The Emerging Delta Smelt Life History Model and Implications for the EWA

(Are We "Dazed and Confused" Yet ?)

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The Goals

OC/ WEDNESDAY, JULY 4, 1990 A3

Second Front Page

Delta Smelt Threatens Water Supply

■ Environment: A state agency says the tiny fish is nearing extinction. Saving it might force a reduction in shipments to Southern California.

By RICHARD C. PADDOCK

SACRAMENTO—In a serio challenge to California's vast wat supply system, a small fish fou only in the Sacramento-San Jo quin River Delta is nearing extin tion, and should be listed as threatened species, the state D partment of Fish and Game h concluded.

Population Ecology of Delta Smelt in the San Francisco Estuary

The "whitepaper"

In review: San Francisco Estuary and Watershed Science

1. Should the species be listed under the ESA; what is the probability of extinction?

2. What is the role of human activities, particularly water export operations, on the population?

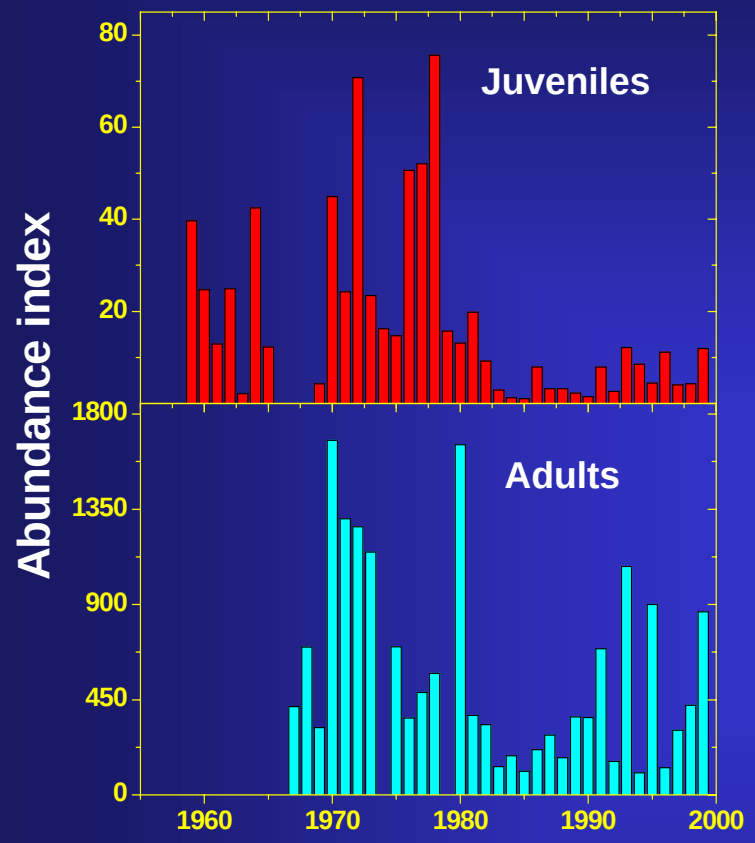
3. What are the potential restoration options?

This Requires 4 Components (at least) !

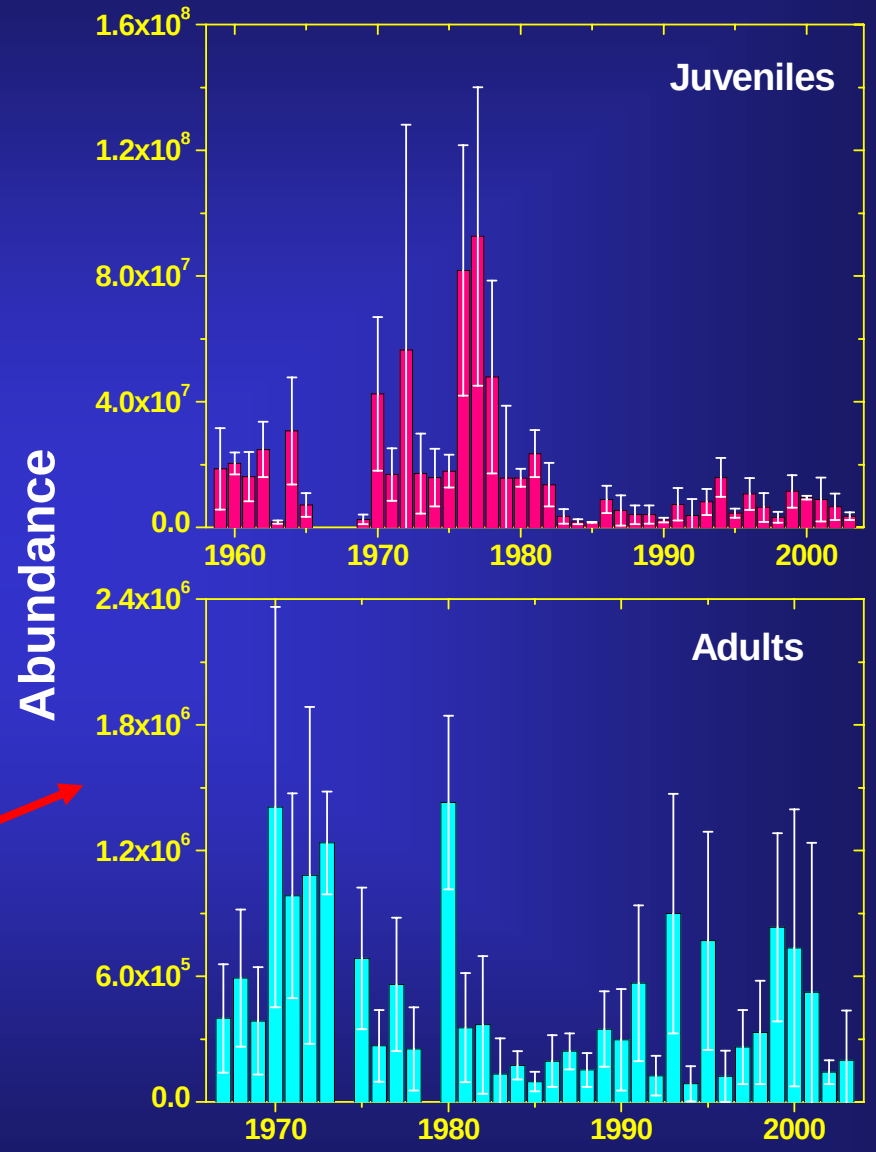
#1- Abundance!

- Indices are dimensionless & static
- Need for population assessments: extinction risks?
- Need to understand survival among life stages.
- Modeling relative influences of natural vs. human factors.

Indices



Abundance



Assumptions

Net efficiency = 100%

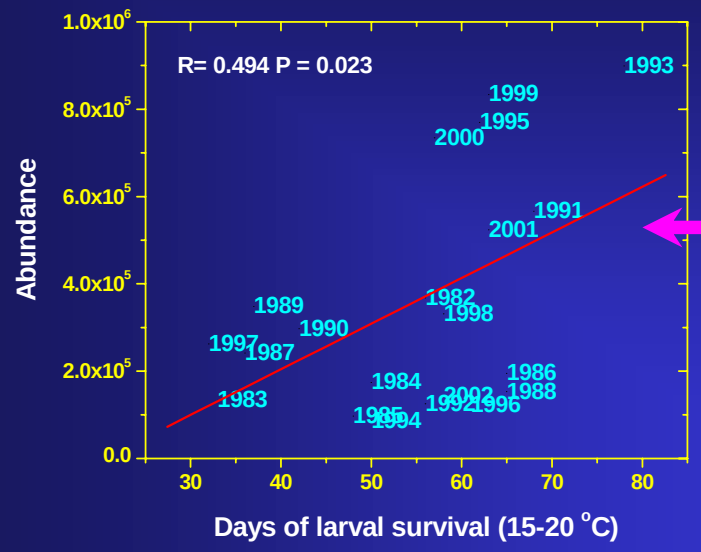
Volume filtered =

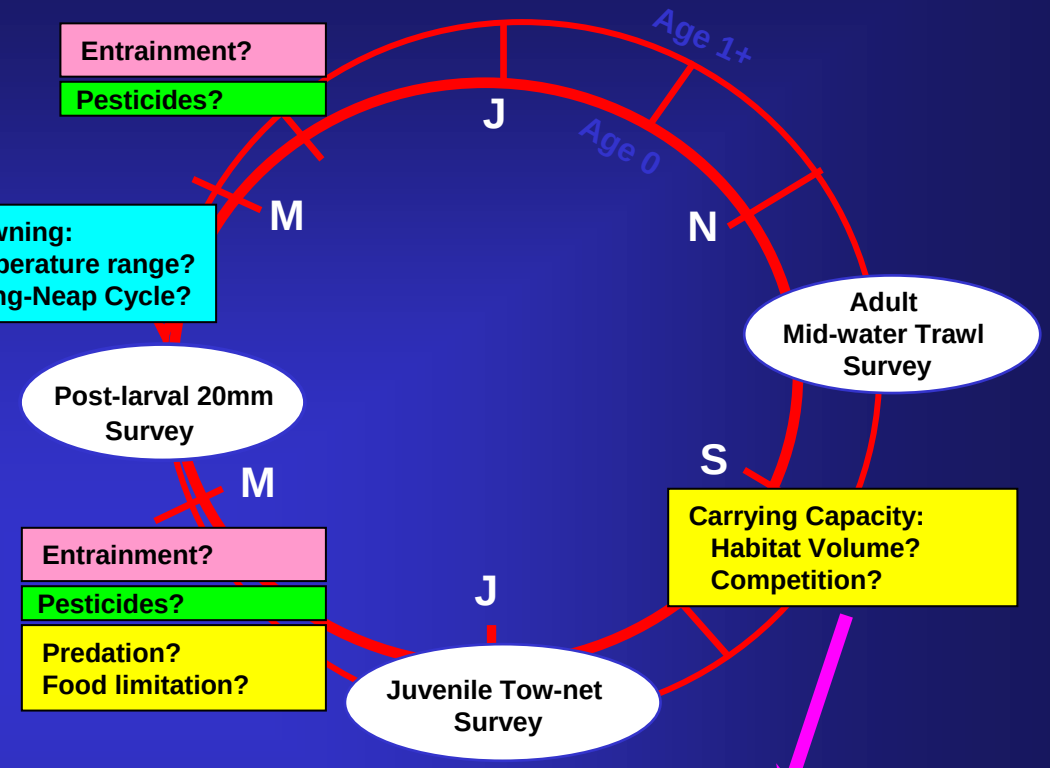
700 m3 (TNS, Juvenile Survey)

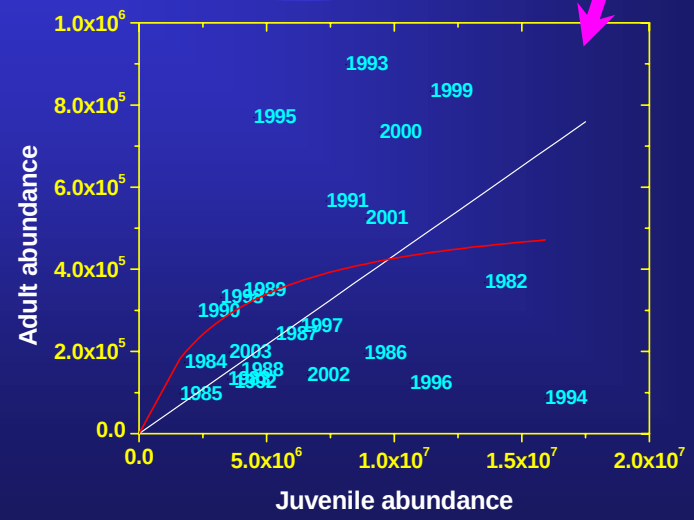
7000 m3 (MWT, Adult Survey)

Kimmerer et al. 2000

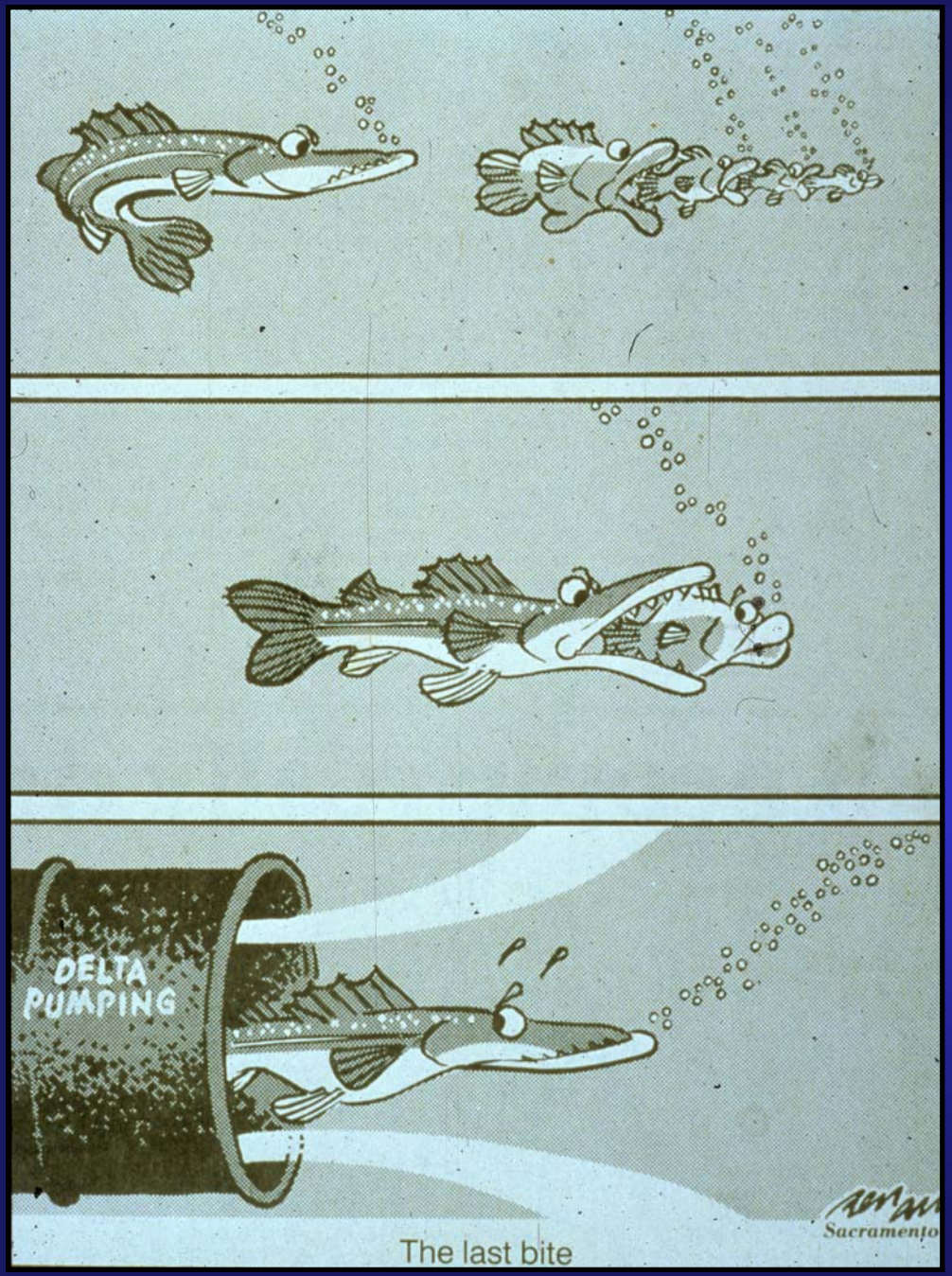
#2- Delta Smelt Conceptual Model







- Must survive the "Wheel of Misfortune".
- Longer spawning seasons produce more adults. Risks are spread among more individuals.
- High juvenile abundance may limit survival to the adult stage. (i.e. Density dependence) in some years



Trouble is that lots of things are happening at the same time….

Not conspicuous!

Subtle or Episodic!

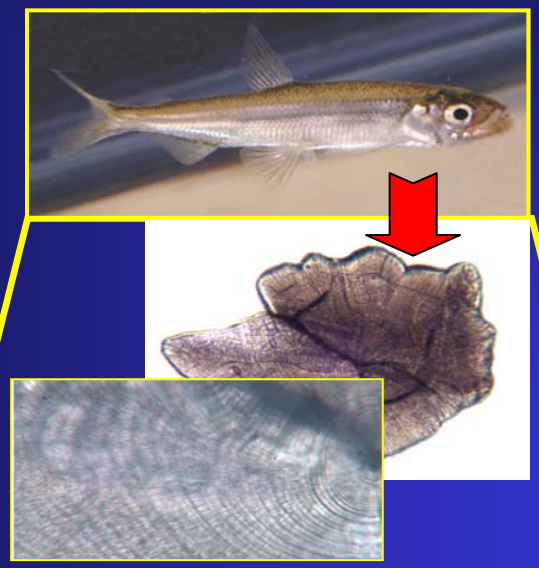
Not mutually exclusive!

Size or Stage-dependent mortality:

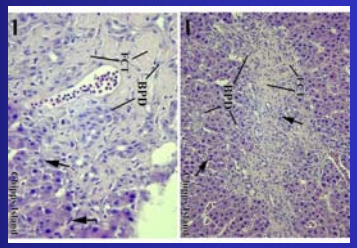
slow growth ☞ higher mortality

Only Olympians make it!

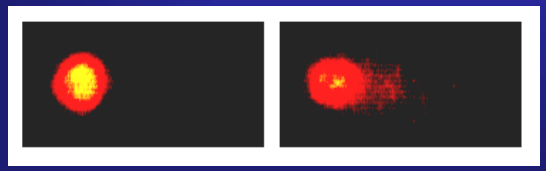
#3 – Directly Quantifying Mechanisms of Mortality



Growth history : Otolith Analyses



Organ health : Histopathology

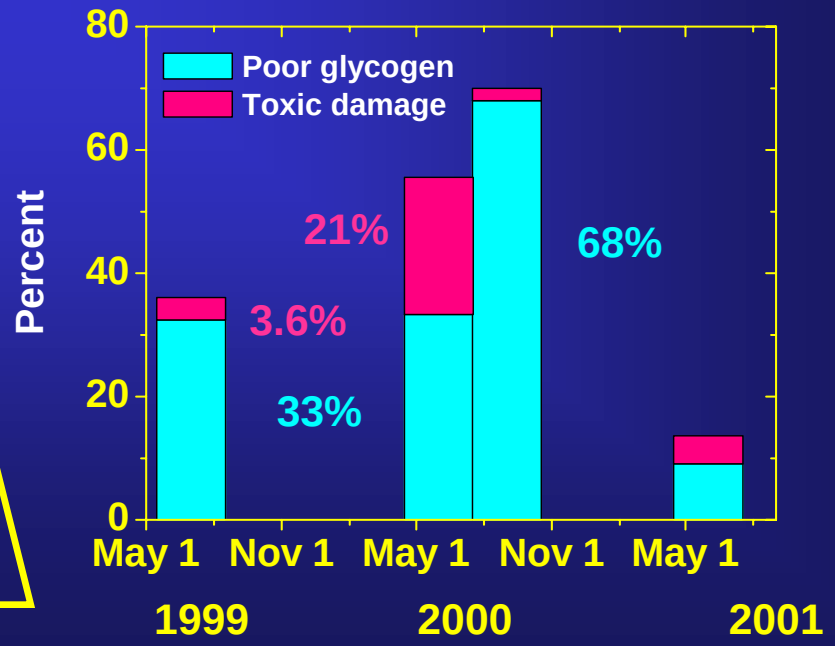


Genetic response to toxics : Comet Assay

OBJECTIVES:

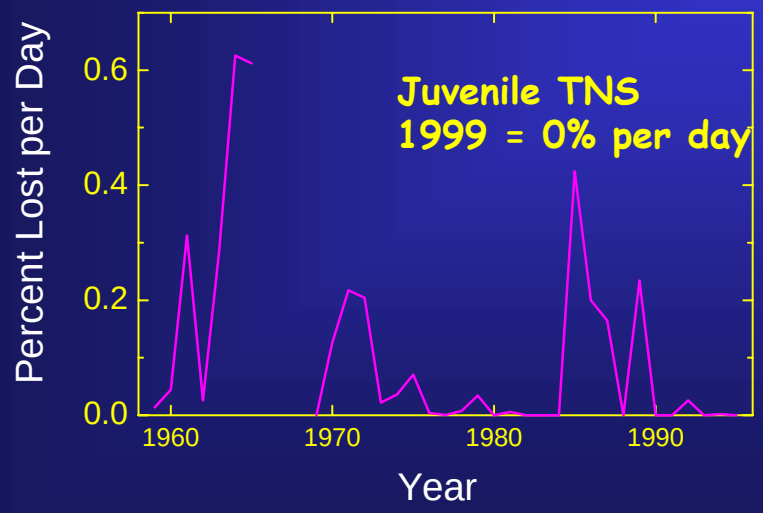
1. Distinguish anthropogenic from natural influences:
   poor feeding success
   exposure to pesticides

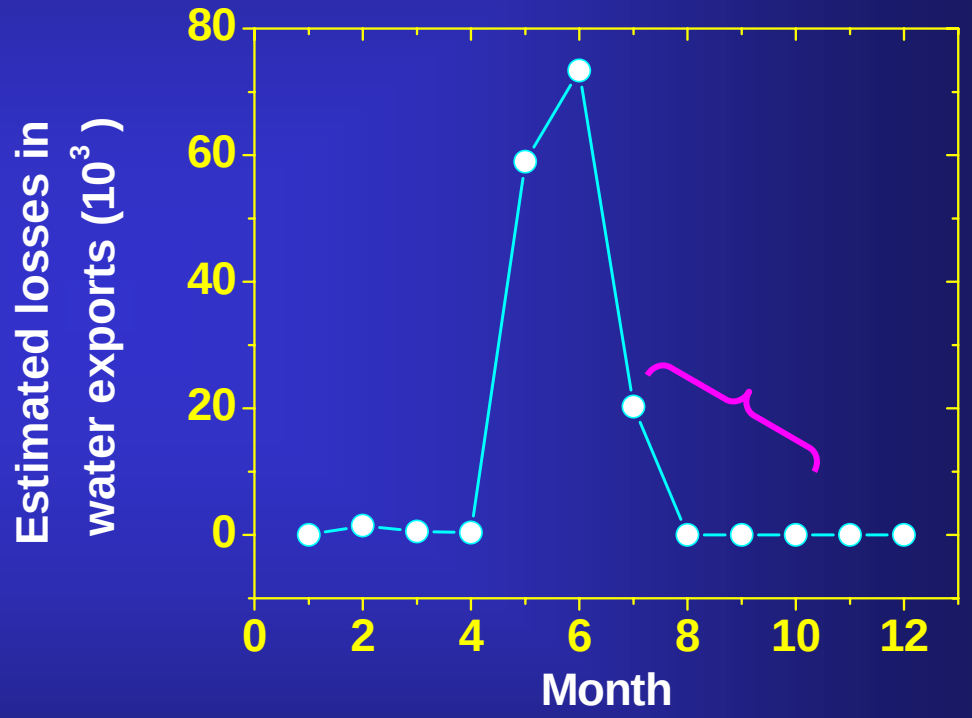
2. Extrapolate to the population level and evaluate with water projects (salvage).



Linking Field Measurements of Potential Mortality to Abundance.

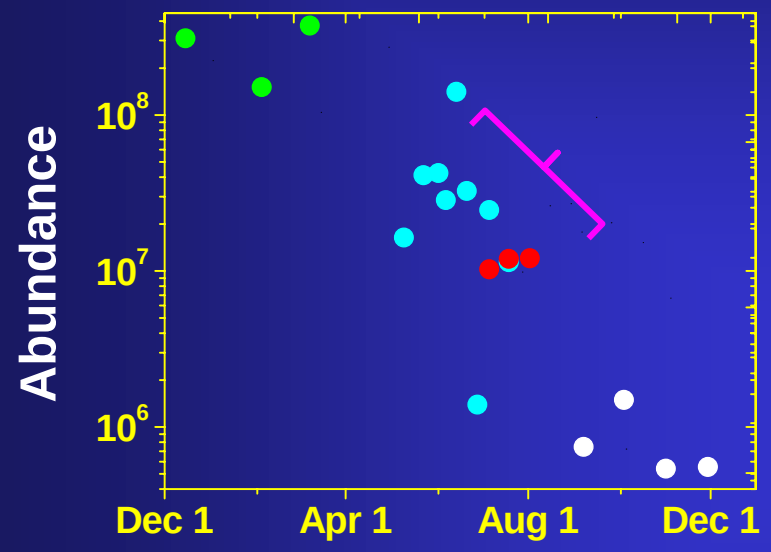
Example: Losses to Water Export Facilities in 1999





Expanded estimate = 20,272

Mortality and Abundance from July to October, 1999 ?

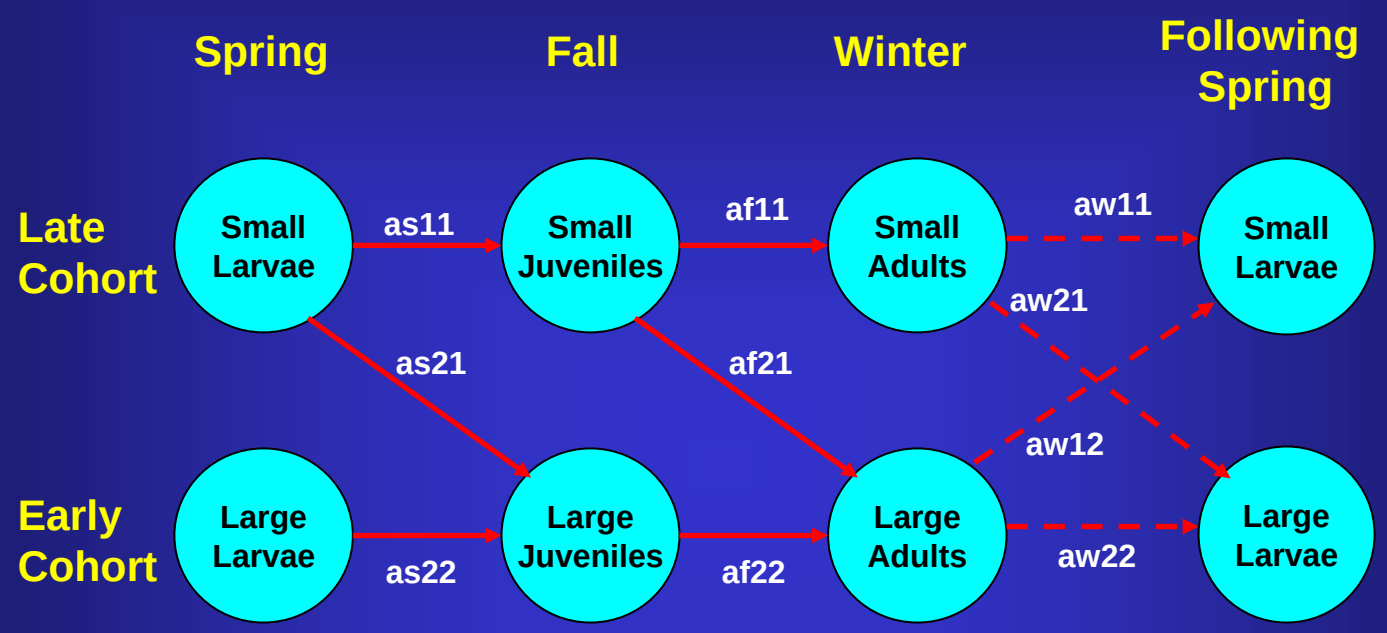


July abundance =	11,970,068
# lost to exports =	20,272 (0.7%)
# lost to toxics =	430,922 (3.6%)
# lost to growth =	+ 5,985,034 (50%)
total lost =	6,436,228
Est. Survivors in Fall =	5,533,840
October abundance =	1,492,653

- Mechanisms that slow growth may be of major importance.
- Exports and toxics can eliminate potential survivors.

#4 - Population Modeling

Periodic Stage-Based Model and Export Mortality

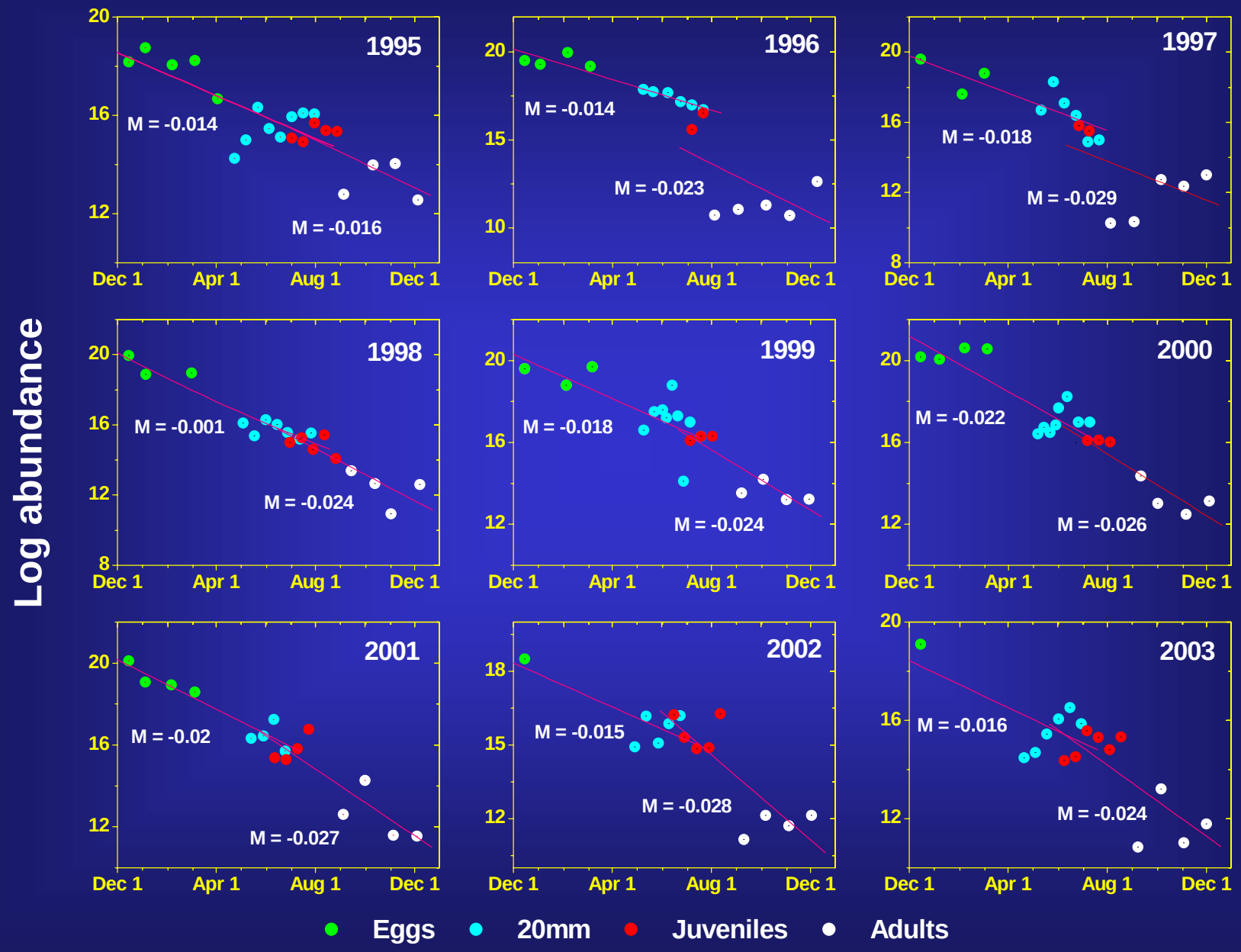


$$\begin{pmatrix} as11 & 0 \\ as21 & as22 \end{pmatrix} \cdot \begin{pmatrix} af11 & 0 \\ af21 & af22 \end{pmatrix} \cdot \begin{pmatrix} aw11 & aw12 \\ aw21 & aw22 \end{pmatrix} = \text{Aggregate population matrix}$$

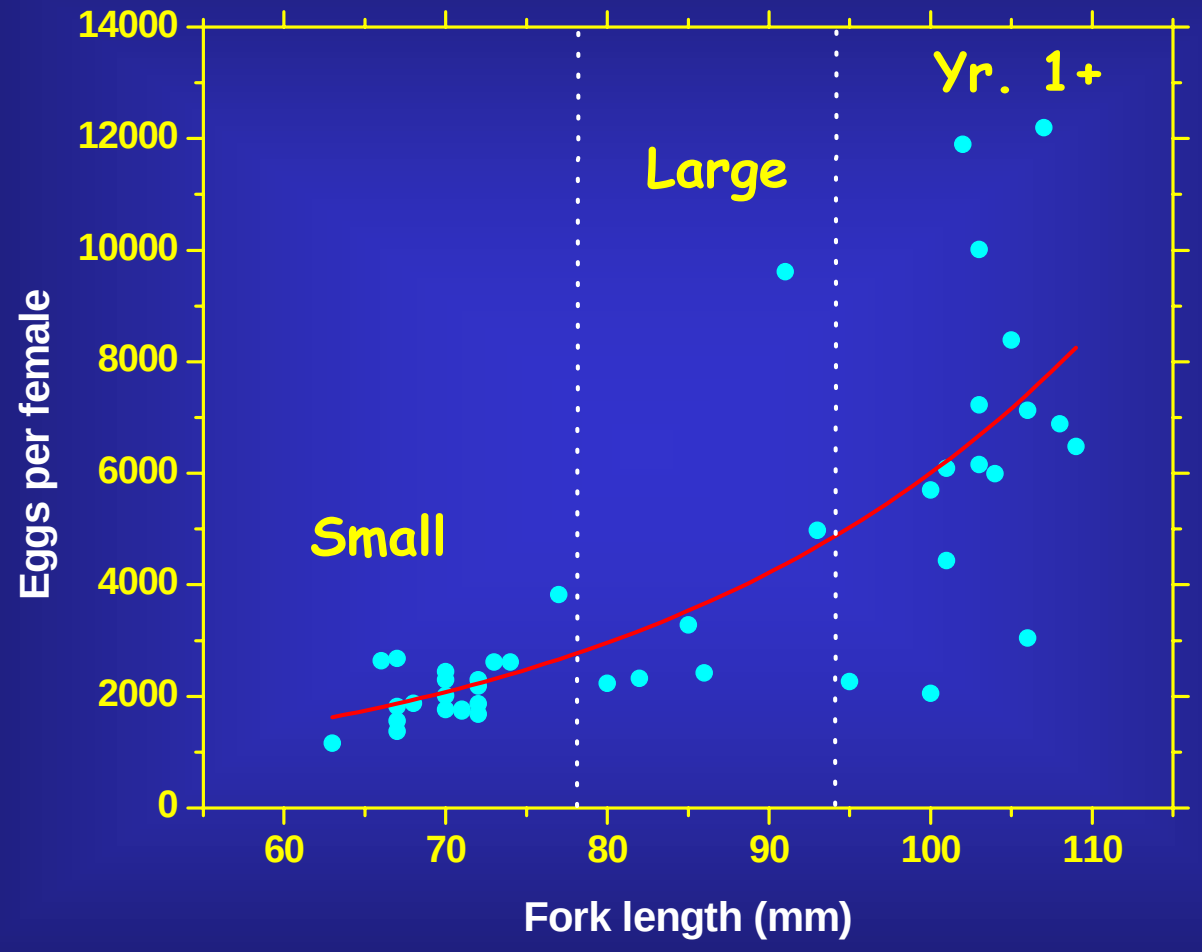
Size or Growth Selection Paradigm:

Larger, or faster growing, fish have a lower probability of encountering mortality

Estimated Mortality Among Life-Stages

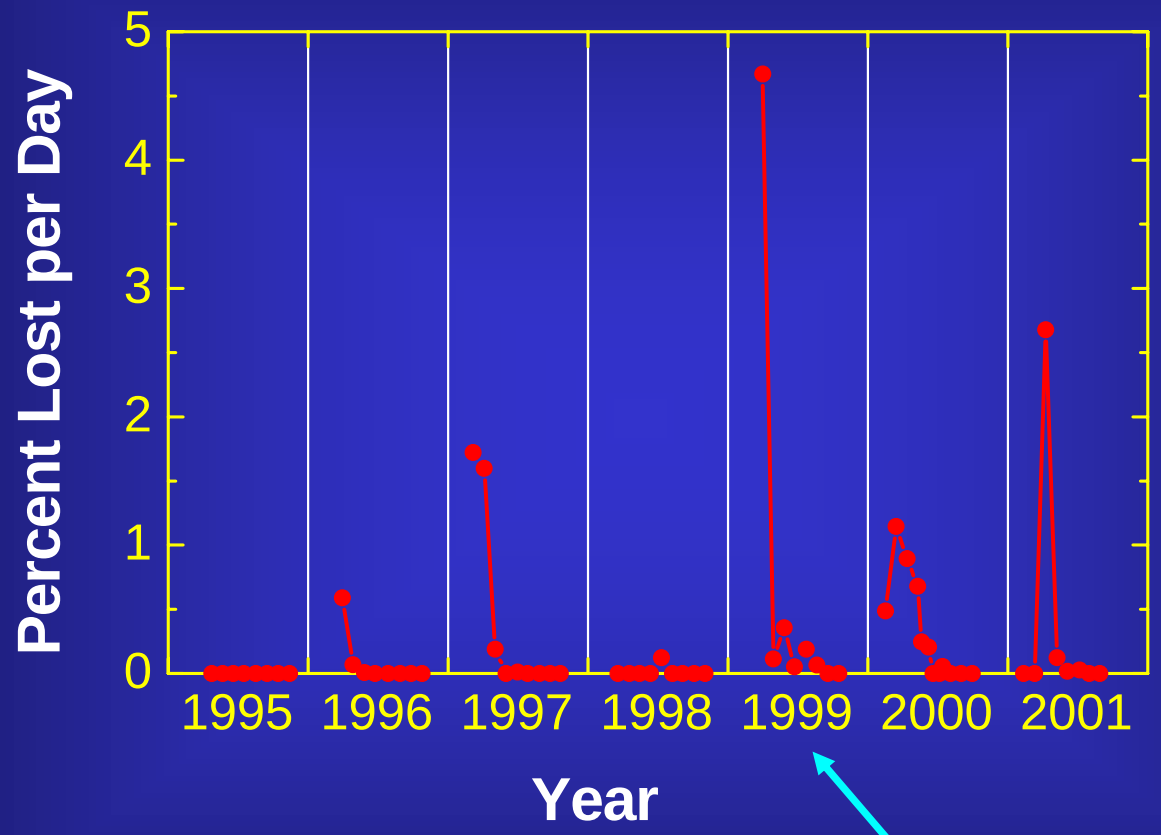


Fecundity



Data source: Brad Baskerville-Bridges, UCD

Daily Mortality due to Water Exports in 20mm Survey



Cummulative = ~60%

Data source: Wim Kimmerer, SFSU

Parameters and Transitions

Transitions	Definition	Estimate
Parameters		
	Fecundity small female eggs	1870/2 = 935
	Fecundity large female eggs	3283/2 = 1642
Survival		
	Fall adult to spring adult	0.59
	Spring egg abundance to larvae	0.018
	Larvae to juvenile	0.83
	Exports during larval stage	0.40
	Juvenile to fall adult	0.09
Spring		
as11	Probability of small larvae becoming a small juvenile	0.83 x 0.75 = 0.62
as21	Probability of small larvae becoming a large juvenile	0.83 x 0.25 = 0.21
as22	Probability of large larvae becoming a large juvenile	0.83
as22*	Probability of large larvae becoming a large juvenile with export mortality	0.83 x 0.40 = 0.332
Fall		
af11	Probability of small juvenile becoming a small adult	0.09*0.75 = 0.067
af21	Probability of small juvenile becoming a large adult	0.09*0.25 = 0.023
af22	Probability of large juvenile becoming a large adult	0.09
Winter		
aw11	Number of small larvae produced by small adults	935*0.018*0.59*0.5 = 4
aw21	Number of large larvae produced by small adults	935*0.018*0.59*0.5 = 4
aw22	Number of large larvae produced by large adults	1642*0.018*0.59*0.75 = 13
aw12	Number of small larvae produced by large adults	1642*0.018*0.59*0.25 = 4

Model Sensitivity

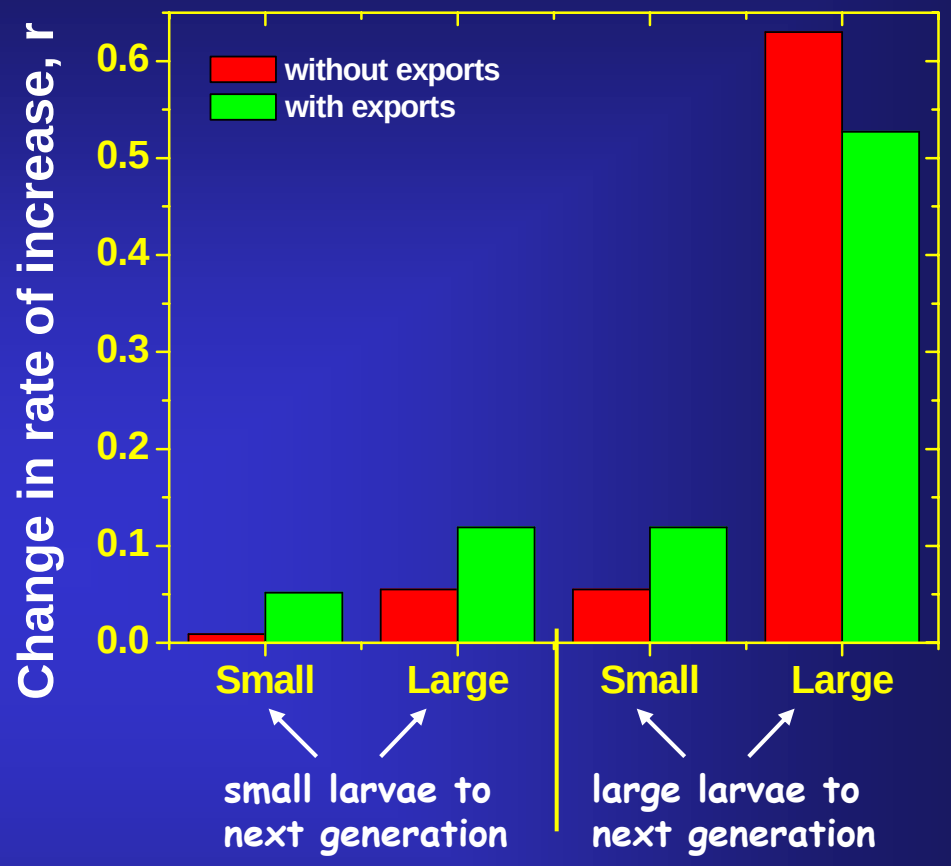
Population Growth "r" ?

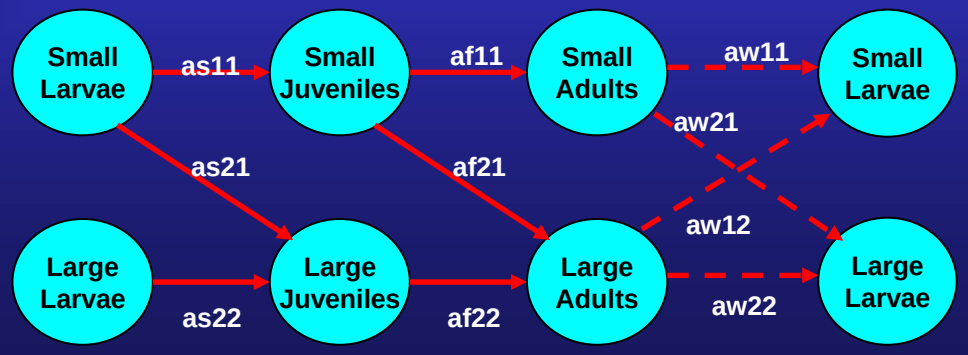
Without exports = + 1.23

With exports = - 0.65

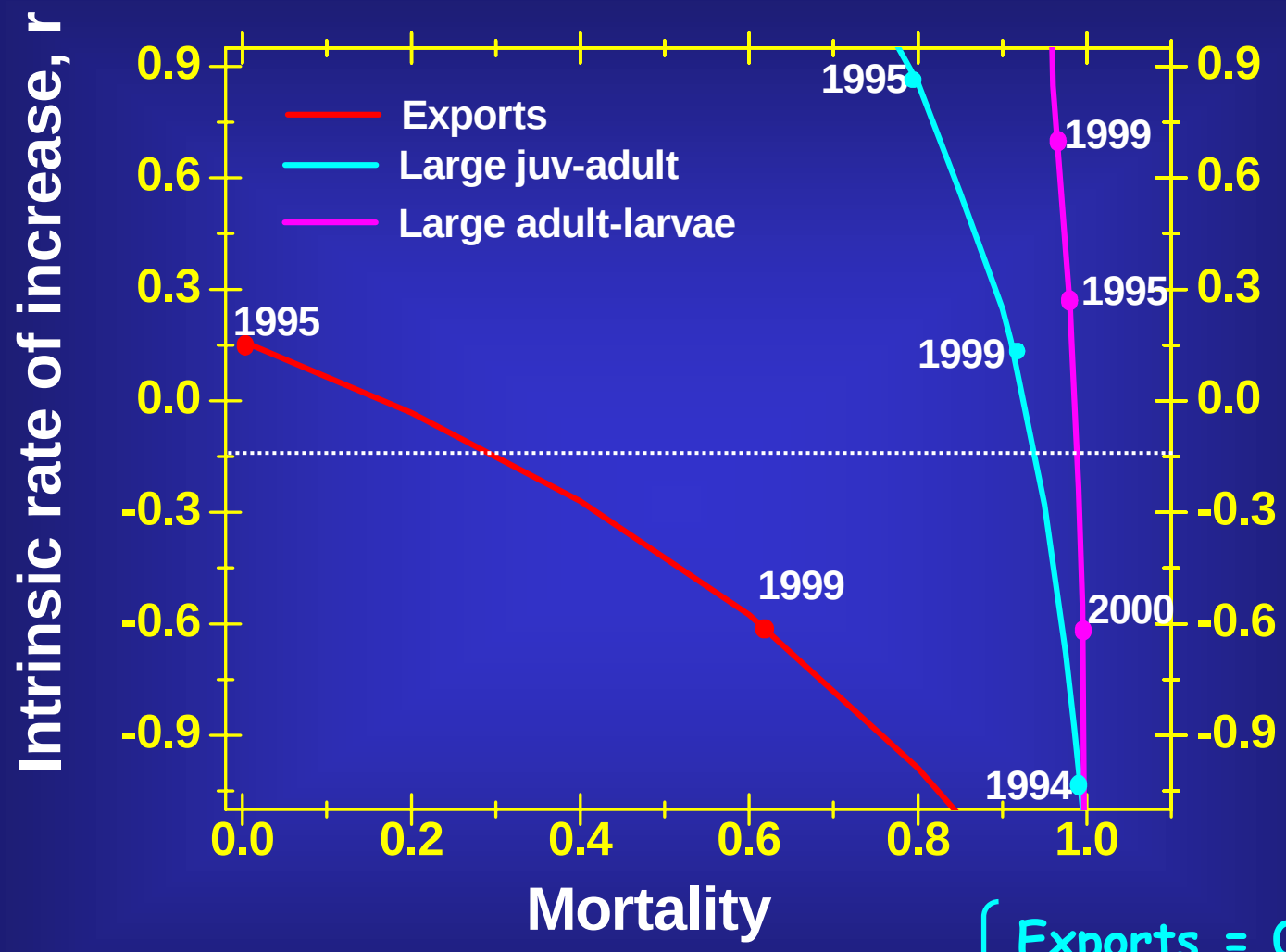
Elasticities ?

The relative importance of each element in the aggregate matrix to population growth?





Changes in Parameter Values and Population Growth

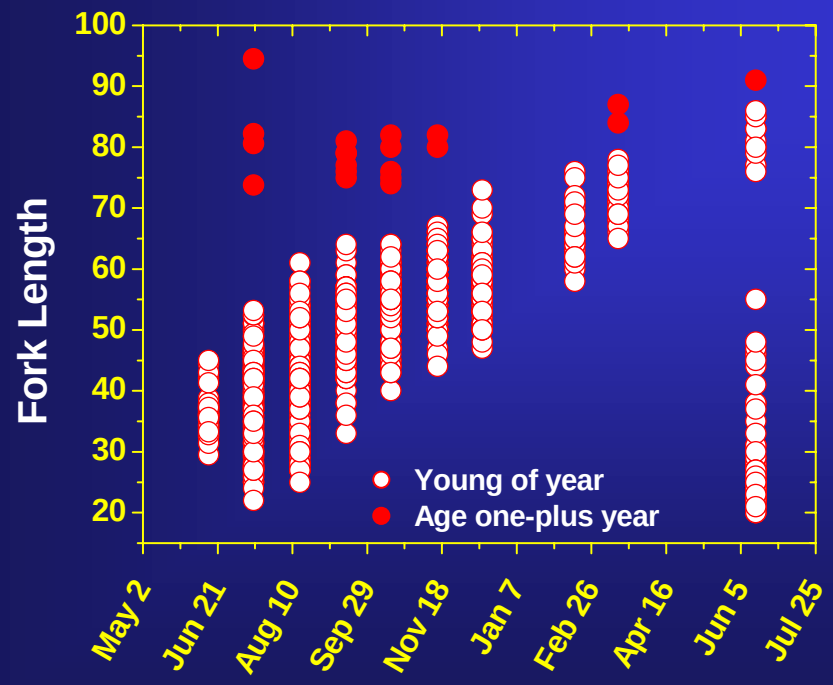


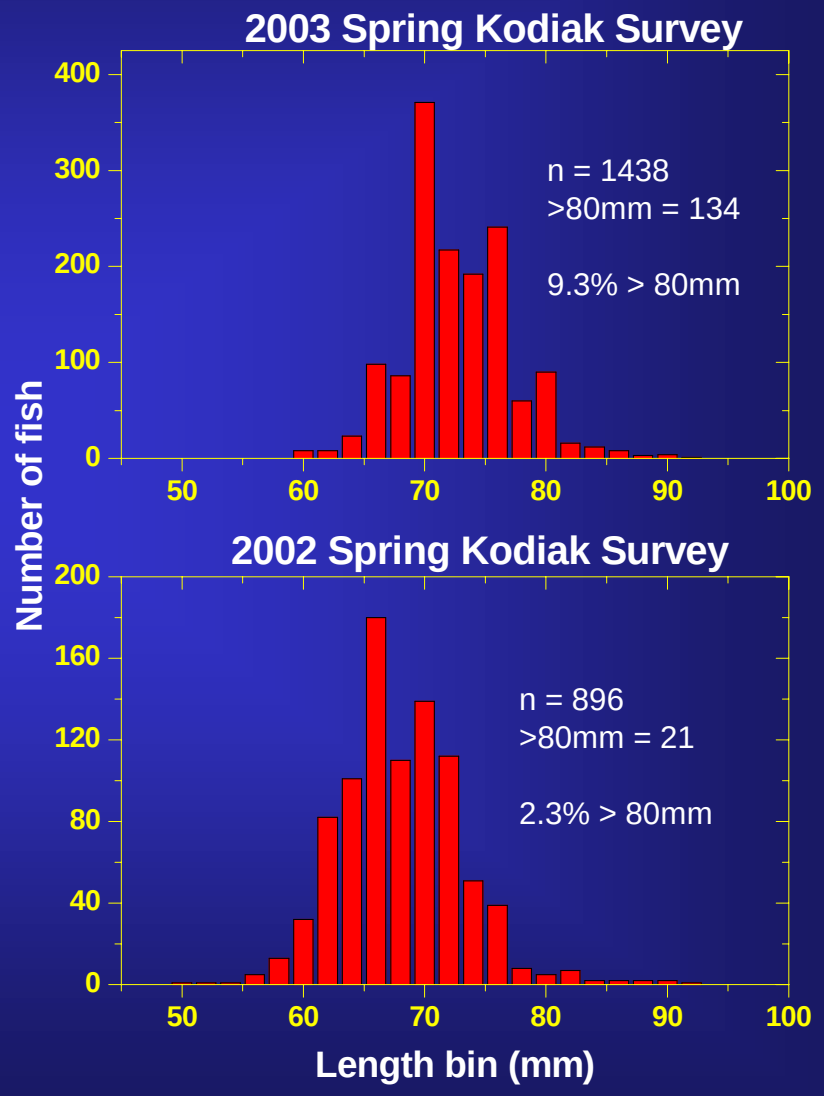
Juvenile – Adult Mortality

- Exports = 0.3%
- Toxics = 6.7%
- Growth= 93.0%

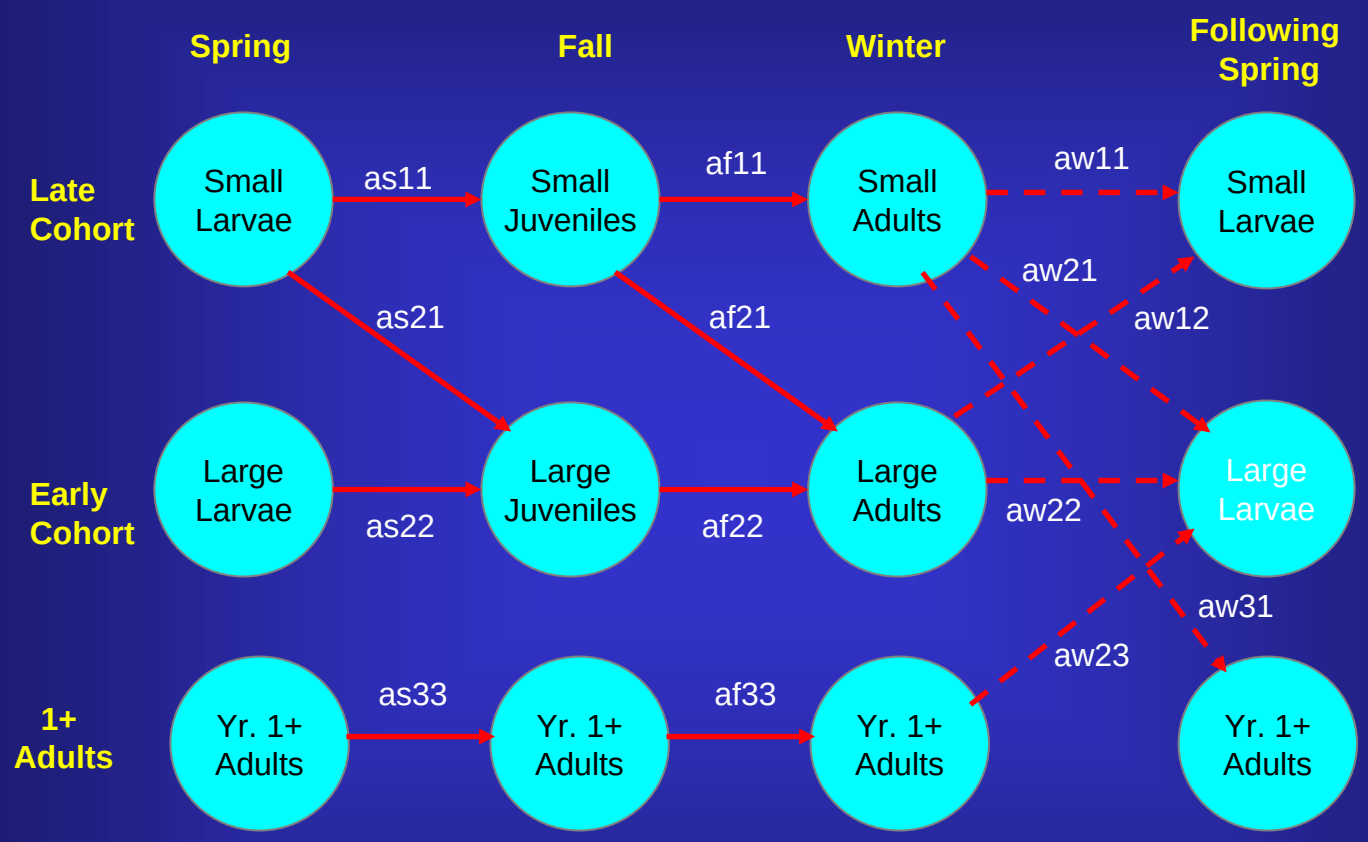
Exploring the Contribution of 1+ Adults

Question: Do 1+ adults contribute to population viability?





Periodic Stage-Based with 1+ Adults



$$\begin{pmatrix} as11 & 0 & 0 \\ as21 & as22 & 0 \\ 0 & 0 & as33 \end{pmatrix} \cdot \begin{pmatrix} af11 & 0 & 0 \\ af21 & af22 & 0 \\ 0 & 0 & af33 \end{pmatrix} \cdot \begin{pmatrix} aw11 & aw12 & 0 \\ aw21 & aw22 & aw23 \\ aw31 & 0 & 0 \end{pmatrix}$$

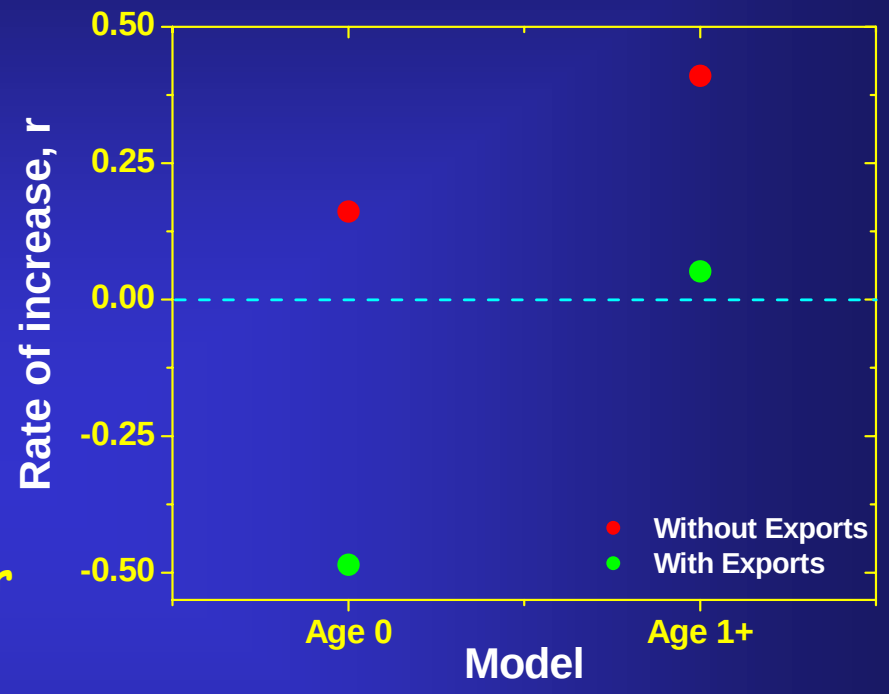
Age 1+ Spawner and Export Effects on Population Growth

Parameters

1+ are larger fish = higher survival

Less than ≈ 10% of population

Lab fecundity data



Probability of 1+ adult surviving into summer

as33 = 0.95

Probability of 1+ adult surviving into winter

af33 = 0.80

Number of small adults surviving into spring

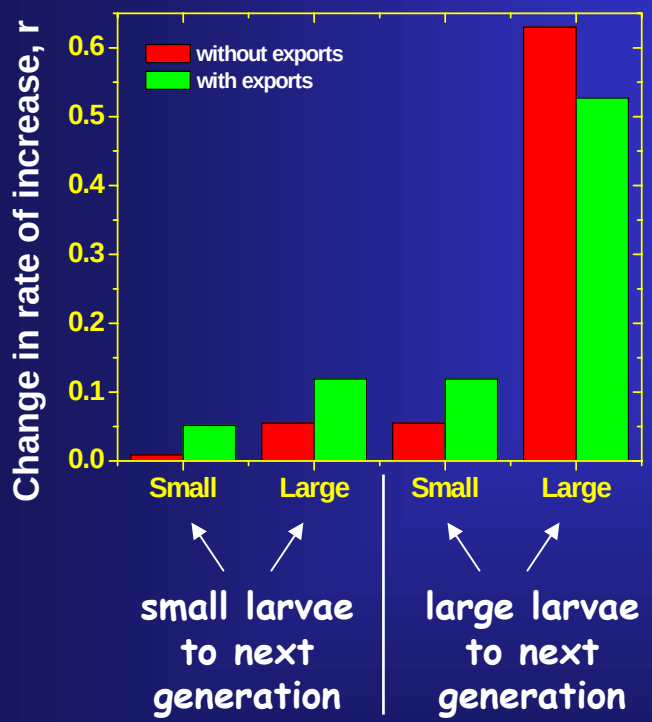
aw31 = 12 (approx. 1%)

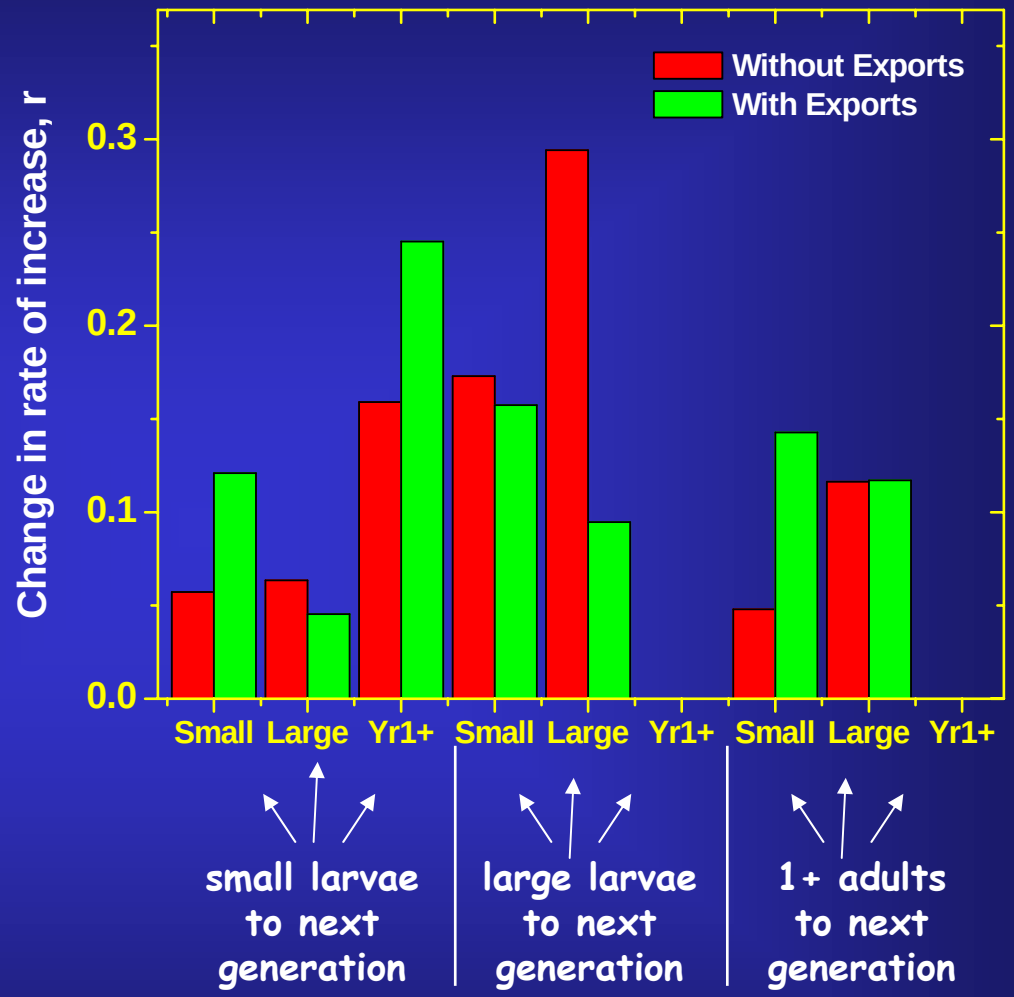
Number of large larvae produced by 1+ adults

aw23 = fecundity/2 * 0.01 * 0.6 = 42

Model Sensitivity with 1+ Adults

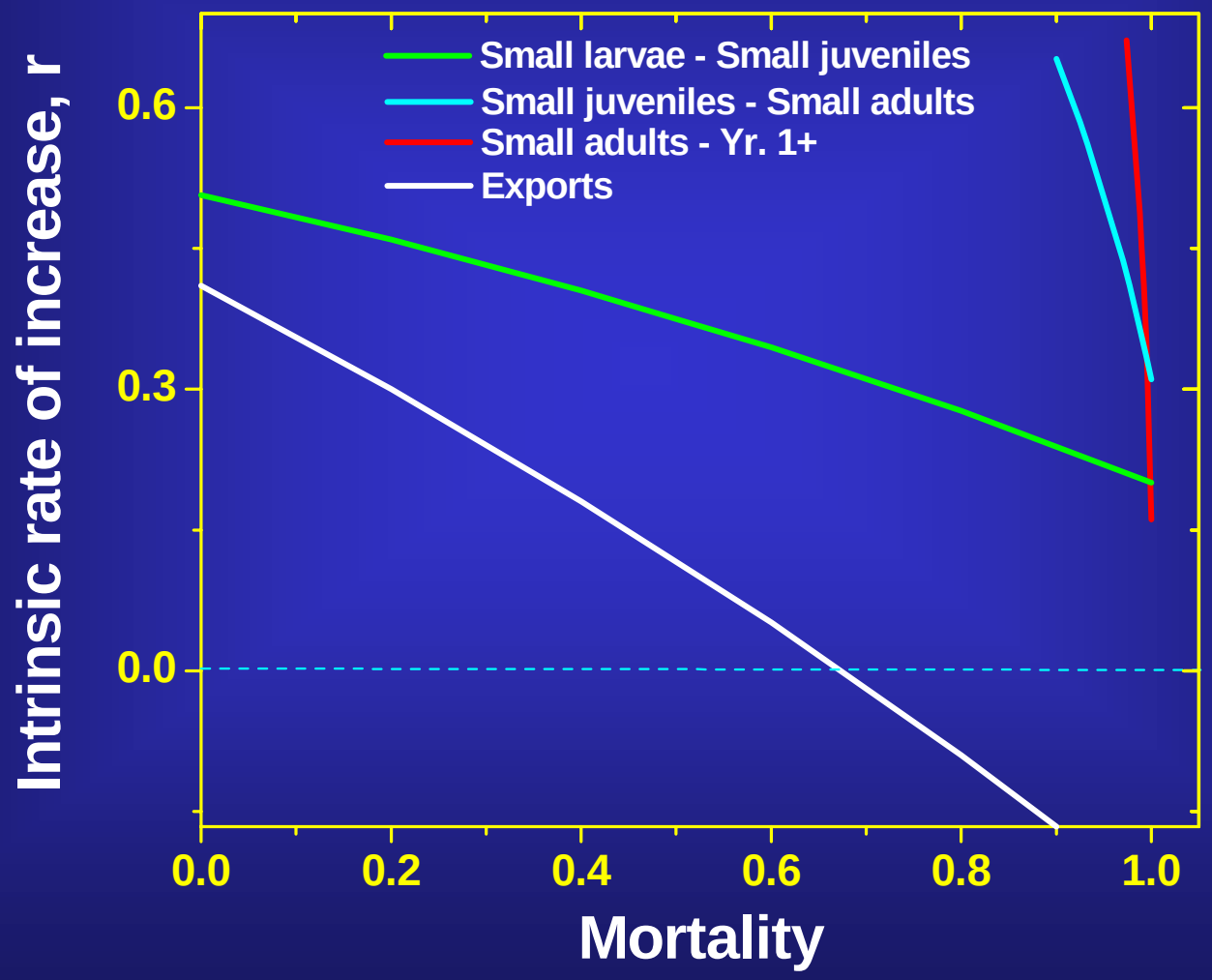
Elasticities: what is the relative importance of each matrix element to population growth?





Assuming 1+ year adults reproduce, model results support the idea that they can buffer against export losses

Parameter Impacts on Population Growth



Implications

1. Abundance estimates combined with direct field measurements are essential !

2. What is the role of human activities, particularly water export operations, on the population?

Exports can have effects, but they may be offset or difficult to measure.

3. What are the potential restoration options?

Potential benefits of EWA may not be large enough to measure.

These answers aren't perfect!

Acknowledgements

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