Q2 and Q6. Extra mortality and climate

Uncertainties/Issues:

- what do we mean by "extra mortality"?
  - mortality of *non-transported fish* occurring outside of juvenile migration corridor, not accounted for by:
    - stock productivity estimates
    - passage model direct mortality estimates
    - common year effects (Delta approach only)

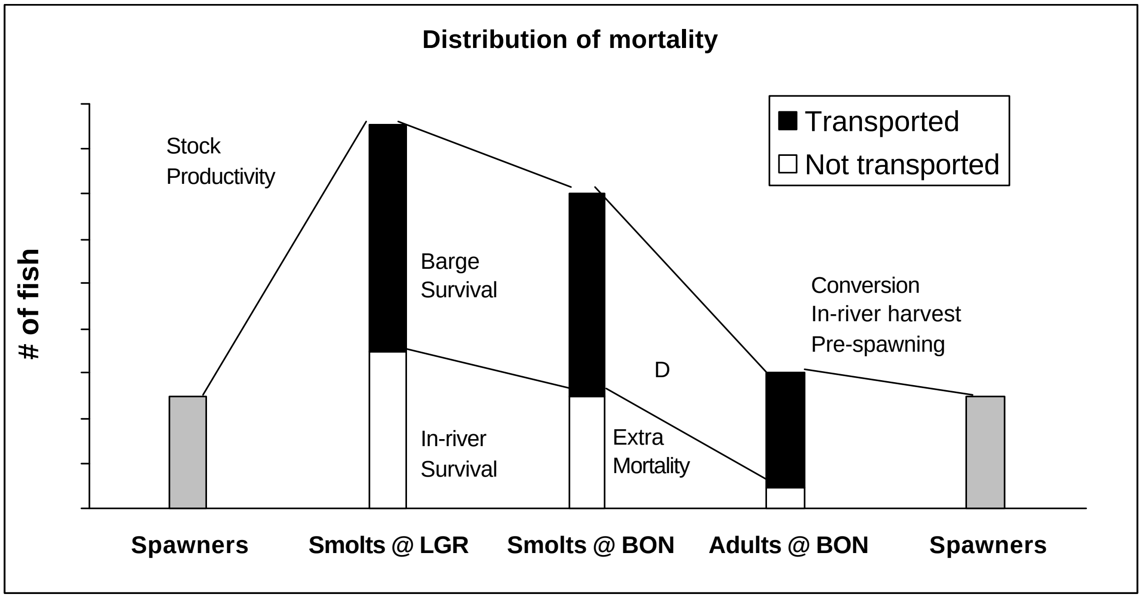
- assuming greater delayed mortality of *transported* fish results in lower extra mortality of *non-transported* fish

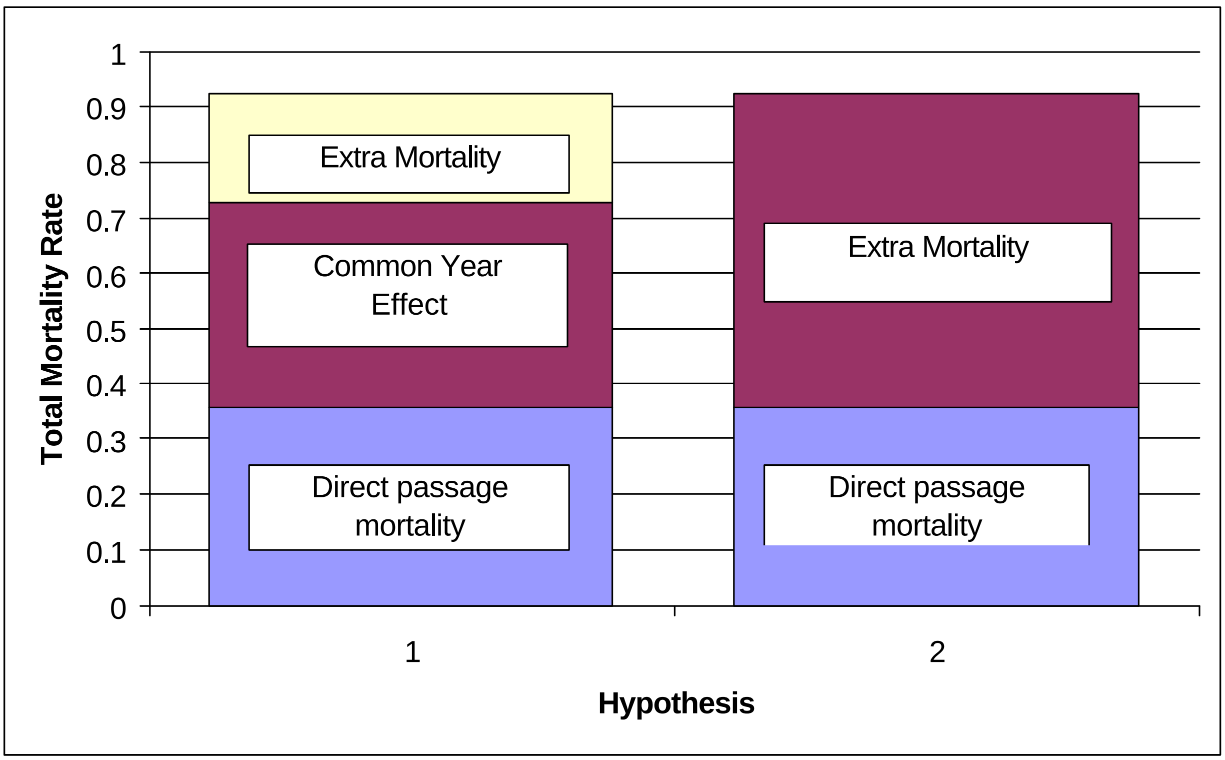
- what assumptions has PATH made about future climate?
  - PATH considered both short and long term fluctuations in climate

  - short term fluctuations may be related to changes in ocean conditions and flow, or historical common year effects, and can be random or cyclical. These various approaches all produce similar results.

  - long term 60-year cycles in climate were considered in one extra mortality hypothesis. It makes a significant difference to the results.

  - all methods assume that future climate will follow patterns established in the past


Distribution of mortality
Transported
Not transported
# of fish
Stock
Productivity
Barge
Survival
In-river
Survival
D
Extra
Mortality
Conversion
In-river harvest
Pre-spawning
Spawners
Smolts @ LGR
Smolts @ BON
Adults @ BON
Spawners


Total Mortality Rate
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Extra Mortality
Common Year
Effect
Direct passage
mortality
Extra Mortality
Direct passage
mortality
1
2
Hypothesis

Uncertainties/Issues cont'd:

- what might cause Extra Mortality (EM)?

  EM1. indirect effects of passage through *hydrosystem*
    - delayed arrival in estuary;
    - stress from crowding/injury;
    - increased vulnerability to predators, etc.

  EM2. stock viability lower due to *BKD,* other factors

  EM3. 60-year cyclical *regime shifts* in climate
    - changes ocean temperatures, predators, prey
    - changes rainfall, snowpack, flows

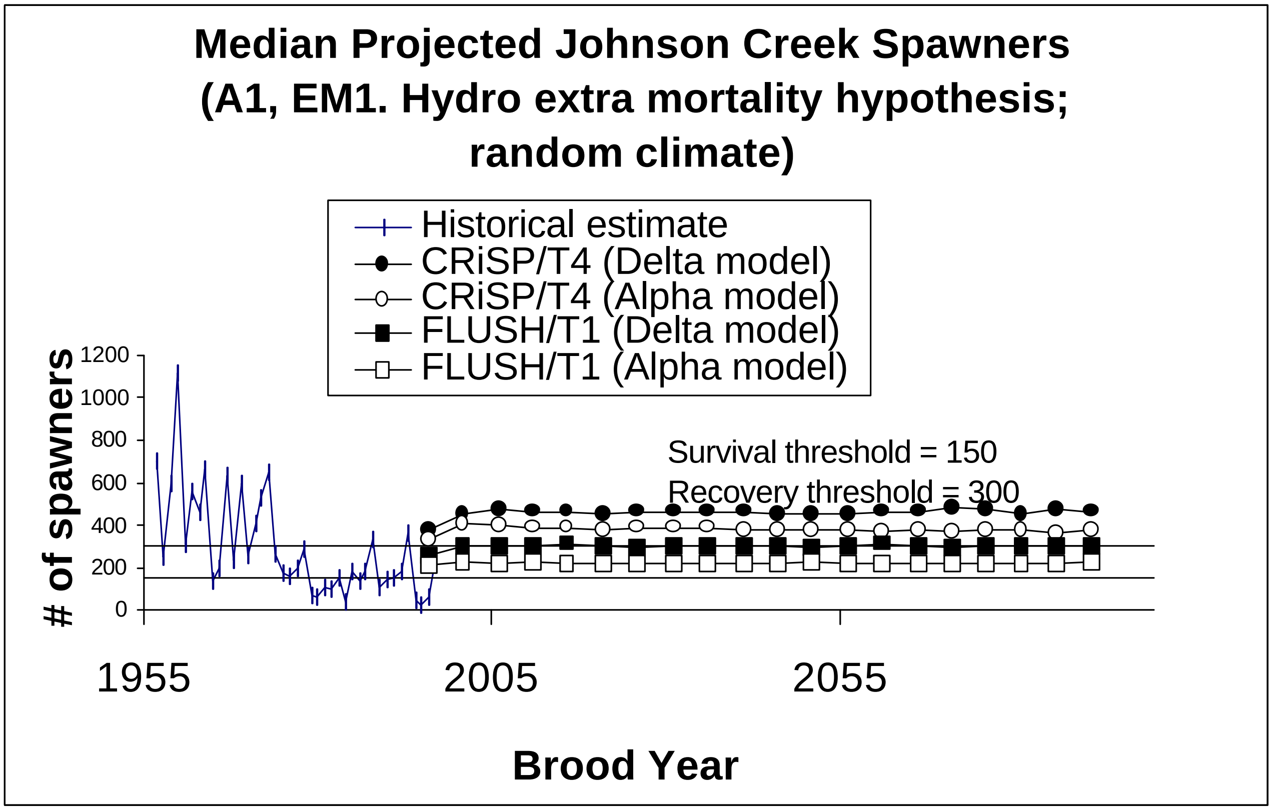
  EM4. *hatchery fish* negatively affect wild fish
    - competition, stress, predation, disease

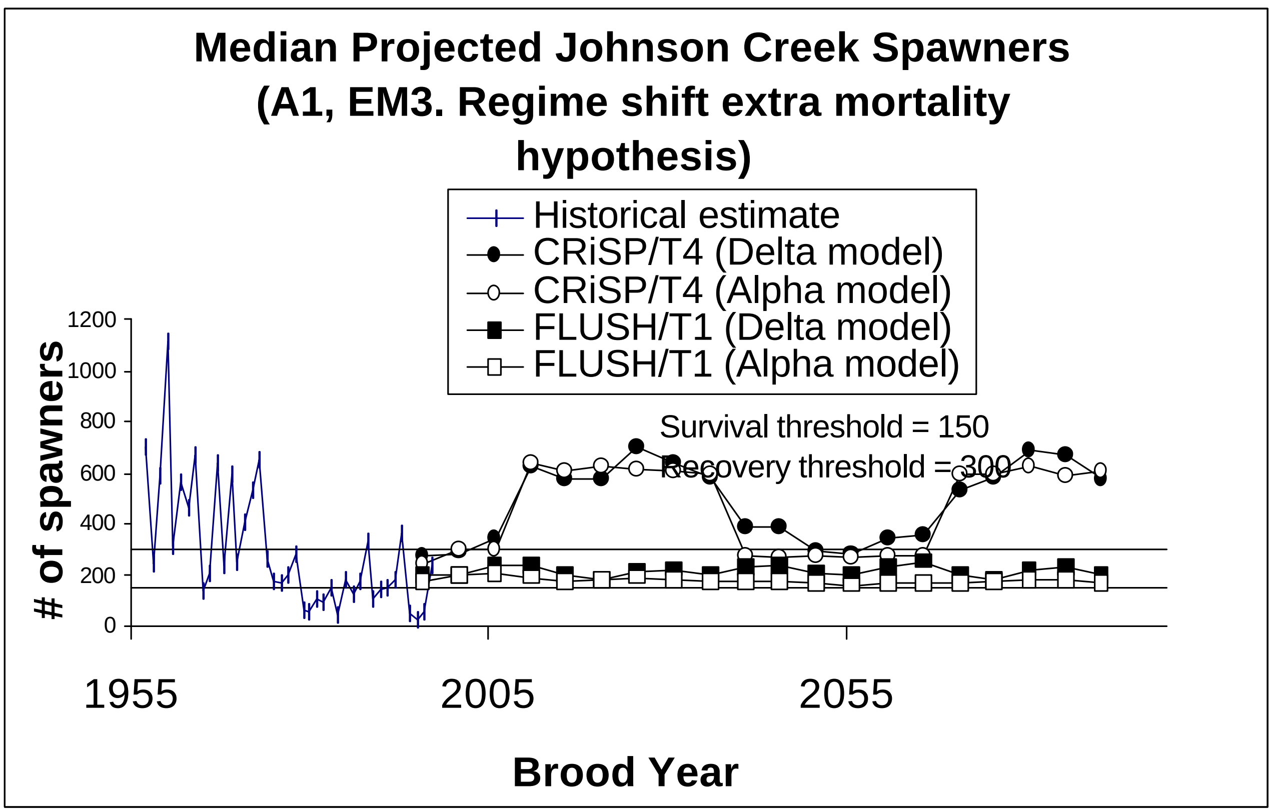
  EM5. other factors + *bird predation* in estuary

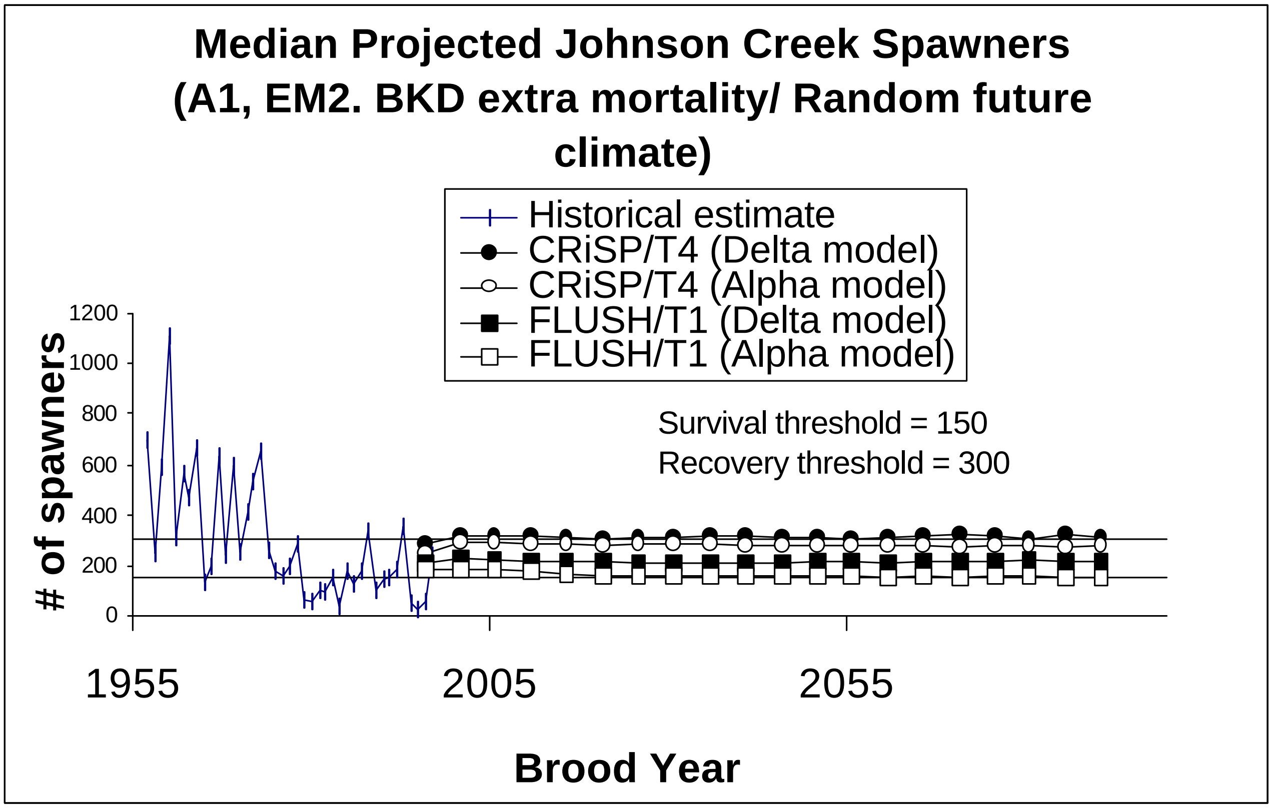
Implementation:

EM1: extra mortality declines as passage survival improves
EM2: extra mortality here to stay, like 1952 to 1990
EM3: high extra mortality from 1975 to 2005, low from 2005 to 2035
EM4: not modeled, considered via EM2
EM5: examined with sensitivity analysis

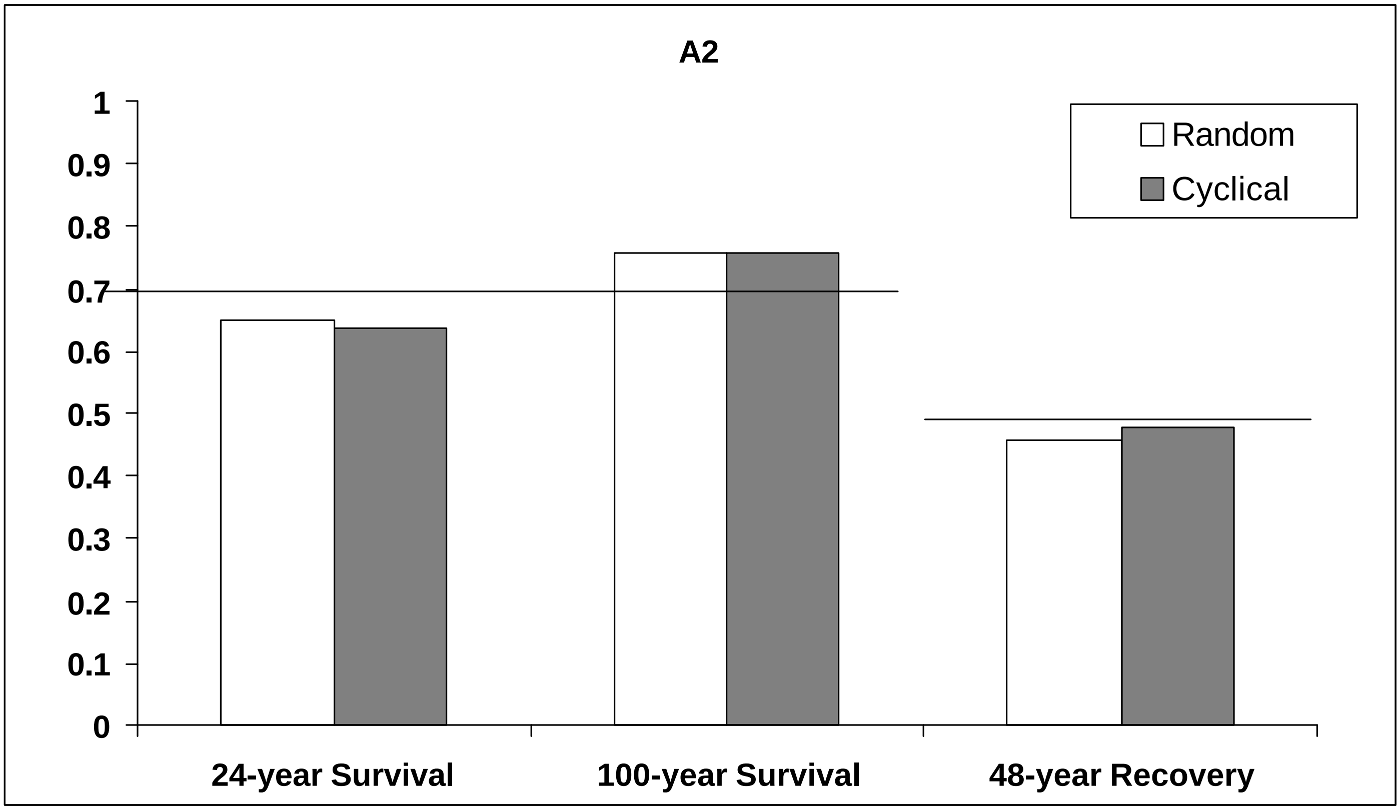
- EM1, EM2 and EM3 make significant difference to projected future escapement

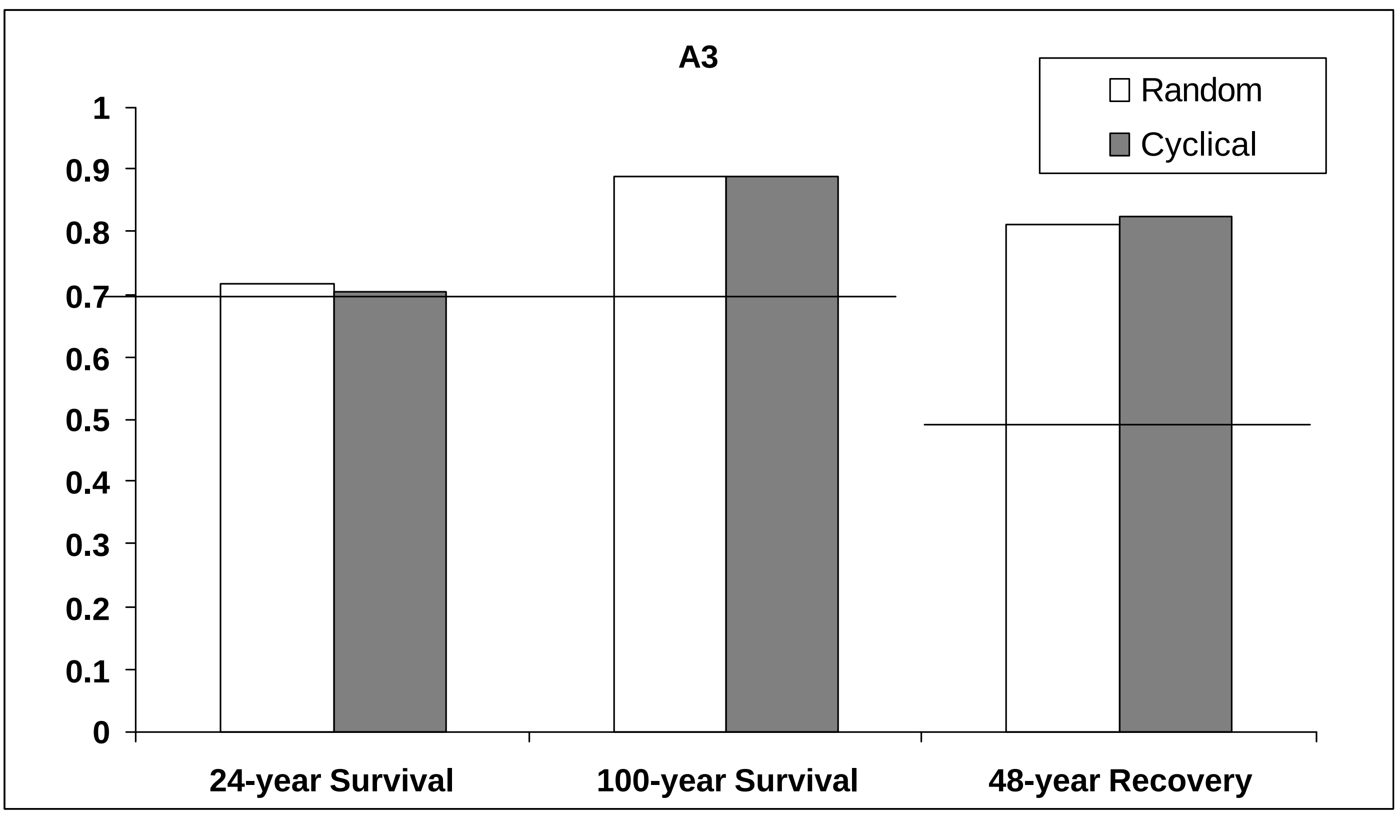

Median Projected Johnson Creek Spawners
(A1, EM1. Hydro extra mortality hypothesis; random climate)
Historical estimate
CRiSP/T4 (Delta model)
CRiSP/T4 (Alpha model)
FLUSH/T1 (Delta model)
FLUSH/T1 (Alpha model)
Survival threshold = 150
Recovery threshold = 300
# of spawners
1200
1000
800
600
400
200
0
1955
2005
2055
Brood Year


Median Projected Johnson Creek Spawners
(A1, EM3. Regime shift extra mortality hypothesis)
Historical estimate
CRiSP/T4 (Delta model)
CRiSP/T4 (Alpha model)
FLUSH/T1 (Delta model)
FLUSH/T1 (Alpha model)
Survival threshold = 150
Recovery threshold = 300
# of spawners
1200
1000
800
600
400
200
0
1955
2005
2055
Brood Year

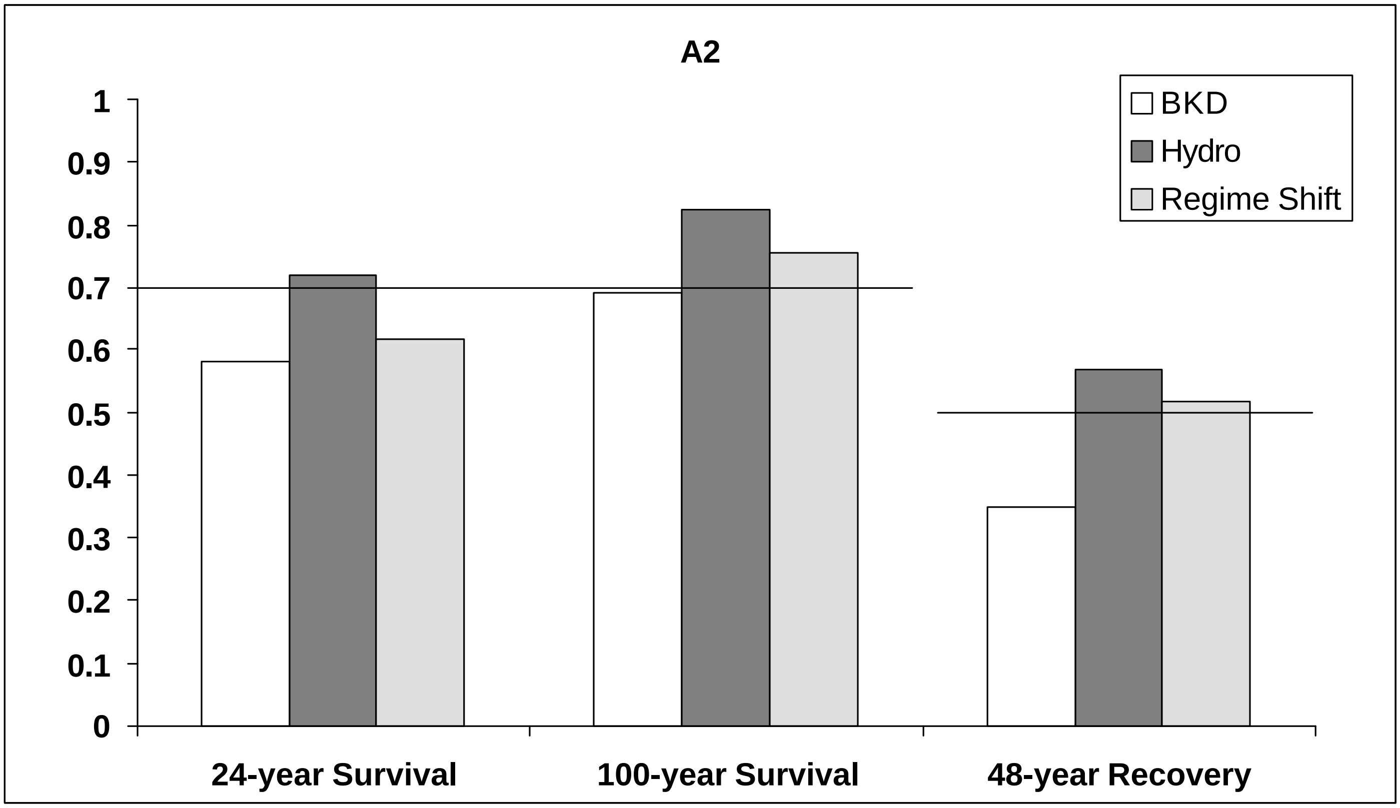

Median Projected Johnson Creek Spawners
(A1, EM2. BKD extra mortality/ Random future climate)
Historical estimate
CRiSP/T4 (Delta model)
CRiSP/T4 (Alpha model)
FLUSH/T1 (Delta model)
FLUSH/T1 (Alpha model)
Survival threshold = 150
Recovery threshold = 300
# of spawners
1200
1000
800
600
400
200
0
1955
2005
2055
Brood Year

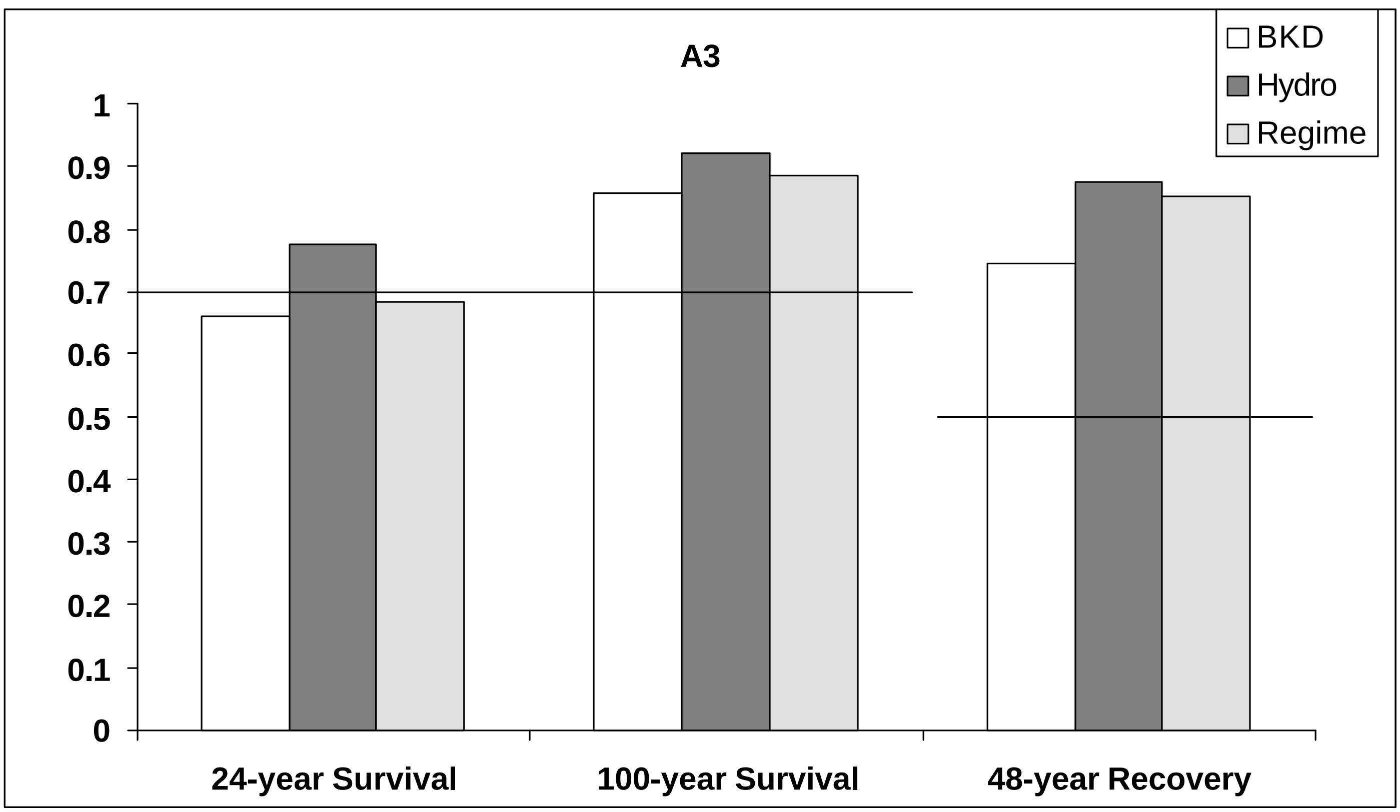
Effects of different short term climate fluctuations:





Effects of Extra Mortality Hypotheses EM1 to EM3





Sensitivity analysis for EM5: incremental mortality due to expanded bird populations

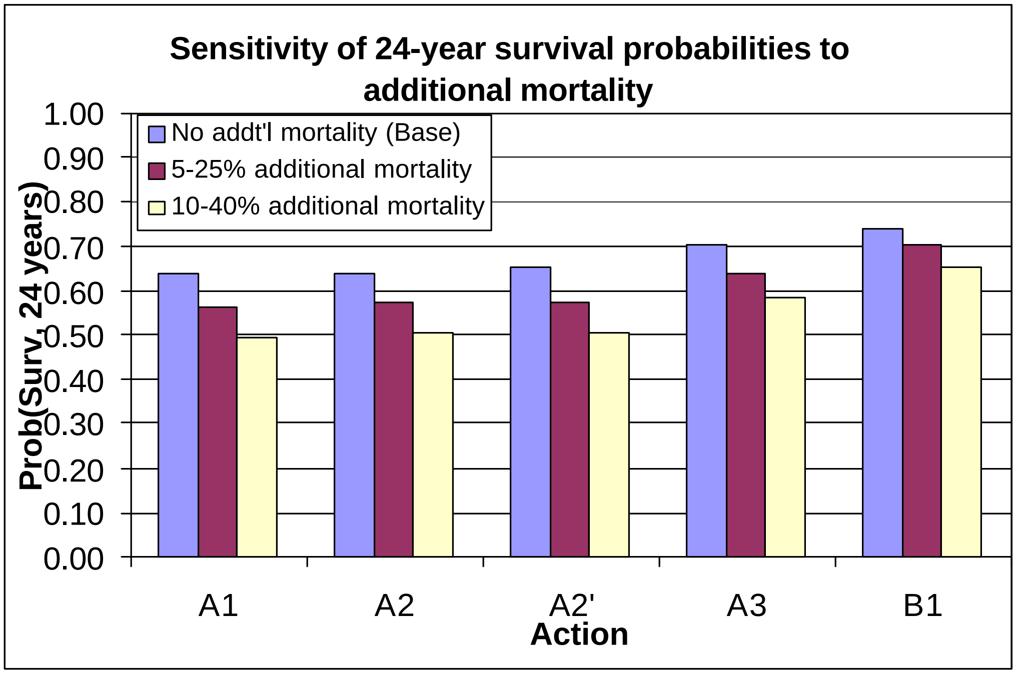
- Shows effects of incorporating sources of mortality that may not be reflected in the historical data (e.g. predation on salmon smolts by bird predators in the estuary)

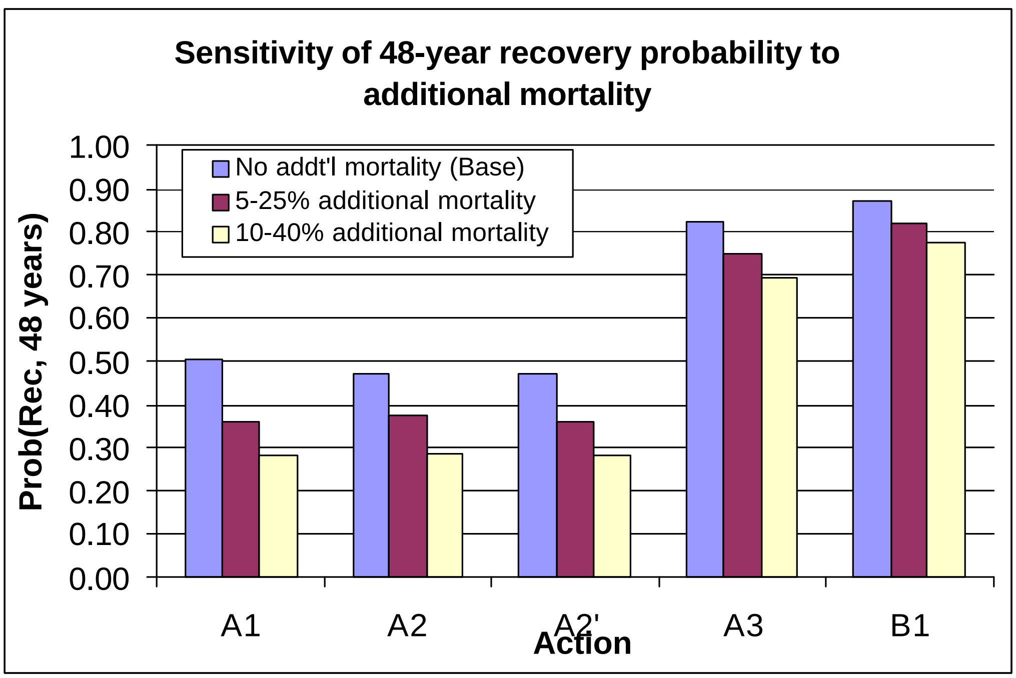
- considered two alternative ranges of incremental mortality:

  5 to 25% (PIT-tag recoveries, bioenergetics model)

  10 to 40% (radio-tagging)

- incremental mortality combined with EM1, EM2 and EM3


Sensitivity of 24-year survival probabilities to additional mortality
No addt'l mortality (Base)
5-25% additional mortality
10-40% additional mortality
Prob(Surv, 24 years)
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
A1
A2
A2'
A3
B1
Action


Sensitivity of 48-year recovery probability to additional mortality
No addt'l mortality (Base)
5-25% additional mortality
10-40% additional mortality
Prob(Rec, 48 years)
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
A1
A2
A2'
A3
B1
Action

<u>Evidence for EM1:</u> *hydrosystem* causes extra mortality of in-river wild fish

- timing of entry into seawater critical
  ⇒*smolts adapt to saltwater over wide range of timing*

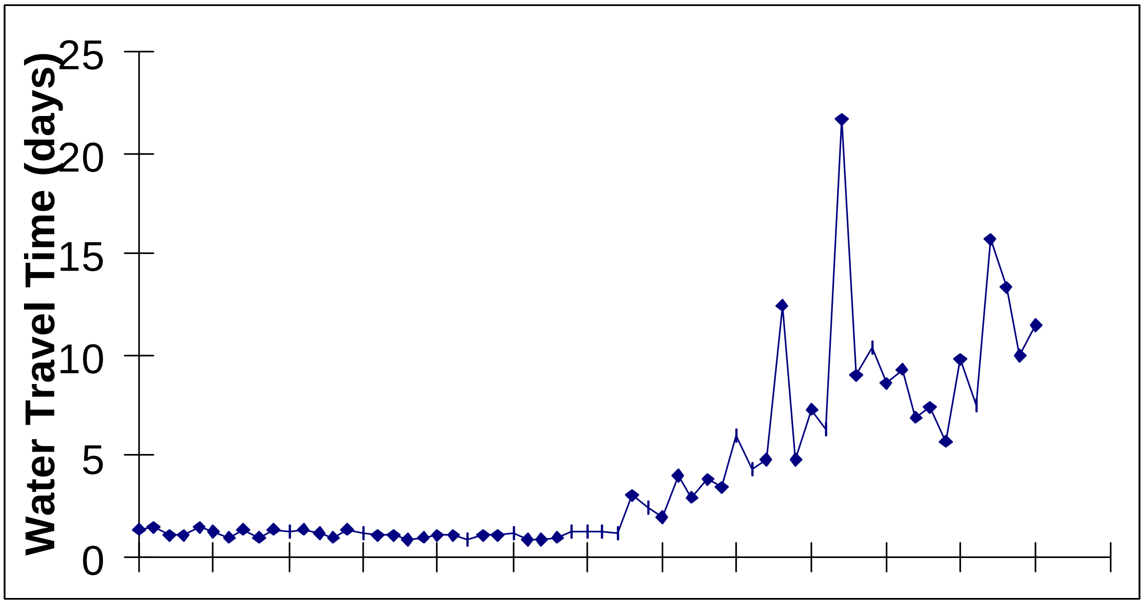
- stress during bypass & holding increases vulnerability to disease and predation below BONN
  ⇒*LGR to BONN predation already in passage models*

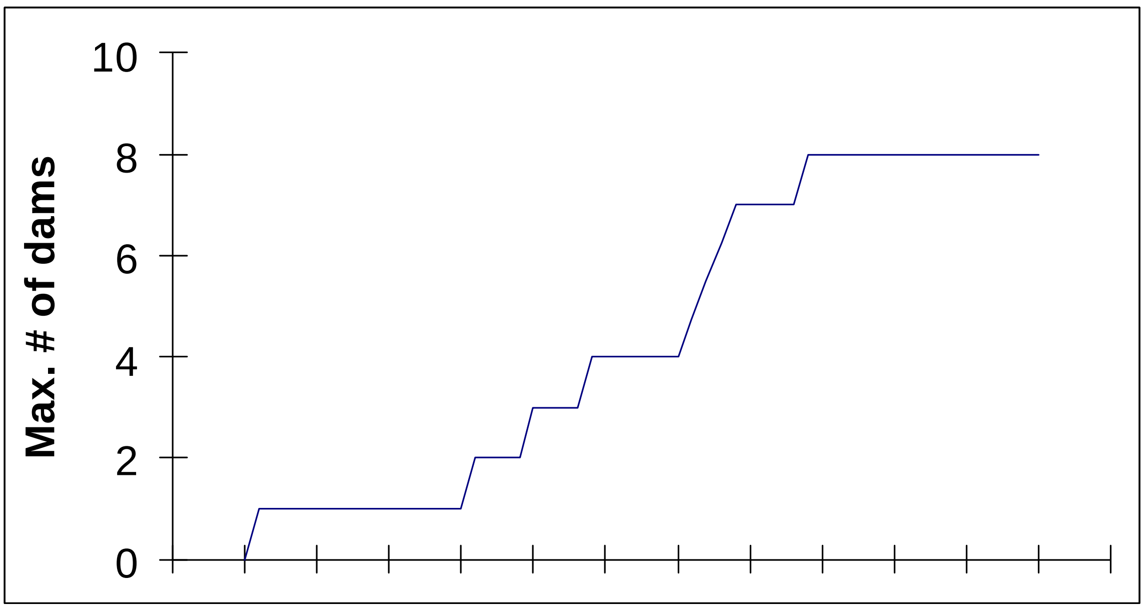
- productivity and survival rate of all stocks above BONN were stable from 1939 to 1970, despite climate variation, then declined
  ⇒*major declines occurred prior to 1950's from habitat / harvest*

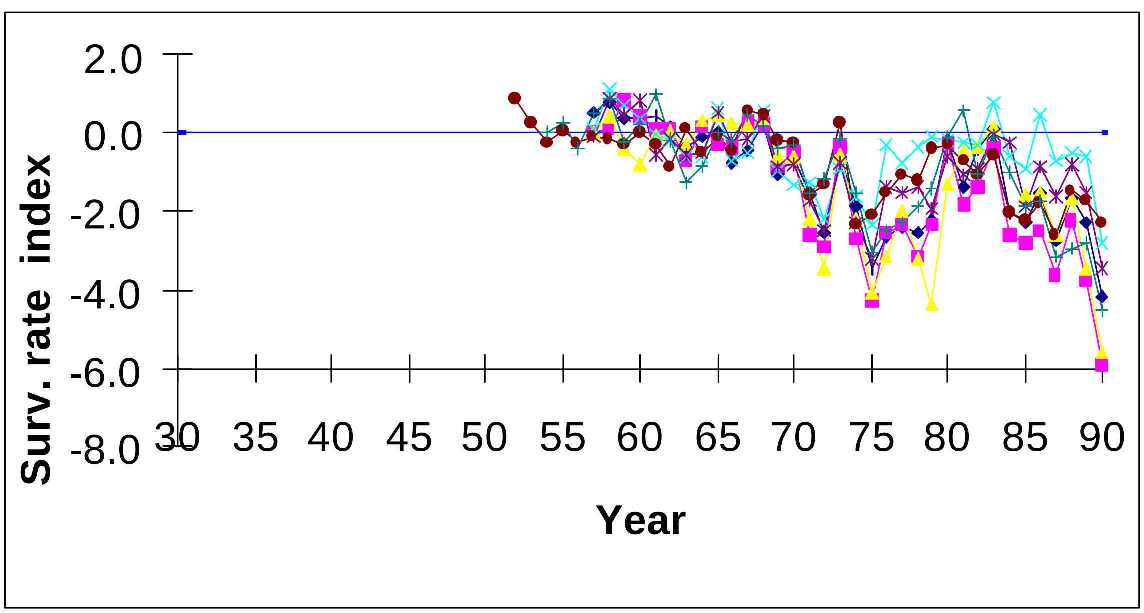
- comparing pre-1970 and post-1975 periods, productivity and survival rate index declined more in Snake River stocks than lower Columbia River stocks, consistent with development of hydrosystem
  ⇒*this is only a correlation; other causes could be responsible for this pattern*
  ⇒*extra mortality of in-river fish shows weak or no relationship with their passage mortality 1952-1990*

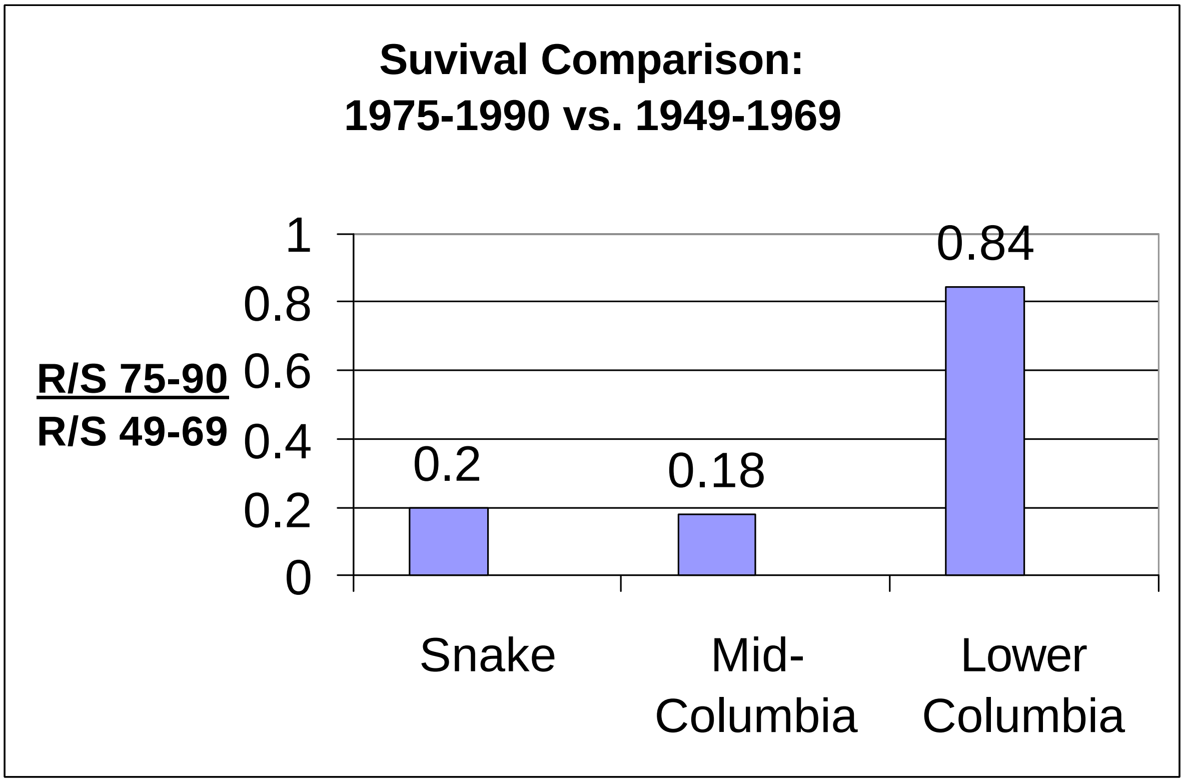
- lack of relationship between extra mortality and passage mortality is not a problem; assuming that extra mortality returns to pre-1970 values under A3 gives similar or higher probabilities of survival and recovery

Snake River stocks Survival Rate Index vs.
Water Travel Time, and # Dams

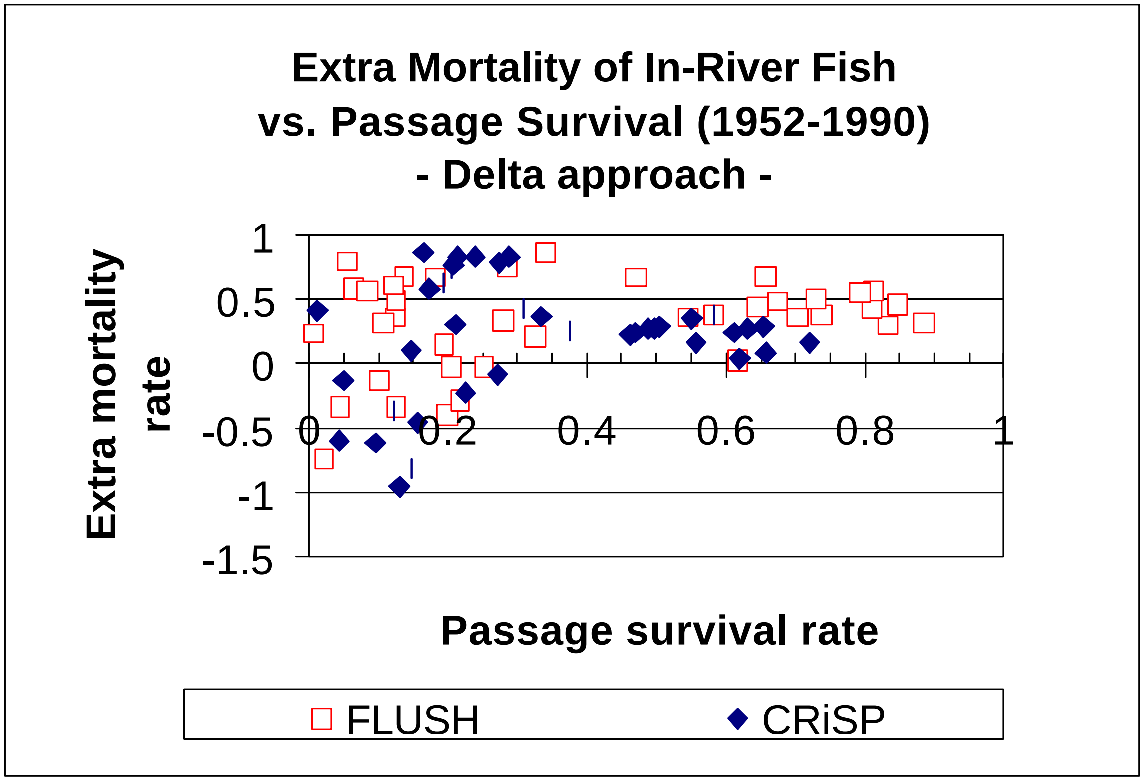


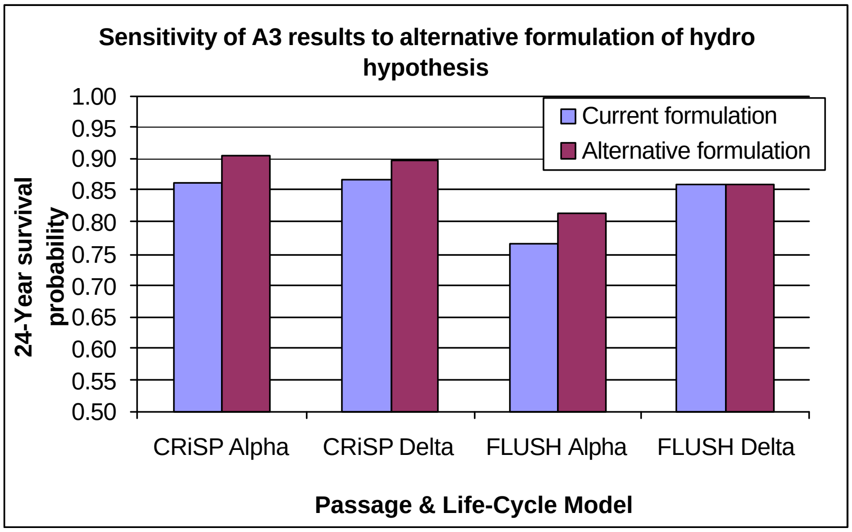


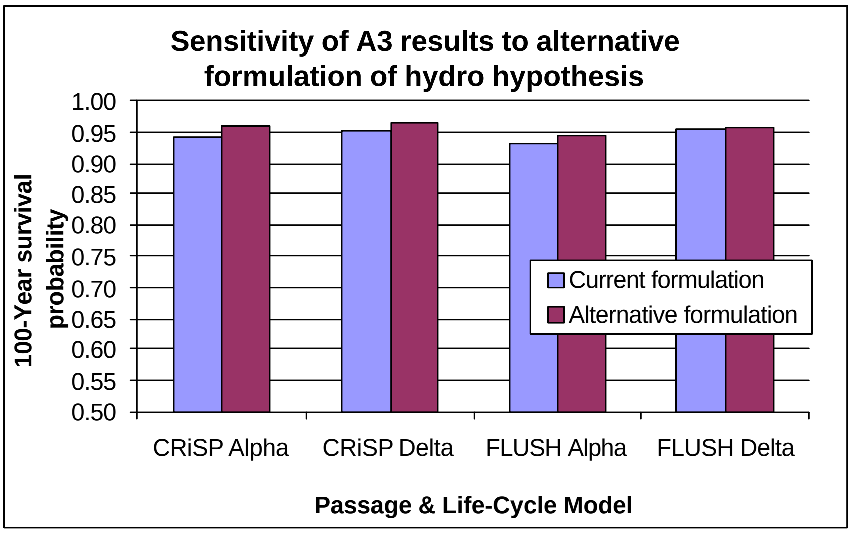


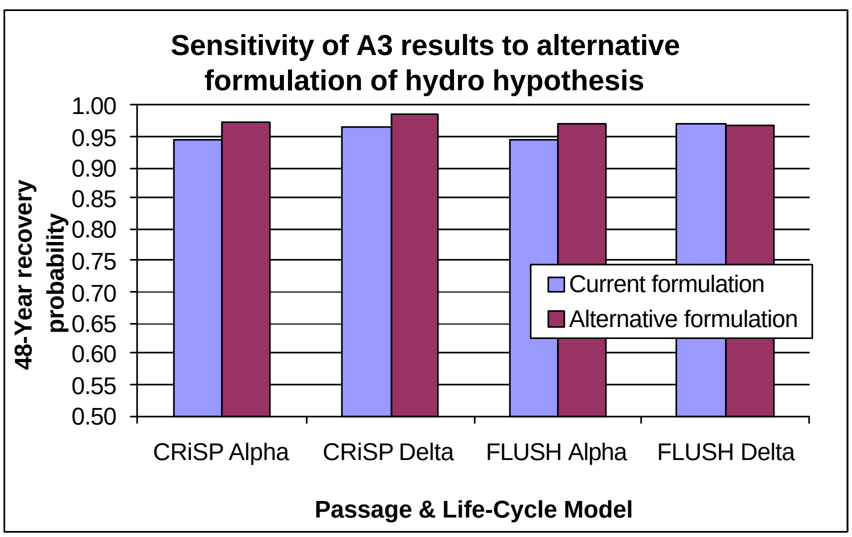

Suvival Comparison:
1975-1990 vs. 1949-1969
R/S 75-90
R/S 49-69
1
0.8
0.6
0.4
0.2
0
0.2
0.18
0.84
Snake
Mid-Columbia
Lower Columbia

If the hydrosystem is responsible for extra mortality of in-river fish, then extra mortality should decline as passage survival increases. But it doesn't.




Sensitivity of A3 results to alternative formulation of hydro hypothesis
24-Year survival probability
1.00
0.95
0.90
0.85
0.80
0.75
0.70
0.65
0.60
0.55
0.50
Current formulation
Alternative formulation
CRiSP Alpha
CRiSP Delta
FLUSH Alpha
FLUSH Delta
Passage & Life-Cycle Model


Sensitivity of A3 results to alternative formulation of hydro hypothesis
100-Year survival probability
1.00
0.95
0.90
0.85
0.80
0.75
0.70
0.65
0.60
0.55
0.50
Current formulation
Alternative formulation
CRiSP Alpha
CRiSP Delta
FLUSH Alpha
FLUSH Delta
Passage & Life-Cycle Model


Sensitivity of A3 results to alternative formulation of hydro hypothesis
48-Year recovery probability
1.00
0.95
0.90
0.85
0.80
0.75
0.70
0.65
0.60
0.55
0.50
Current formulation
Alternative formulation
CRiSP Alpha
CRiSP Delta
FLUSH Alpha
FLUSH Delta
Passage & Life-Cycle Model

<u>Evidence for EM2 and EM4:</u> *hatchery fish* cause extra mortality of in-river wild fish

- extra mortality is correlated with # hatchery releases
  - ⇒*correlation is not causation; extra mortality equally well correlated with increase in transportation*

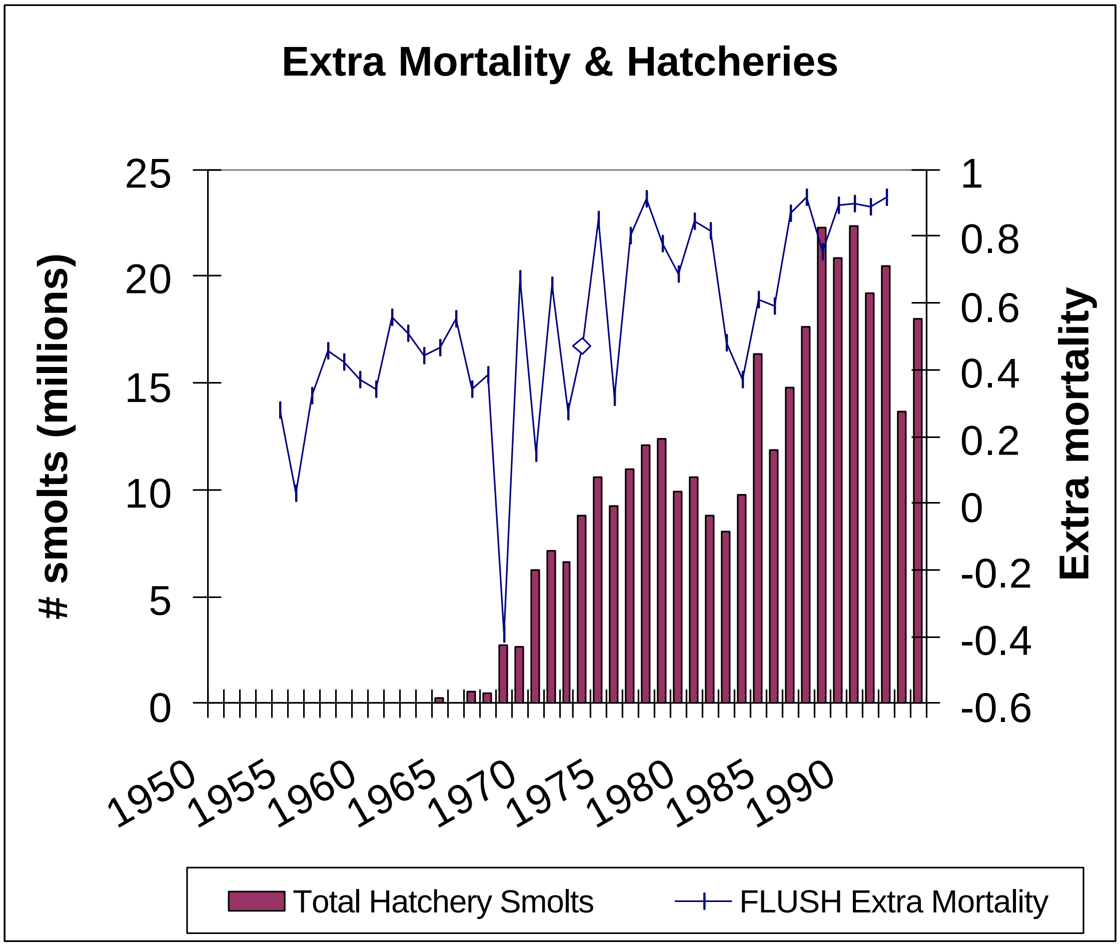
- BKD transmitted to wild Snake R. fish from hatchery fish will cause mortality with or without dams
  - ⇒*BKD equally prevalent in lower Columbia stocks*
  - ⇒*disease transmission greatest with transportation*

- larger # and biomass of hatchery fish may reduce carrying capacity of migration corridor, limiting growth and energy reserves of wild spring/summer chinook
  - ⇒*migration corridor handled much larger numbers of smolts and adults in the past*
  - ⇒*no observed declines in smolts per spawner in Snake River aggregate stock*

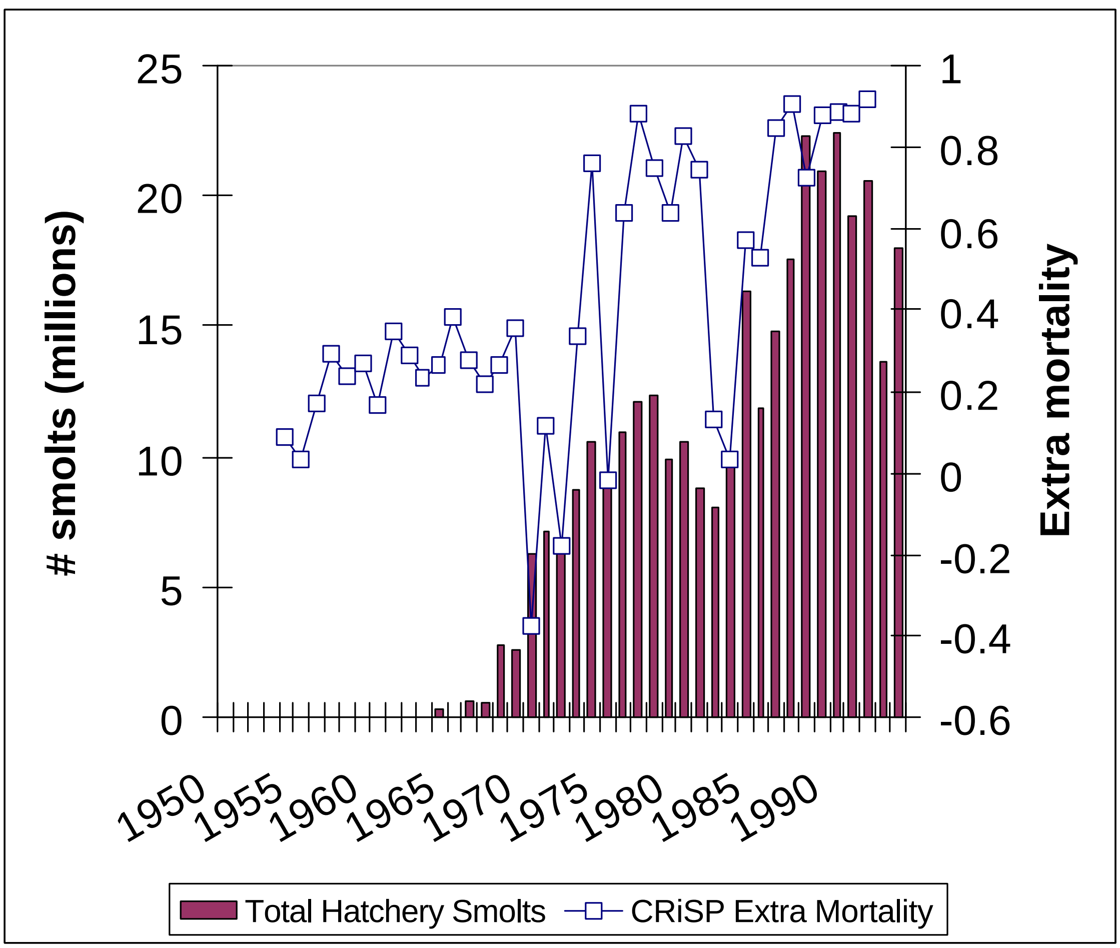
- hatchery fish increase stress in forebays, possibly increasing disease and predation mortality in wild fish
  - ⇒*this can't be separated from effects of hydrosystem*

- hatchery fish more strongly affect Snake R. wild chinook due to: longer distance of co-migration, greater co-mixing of hatchery & wild fish
  - ⇒*there are no experiments or data to support these hypothesized impacts*

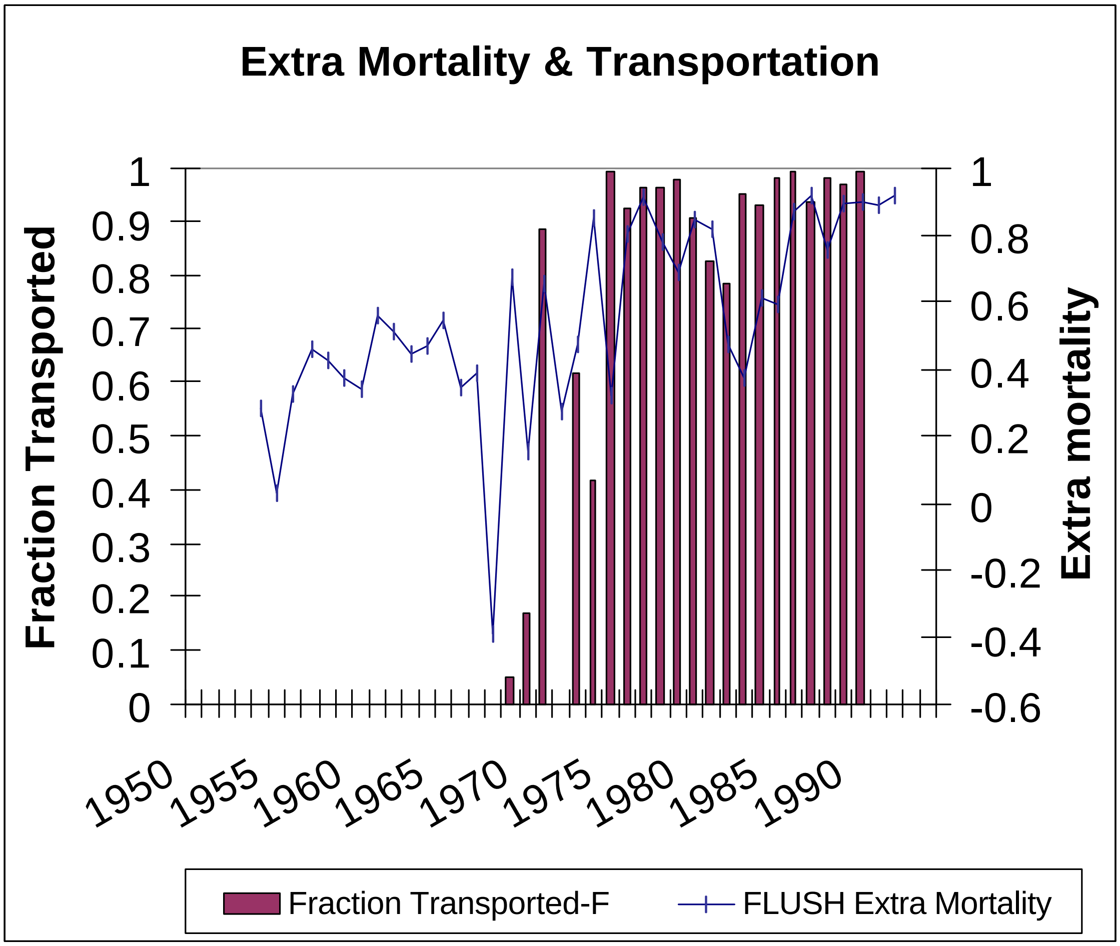
- PATH has not yet modeled possible effects of reduction in # hatchery fish; experimental management reductions in hatchery smolts recommended by SRP

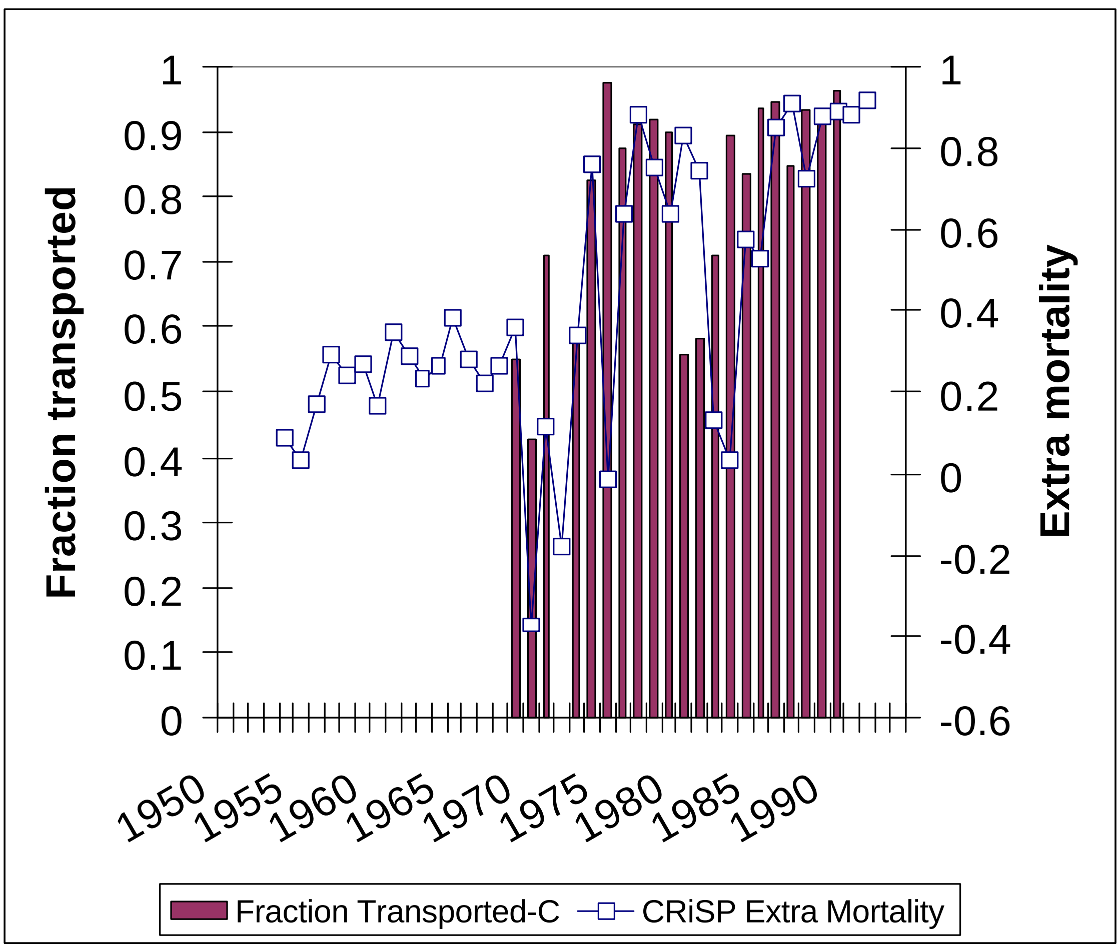


Extra Mortality & Hatcheries
smolts (millions)
Extra mortality
25
20
15
10
5
0
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
1950
1955
1960
1965
1970
1975
1980
1985
1990
Total Hatchery Smolts
FLUSH Extra Mortality



smolts (millions)
Extra mortality
25
20
15
10
5
0
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
1950
1955
1960
1965
1970
1975
1980
1985
1990
Total Hatchery Smolts
CRiSP Extra Mortality


Extra Mortality & Transportation
Fraction Transported
Extra mortality
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
1950
1955
1960
1965
1970
1975
1980
1985
1990
Fraction Transported-F
FLUSH Extra Mortality


Fraction transported
Extra mortality
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
1950
1955
1960
1965
1970
1975
1980
1985
1990
Fraction Transported-C
CRiSP Extra Mortality

<u>Evidence for EM3:</u> *climate regime shifts* cause extra mortality of in-river wild fish

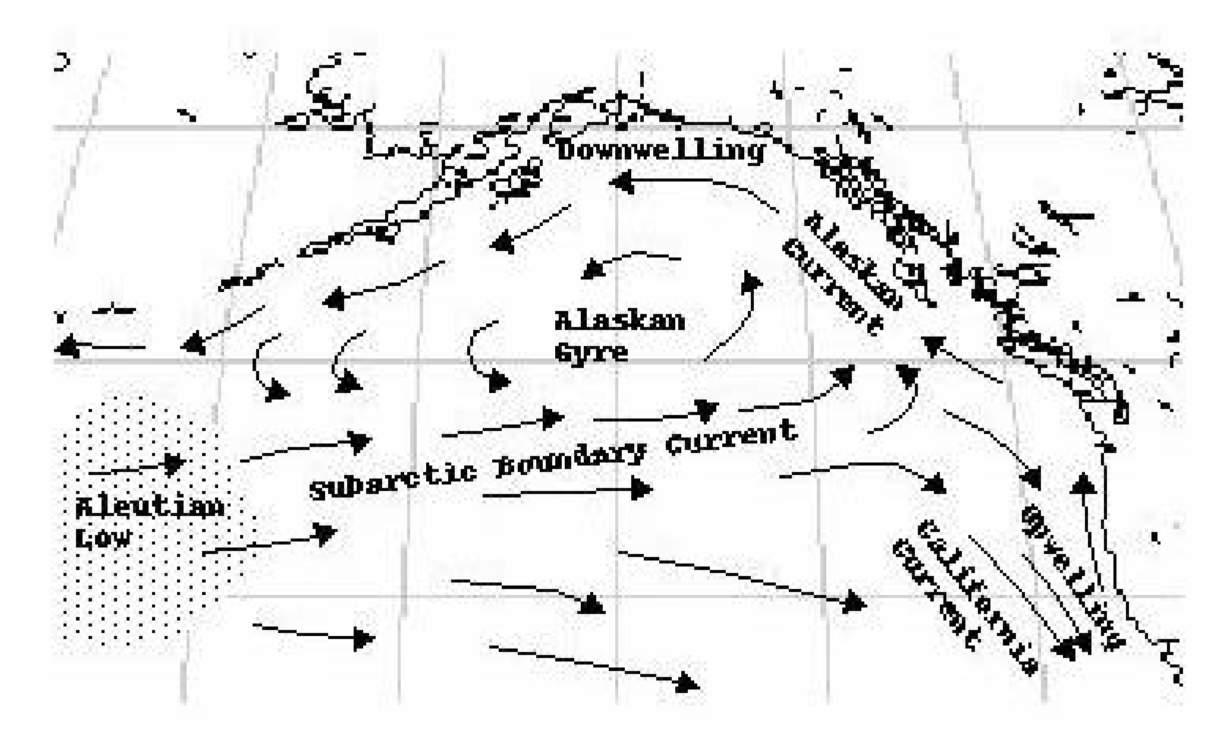
- oceanographic and tree ring evidence that Pacific Decadal Oscillation (PDO) occurs every 30 years, changing air & ocean temperatures; stream flow; zooplankton production; fish catch. Inverse changes in Alaska.

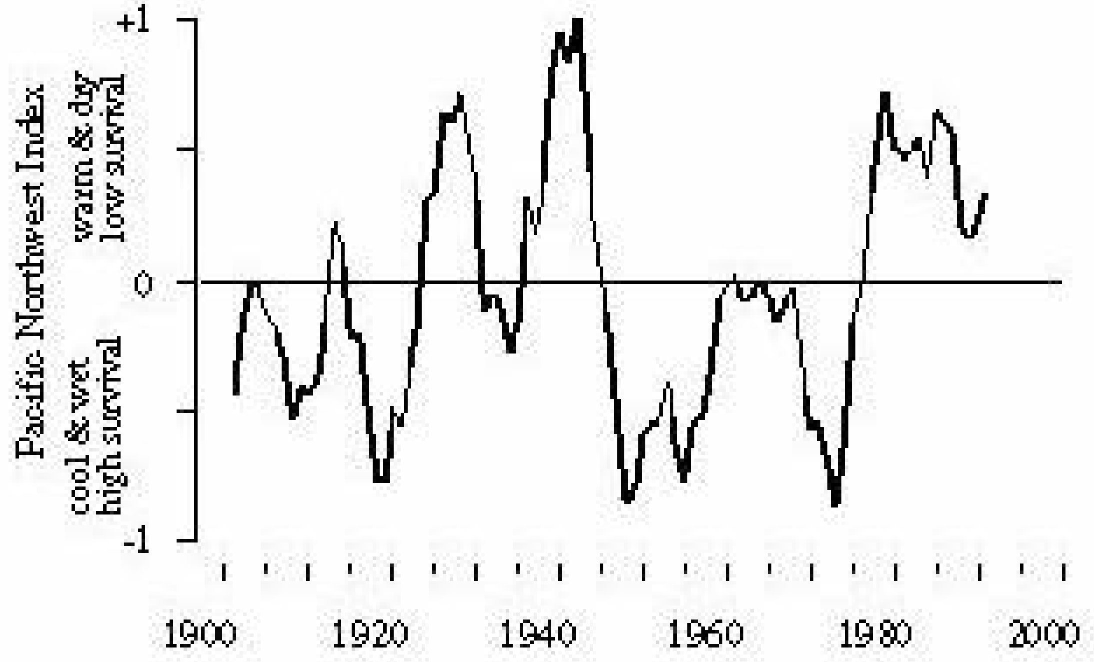
- climate changed from warm/dry (poor) to cold/wet (good) about 1947, then back to warm/dry in 1977
  - ⇒*evidence doesn't show climate affects Snake River and lower Columbia River stocks differently*
  - ⇒*common year effects also correlated with PDO*
  - ⇒*Alaska sockeye productivity increased 3-fold after 1977, but Fraser R. sockeye showed no change*
  - ⇒*catch poor estimate of productivity, survival*

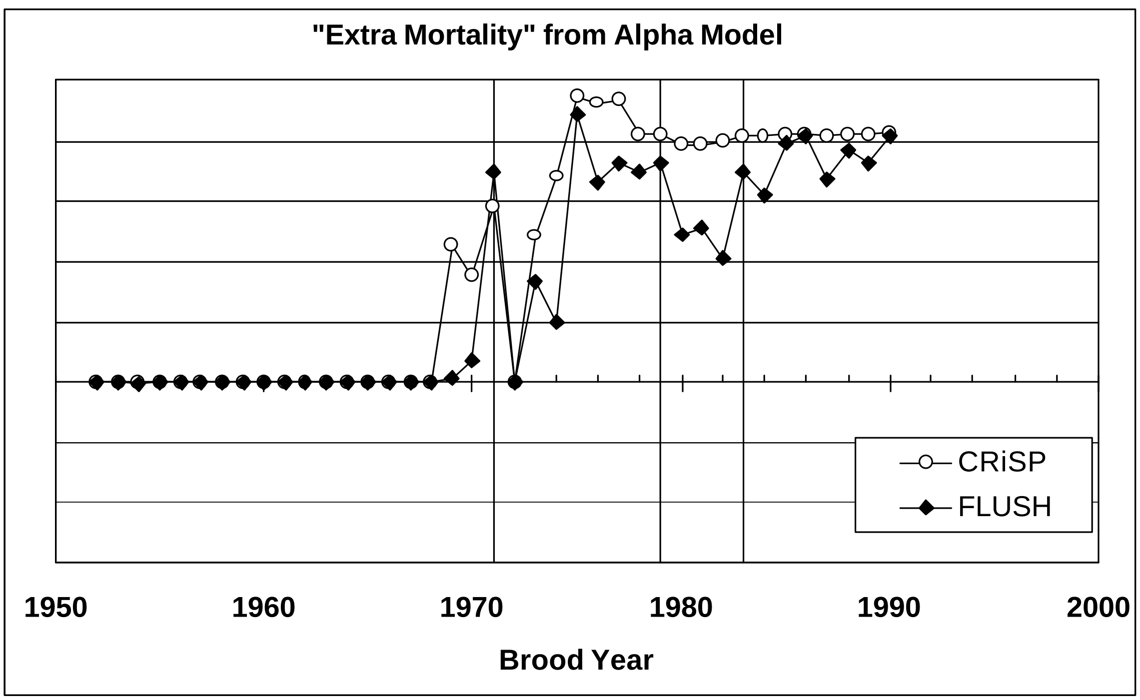
- changes in river flow affect estuary and ocean survival, and discharge not affected by actions we're considering
  - ⇒*flow affected by storage reservoirs (hydrosystem).*
  - ⇒*does not explain differential decline in Snake River and Lower Columbia R. stocks*

- Alpha approach and CRiSP generate increased extra mortality in 1977, consistent with changes in PDO and regime shift hypothesis
  - ⇒*weak regime shift estimated with FLUSH*
  - ⇒*correlations with PDO driven by transportation assumptions (D)*
  - ⇒*recent period (1987-1989) shows high extra mortality though PDO is favourable*

Regime Shifts in Spring Chinook Run Size




Pacific Northwest Index
warm & dry
low survival
cool & wet
high survival
+1
0
-1
1900
1920
1940
1960
1980
2000


"Extra Mortality" from Alpha Model
CRiSP
FLUSH
1950
1960
1970
1980
1990
2000
Brood Year