The quest for models and variables that explain annual variation in upriver spring Chinook age structure

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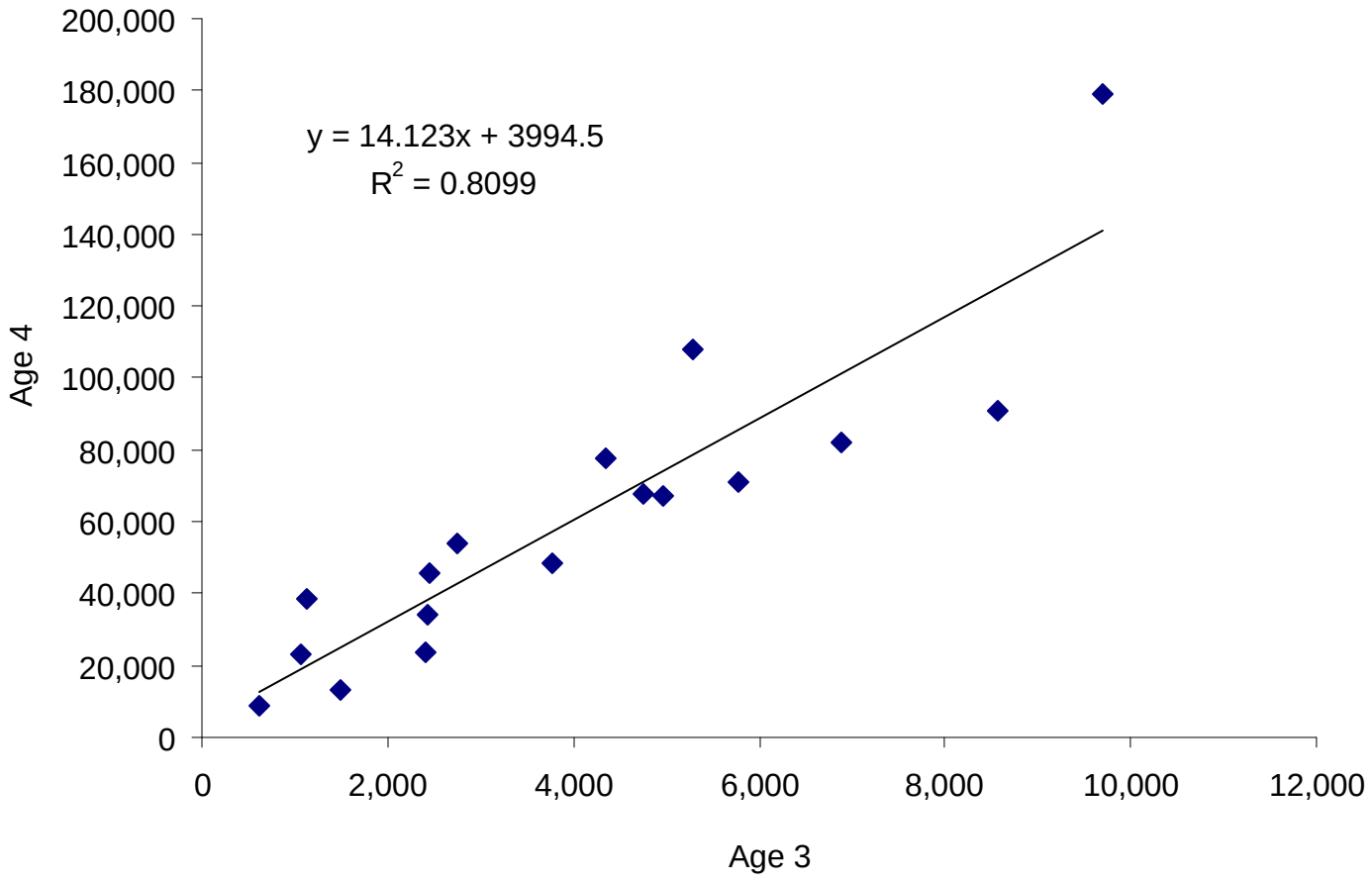
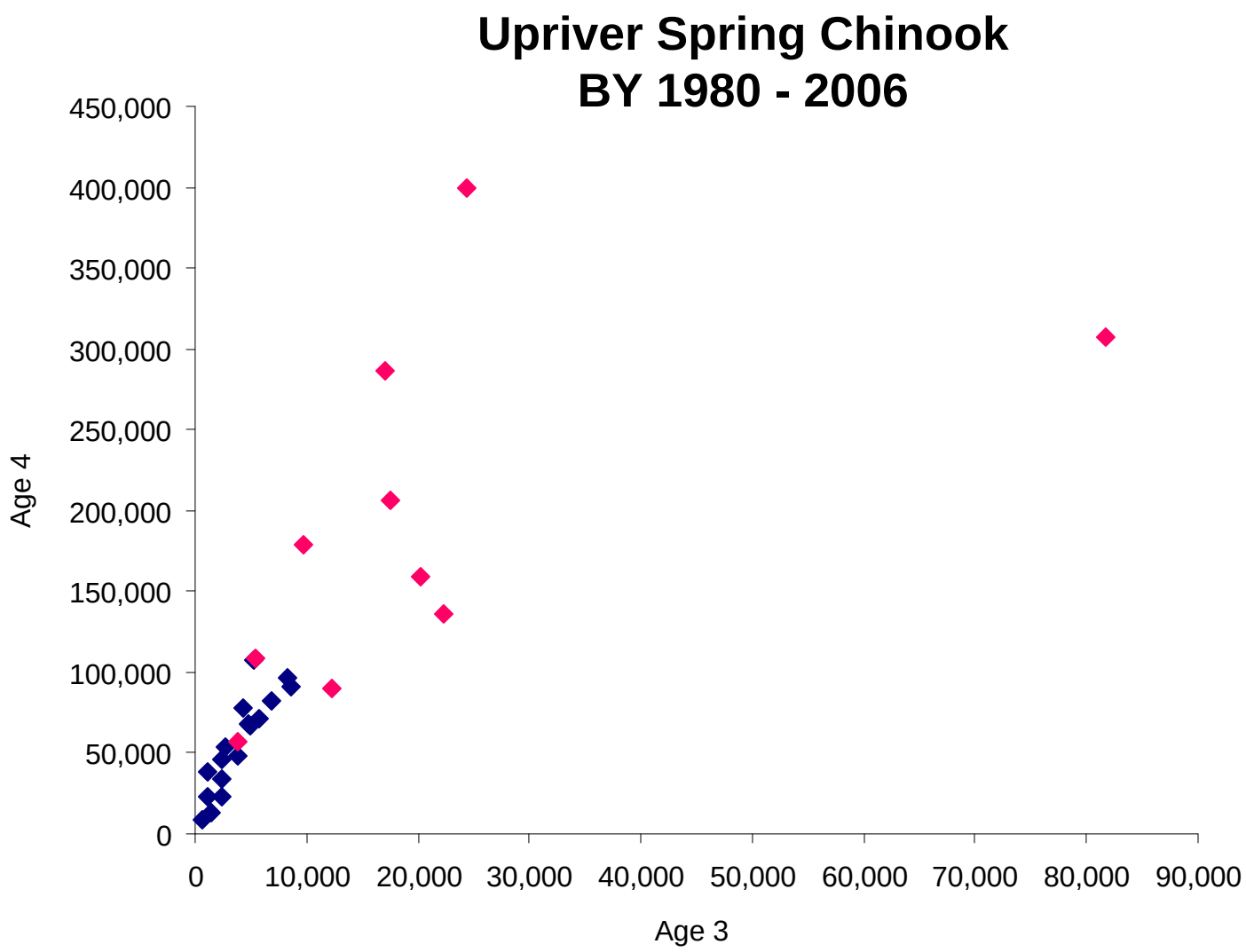
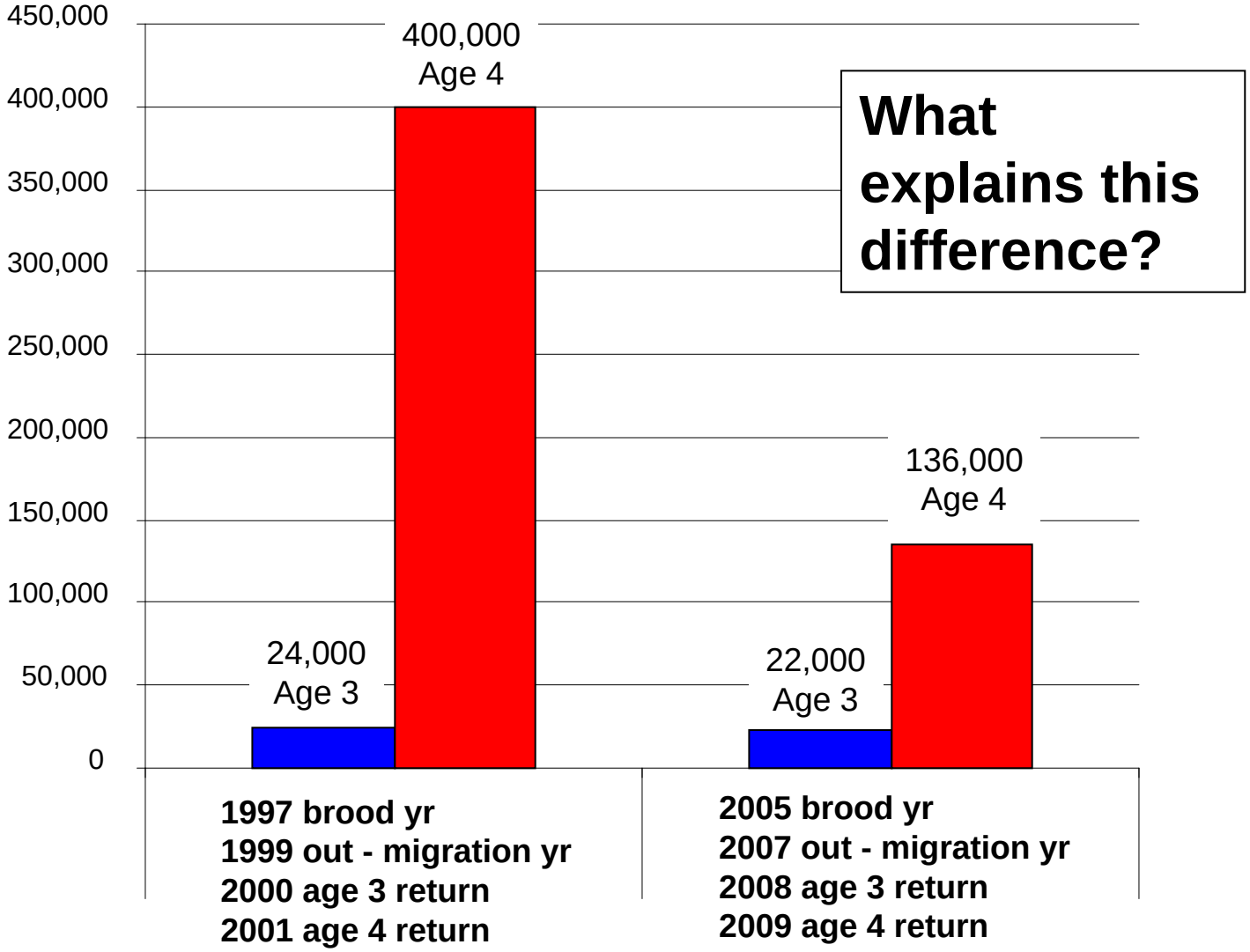
US v Oregon Technical Advisory Committee

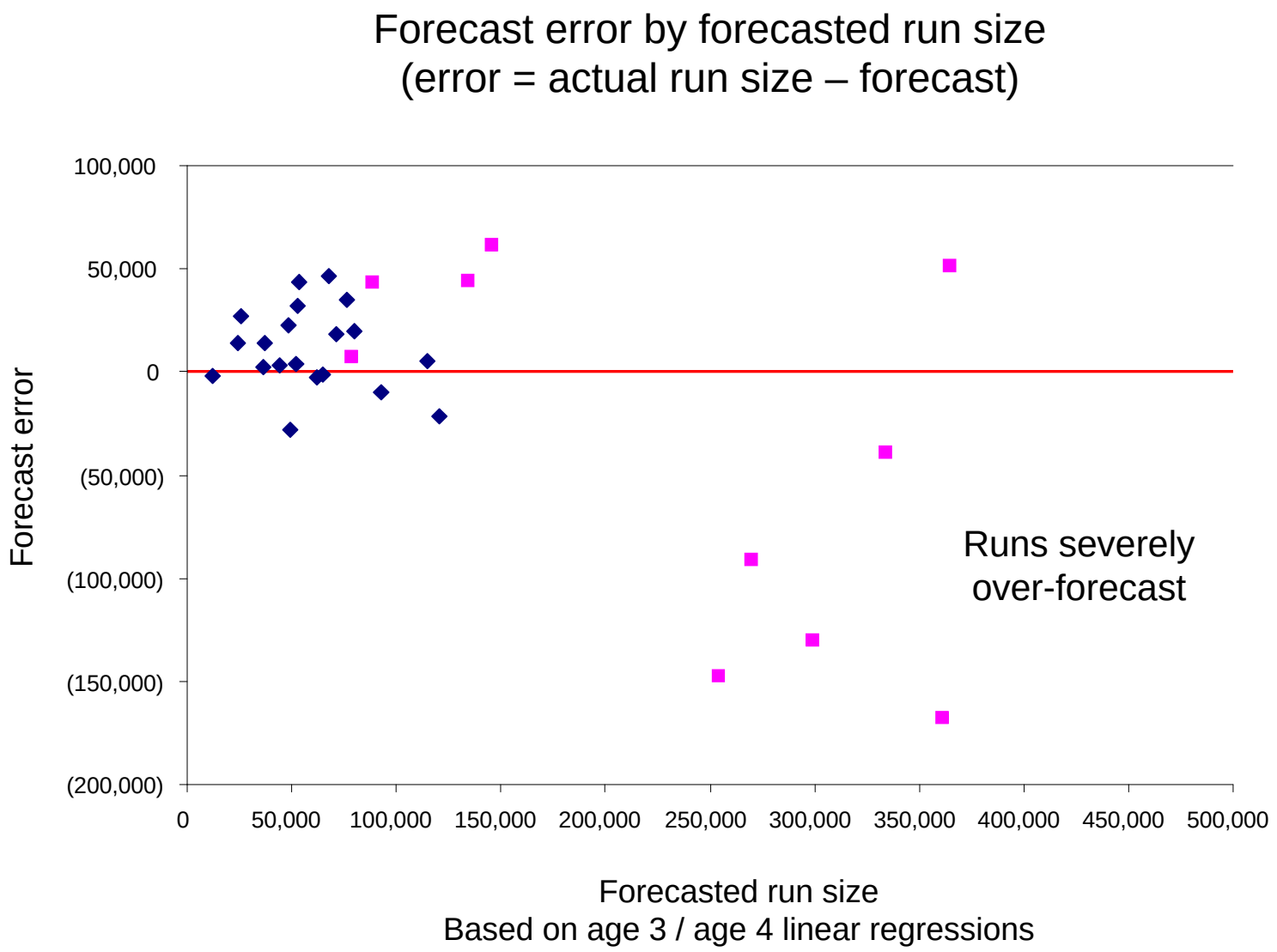
Upriver Spring Chinook
BY 1980 - 1996

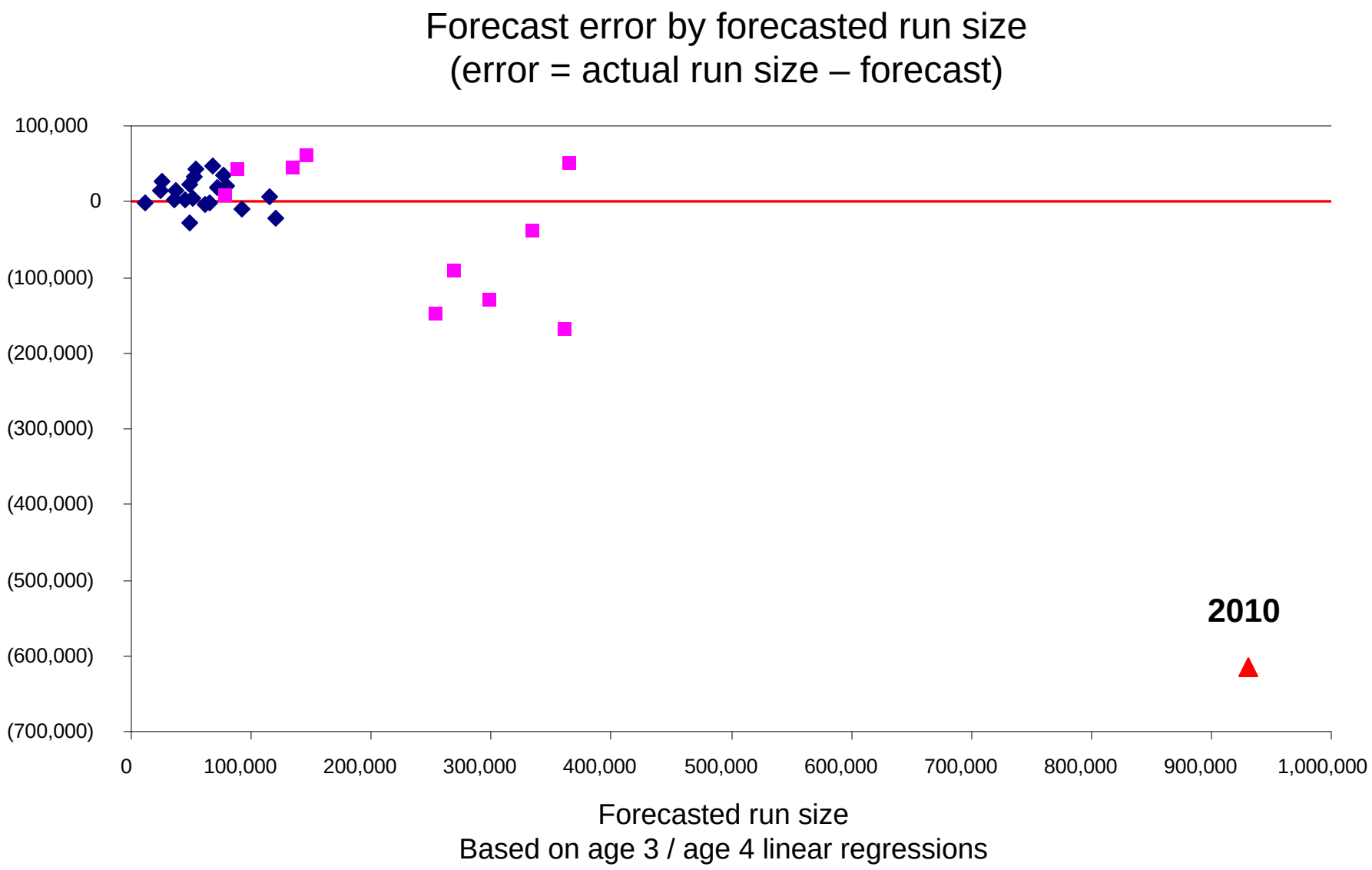



Upriver Spring Chinook
BY 1980 - 2006
450,000
400,000
350,000
300,000
250,000
200,000
150,000
100,000
50,000
0
Age 4
0
10,000
20,000
30,000
40,000
50,000
60,000
70,000
80,000
90,000
Age 3

Upriver Spring Chinook
BY 1997 vs 2005




Forecast error by forecasted run size
(error = actual run size – forecast)
100,000
50,000
0
(50,000)
(100,000)
(150,000)
(200,000)
Forecast error
0
50,000
100,000
150,000
200,000
250,000
300,000
350,000
400,000
450,000
500,000
Runs severely over-forecast
Forecasted run size
Based on age 3 / age 4 linear regressions


Forecast error by forecasted run size
(error = actual run size – forecast)
100,000
0
(100,000)
(200,000)
(300,000)
(400,000)
(500,000)
(600,000)
(700,000)
0
100,000
200,000
300,000
400,000
500,000
600,000
700,000
800,000
900,000
1,000,000
2010
Forecasted run size
Based on age 3 / age 4 linear regressions

Question:

Can we find different models or new variables that help explain the relationship between the number of Age 3 and Age 4 Spring Chinook returning to the Columbia River?

Is it due to:

- Age at maturation?
- Survival from age class to age class?
- Environmental variation?
  - In freshwater?
  - In the ocean?
- Hatchery practices?
- Density dependence effects at high abundance?
- Harvest?
- Evolutionary/genetic changes?
- Proximate changes?
- Something else?
- All of the above?

A useful variable or model:

- **Has to be something we can represent mathematically**
  - **Selection of models and indices**
- **Has to be available in a long-term time series**
  - **1980 - 2010**
- **Has to significantly explain some of the variation in the relative return of age 3s and 4s**
  - **Statistical power of the model**
- **Has to show predictive power**
  - **Demonstrated by hind-casting**
    (less error than a simple linear regression)

Models and Variables?

"Surface phytoplankton and zooplankton concentrations were the highest in a decade of observations across the Gulf of Alaska in August and September 2008. The cause is as-yet uncertain, but injection of iron by winds or currents is suspected … several volcanoes erupted in summer 2008 in the Aleutian Islands, so volcanic dust is a possible source of iron."

Canadian Science Advisory Secretariat Science Advisory Report 2009/030

Age at maturation?

OR

Survival from age class to age class?

- **Likely all of the above**

Proximate changes?

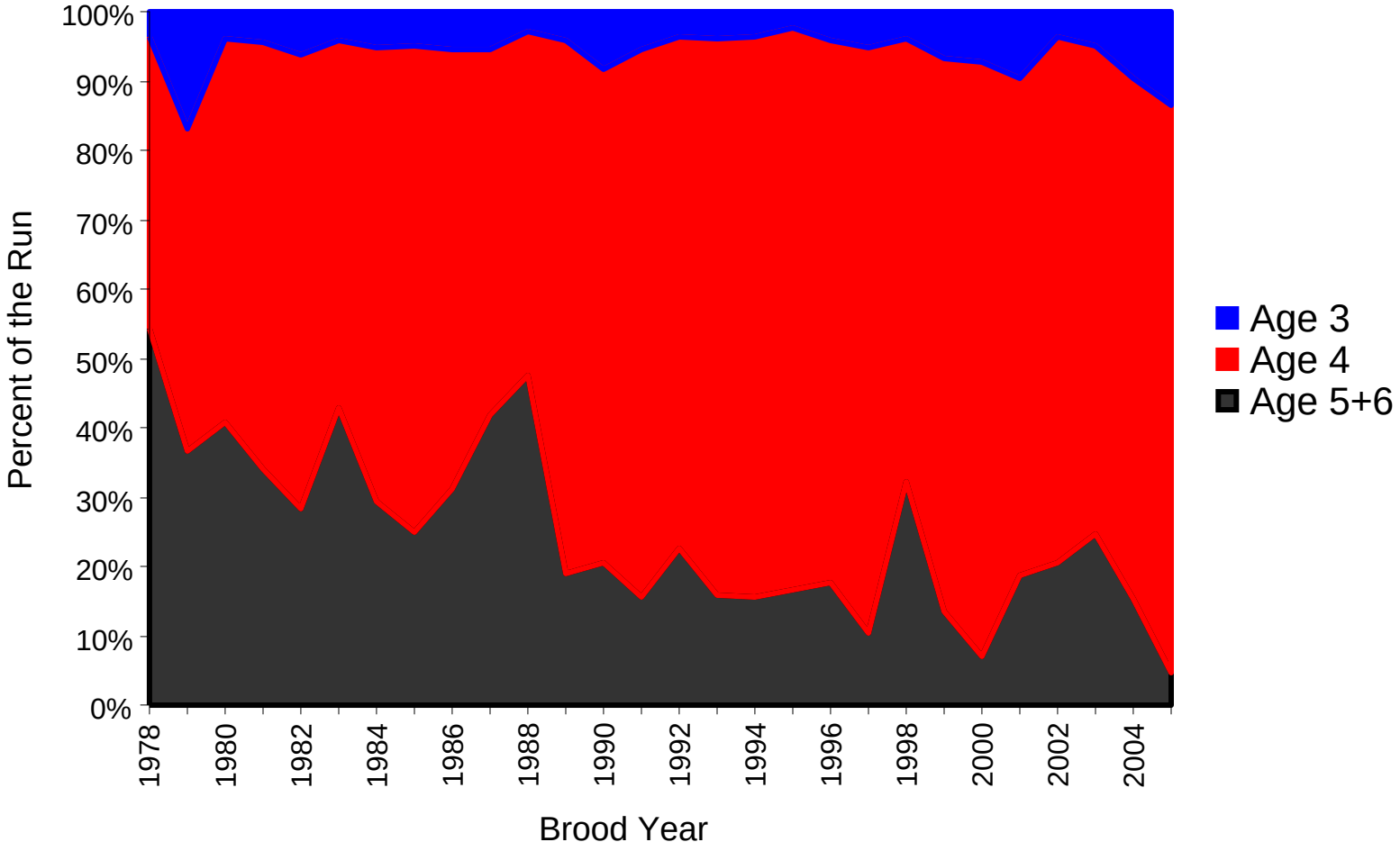
OR

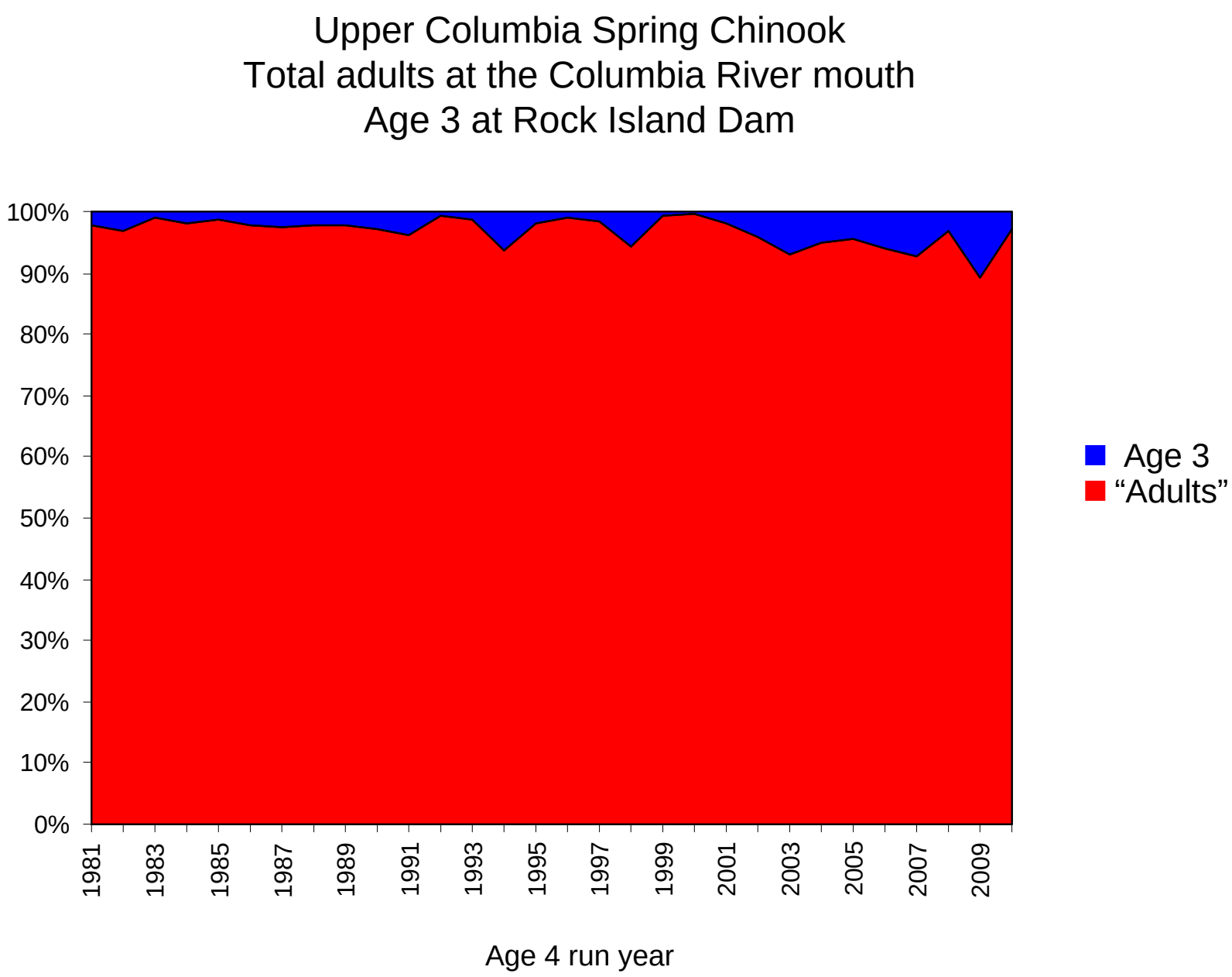
Evolutionary / genetic changes?

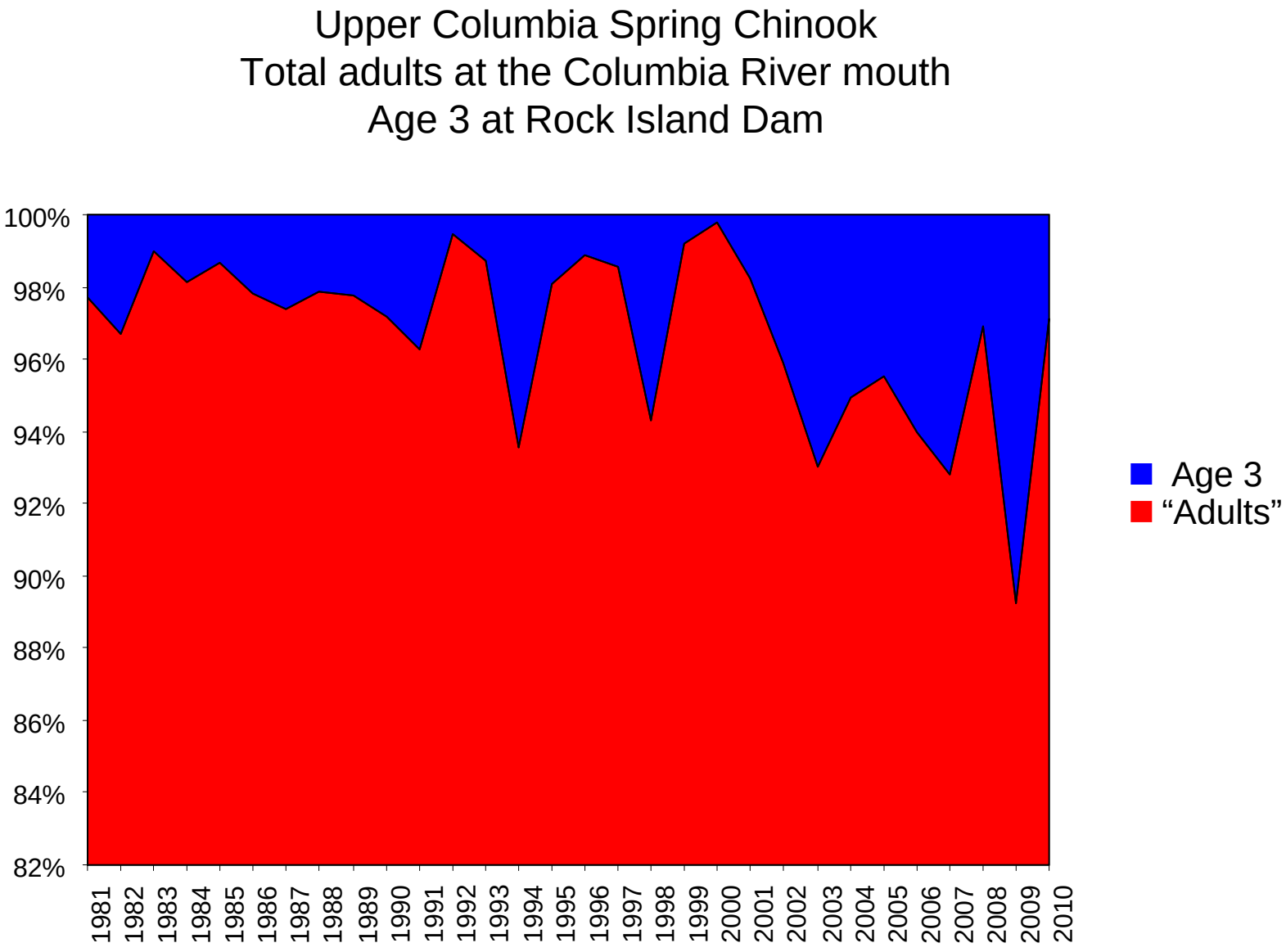
➢ Likely proximate changes

- Only in last 10 years
- Only when abundance is high
- High annual variation
- Directional change in relative numbers of age 3 / age 4??

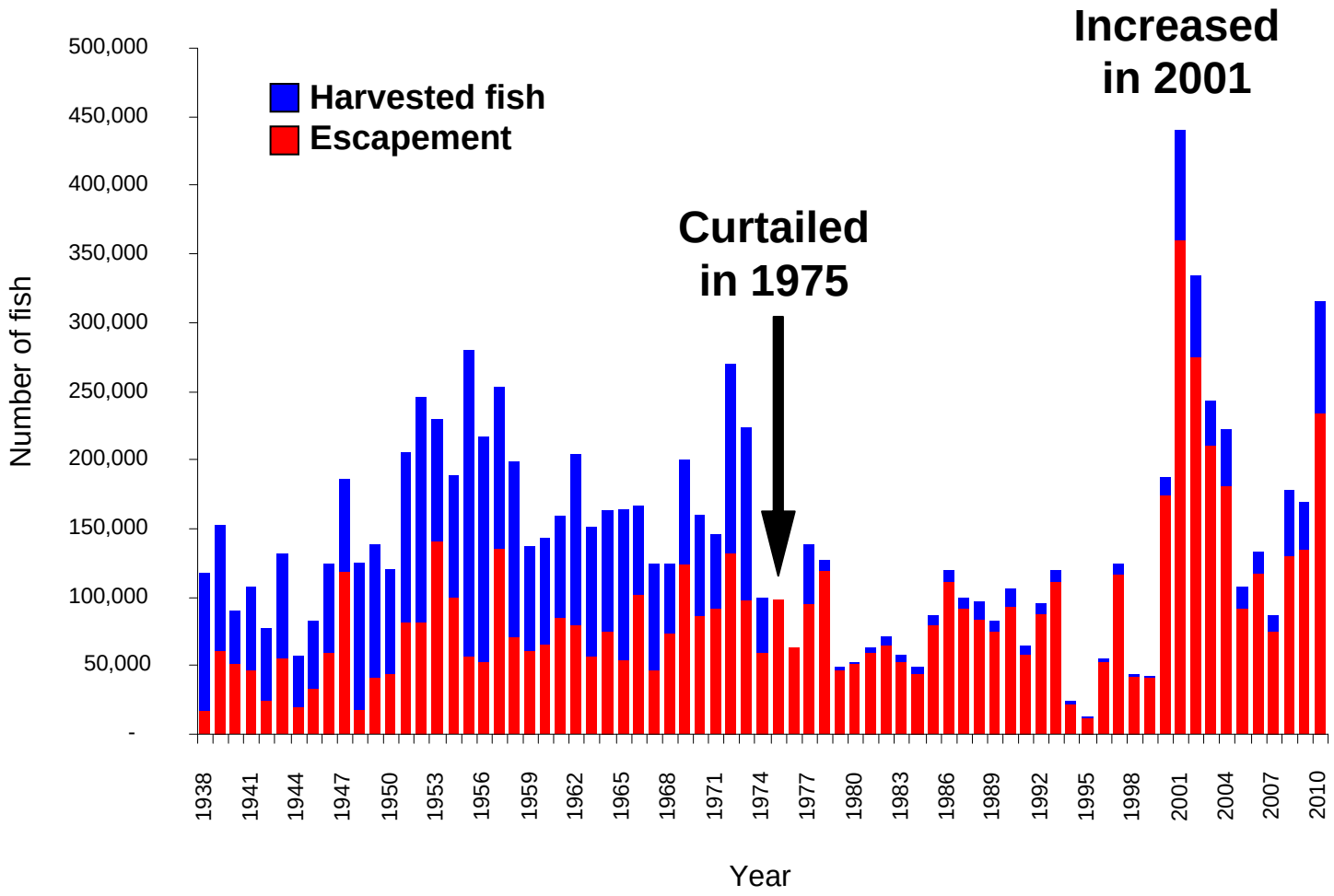
Proportional Age Distribution
"Up-river Spring Chinook"



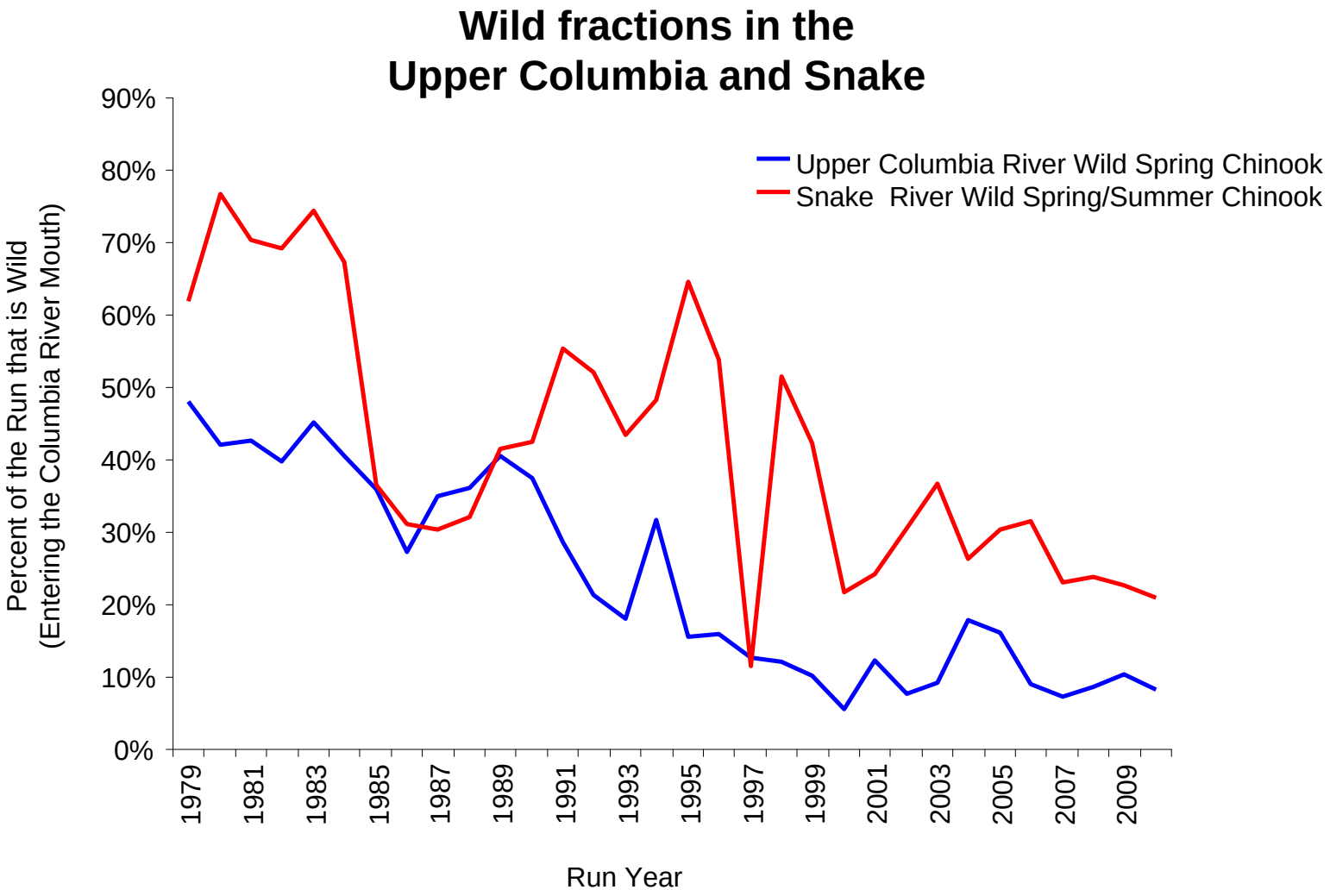

Upper Columbia Spring Chinook
Total adults at the Columbia River mouth
Age 3 at Rock Island Dam
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
1981
1983
1985
1987
1989
1991
1993
1995
1997
1999
2001
2003
2005
2007
2009
Age 4 run year
Age 3
“Adults”


Upper Columbia Spring Chinook
Total adults at the Columbia River mouth
Age 3 at Rock Island Dam
100%
98%
96%
94%
92%
90%
88%
86%
84%
82%
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
Age 3
“Adults”

Harvest?


Increased in 2001
Harvested fish
Escapement
Curtailed in 1975
Number of fish
500,000
450,000
400,000
350,000
300,000
250,000
200,000
150,000
100,000
50,000
-
1938
1941
1944
1947
1950
1953
1956
1959
1962
1965
1968
1971
1974
1977
1980
1983
1986
1989
1992
1995
1998
2001
2004
2007
2010
Year

Hatcheries?

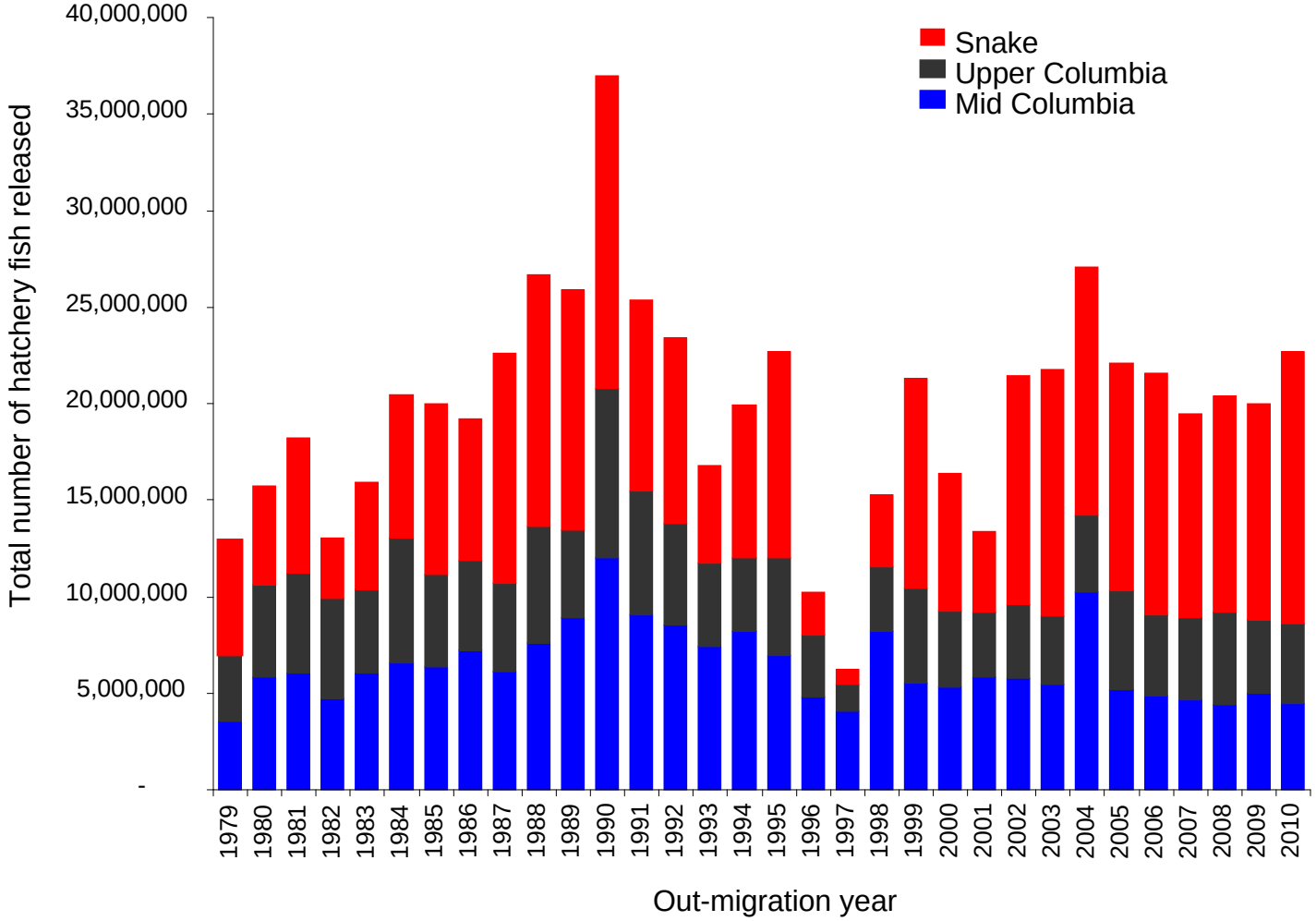

Wild fractions in the
Upper Columbia and Snake
Upper Columbia River Wild Spring Chinook
Snake River Wild Spring/Summer Chinook
Percent of the Run that is Wild
(Entering the Columbia River Mouth)
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
1979
1981
1983
1985
1987
1989
1991
1993
1995
1997
1999
2001
2003
2005
2007
2009
Run Year

Hatcheries?

- **Relatively more hatchery fish in the basin**
- **Some indication of increased age 3 fish in some individual hatchery programs**
- **Some evidence this is related to accelerated growth rates in hatcheries**
- **Challenge: how to capture this effect in a regional model or variable we can use?**
  - **Number of hatchery fish released?**
  - **Average size – at – release?**
  - **Average growth rates prior to release?**

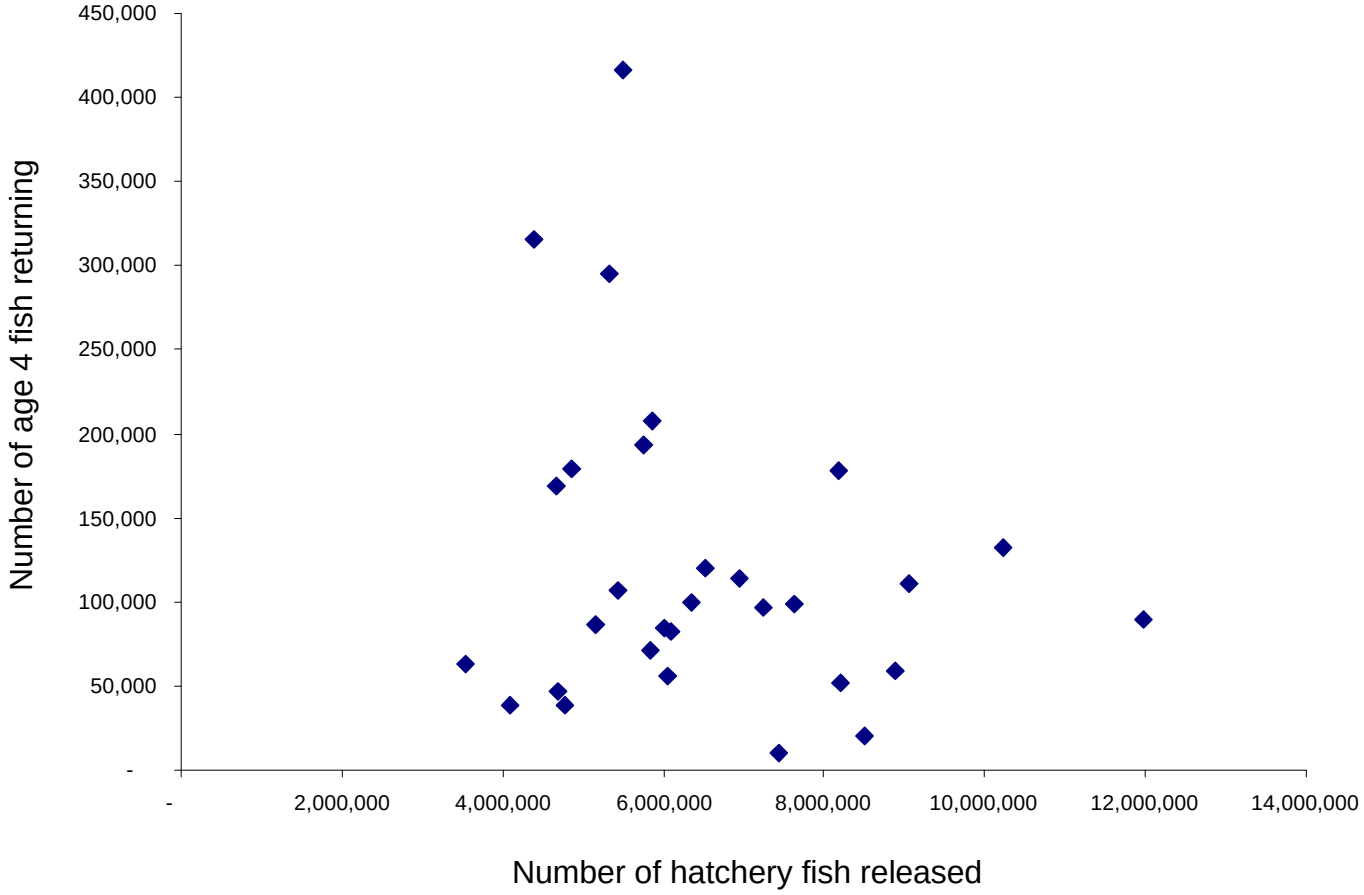
Hatcheries?

Number of hatchery fish released



Hatcheries?

No relationship between the number of hatchery fish released and the number of either age 3 or age 4 fish returning

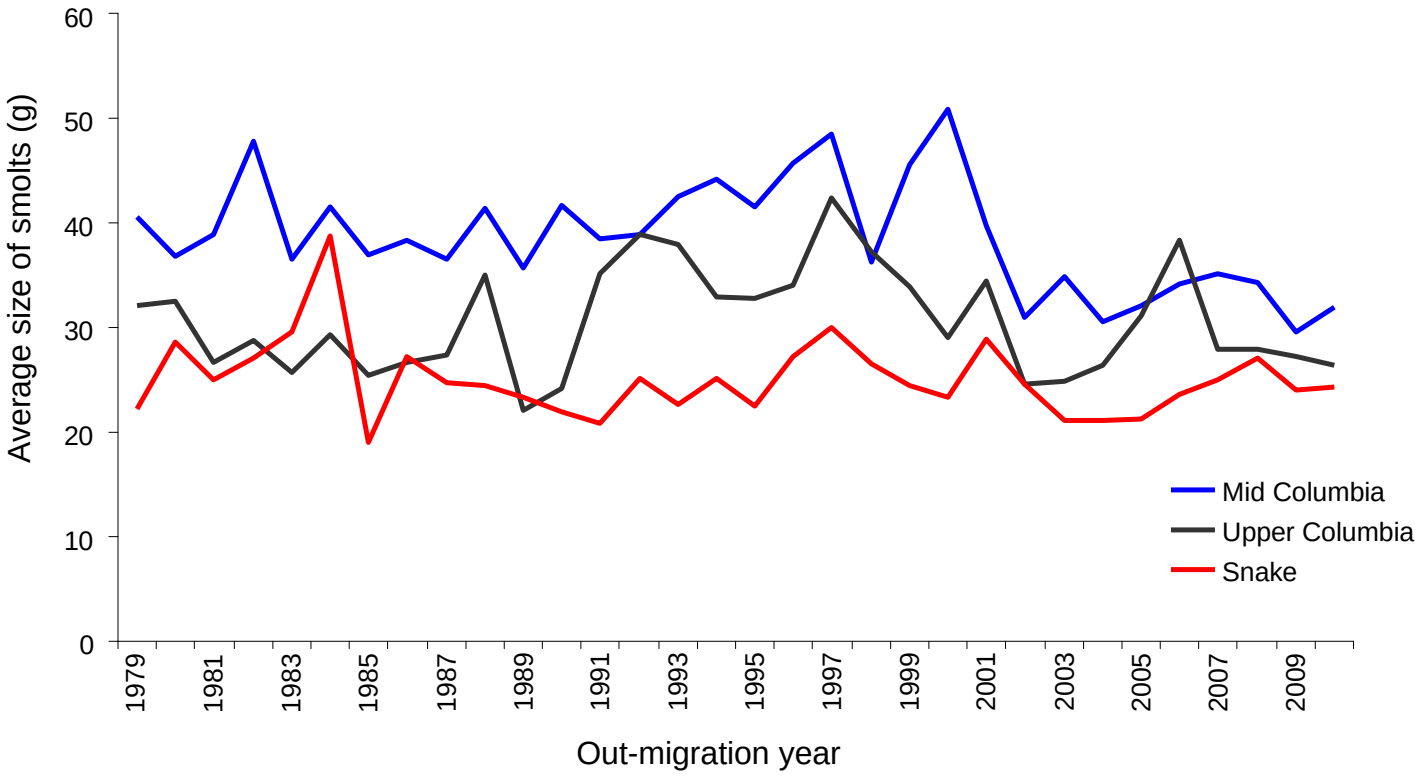


Hatcheries?

Size of hatchery smolts?

No significant relationship between size of smolts and number of jacks returning

Growth rates in hatcheries? Unable to model so far…



Environmental Variables?

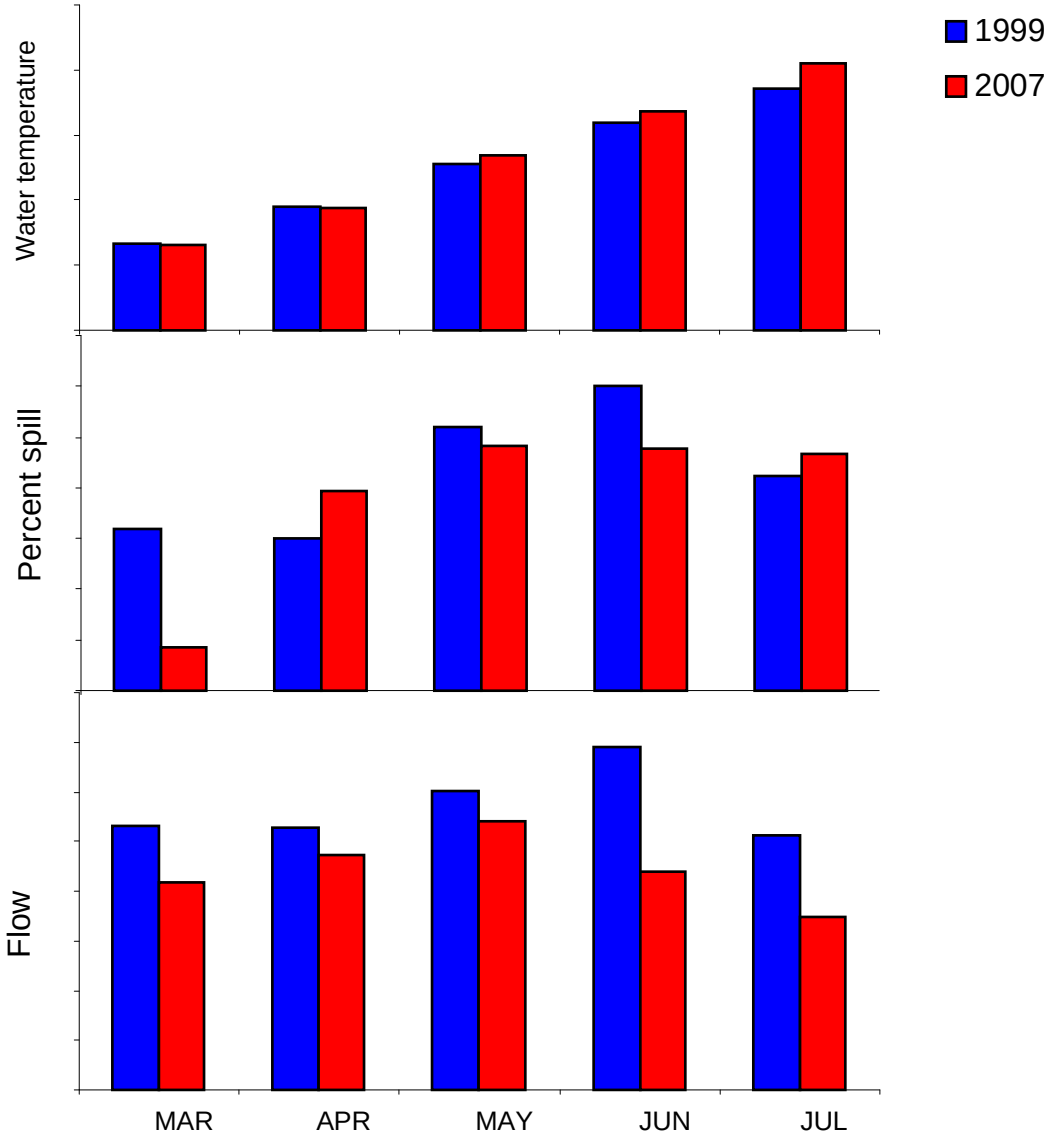
- Many variables to consider
- Easy to index and model
- Long enough data series
- Does explain some variation in survival and adult returns
- Early hind - casting tests promising

Environmental Variables?

Conditions in the Columbia River during juvenile out – migration correlate with survival:

Higher flow, more spill, cooler water = better survival

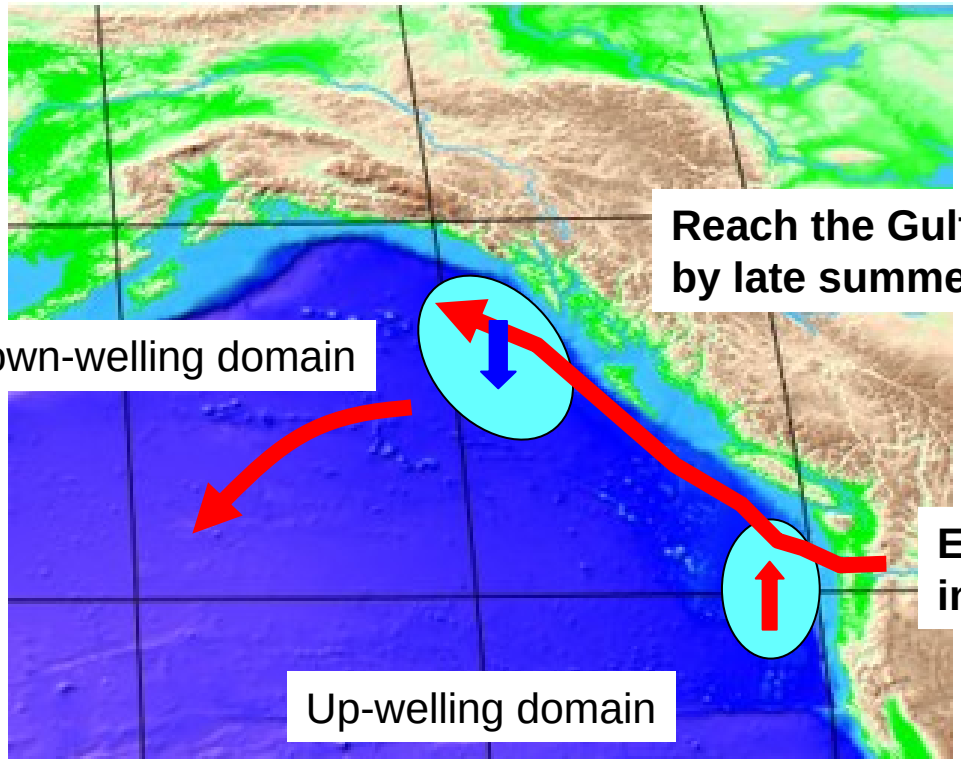
Low flow, less spill, warmer water = poorer survival



Environmental Variables?

Ocean Productivity

Where are upriver spring Chinook while they are in the ocean?



Fisher & Pearcy 1995, Pearcy 1997, Trudel et al. 2009

Ocean environment

	1999	2000	2007	2008
PDO (December-March)	4	1	5	2
PDO (May-September)	2	4	8	1
MEI Jan-June	2	3	8	1
SST at 46050 (May-Sept)	2	4	10	2
SST at NH 05 (May-Sept)	2	1	9	3
SST winter before going to sea	6	4	2	1
Physical Spring Trans (Logerwell)	6	2	3	5
Upwelling (Apr-May)	1	10	2	4
Deep Temperature	4	6	5	1
Deep Salinity	3	3	1	1
Length of upwelling season	4	3	5	2
Copepod richness	2	1	6	4
N. Copepod Anomaly	8	3	4	1
Biological Transition	6	3	2	1
June-Chinook Catches	2	3	4	1
Sept-Coho Catches	2	1	8	6
Mean of Ranks	3.6	3.4	4.9	2.0
RANK of the mean rank	2	3	6	1

Difficult to combine into a single index

Short time series

Investigated individual components that have long time series

(Peterson et al 2009)

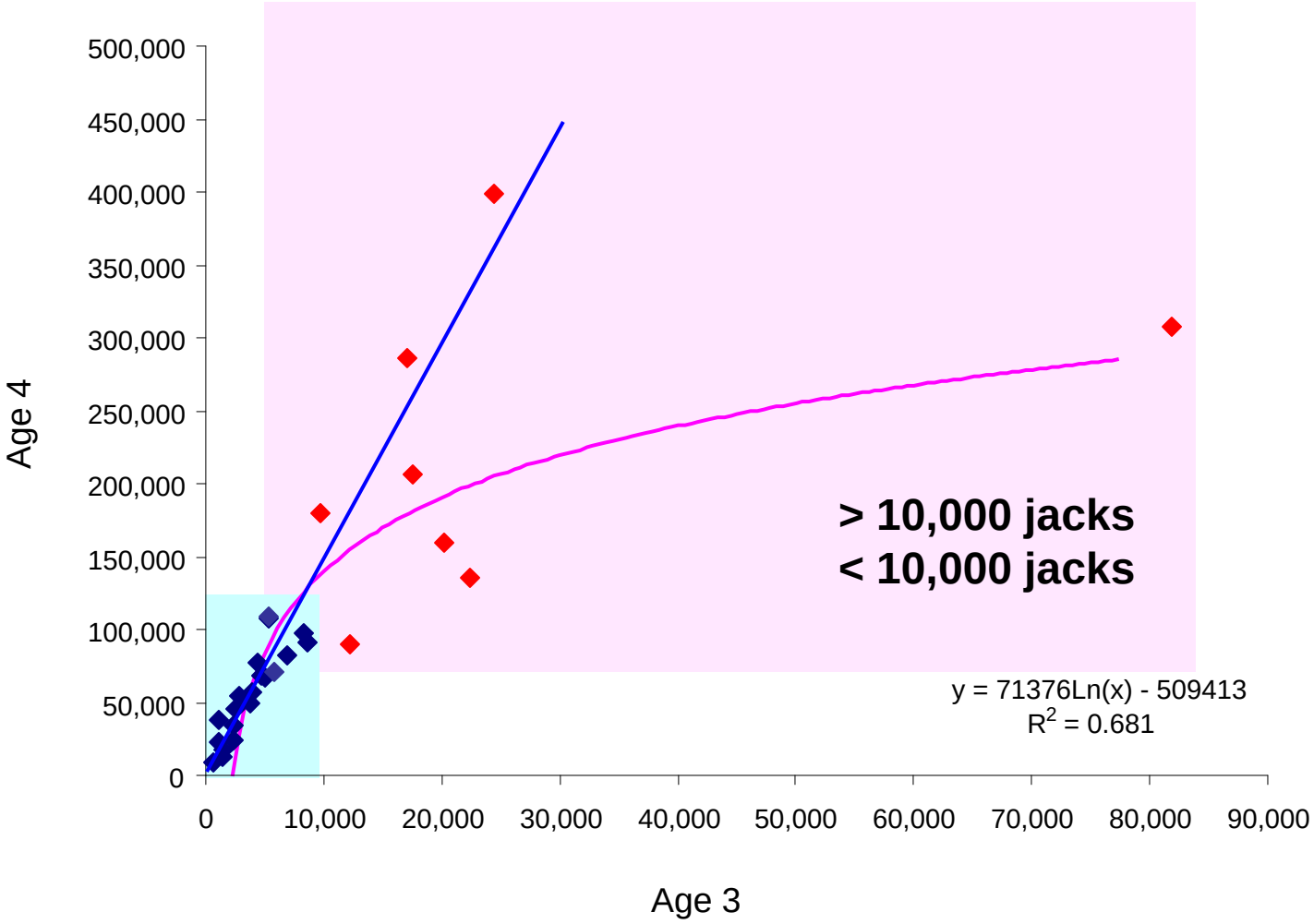
Environmental Variables?

Ocean Productivity

- **Ocean anomalies appear to correlate with Chinook survival**
  - Extreme highs = good survival; and lows = poor survival
  - Spring Chinook: coastal shelf conditions in their first summer of ocean entry
  - What affects age 3 → age 4 survival?
  - Ocean anomalies, productivity, abundance and density dependence triggers?
- **Ocean anomalies may influence age at maturation**
  - Extreme highs = faster growth = younger maturation and lows = slower growth = older maturation
  - Except at furthest extreme lows = younger maturation
- **Average ocean / moderate variation unrelated to Chinook survival or maturation**

(Sharma et al. unpublished)

Model Structure:
Different behavior at different abundances?

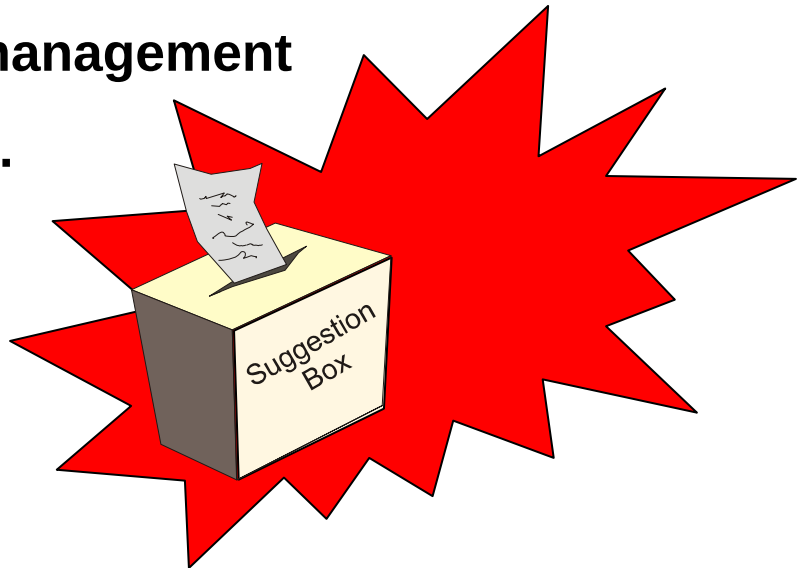


Abundance – related ?

- **Density – dependence effects?**
- **Statistical error structure?**
- **Alternative model structure?**
  - **Linear**
  - **Log – normal**
  - **Log – log**
- **Different models for different abundances?**
  - **Nothing works better than a simple linear regression when age 3 abundance < 10,000**
  - **Log models work better when age 3 abundance > 10,000; errors still high; addition of other variables may be helpful**

Bottom Line (so far)

- **No single, reliable explanation has been found**
  - **Unpredictability occurs when age 3 abundance exceeds 10,000**
- **Multiple models / ensemble means**
- **Anticipate high error rates**
  - **Conservative pre-season planning**
  - **Active in-season management**
- **The quest continues……**



P.S.-

How are we doing for 2011?

- ~16,000 jacks in 2010 (more than 10,000)
- explored ~70 models
- used an ensemble mean of the best ones to forecast 198,000 adults
- current in-season projection is that the run will exceed the forecast by about 5 - 10%
- another large jack count in 2011; >40,000 so far (yikes!!)