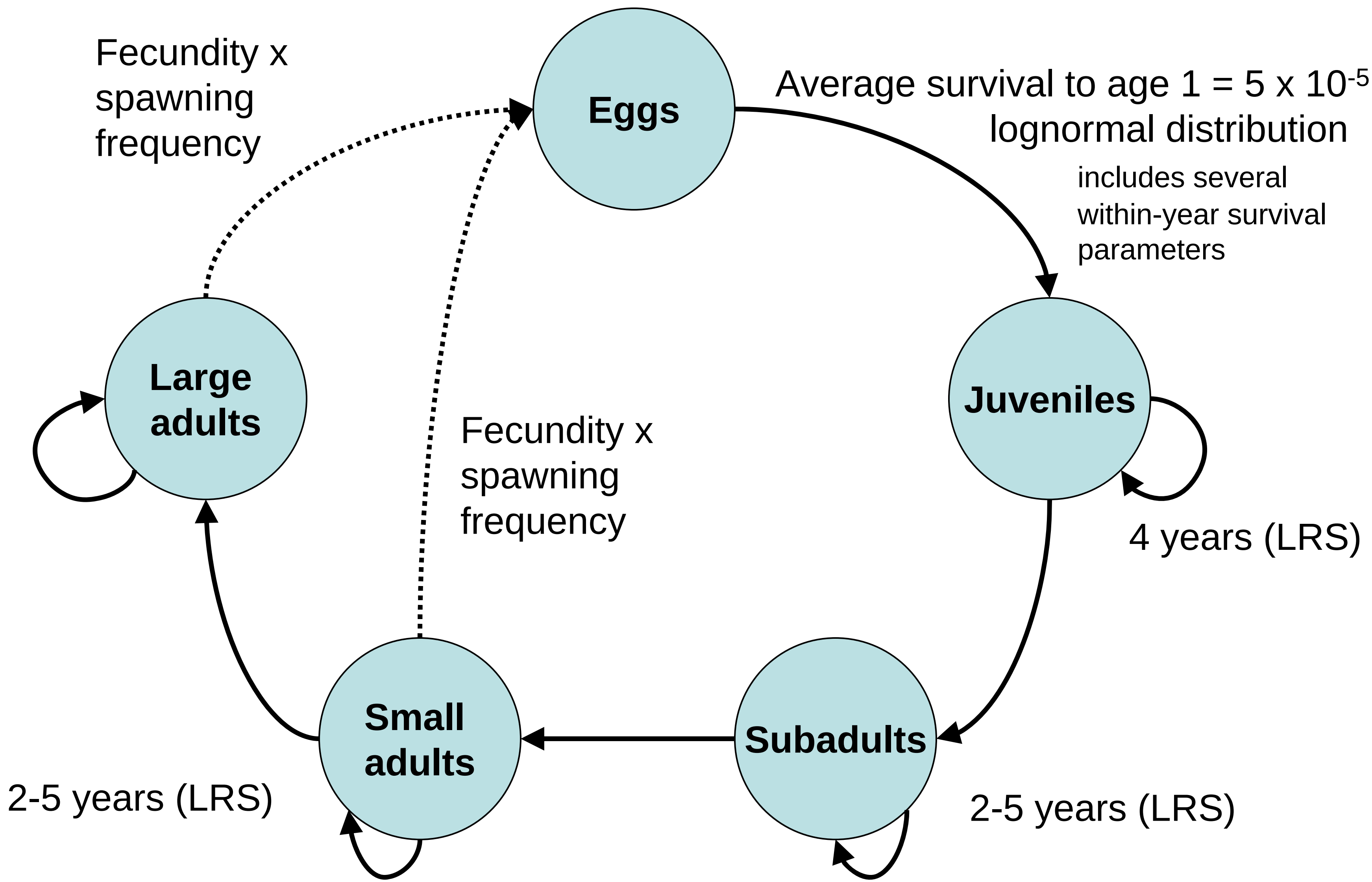
Rollie White

Primary Objectives

- to develop a life cycle model to determine
  - population viability for the two species, based on stochastic simulations, and
  - the long-term implications of increased adult mortality in fish kill years
- To produce a user-friendly tool for analysis of potential management options and/or recovery planning

Questions

- What ratio of “good” vs. “bad” years is necessary for the species to persist
- What is the best way to develop a model so that it may be adapted through time as availability and accuracy of data increases and management options are considered?
- Can we account for the uncertainty in the system and how does that affect population trajectories?


Fecundity x spawning frequency
Eggs
Average survival to age 1 = 5 x 10-5
lognormal distribution
includes several within-year survival parameters
Large adults
Juveniles
Fecundity x spawning frequency
4 years (LRS)
Small adults
Subadults
2-5 years (LRS)
2-5 years (LRS)

Data

- Literature review provided baseline data for the model
- When published data was unavailable it was supplemented with unpublished data from ongoing research
  - Larval and juvenile data
    - Production, survival rates
    - Doug Markle (OSU)
  - Adult data
    - Age distribution, growth, survival rates
    - Rip Shively, Eric Janney (USGS)

Parameters based on available data

Species	Parameter	Life Stage	Value	Source
Lost River	**Fecundity**	Subadult	45,000	Buettner & Scoppettone 1990, USFWS 2002
		Small Adult	85,000	Buettner & Scoppettone 1990, USFWS 2002
		Large Adult	125,000	Buettner & Scoppettone 1990, USFWS 2002
	Survival	Larvae	0.000053985	Markle unpub
		Juvenile	0.7	Expert Opinion
		Adult	Normal Year: range- 0.70-0.99 mean- 0.88	Janney et al unpub, Hendrix unpub See fig 1a
			Fish Kill: range- 0.08-0.84 mean- 0.44	Janney et al unpub, Hendrix unpub See fig 1b
	Age at Maturity		6-9 years	Buettner & Scoppettone 1990

Parameters based on available data

Shortnose	**Fecundity**	Subadult	25,000	Buettner & Scoppettone 1990, USFWS 2002
		Small Adult	45,000	Buettner & Scoppettone 1990, USFWS 2002
		Large Adult	65,000	Buettner & Scoppettone 1990, USFWS 2002
	Survival	Larvae	0.000053985	Markle unpub
		Juvenile	0.7	Expert Opinion
		Adult	Normal Year: range- 0.61-0.88 mean- 0.75	Janney et al unpub, Hendrix unpub See fig 9a
			Fish Kill: range- 0.13-0.88 mean- 0.51	Janney et al unpub, Hendrix unpub See fig 9b
	Age at Maturity		5-7 years	Buettner & Scoppettone 1990

Starting values

Adult females

Affects mortality rate of juveniles in Fish Kill years, as a proportion of the severity of the effect on adults

Minimum population size for species recovery

Parameter	Starting Population Size	Probability of Fish Kill	Fish Kill Impact Juvenile:Adult	YOY Ceiling	Quasi-Extinction Threshold	Recruitment Multiplier Standard Deviation
Value	20,000	0	0.5	100,000	500	0.5

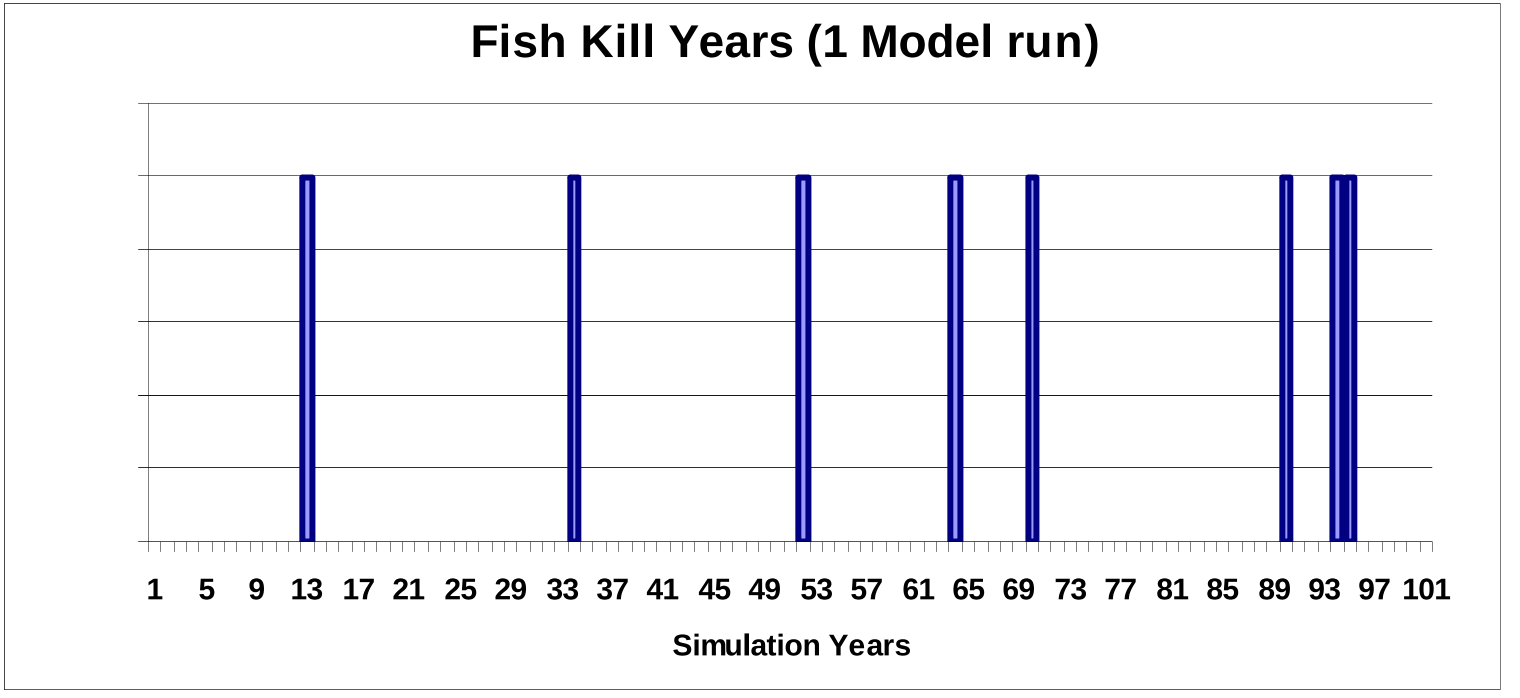
Affects adult survival rate distribution for a particular year

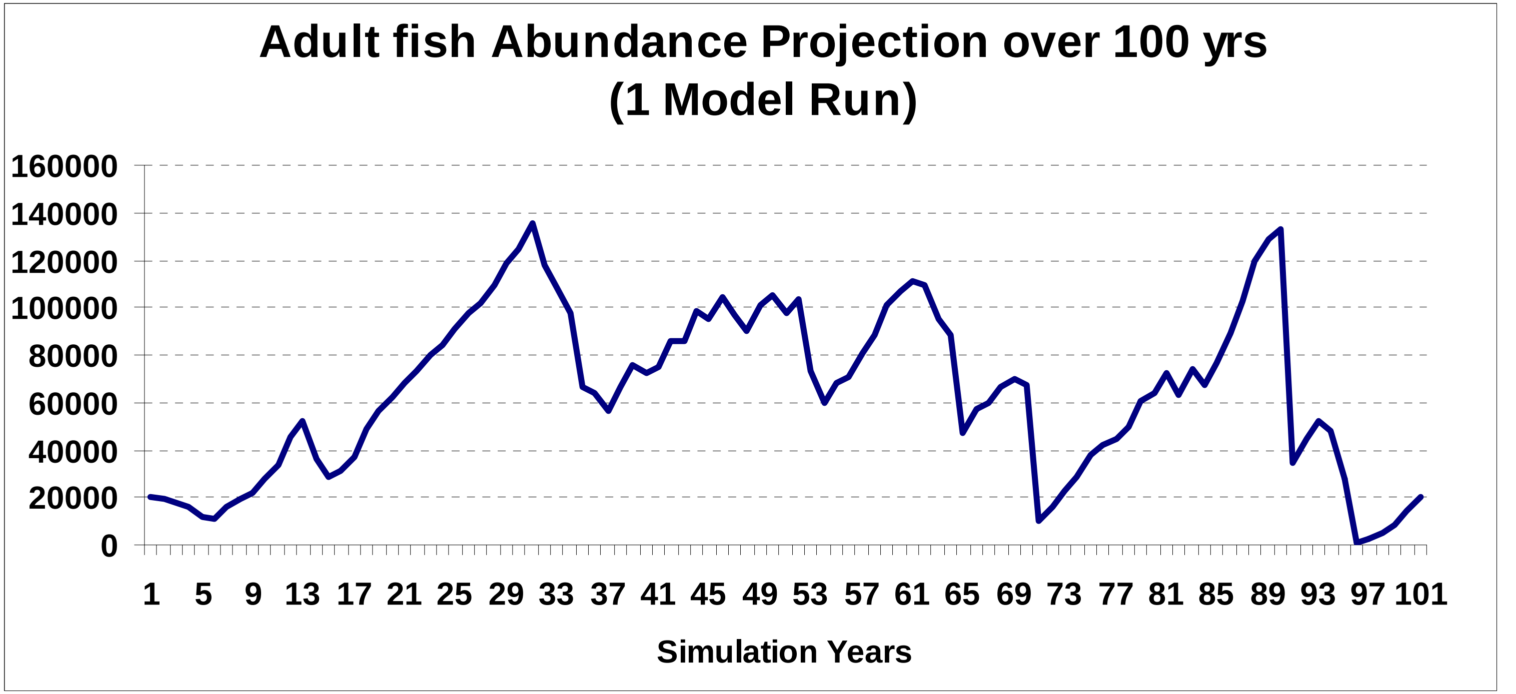
Creates a “hockey-stick” stock-recruit function

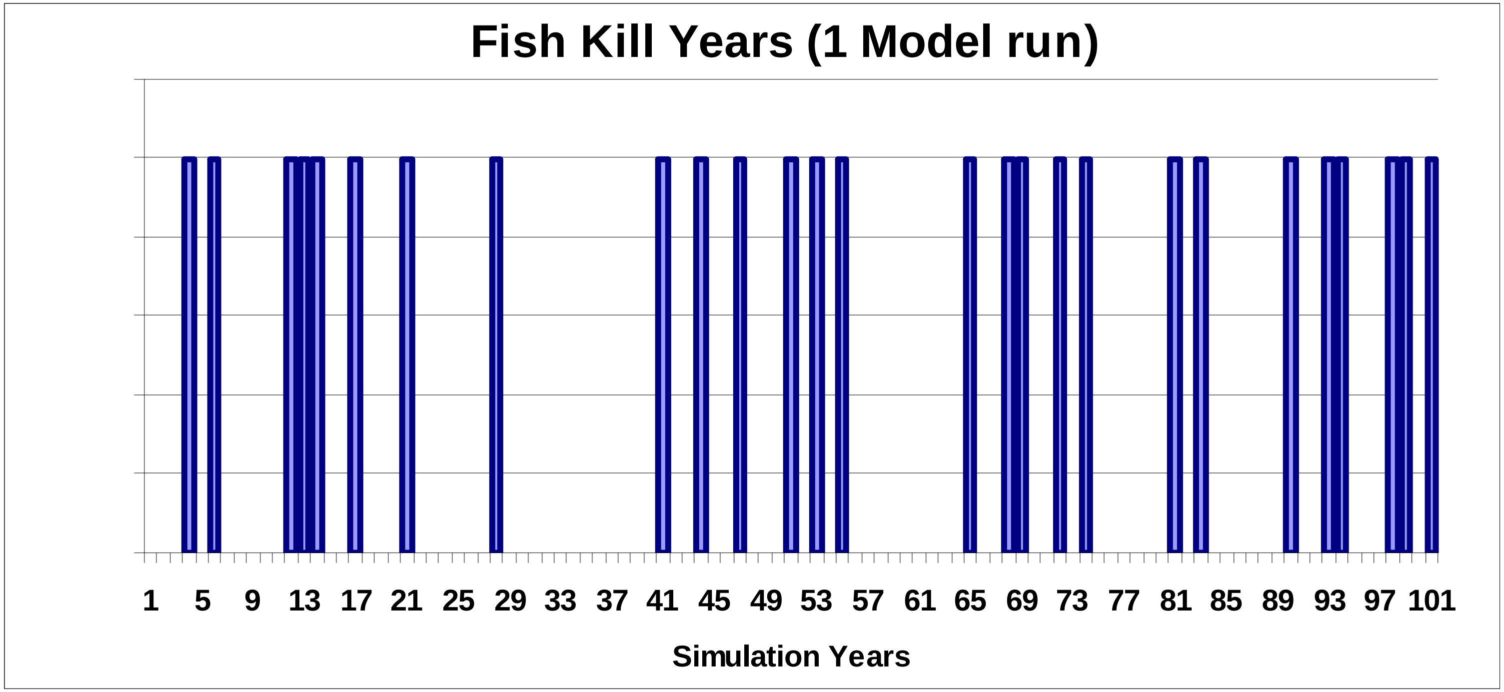
Adds additional variance in larval survival through a log-normally distributed random multiplier

“Good years” and “Bad years”

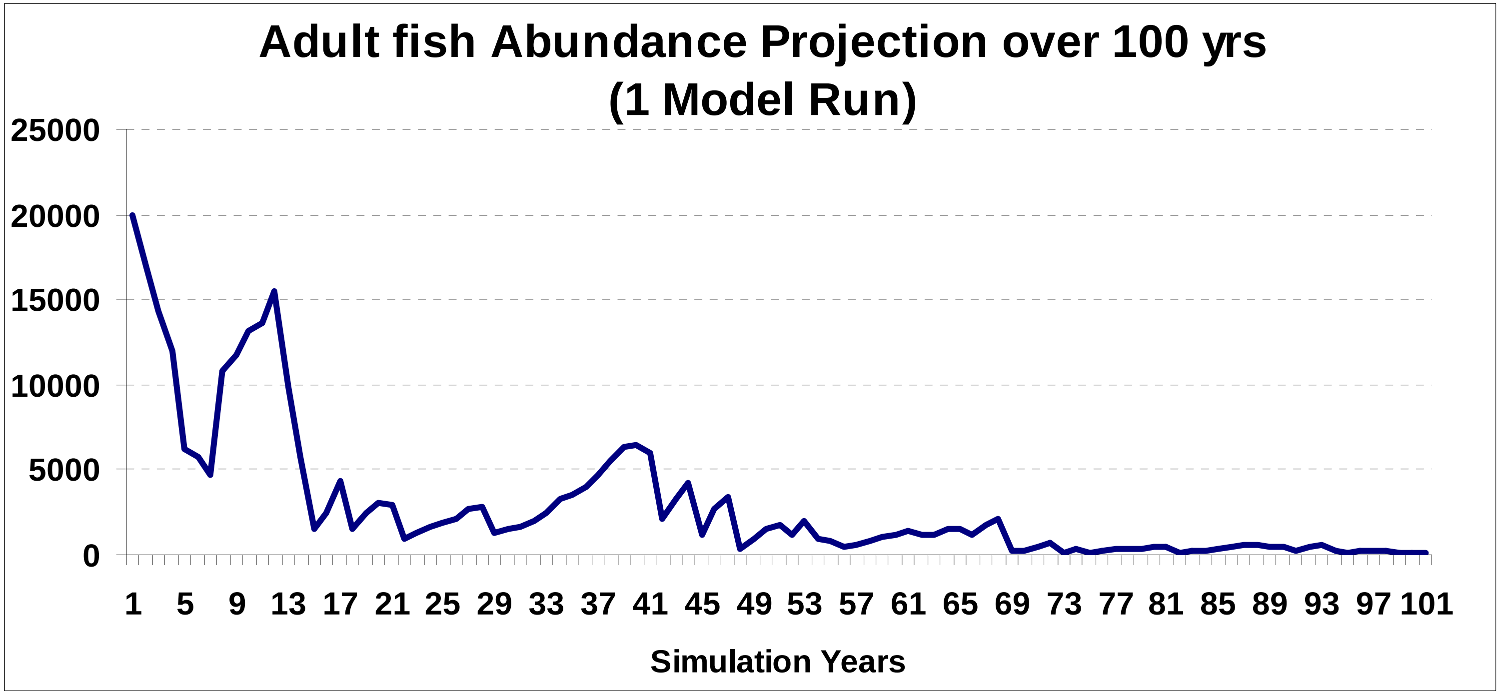
- Adult survival rate for year is drawn from a beta distribution with mean and variance set according to analysis of available data (N. Hendrix)
- Juvenile survival can be fixed or be correlated with adult survival
  - Parameter value = 1 then survival is reduced by same proportion as adult
  - Parameter value = 0.5 then survival is reduced by ½ of the proportional reduction in adult survival


Fish Kill Years (1 Model run)
1 5 9 13 17 21 25 29 33 37 41 45 49 53 57 61 65 69 73 77 81 85 89 93 97 101
Simulation Years

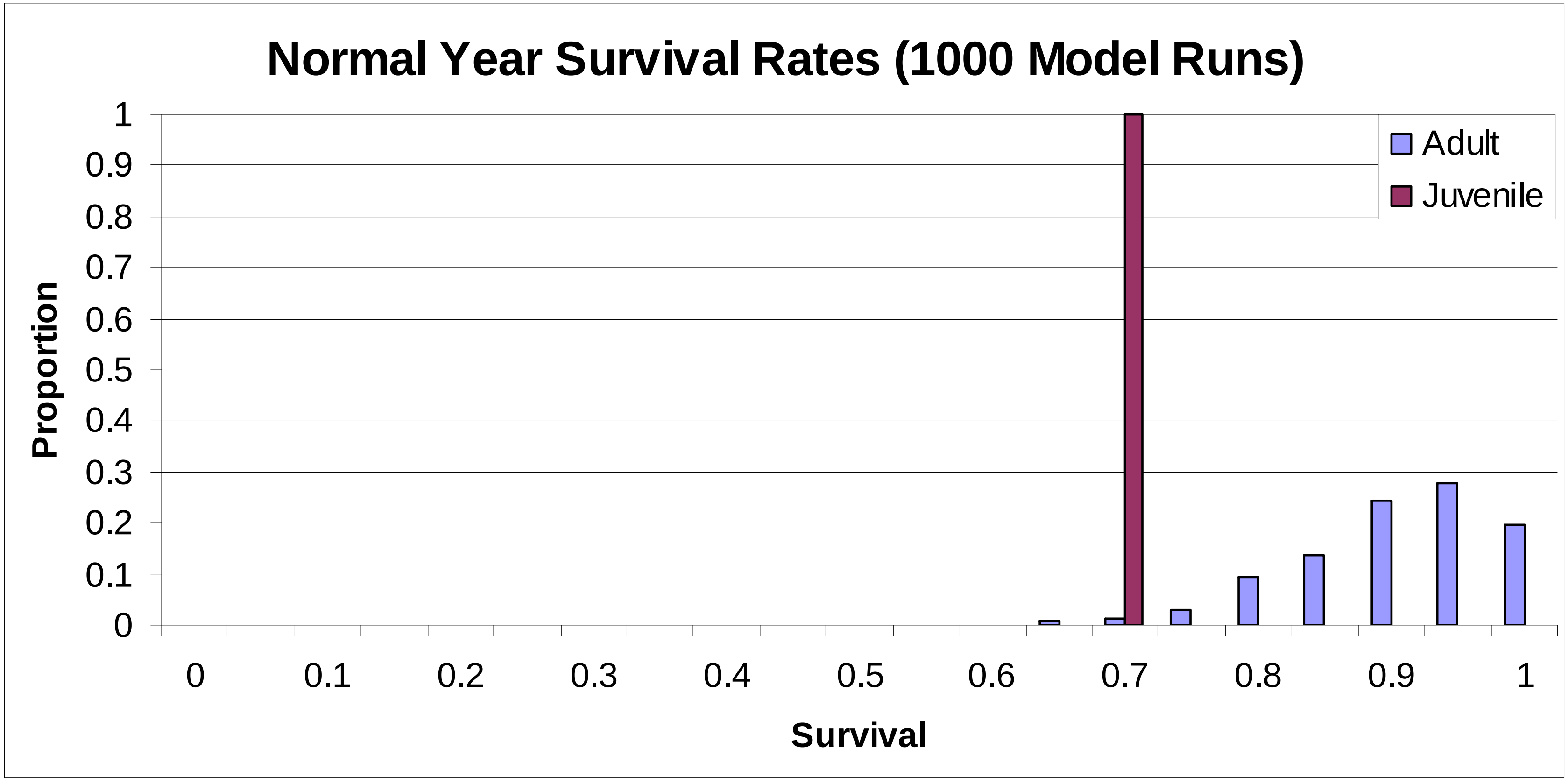

Adult fish Abundance Projection over 100 yrs
(1 Model Run)
160000
140000
120000
100000
80000
60000
40000
20000
0
1 5 9 13 17 21 25 29 33 37 41 45 49 53 57 61 65 69 73 77 81 85 89 93 97 101
Simulation Years



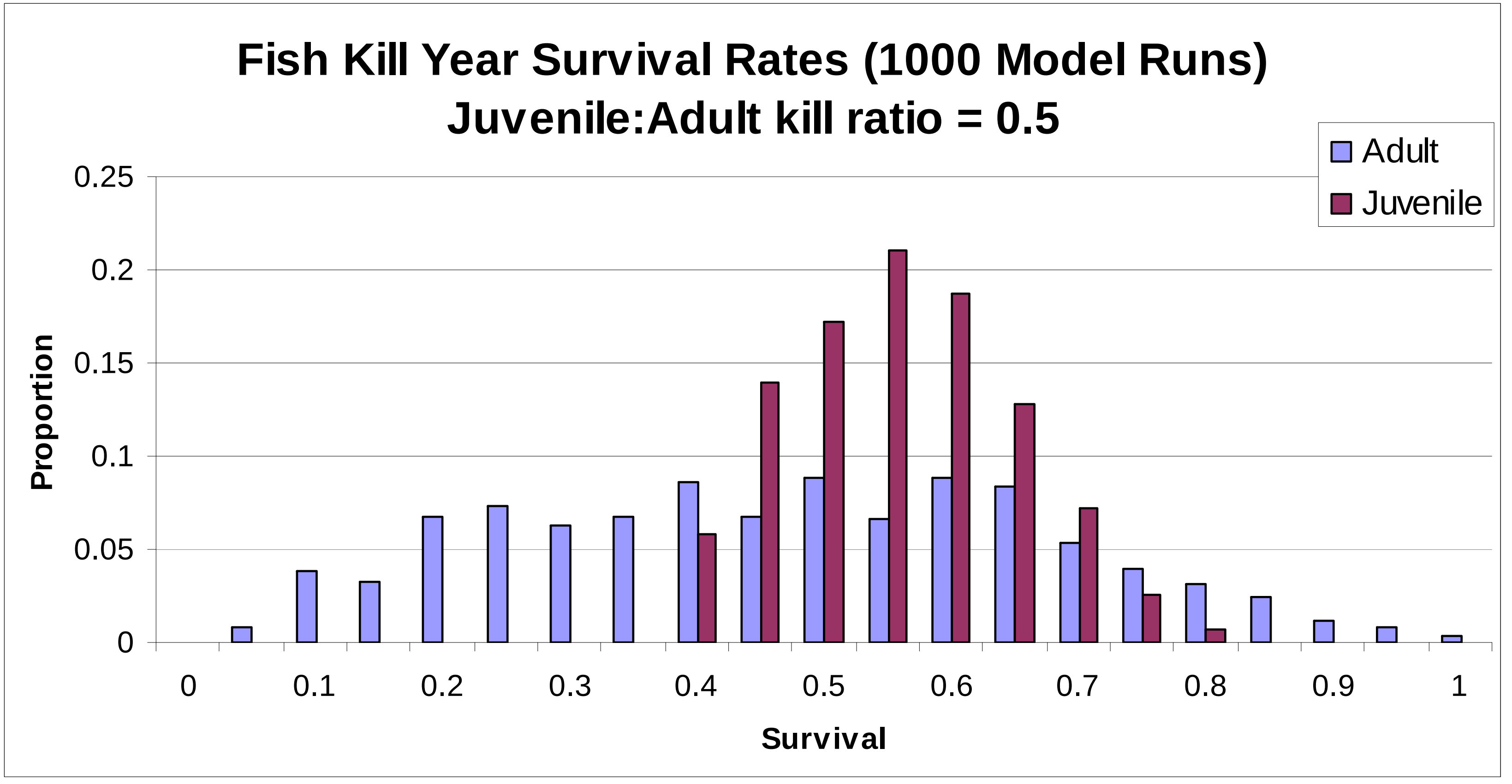
Fish Kill Years (1 Model run)
1 5 9 13 17 21 25 29 33 37 41 45 49 53 57 61 65 69 73 77 81 85 89 93 97 101
Simulation Years



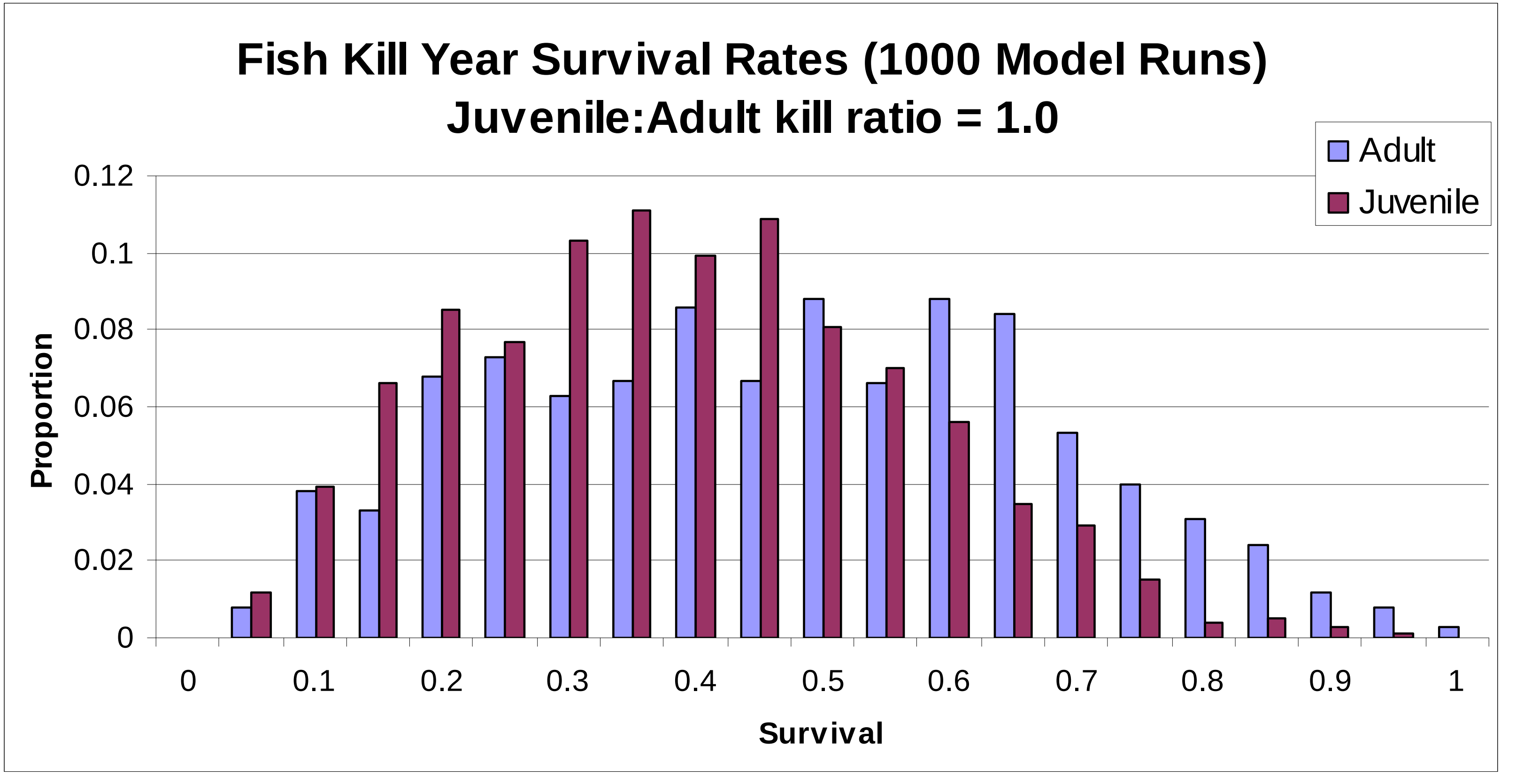
Adult fish Abundance Projection over 100 yrs (1 Model Run)
25000
20000
15000
10000
5000
0
1 5 9 13 17 21 25 29 33 37 41 45 49 53 57 61 65 69 73 77 81 85 89 93 97 101
Simulation Years



Normal Year Survival Rates (1000 Model Runs)
Proportion
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Adult
Juvenile
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Survival

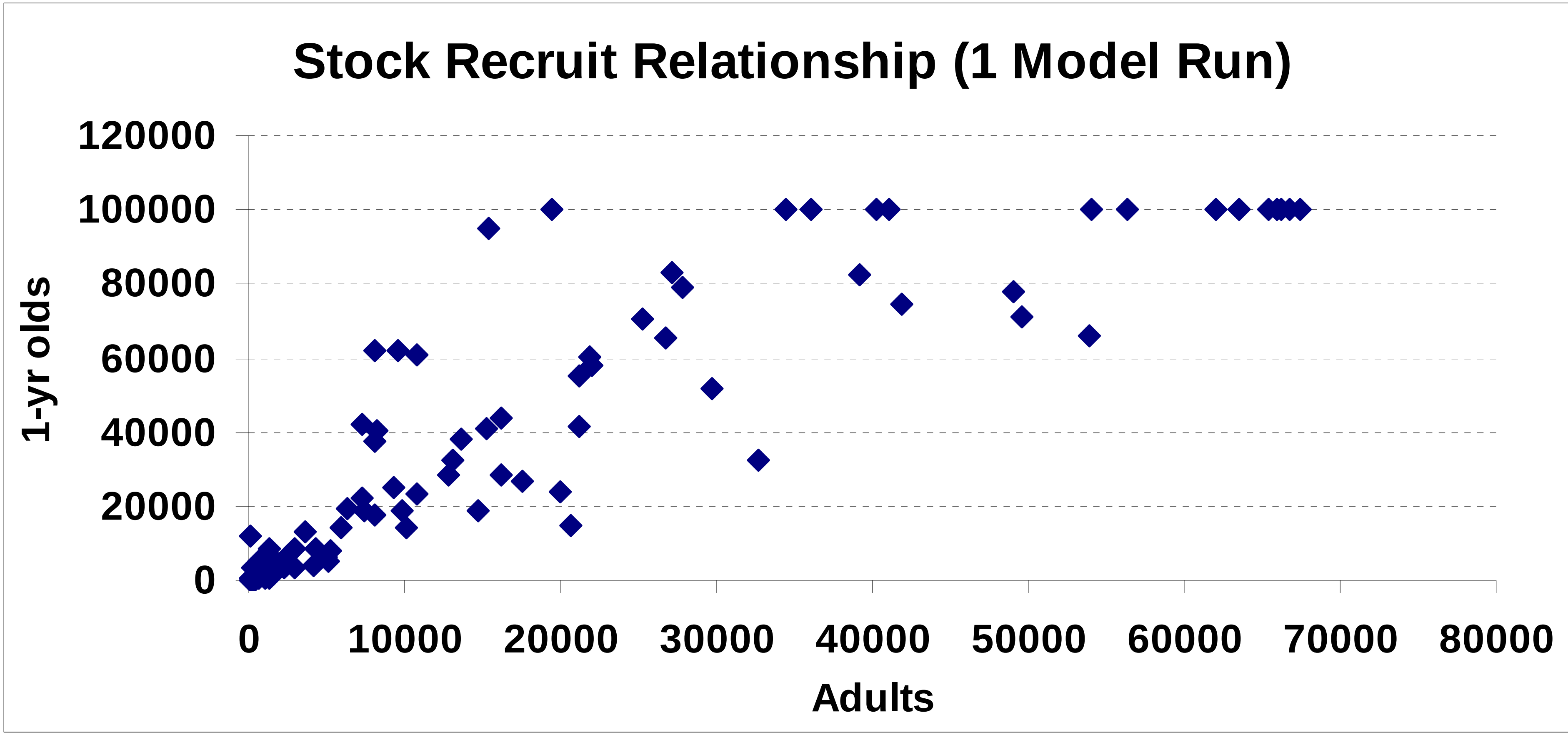


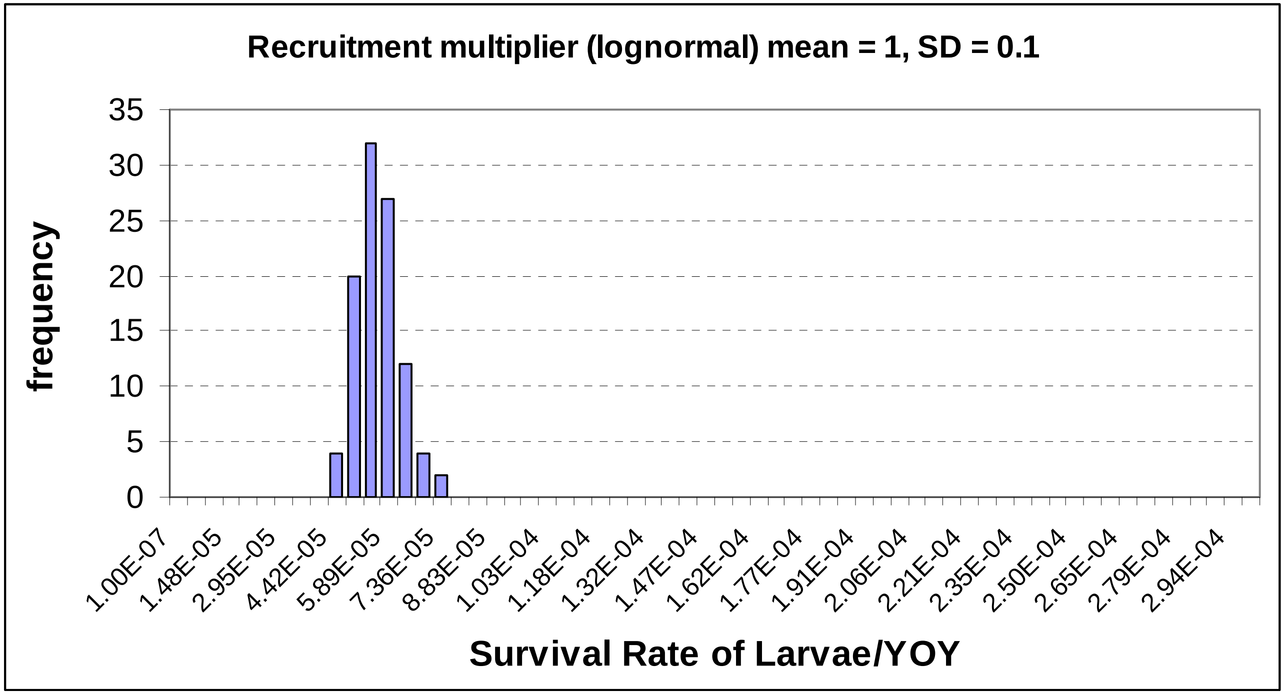
Fish Kill Year Survival Rates (1000 Model Runs)
Juvenile:Adult kill ratio = 0.5
Adult
Juvenile
Proportion
0.25
0.2
0.15
0.1
0.05
0
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Survival

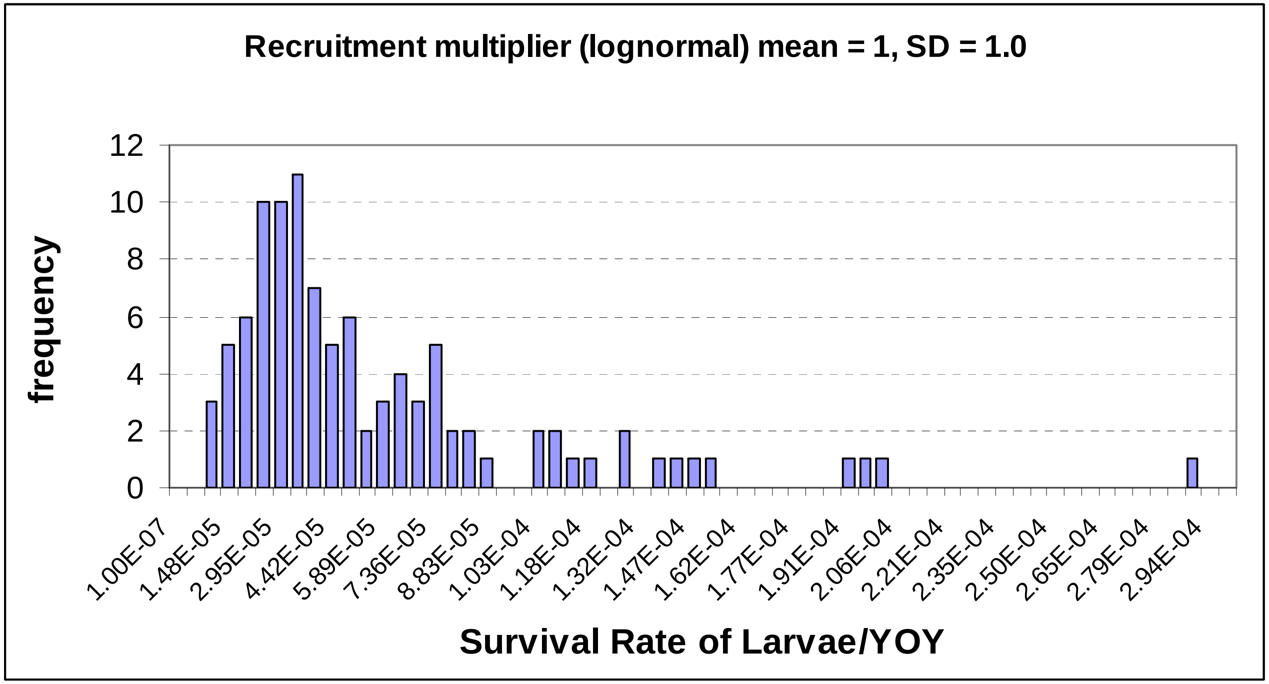

Fish Kill Year Survival Rates (1000 Model Runs)
Juvenile:Adult kill ratio = 1.0
Adult
Juvenile
Proportion
0.12
0.1
0.08
0.06
0.04
0.02
0
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Survival

Example from simulation model – annual survival rates

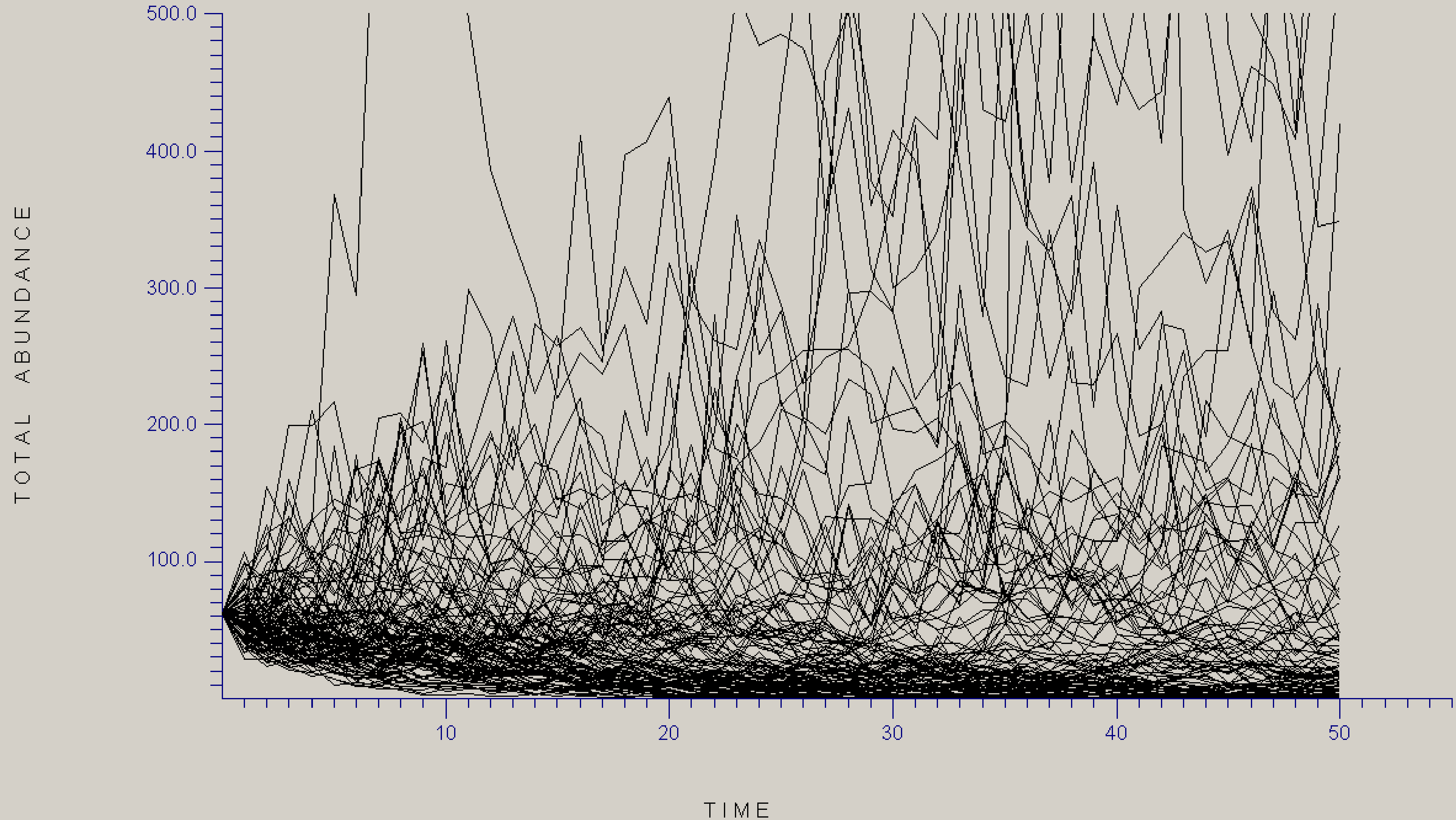
larvae	5.54E-05	8.44E-05	3.51E-05	4.60E-05	5.23E-05	6.36E-05
Juvenile	0.70	0.55	0.70	0.43	0.70	0.70
Juvenile	0.70	0.55	0.70	0.43	0.70	0.70
Juvenile	0.70	0.55	0.70	0.43	0.70	0.70
Juvenile	0.70	0.55	0.70	0.43	0.70	0.70
Subadult	0.99	0.52	0.87	0.21	0.95	0.88
Small Adult	0.99	0.52	0.87	0.21	0.95	0.88
Large Adult	0.99	0.52	0.87	0.21	0.95	0.88
fish kill	Normal Year	Fish Kill Year	Normal Year	Fish Kill Year	Normal Year	Normal Year


Stock Recruit Relationship (1 Model Run)
120000
100000
80000
60000
40000
20000
0
1-yr olds
0
10000
20000
30000
40000
50000
60000
70000
80000
Adults

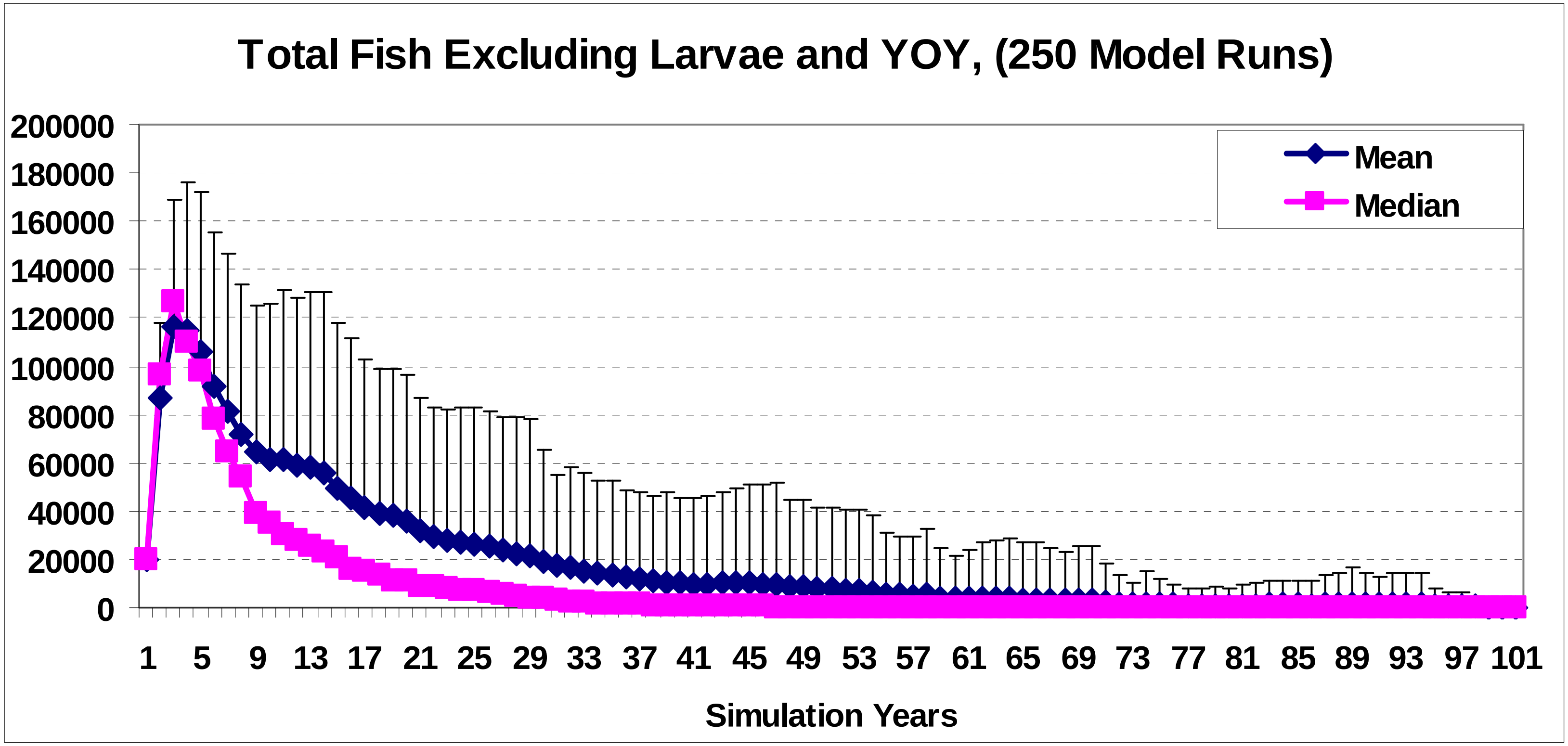

Recruitment multiplier (lognormal) mean = 1, SD = 0.1
frequency
0
5
10
15
20
25
30
35
1.00E-07
1.48E-05
2.95E-05
4.42E-05
5.89E-05
7.36E-05
8.83E-05
1.03E-04
1.18E-04
1.32E-04
1.47E-04
1.62E-04
1.77E-04
1.91E-04
2.06E-04
2.21E-04
2.35E-04
2.50E-04
2.65E-04
2.79E-04
2.94E-04
Survival Rate of Larvae/YOY


Recruitment multiplier (lognormal) mean = 1, SD = 1.0
frequency
0
2
4
6
8
10
12
1.00E-07
1.48E-05
2.95E-05
4.42E-05
5.89E-05
7.36E-05
8.83E-05
1.03E-04
1.18E-04
1.32E-04
1.47E-04
1.62E-04
1.77E-04
1.91E-04
2.06E-04
2.21E-04
2.35E-04
2.50E-04
2.65E-04
2.79E-04
2.94E-04
Survival Rate of Larvae/YOY

Trajectories



Replication: 125 | Time step: 50 | 00:00:05 | Simulation cancelled

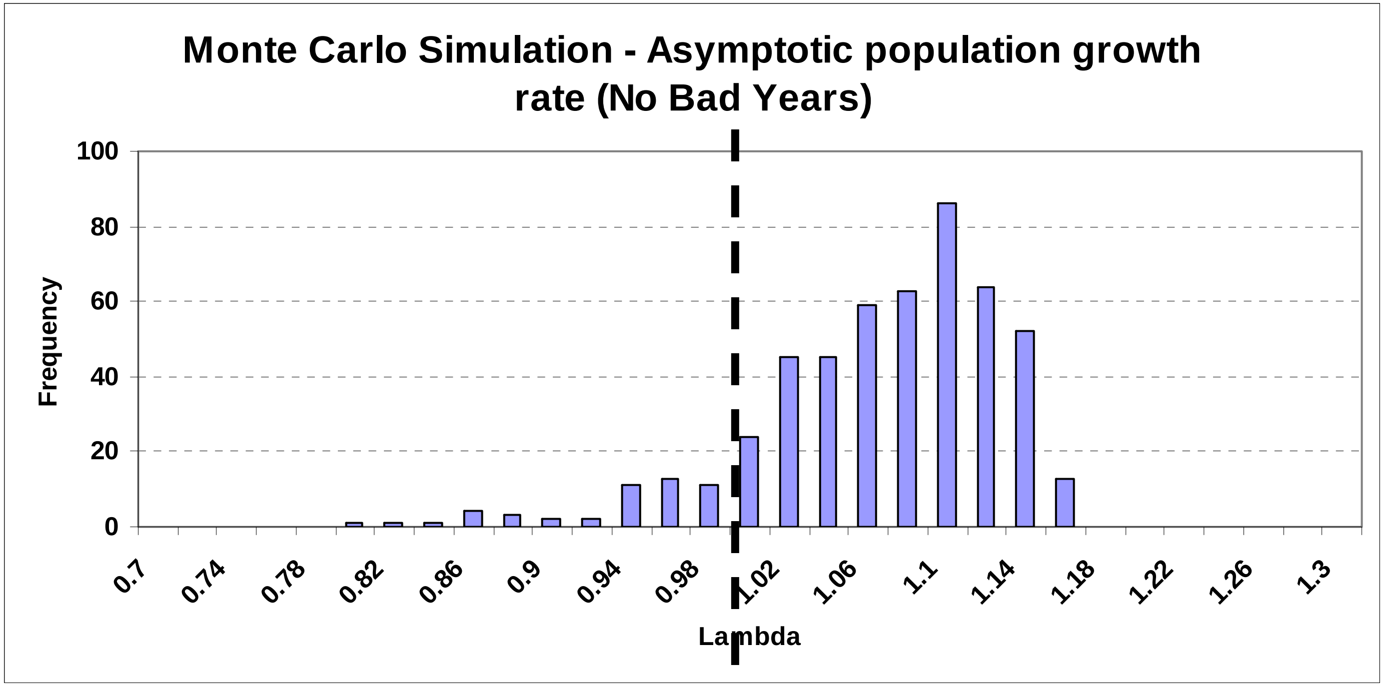

Total Fish Excluding Larvae and YOY, (250 Model Runs)
200000
180000
160000
140000
120000
100000
80000
60000
40000
20000
0
Mean
Median
1
5
9
13
17
21
25
29
33
37
41
45
49
53
57
61
65
69
73
77
81
85
89
93
97
101
Simulation Years

Stochasticity vs. Uncertainty

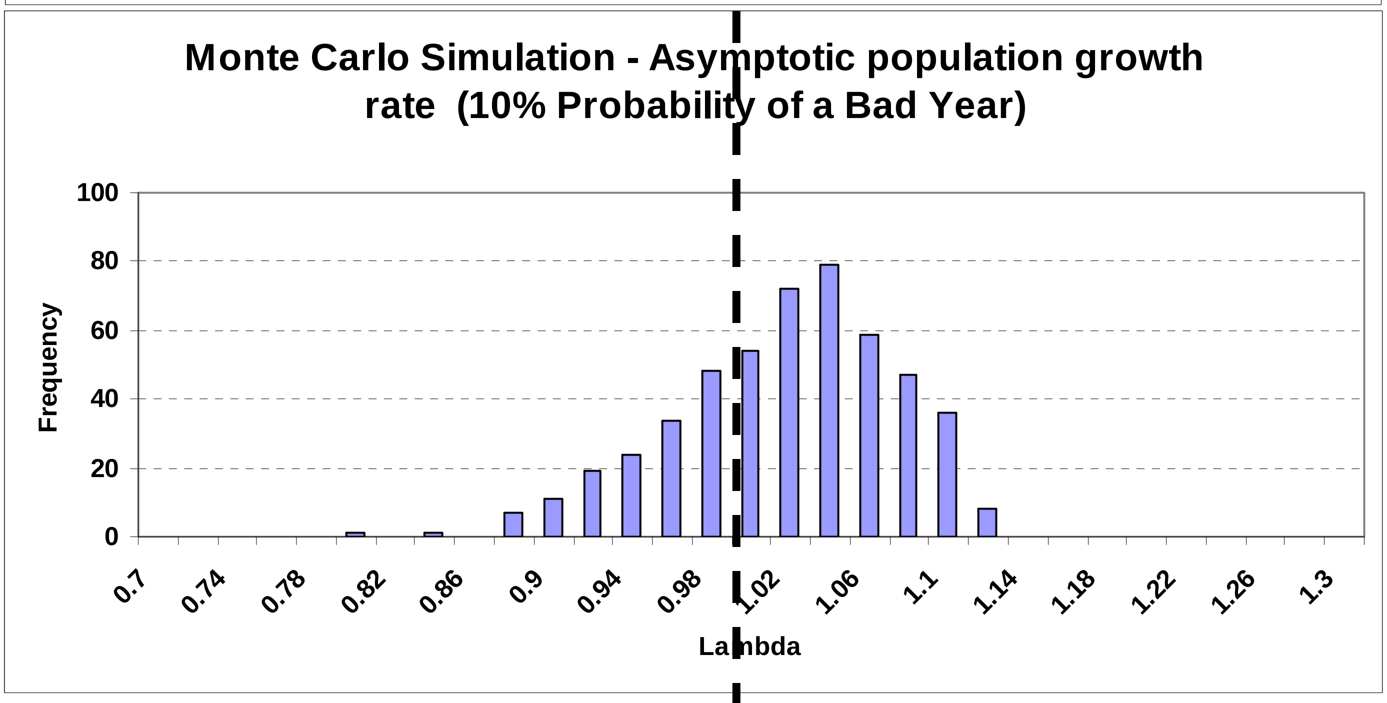
- Stochasticity represents “process error” – variance in the environment that affects vital rates
- Uncertainty is “model error” or “measurement error”, or more simply, the range of possibilities to consider because we don’t have the “true” estimate or can’t measure the parameter very well
- In a “Monte Carlo” simulation like this one, ***stochasticity and uncertainty are not well separated,*** so results should be interpreted as a range of possibilities based on what we know (and don’t know) about suckers
  - ***Qualitative, rather than predictive***

Response Variables

- Lambda (deterministic)
  - Asymptotic population growth rate
- Elasticity analysis (deterministic)
  - Shows proportional contribution of each life stage to lambda
- Extinction risk (stochastic)
  - Proportion of the simulated populations that drop below quasi extinction threshold
- Mean/Median # of individuals (stochastic)
  - # of adults, juveniles, etc. produced during repeated simulations under varying parameter values

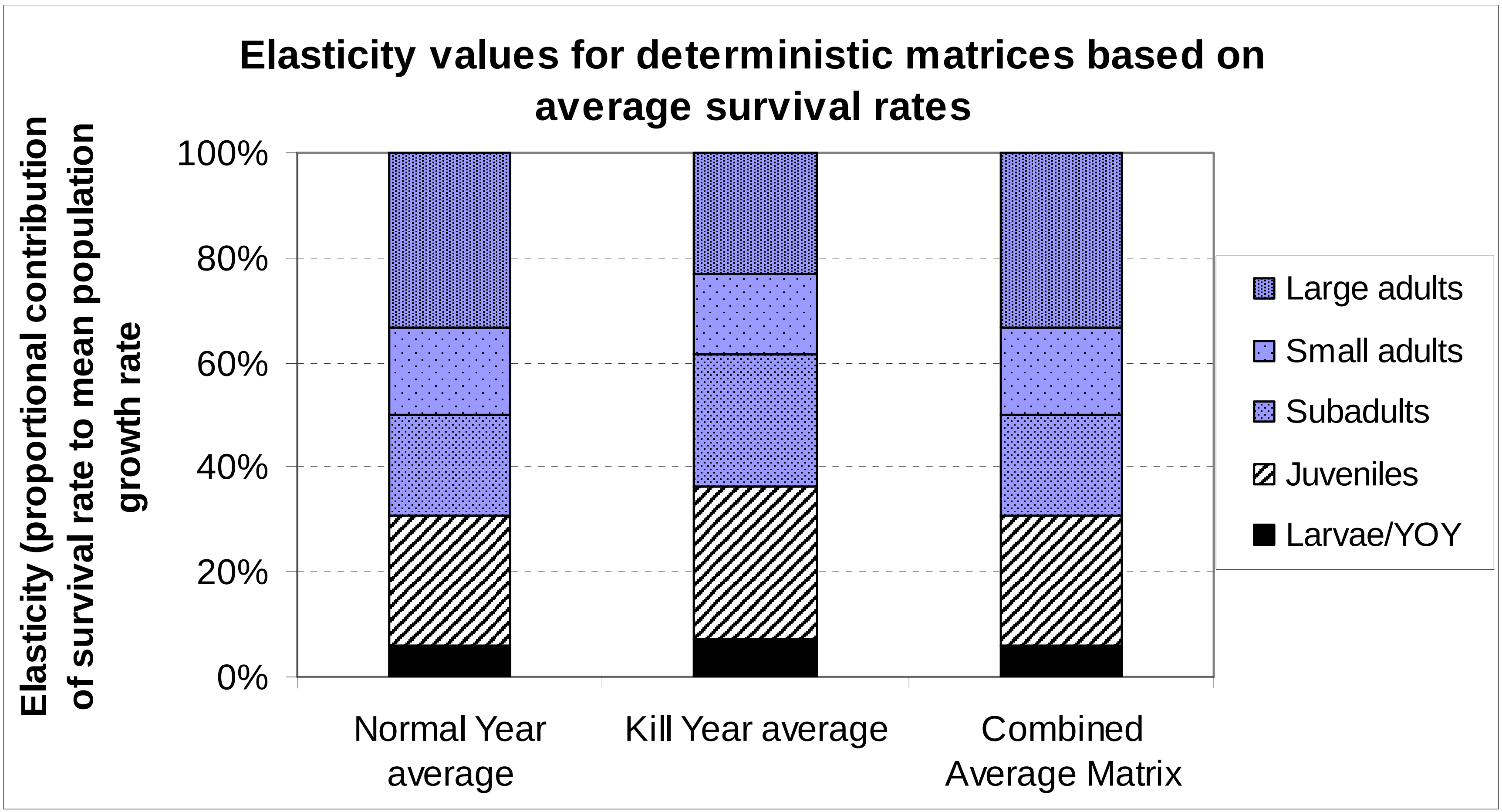


Monte Carlo Simulation - Asymptotic population growth rate (No Bad Years)
Frequency
0
20
40
60
80
100
0.7
0.74
0.78
0.82
0.86
0.9
0.94
0.98
1.02
1.06
1.1
1.14
1.18
1.22
1.26
1.3
Lambda

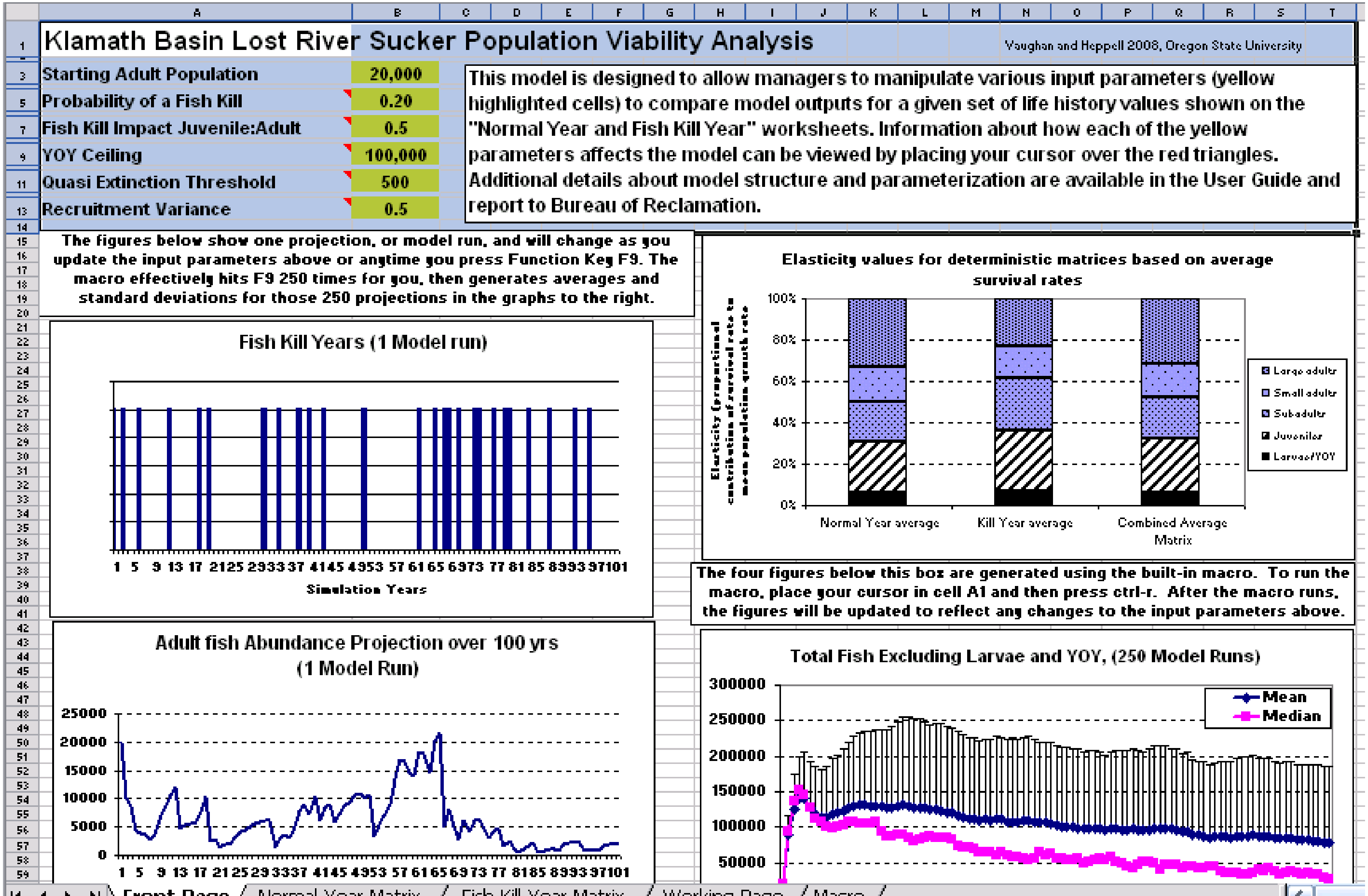


Monte Carlo Simulation - Asymptotic population growth rate (10% Probability of a Bad Year)
Frequency
0
20
40
60
80
100
0.7
0.74
0.78
0.82
0.86
0.9
0.94
0.98
1.02
1.06
1.1
1.14
1.18
1.22
1.26
1.3
Lambda

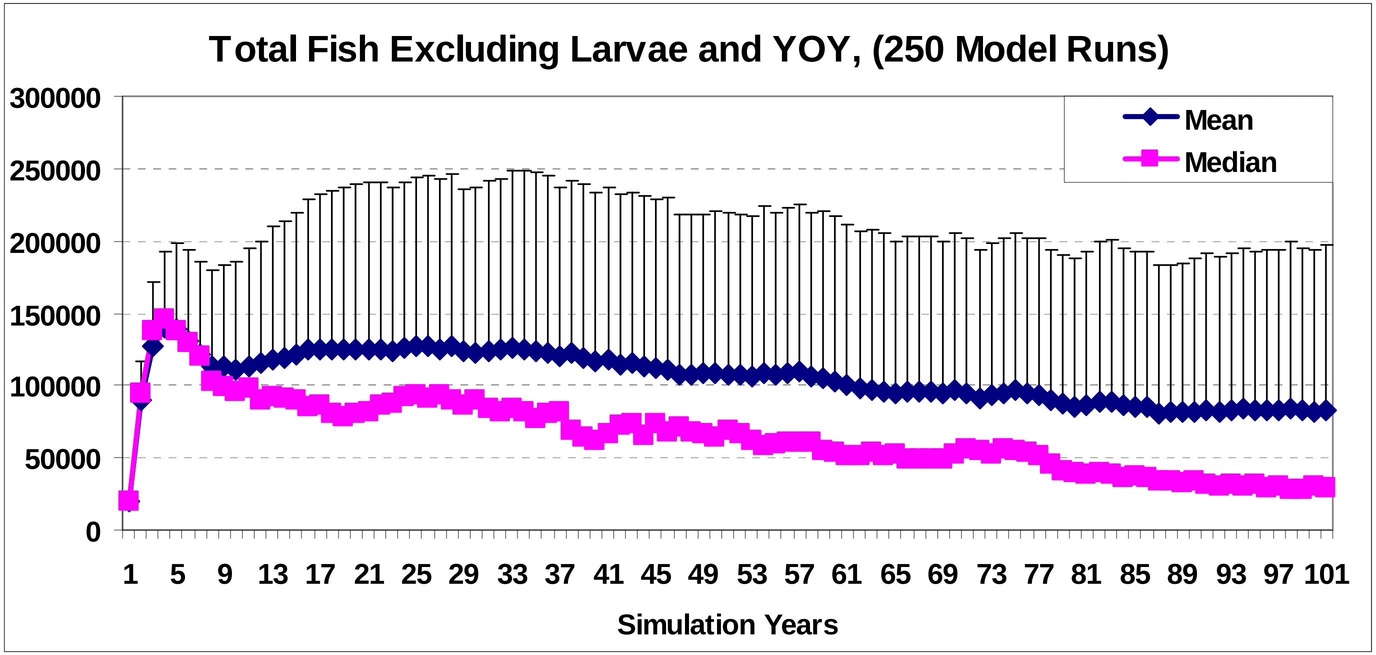
Elasticity = proportional contribution of the stage-specific survival rate to the exponential growth rate

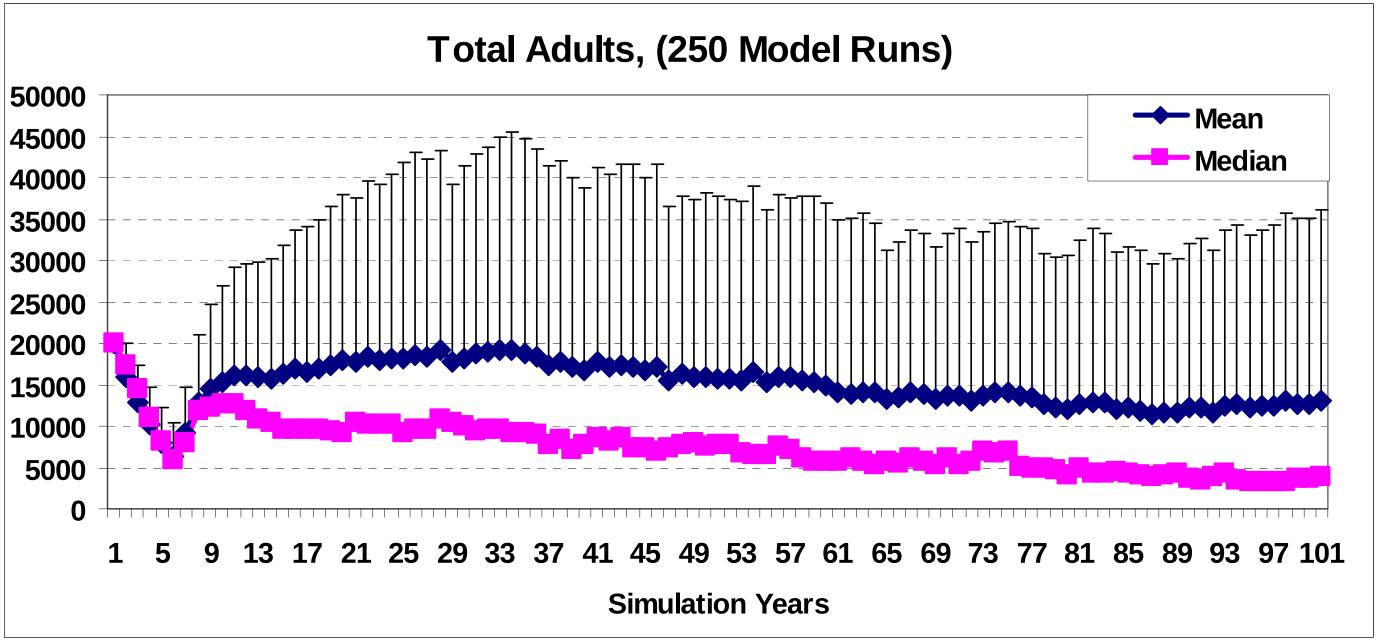


“Front Page”


Klamath Basin Lost River Sucker Population Viability Analysis
Vaughan and Heppell 2008, Oregon State University
Starting Adult Population 20,000
Probability of a Fish Kill 0.20
Fish Kill Impact Juvenile:Adult 0.5
YOY Ceiling 100,000
Quasi Extinction Threshold 500
Recruitment Variance 0.5
This model is designed to allow managers to manipulate various input parameters (yellow highlighted cells) to compare model outputs for a given set of life history values shown on the "Normal Year and Fish Kill Year" worksheets. Information about how each of the yellow parameters affects the model can be viewed by placing your cursor over the red triangles. Additional details about model structure and parameterization are available in the User Guide and report to Bureau of Reclamation.
The figures below show one projection, or model run, and will change as you update the input parameters above or anytime you press Function Key F9. The macro effectively hits F9 250 times for you, then generates averages and standard deviations for those 250 projections in the graphs to the right.
Fish Kill Years (1 Model run)
Simulation Years
Elasticity values for deterministic matrices based on average survival rates
Elasticity (proportional contribution of survival rate to mean population growth rate)
Large adults
Small adults
Subadults
Juveniles
Larvae/YOY
Normal Year average
Kill Year average
Combined Average Matrix
The four figures below this box are generated using the built-in macro. To run the macro, place your cursor in cell A1 and then press ctrl-r. After the macro runs, the figures will be updated to reflect any changes to the input parameters above.
Adult fish Abundance Projection over 100 yrs (1 Model Run)
Total Fish Excluding Larvae and YOY, (250 Model Runs)
Mean
Median
Front Page
Normal Year Matrix
Fish Kill Year Matrix
Working Page
Macro

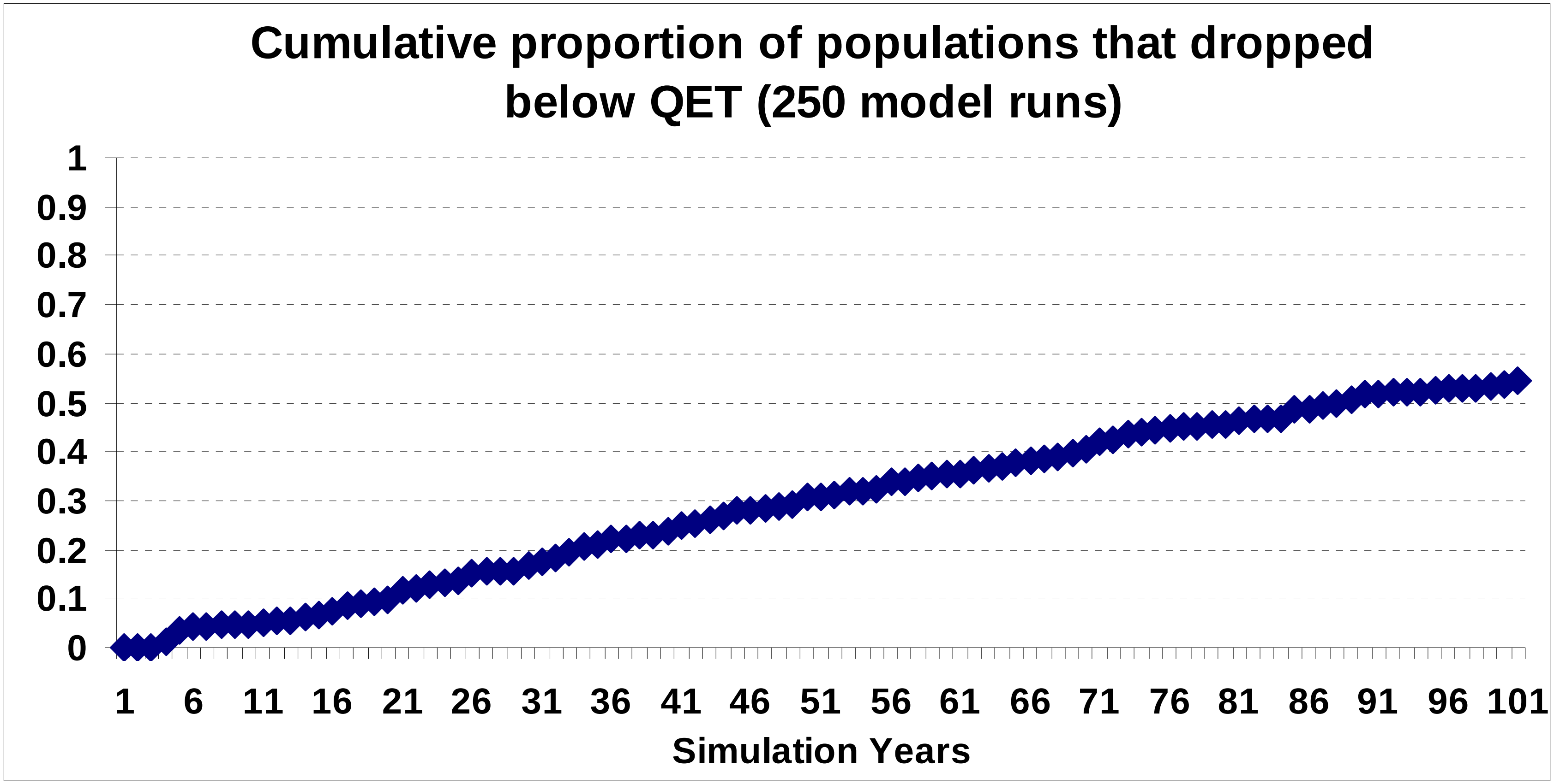
c. LRS model projections: fish kill year frequency = 20%





“Extinction risk” with fish kill year probability = 20% and extinction threshold = 500 female fish

c. 20% chance of a fish kill



Application to evaluation of management proposals

- To identify the likely effects of a management plan on endangered species recovery requires two primary quantitative steps:
  - Determine level of effect of management on vital rates (survival, growth, reproduction) or carrying capacity (life stage specific)
  - Determine sensitivity of population processes to those changes
- Model outputs must also be evaluated for sensitivity to uncertainty and model assumptions (are the results “robust”?)

Thanks

selina.heppell@oregonstate.edu