Quantifying fishing impacts on past and future killer whale growth rates

Eric Ward

Outline

- 1. Recap from workshop 1, sci. panel requests
- 2. Estimating parameters
- 3. Evaluating historic effects of fishing
- 4. Evaluating future effects of fishing
  - And population viability / recovery goals

Checklist

- Projections based on current age / sex structure [high, p 6]
- PVA should be re-done, without the focus on extinction [medium high, p 24]
- Examine KW growth rate in presence/absence of fisheries [high, p 24]
- Analyses should be done for NRKW / SRKW [high, p 24]

Requests from workshop 1

- Additionally: quantify how probable are recovery criteria?

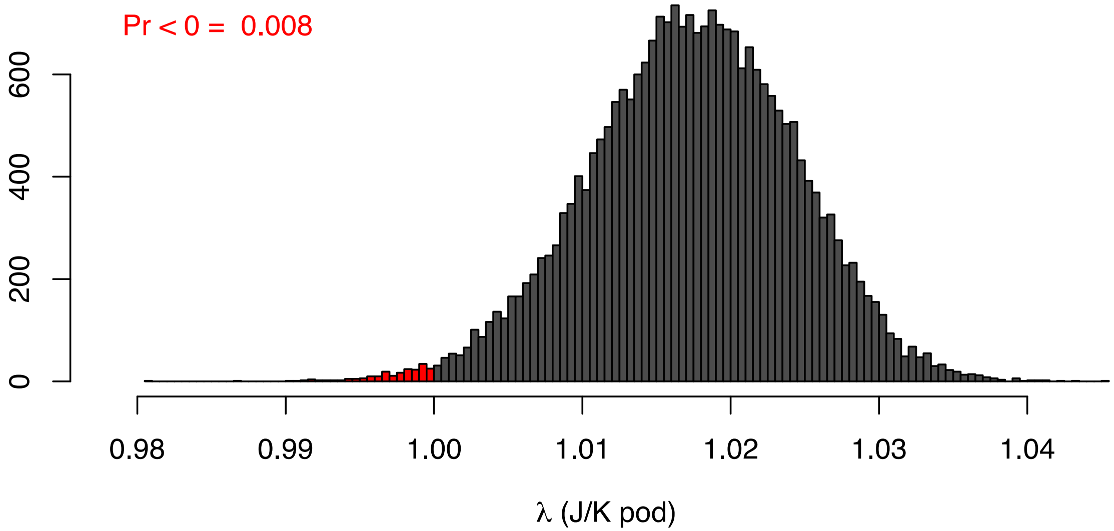
- This could be done across salmon indices:
- FRAM (workshop # 1)
- CTC indices (follow up to workshop # 1)
  - NBC
  - WCVI
- Parken-Kope indices (focus of this talk)
  - Fall & Fall / summer group (no southern stocks)

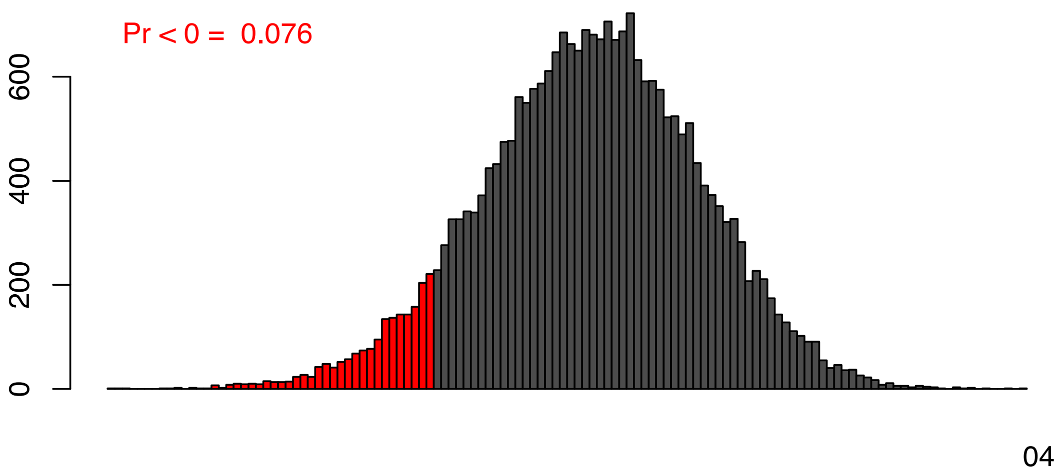
What we've learned since workshop 1

- SRKW have significantly lower growth rate
  - SRKW / NRKW demographic rates appear to have similar response to salmon, suggesting salmon may not explain the difference
- Of all salmon indices, Parken-Kope indices appear to correlate a bit more strongly than CTC/FRAM
  - Fall / north migrating stocks seem to be in the top models
  - Survival positively correlated, fecundity weak

- Analyses with covariates are purely correlative
  - Sci panel report (p5): “How do we determine if there is cause and effect”?
- Without other data, we can’t model the mechanism

Posteriors of deterministic λ (no salmon as covariate)

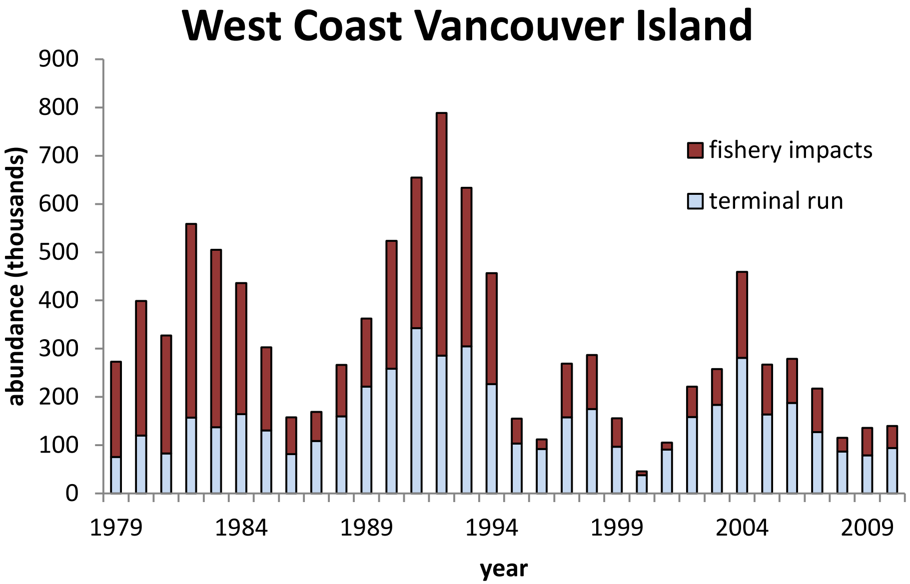




Some issues with CTC indices

- We don’t have harvest in #s
  - Model based

- Parken-Kope time series
  - terminal run and fishery impact / catch
  - Fall index fits the data better than CTC / no salmon models
  - More empirical


West Coast Vancouver Island
abundance (thousands)
fishery impacts
terminal run
year
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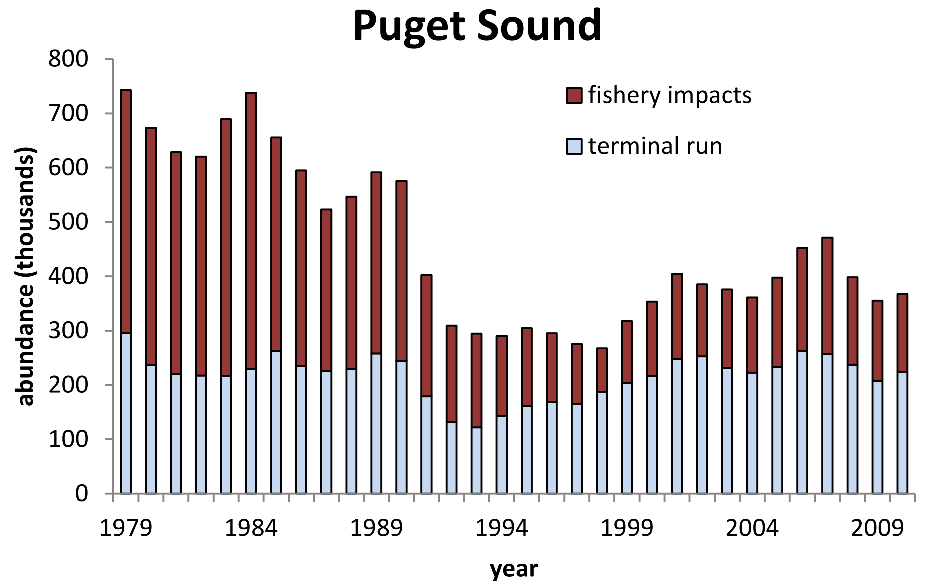
Puget Sound
abundance (thousands)
fishery impacts
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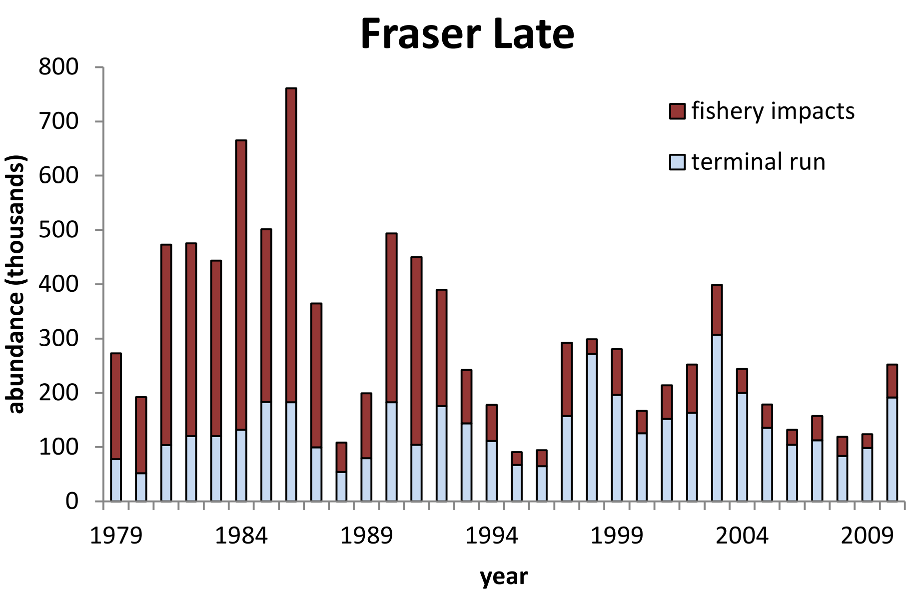
Fraser Late
abundance (thousands)
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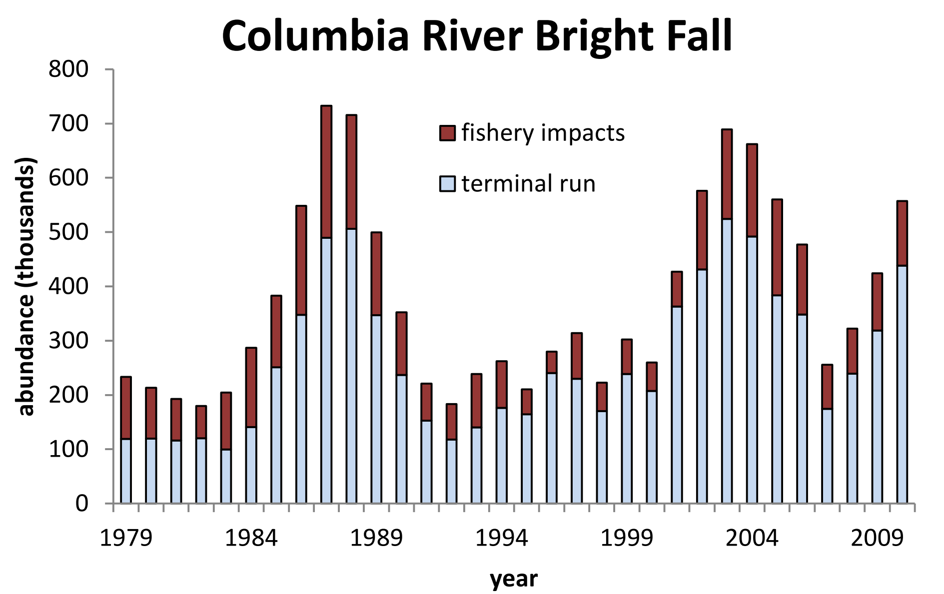
Columbia River Bright Fall
abundance (thousands)
fishery impacts
terminal run
year
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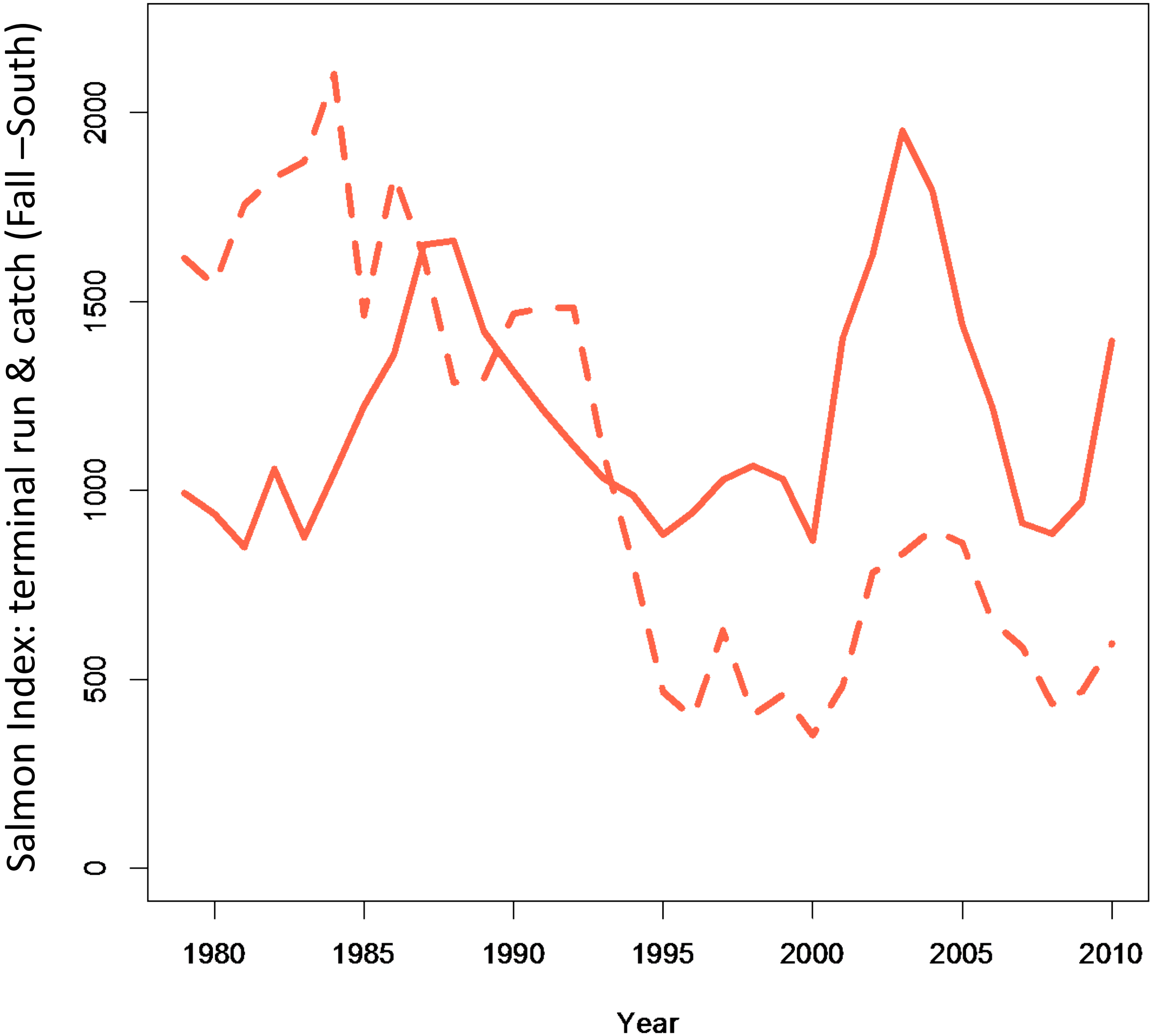
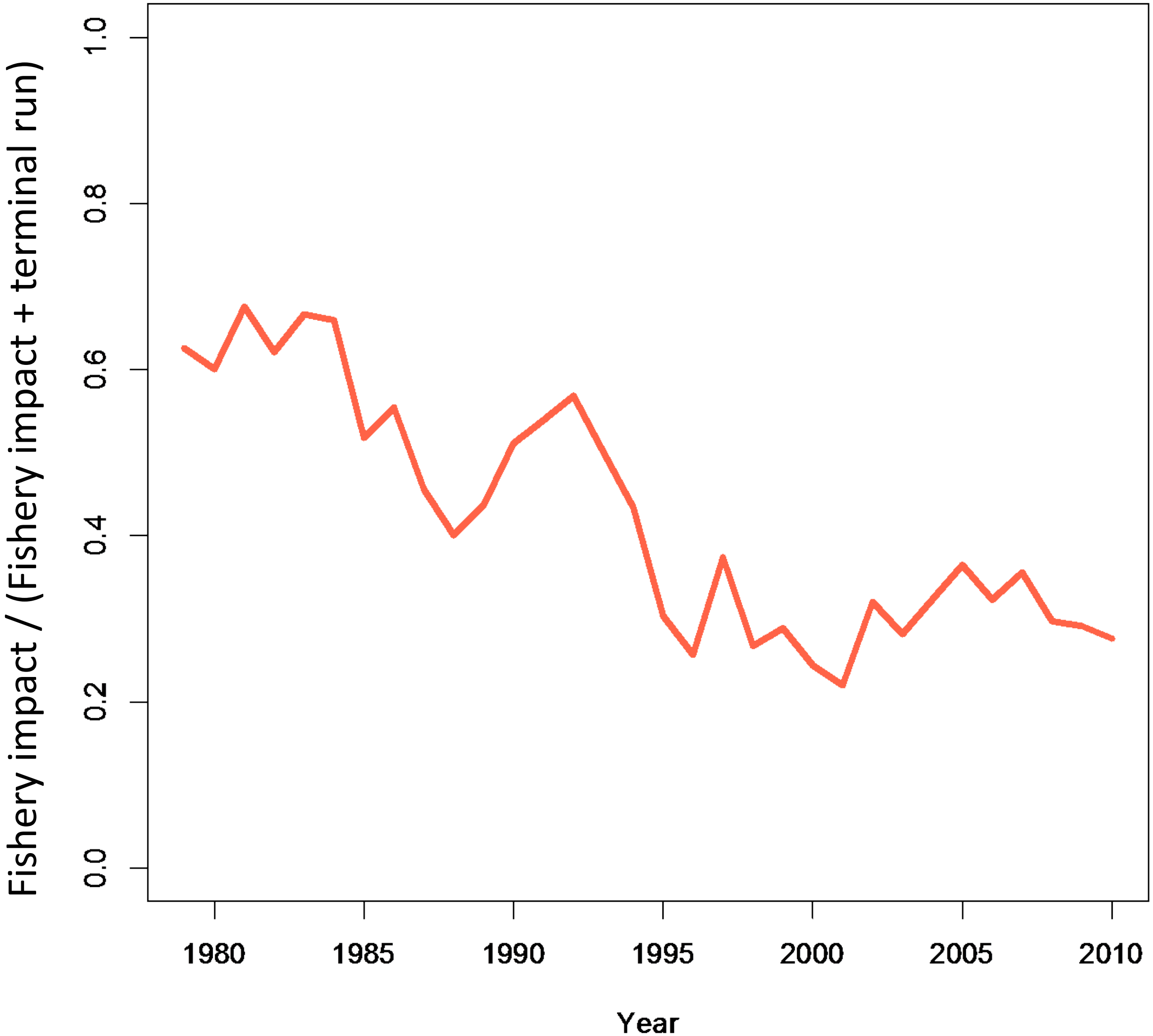
Fall terminal run (solid line) & catch (dashed line)



Harvest % generally declines (fall)



* Other sources of mortality would make harvest % < 20% in recent years

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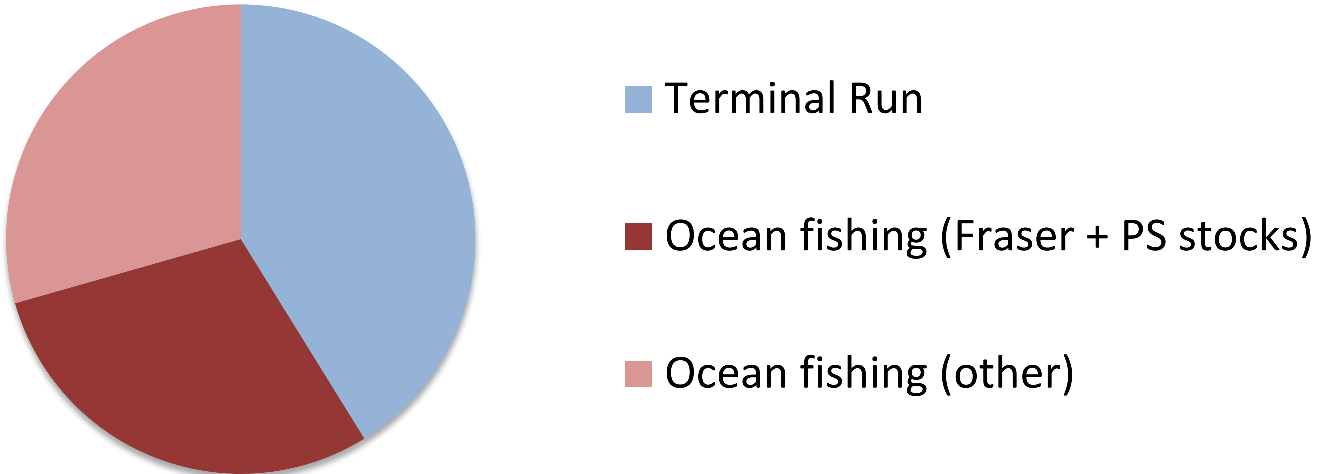
Parameter estimation

- Logistic regressions on fecundity / survival
  - Fecundity age – based (1-year lag)
    - Exclude several females with age "40"
  - Survival stage-based (no lag)
    - Allow L pod to have lower survival
    - Exclude calves that disappear with moms
  - Time period: 1979-2010
  - Salmon abundance (terminal run) as covariate
    - Linear in logit-space, non-linear in normal-space

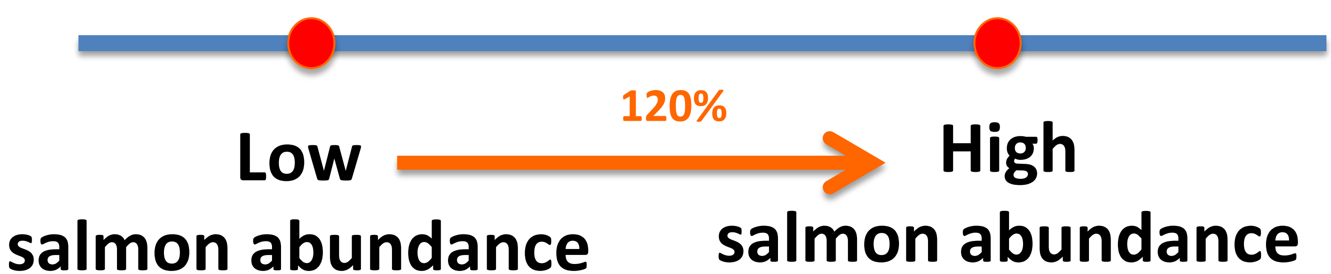
This analysis differs slightly from previous Fall + Fall/Summer (-California) in model selection

- Fit demographic data to terminal index only (no ocean fishery impacts)
  - Previous Fall (-California) index included fishing impacts for coastal stocks
- Add fishery impacts back in, re-fit

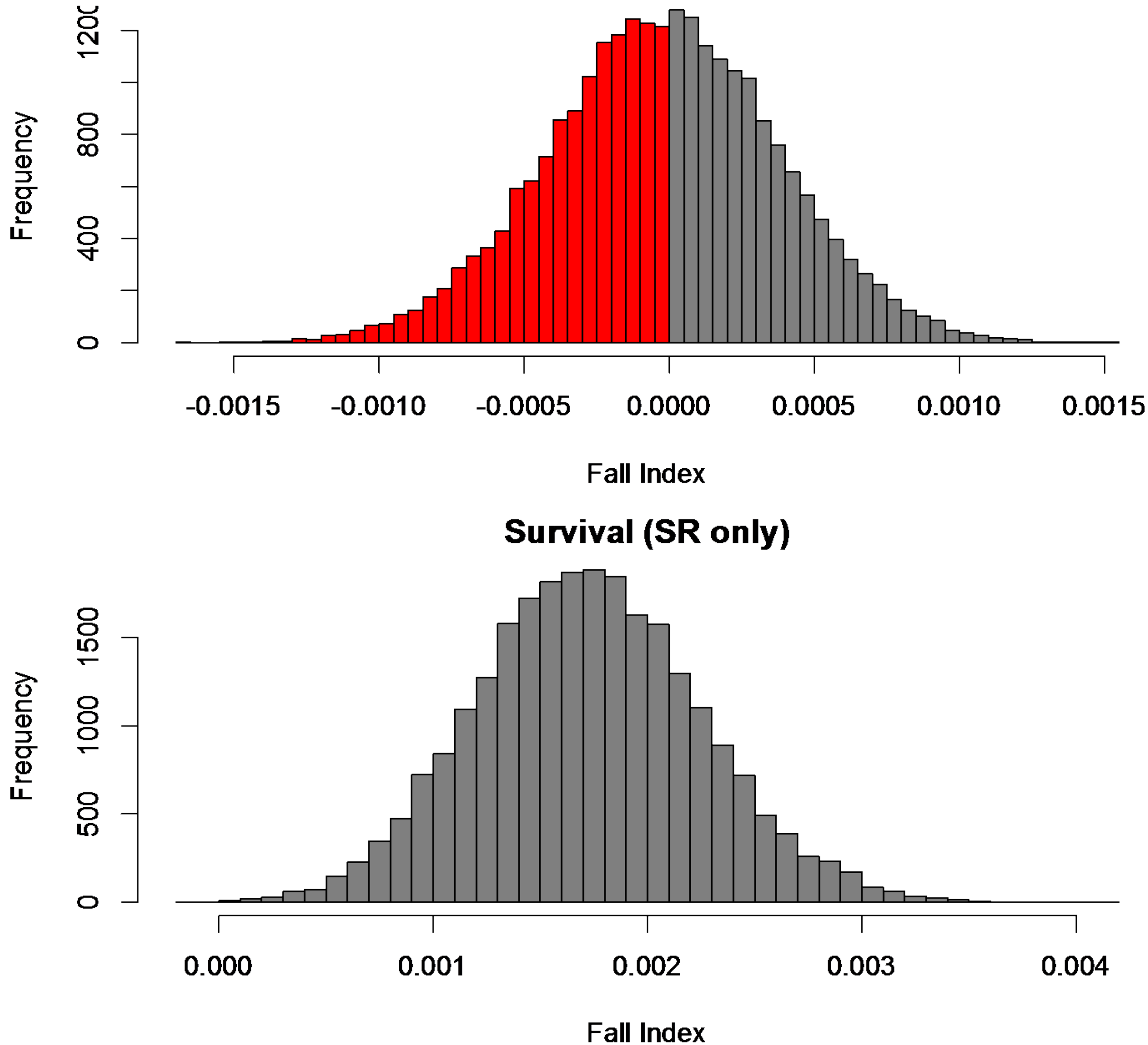


Interpretation

- I am manipulating total salmon abundance – not explicitly modeling fishing
  - Focus on future effects that are similar in magnitude to recent fishing (~ 20%)



Posterior distributions of regression coefficients (Parken-Kope Fall terminal index)



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Scenarios: with and without fishing (historical)

- We have a terminal and a fishery impact (catch) index for fall migrating stocks
  - (Fall + Fall/Summer, no California)

- 1. Calculate growth rates fit only to the terminal run size

- 2. Add the fishery impact back into the terminal run size, and quantify change in growth rate

Calculation

- Define λ^* as the *expected* growth rate conditioned on age/sex structure at time (*t*)

λ^* = (E[animals that survive from t to t+1] + E[births at time t+1]) / (animals alive at time t)

- Differs from λ, which is the expected growth rate of a population at equilibrium (stable age / sex distribution)

Caveats

- Females only (< 42), 3 groups:
  1. Females available to give birth
  2. Females not available to give birth
  3. Juveniles of unknown sex
- No demographic / environmental stochasticity
  - Because this is historical, we know what happened
  - DO include uncertainty in sex ratio at birth

Metrics for evaluating fishing v no fishing scenarios

- 1. Absolute improvement in λ^*
- 2. Percent improvement in λ^*
- 3. Percent reduction in negative growth
  - $\Pr(\lambda^* < 0)$

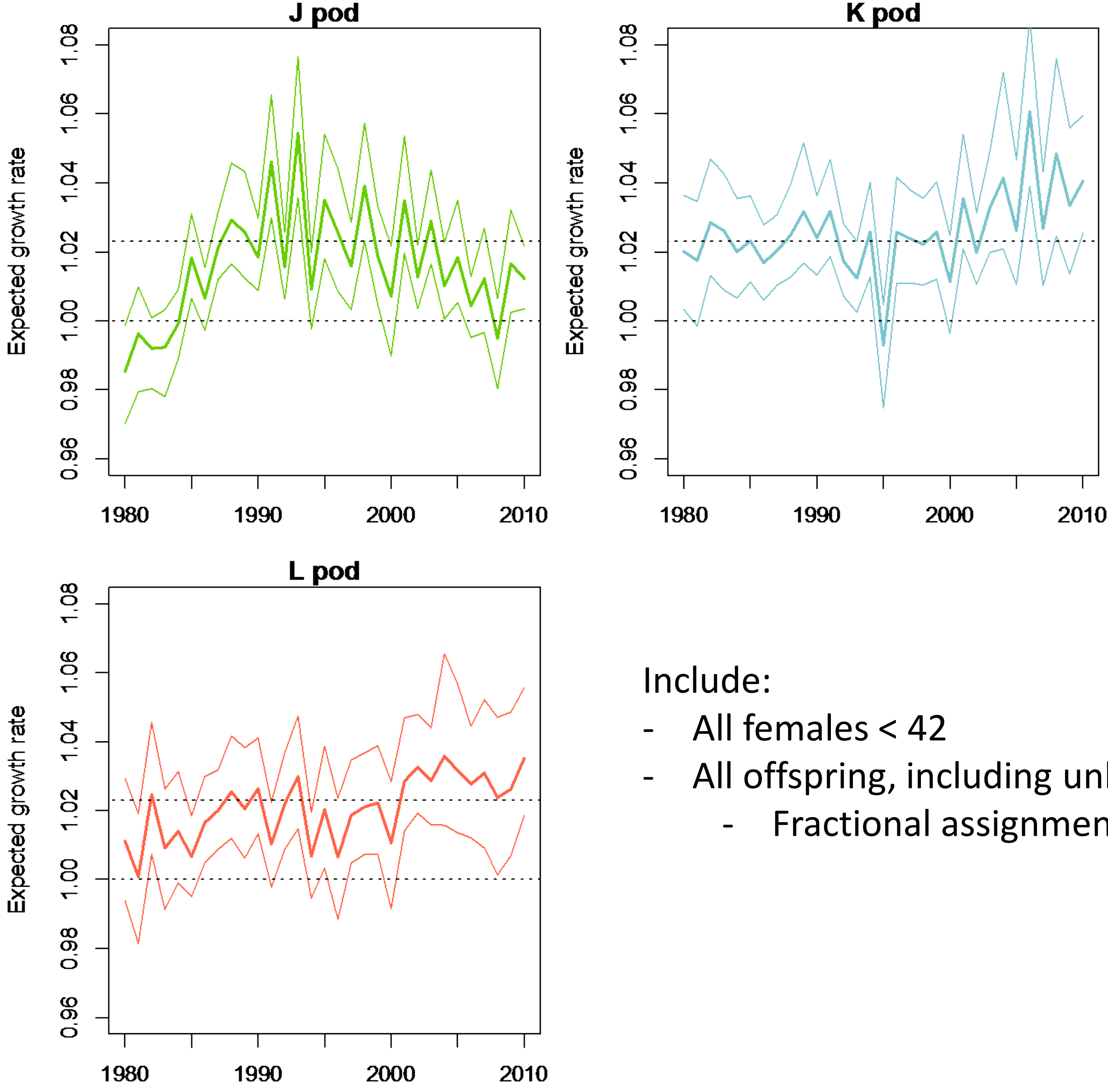
Metric 1: Absolute improvement

- Calculated as

  λ^* (total run) – λ^* (terminal run)

- Positive value interpreted as the net change in growth, e.g. 1.02 – 1.01 = 0.01

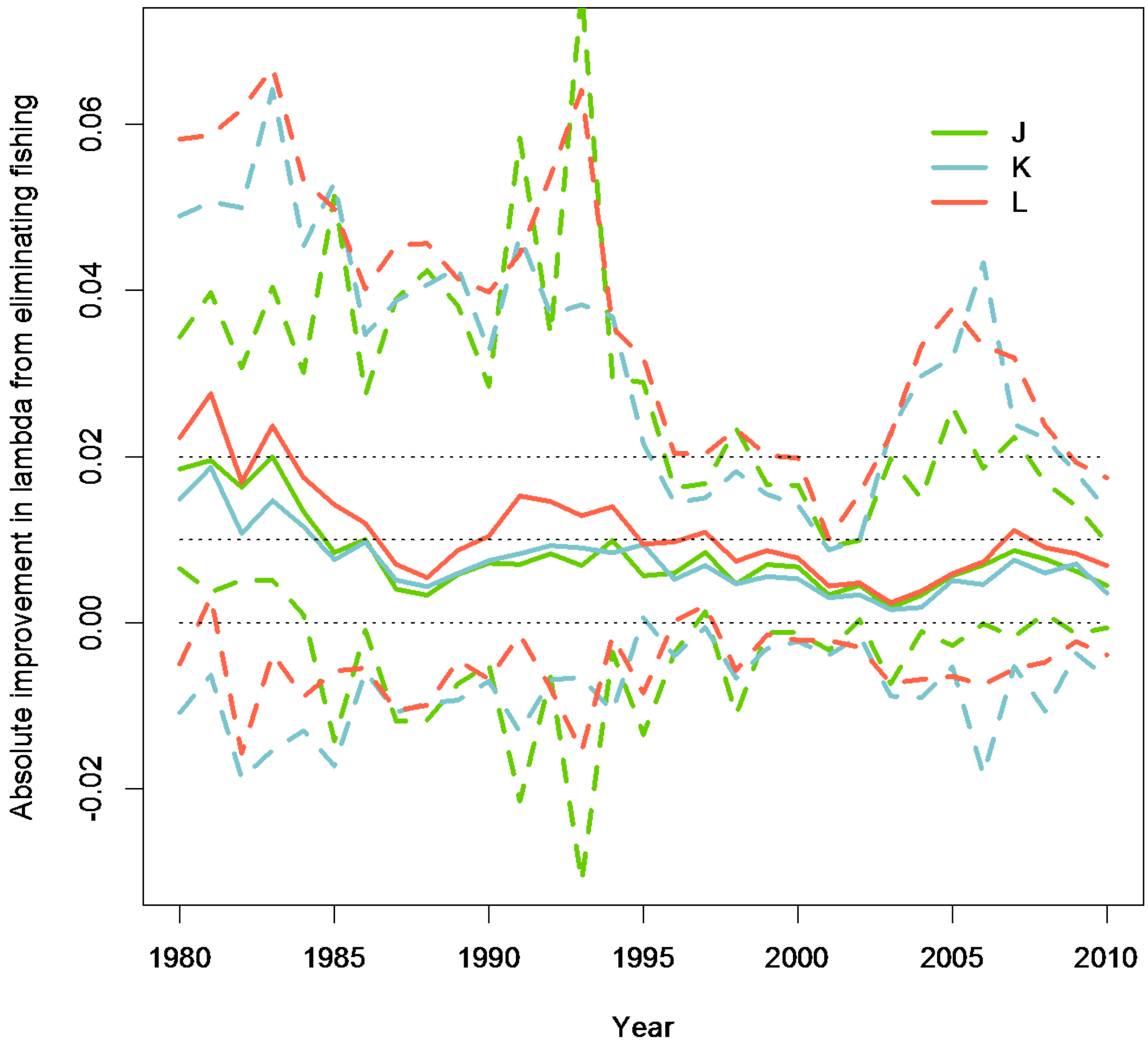
Growth by pod with fishing (terminal run as predictor)



Include:

- All females < 42
- All offspring, including unknown sex
    - Fractional assignment as female

Absolute improvement in λ*



In recent years, increasing Chinook by ~ 20% would increase SRKW λ by ~ 0.005

a λ of 1.015 would -> 1.02

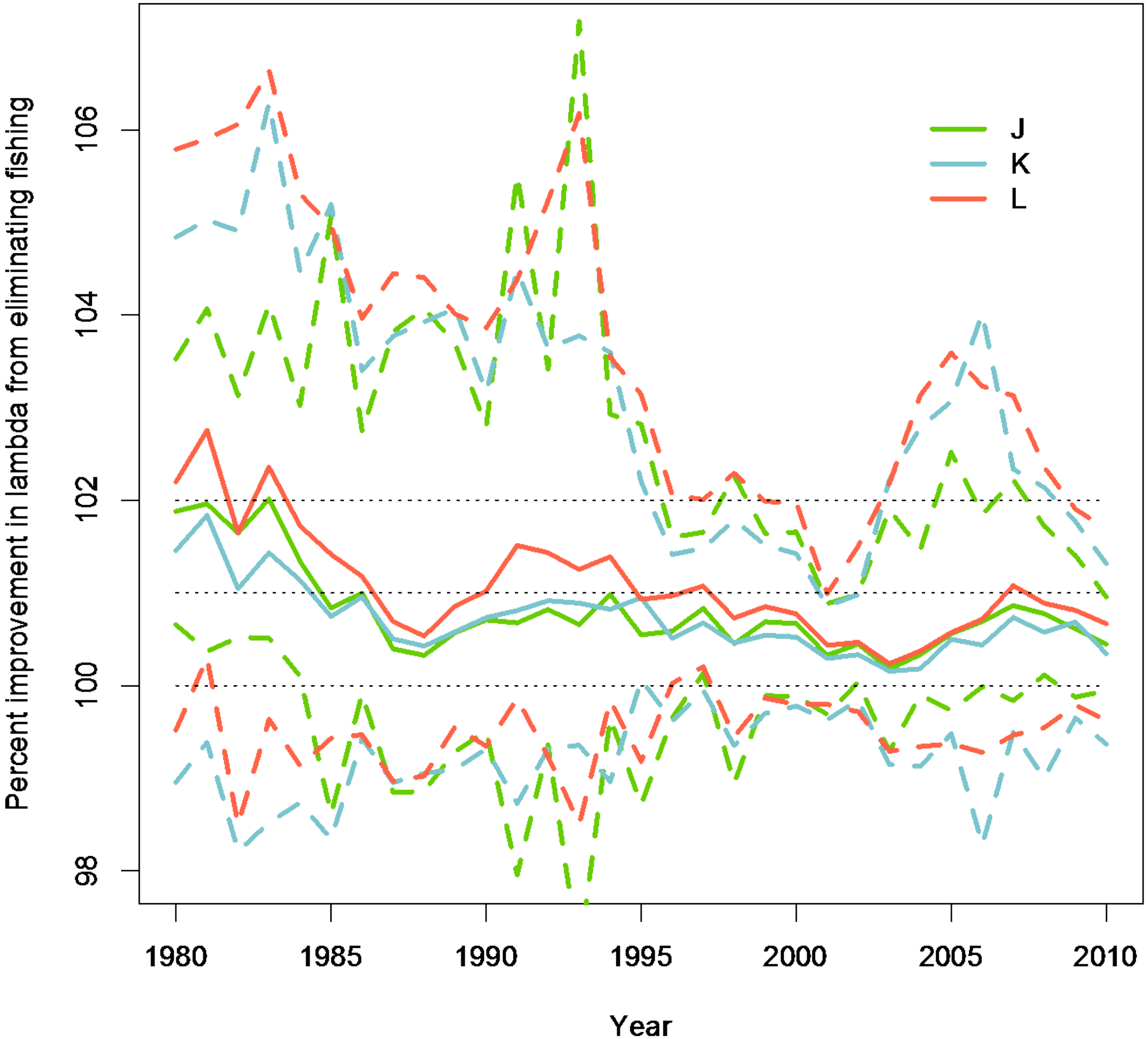
Metric 2: Percent improvement

- Calculated as

$$100 \times \lambda^{*} \text{ (total run)} / \lambda^{*} \text{ (terminal run)}$$

- Positive value interpreted as the percent change in growth, e.g. 1.02 / 1.01 = ~ 0.99% increase

Percent improvement in λ*



In recent years, increasing Chinook salmon abundance by ~ 20% would change SRKW λ by ~ 100.5%

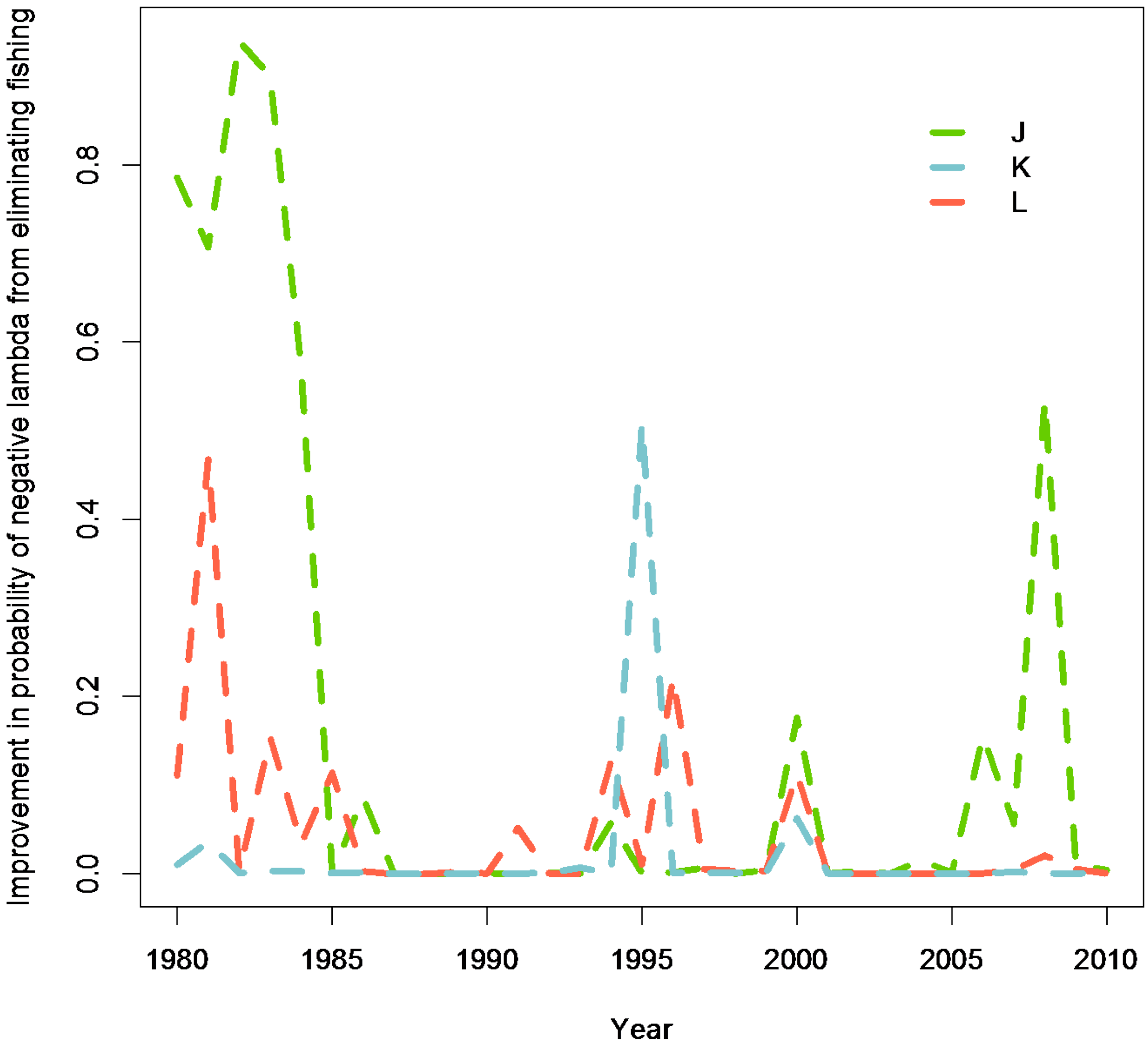
Metric 3: Percent reduction in probability of negative growth ($\lambda^* < 1$)

- Calculated as

  $- [Pr(\lambda^*<1)$ (total run) $- Pr(\lambda^*<1)$ (terminal run) $]$

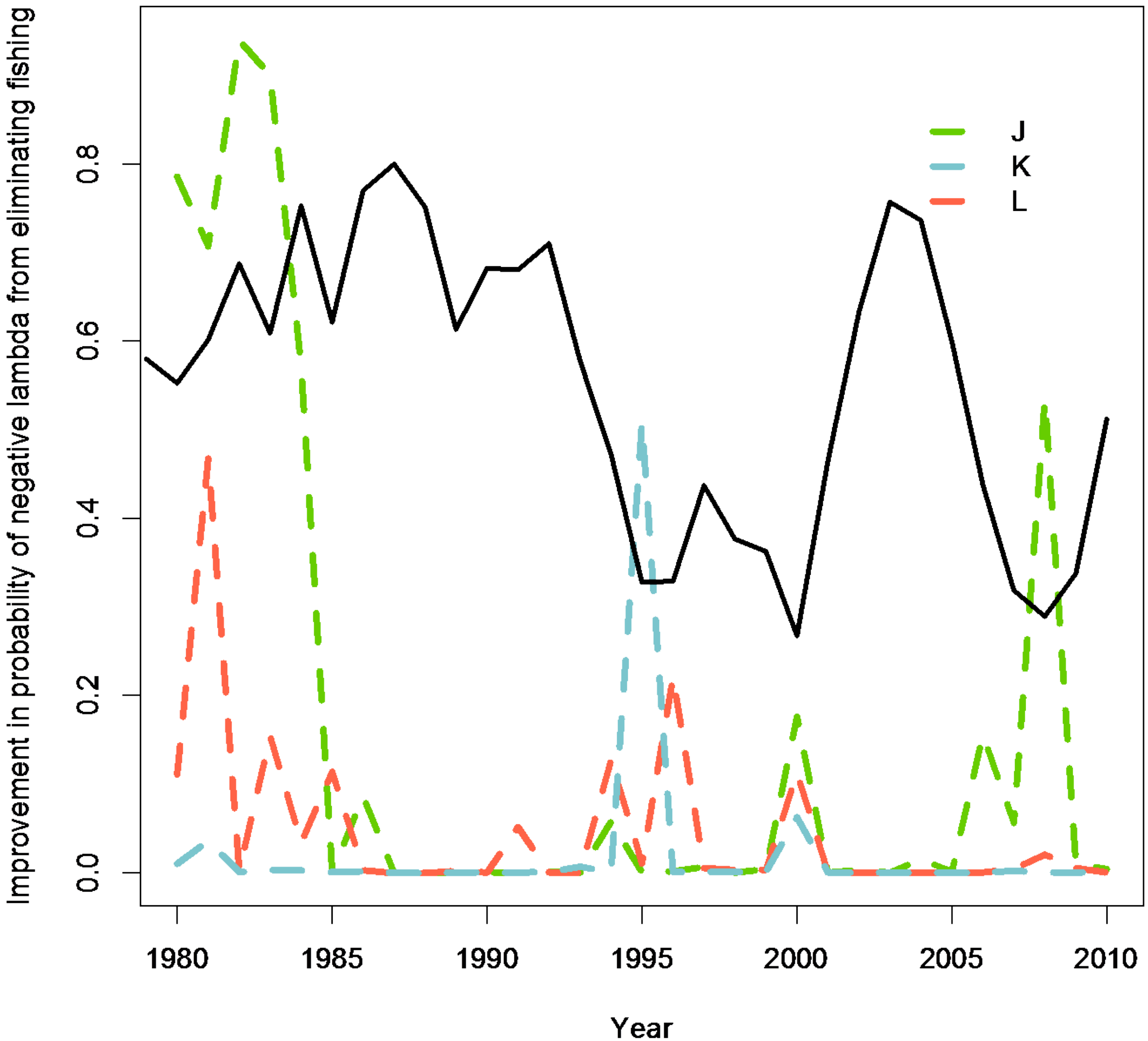
- Negative value interpreted as the percent change in growth, e.g. $-[0 – 0.02] = 0.02$
  - This represents a 2% decrease in the probability of negative growth

Improvement in Pr(λ < 0)



In early years, J pod would have a ~ 80% reduction in the probability of negative growth

Improvement in Pr(λ < 0)



If we overlay total run of the fall group, the biggest improvement since 1990 in the years with low salmon runs (not high fishing)

Summary of historical effect of fishing v. no fishing scenarios

- 1. Absolute improvement in λ^*
  - Recent effects = increase of 0.005
- 2. Percent improvement in λ^*
  - Recent effects = increase 0.5% (100 * 1.02/1.015)
- 3. Percent reduction in negative growth, Pr(λ^* < 0)
  - Not very informative for most years, but biggest effect recently in low salmon years

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Effects of fishing on stochastic growth rate (future)

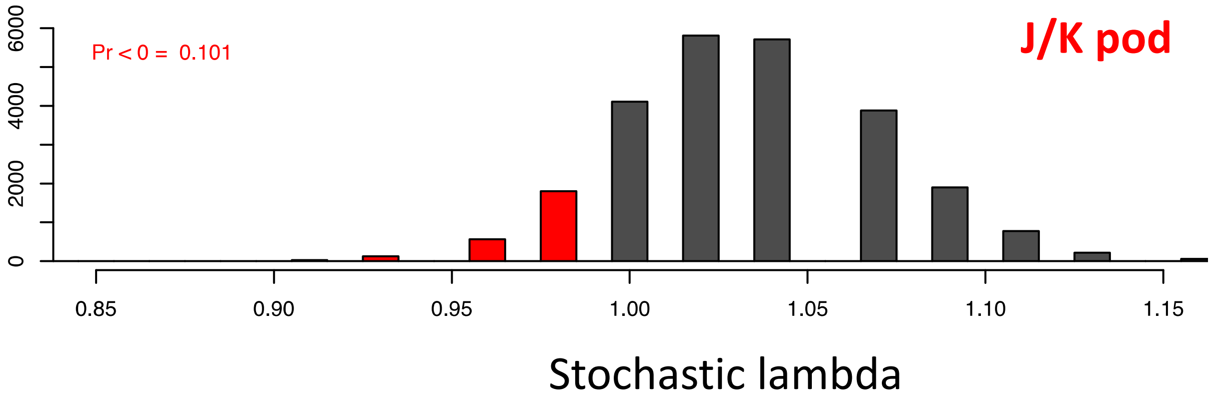
- 1. Begin with projections of no salmon model
  - Understand implications of age/sex structure
  - What are implications for where we are now??

- 2. Project model under different levels of salmon (fall index terminal run size)

Time projections: 50 years

- Previous work (P. Wade did projections based on 100s of years)
- Panel recommended shorter projections (3-5 years)
  - Scenarios blend together more as time increases
  - Especially if salmon is included and stochastic
- 50 years includes timeframe for recovery goals
  - 2.3% 14 years
  - 2.3% 28 years

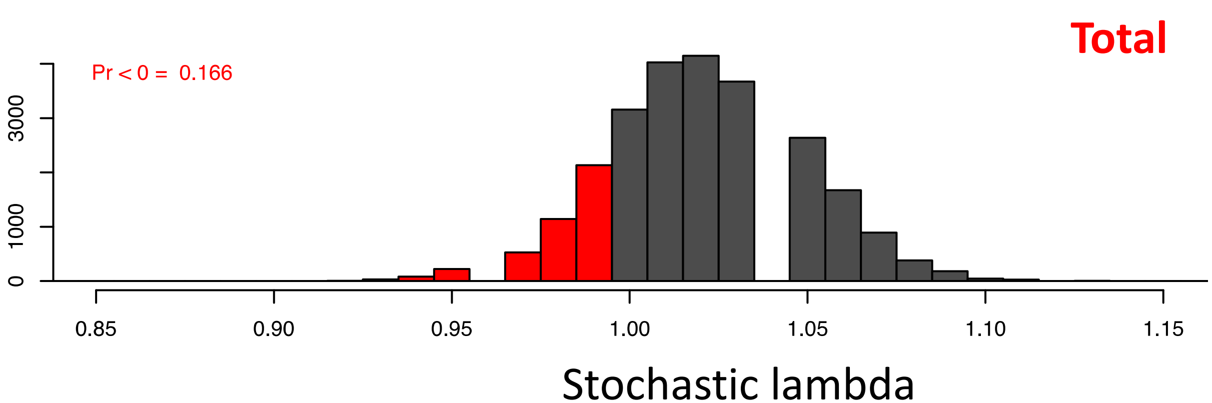
Stochastic growth rates (1 year)



L pod

316

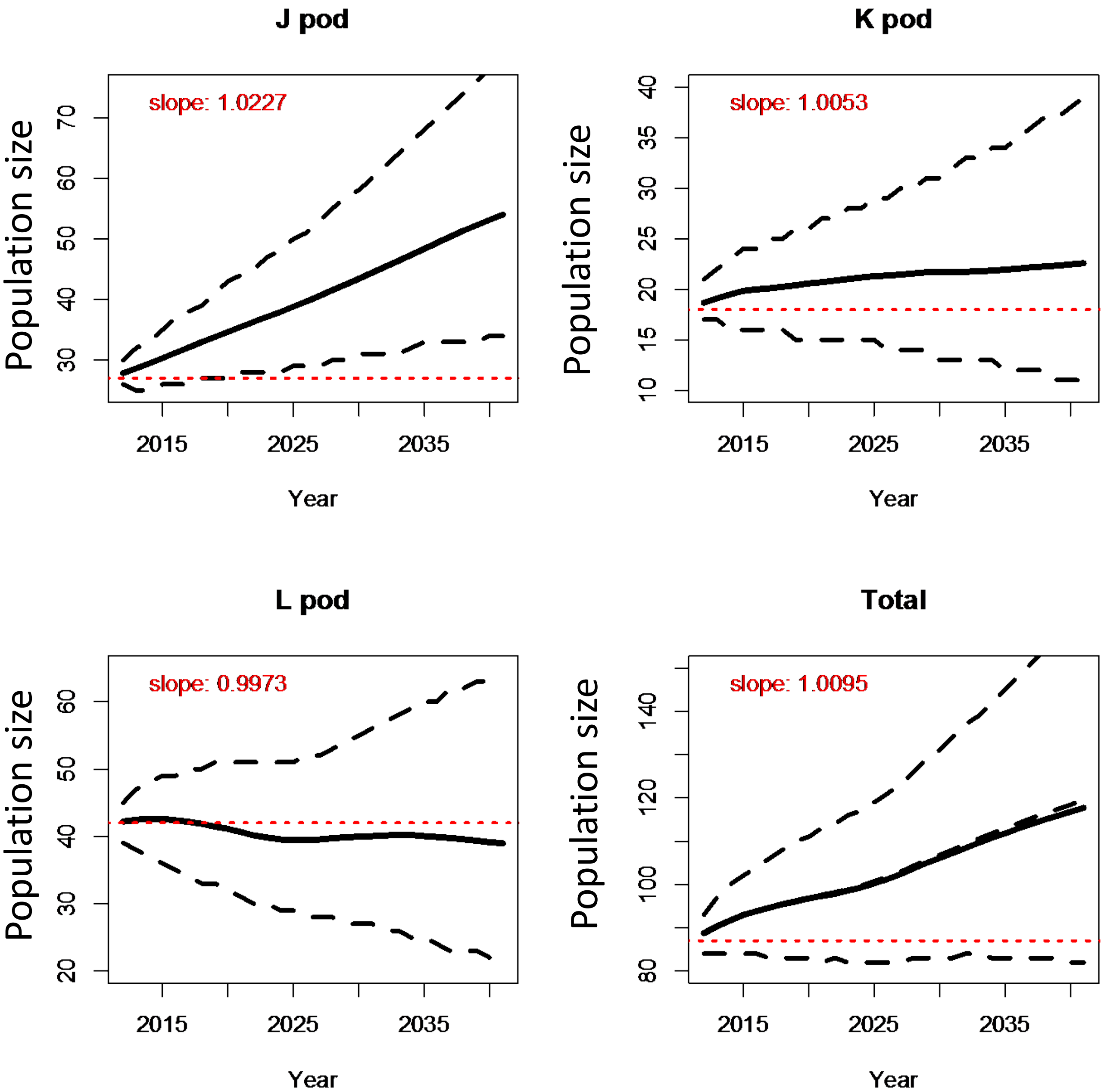
Stochastic lambda



1. More uncertainty than deterministic lambdas
- variance increases with time

2. Point estimates (means) conditioned on 2011 age/ sex structure

Projections: conditions don't change



- Recovery will be powered by J pod (lots of females, pod most often in inland waters)

L pod will likely go down a little before recovery criteria are met

K and L pod's growth is slow because of few young females

Females 15 or younger:
J pod: 10
K pod: 3
L pod: 3

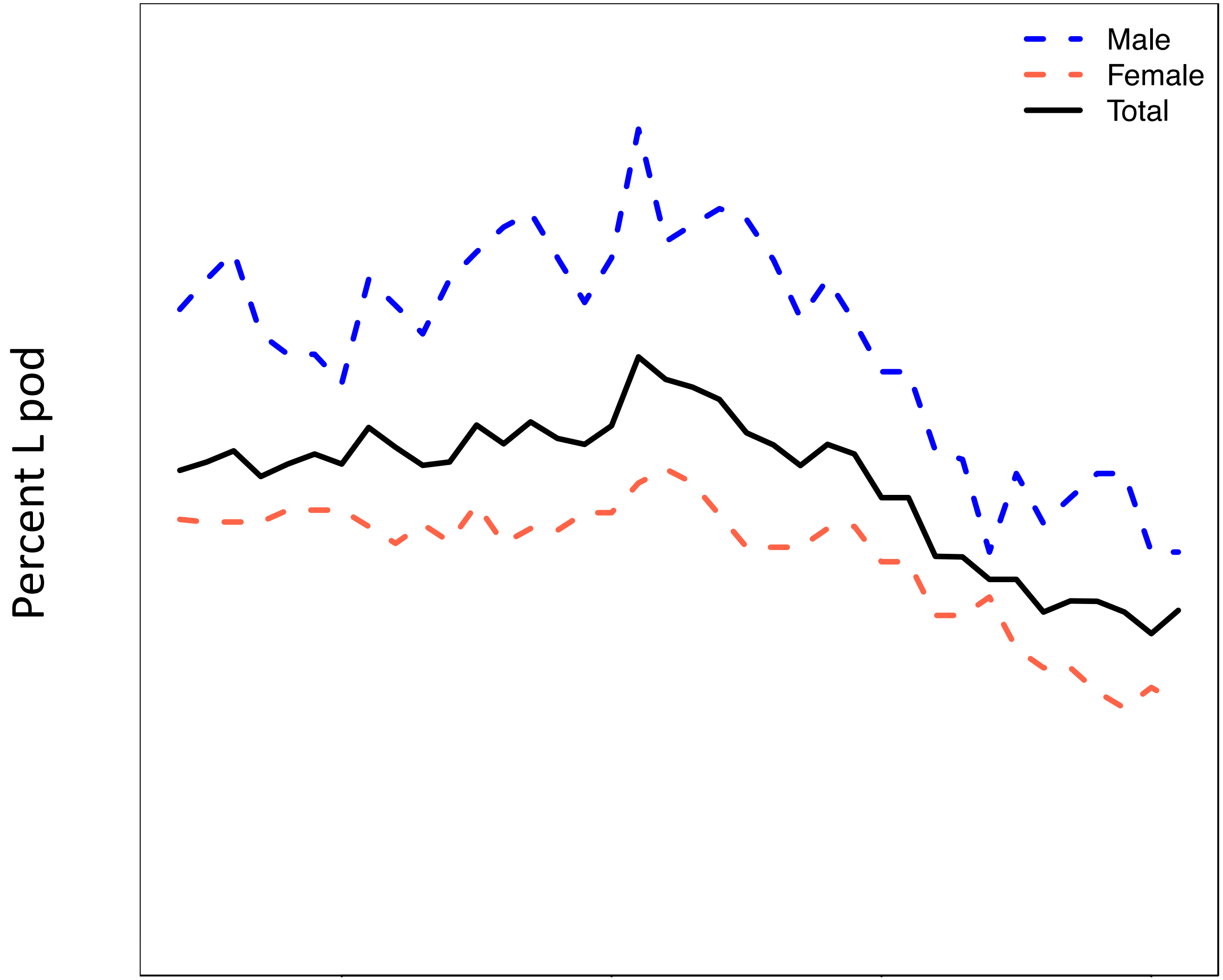
Unknown sex animals:
J pod: 0
K pod: 0
L pod: 4

J	K	L
1	1	1
1	3	2
4	6	8
6	17	16
6	24	16
8	25	18
10	26	20
11	33	21
13	39	21
15		24
16		25
18		34
26		34
32		34
34		37
37		
39		

<- L112

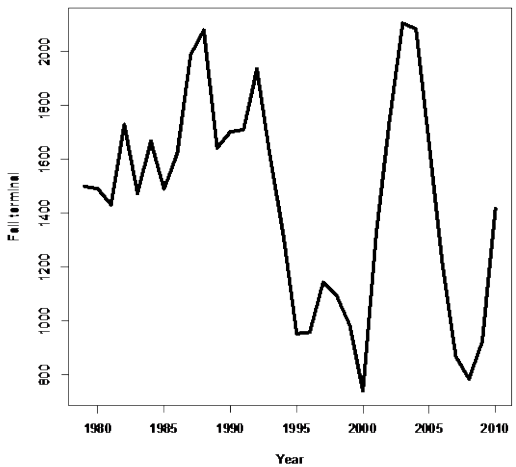
Ages of SRKW females < 40

L pod has made up a smaller fraction of the total population over time, and that trend will likely continue in the short term

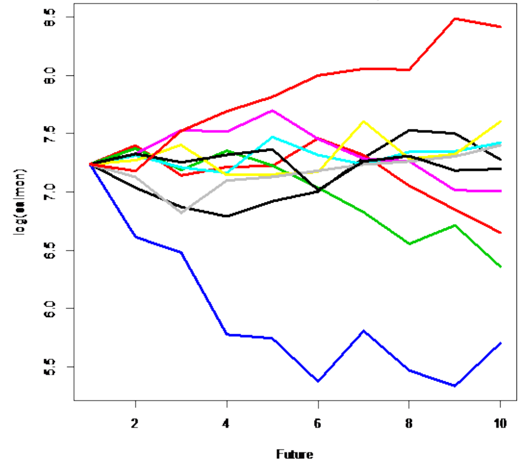


Schematic of salmon projections

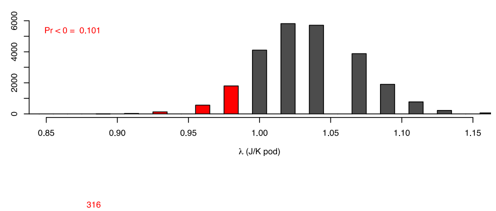
Begin with fall terminal index (Parken-Kope)

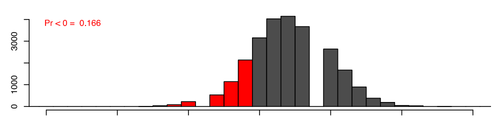


Simulate salmon trajectories



Calculate λ and recovery criteria





Project kw population:

- use posteriors from logistic regression models
- stochastic births and deaths
- uncertainty in sex ratio at birth
- simple rules for mating

Salmon projections

- Autocorrelated random walk

- De-trended
- Standardized to have target CV (5%, 20%)
- De-meaned to specified value of salmon abundance

- Different than Paul Wade's model
  - Alternating 7 years good luck, 7 years bad

Scenarios with salmon

- Case 1: No salmon in fecundity or survival relationships

- Case 2: Salmon (low variability, 5% CV)

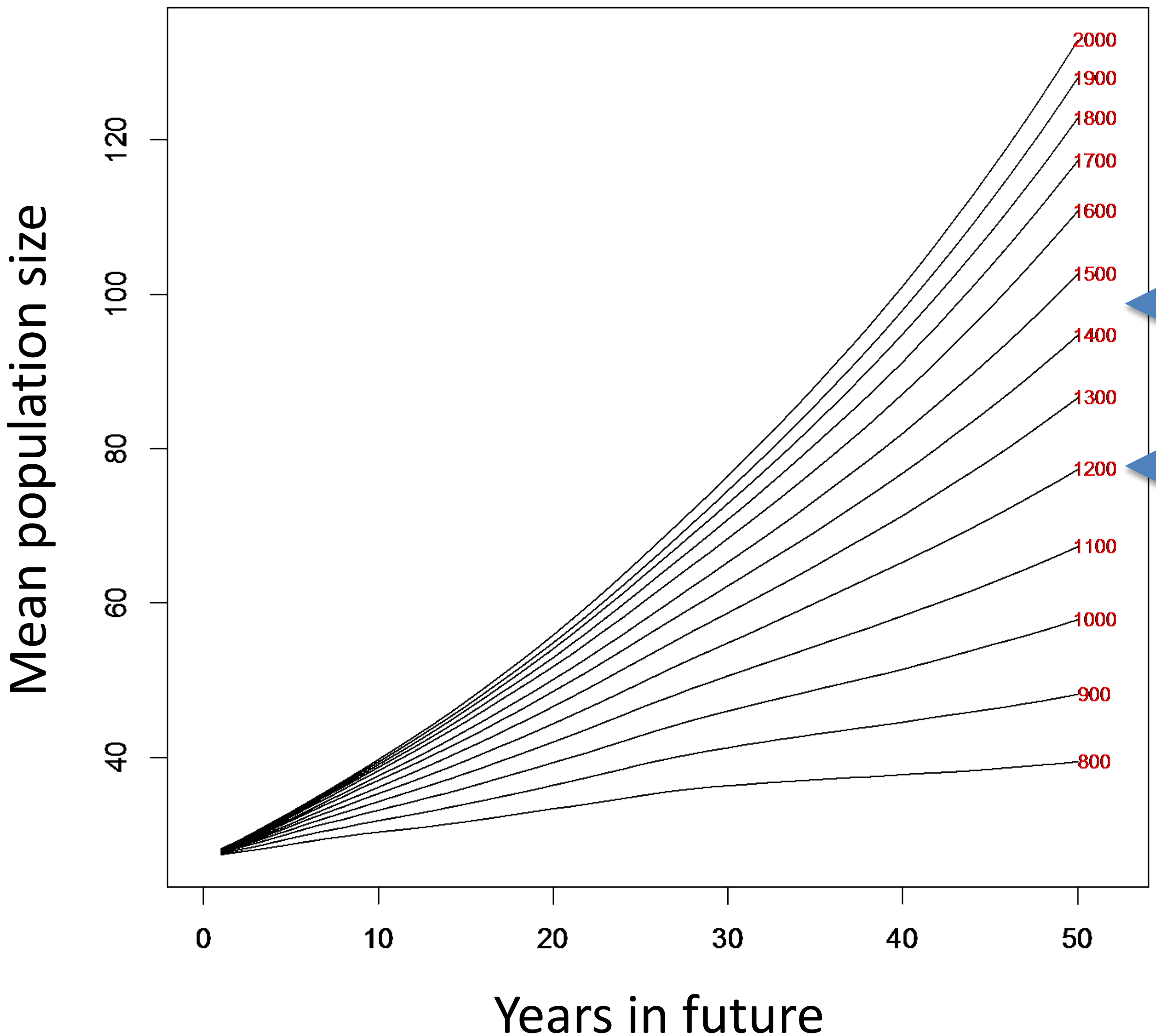
- Case 3: Salmon (high variability, 20% CV)

- To evaluate effect of fishing v no fishing, we can compare different forecasts, e.g. terminal run size of 1200 versus 1450 (an increase of ~ 20%)

Metrics to quantify effects

- Pod / total population size
  - Whales per year
- Probability of 95 whales by 2020 (Puget Sound Partnership)
- Probability of delisting / downlisting
- Future growth rate
  - Probability of negative growth
  - Probability of growth > 2.3%

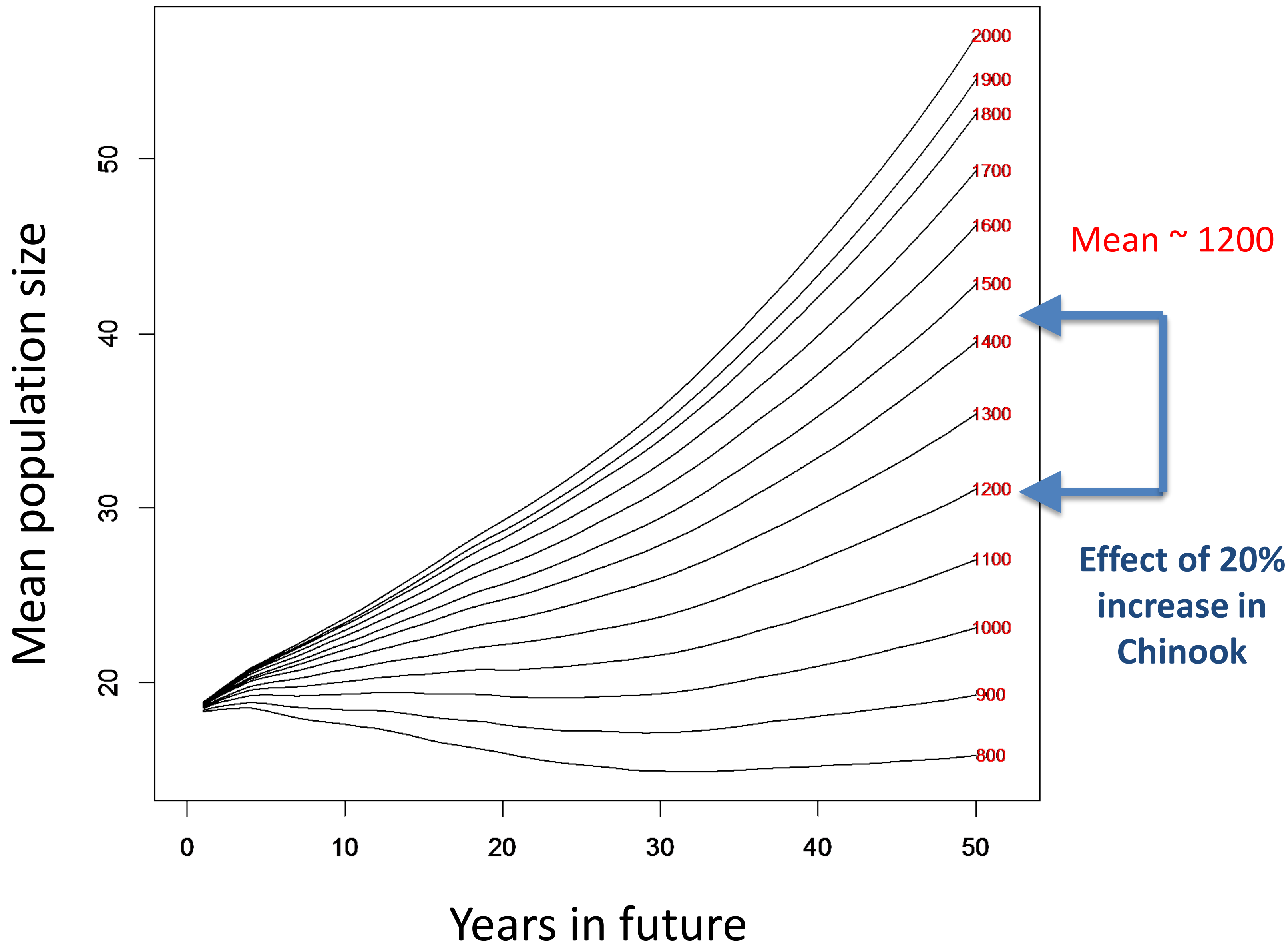
Case 2: Low salmon variability: J



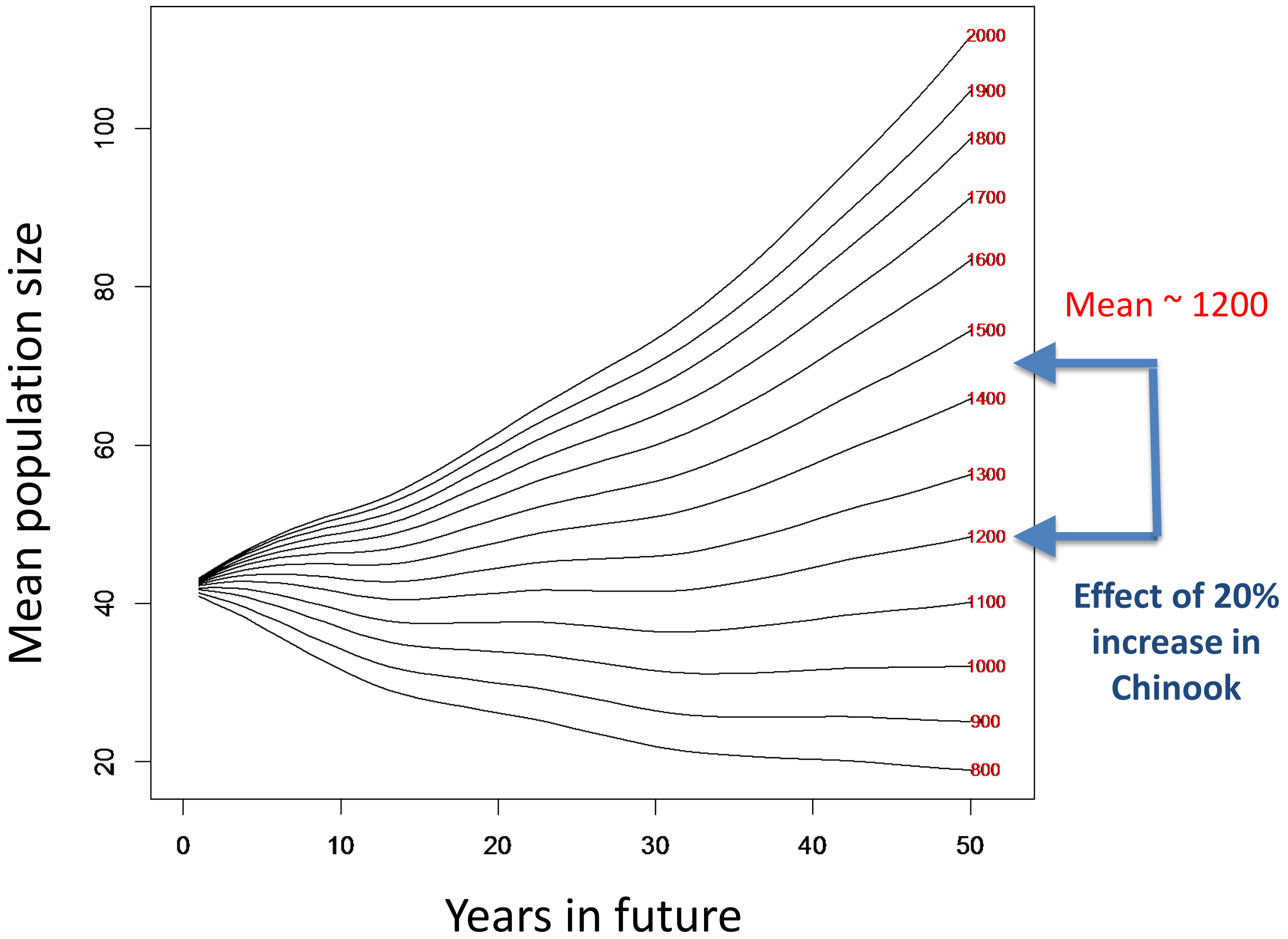
Mean ~ 1200

Effect of 20% increase in Chinook

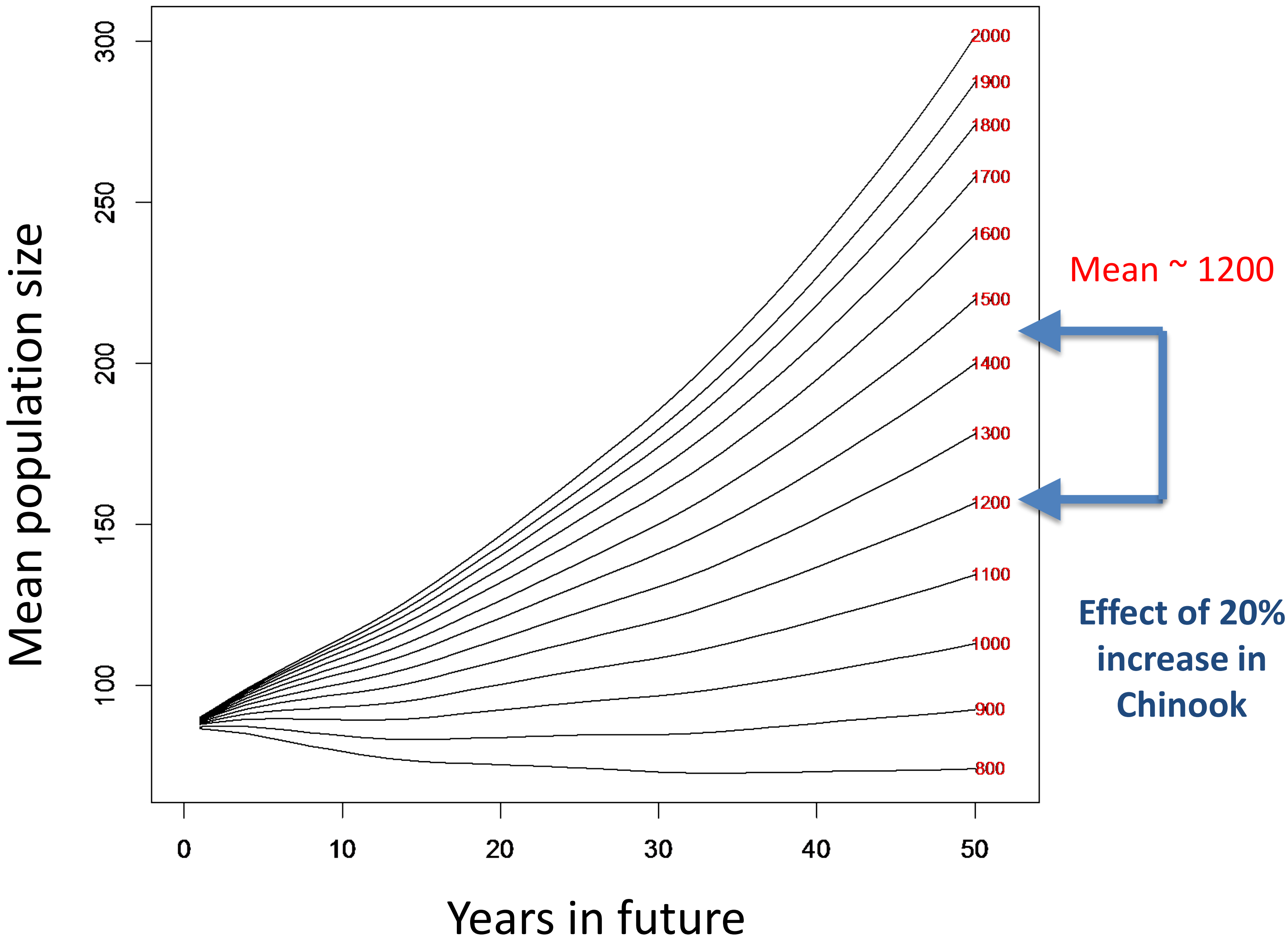
Case 2: Low salmon variability: K



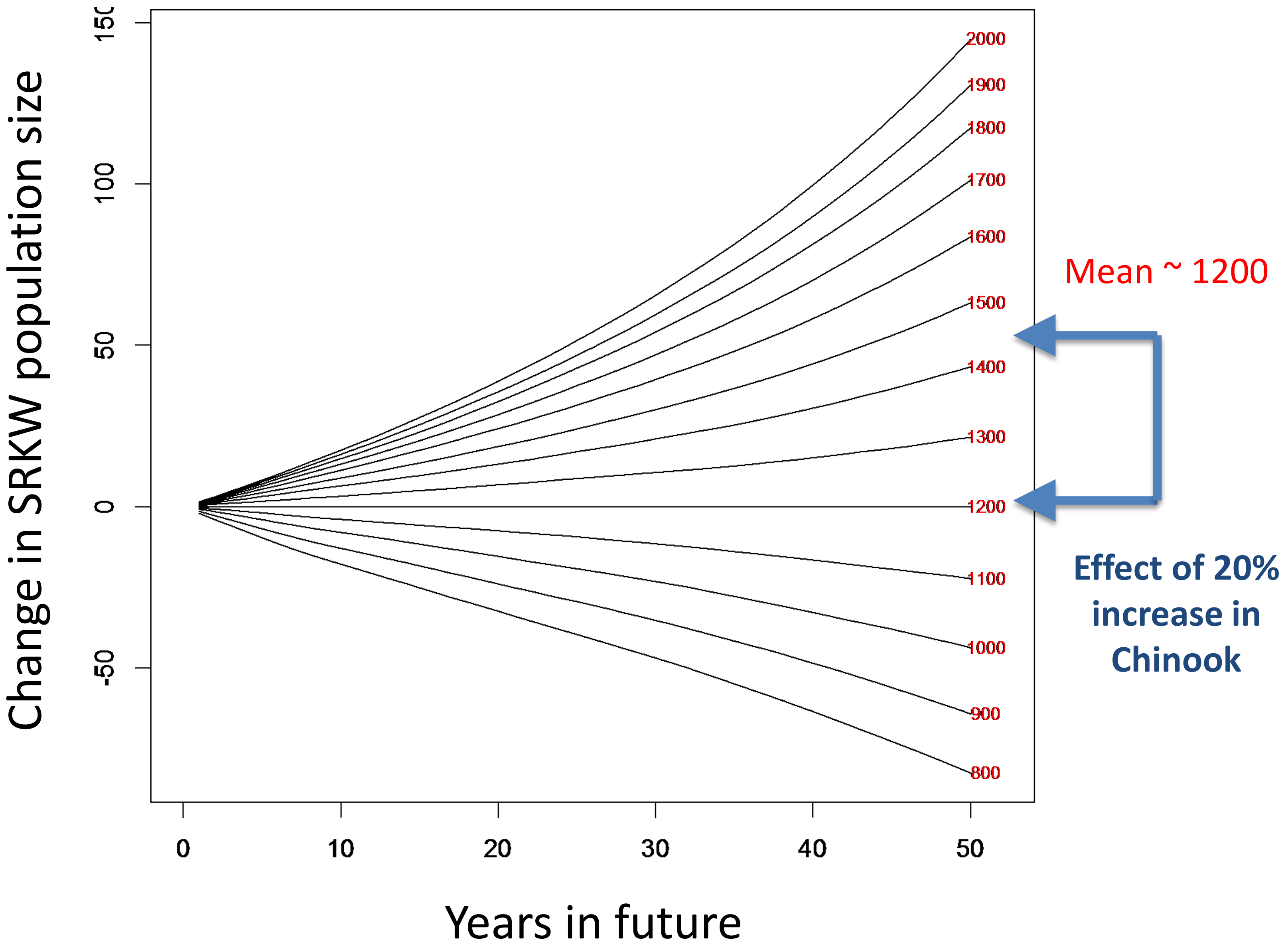
Case 2: Low salmon variability: L



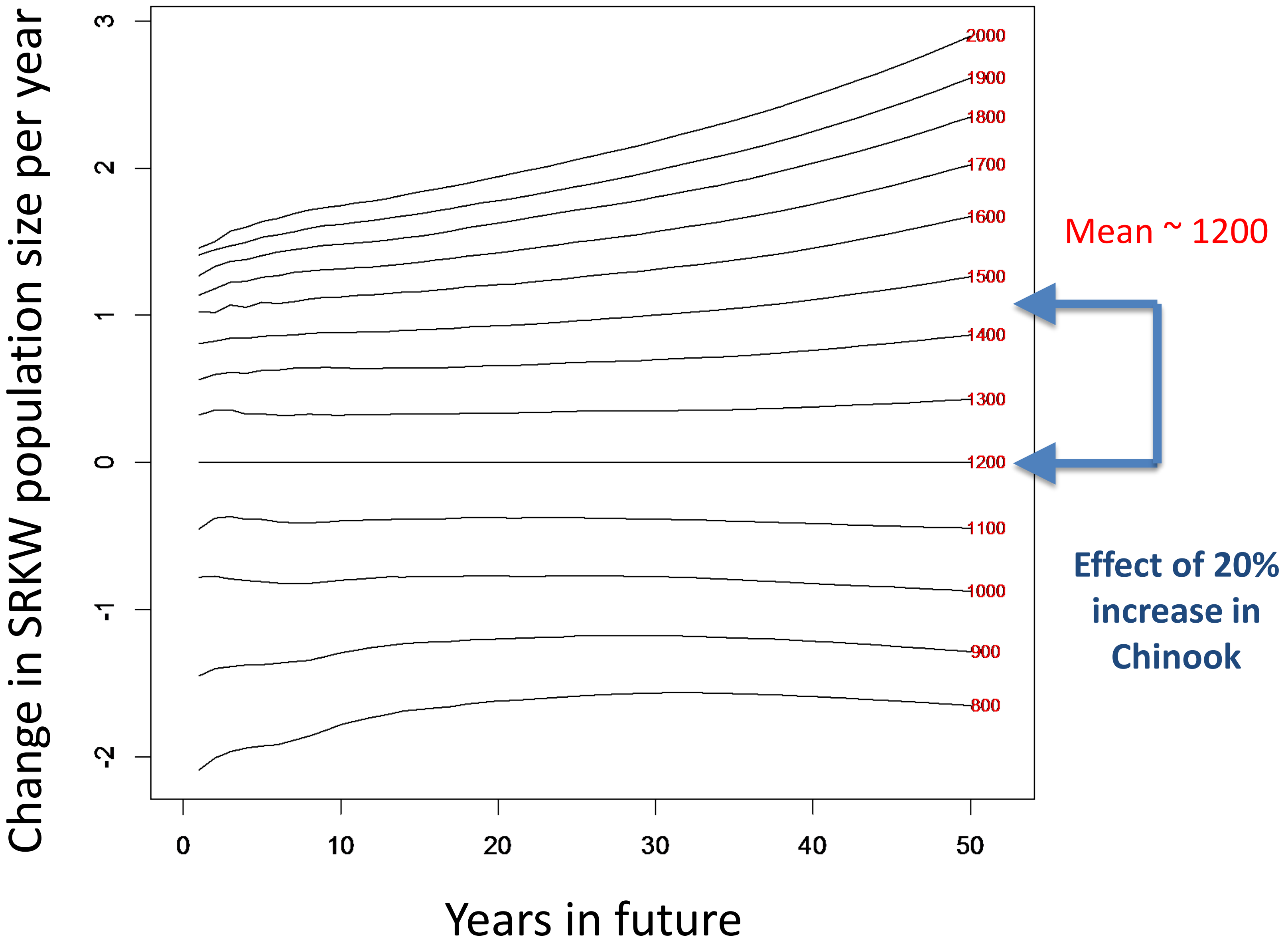
Case 2: Low salmon variability: all



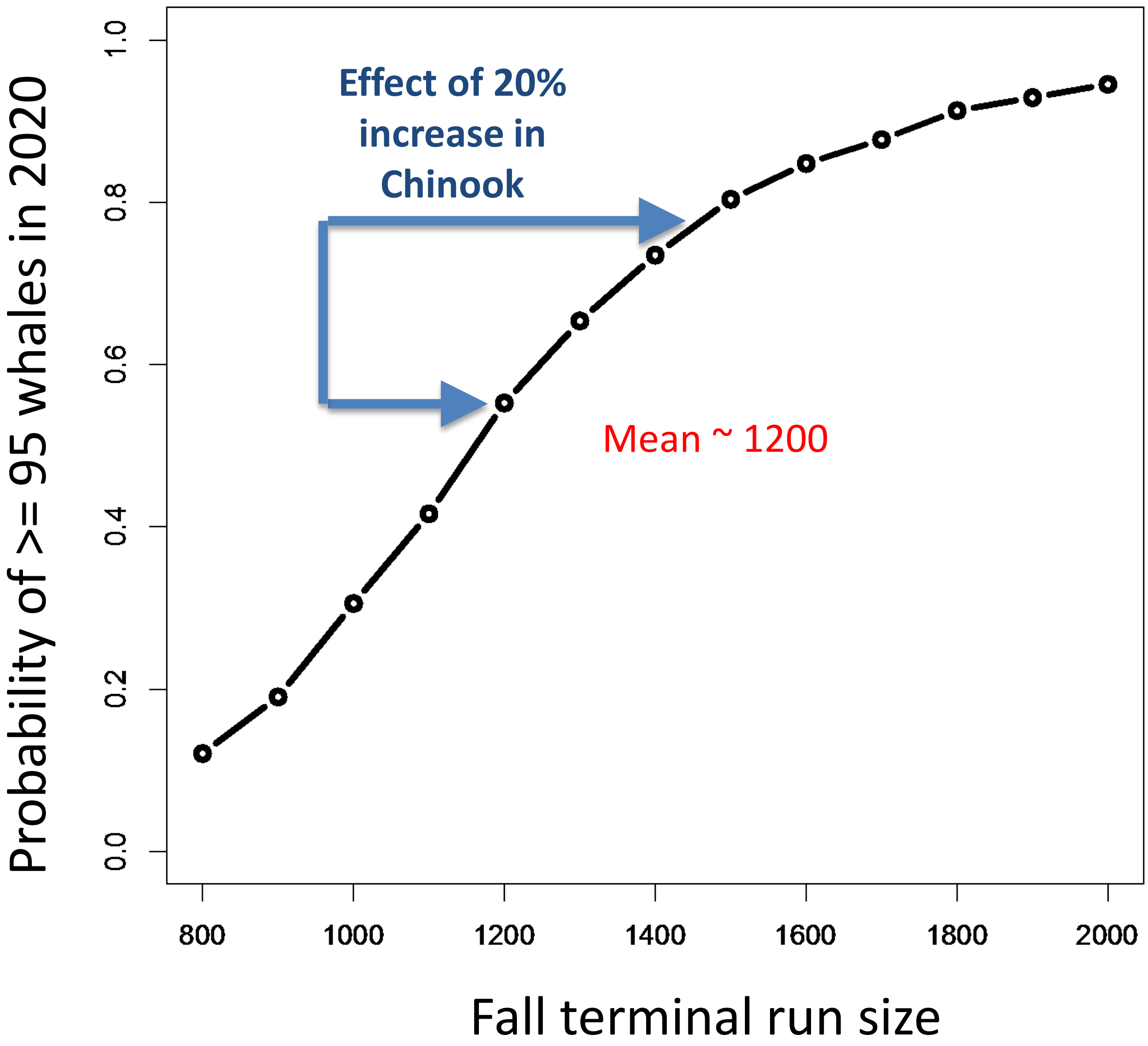
Case 2: Low salmon variability: all



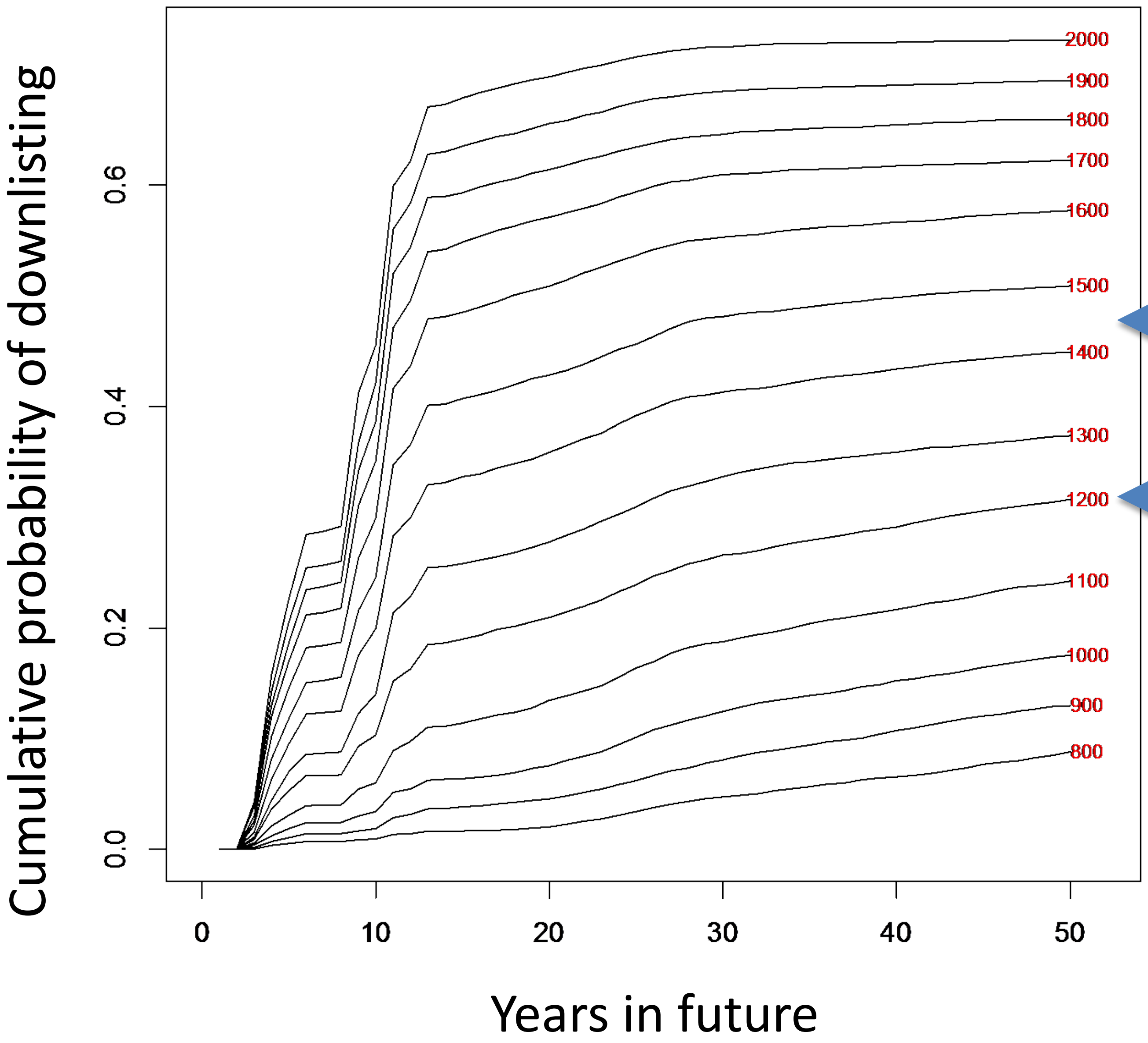
Case 2: Low salmon variability: all



Case 2: Low salmon variability: PSP goal



Case 2: Low salmon variability

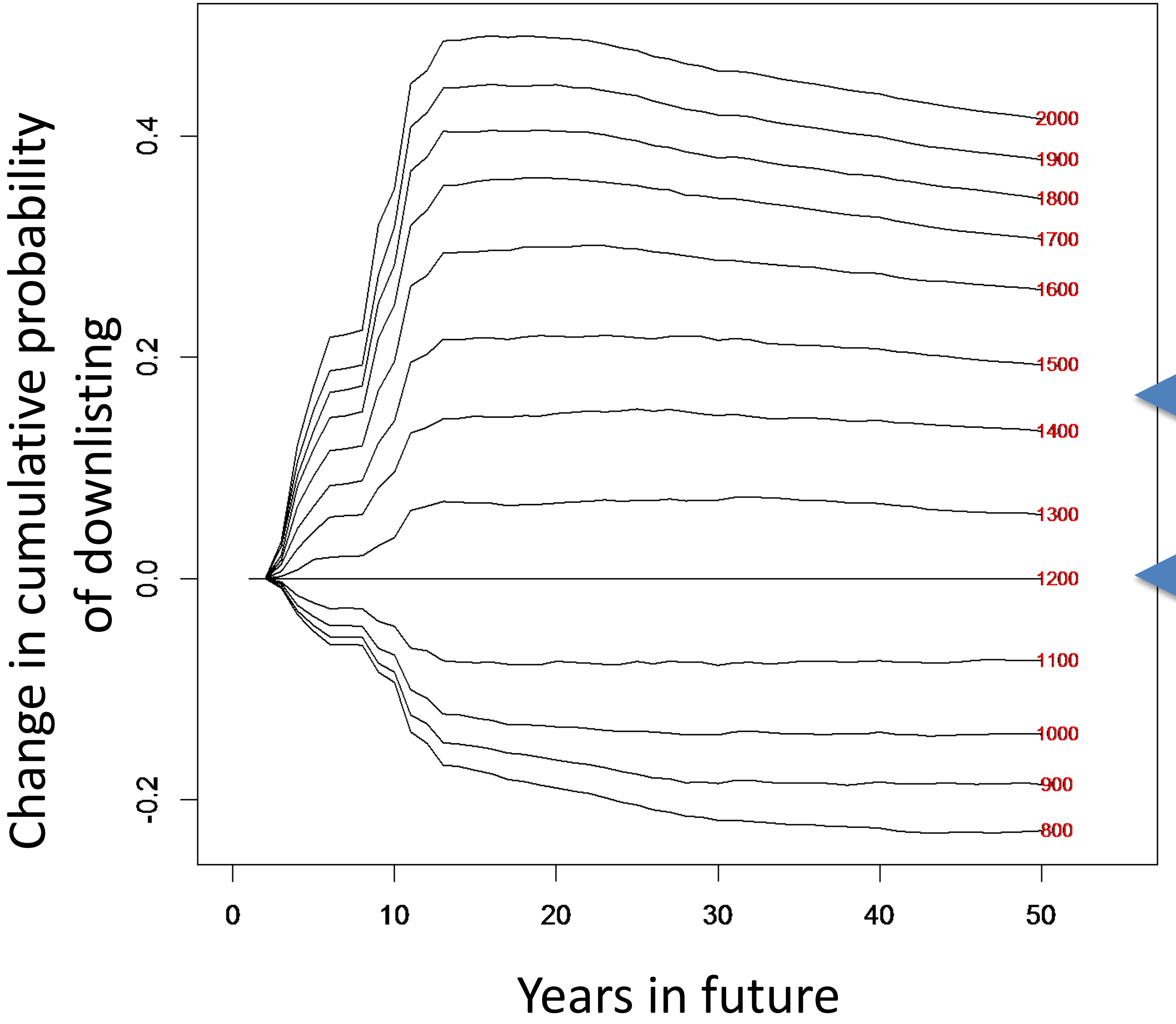


Downlisting:
2.3% growth for 14 years

Mean ~ 1200

Effect of 20% increase in Chinook

Case 2: Low salmon variability



<u>Downlisting</u>:
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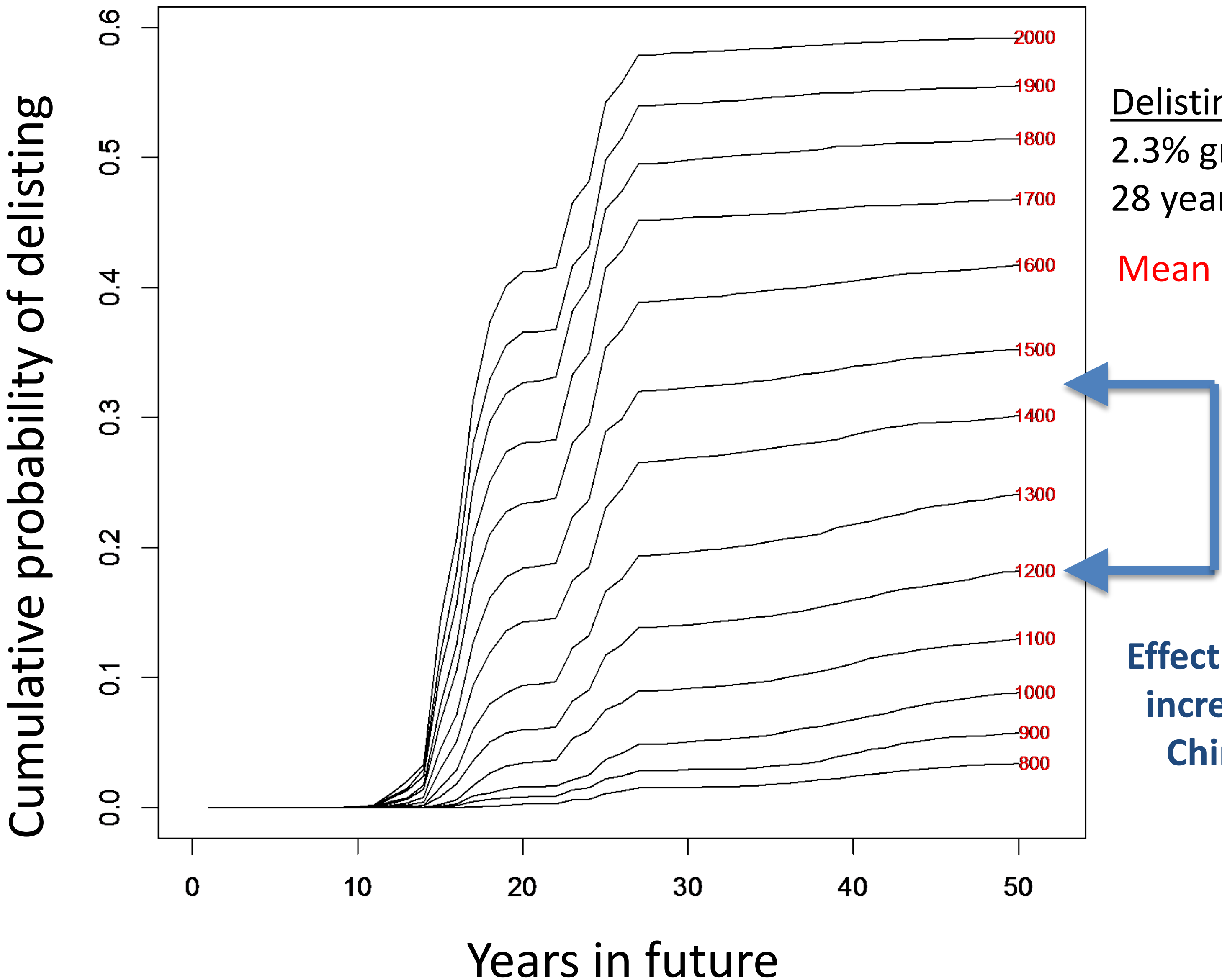
Effect of 20% increase in Chinook

Case 2: Low salmon variability

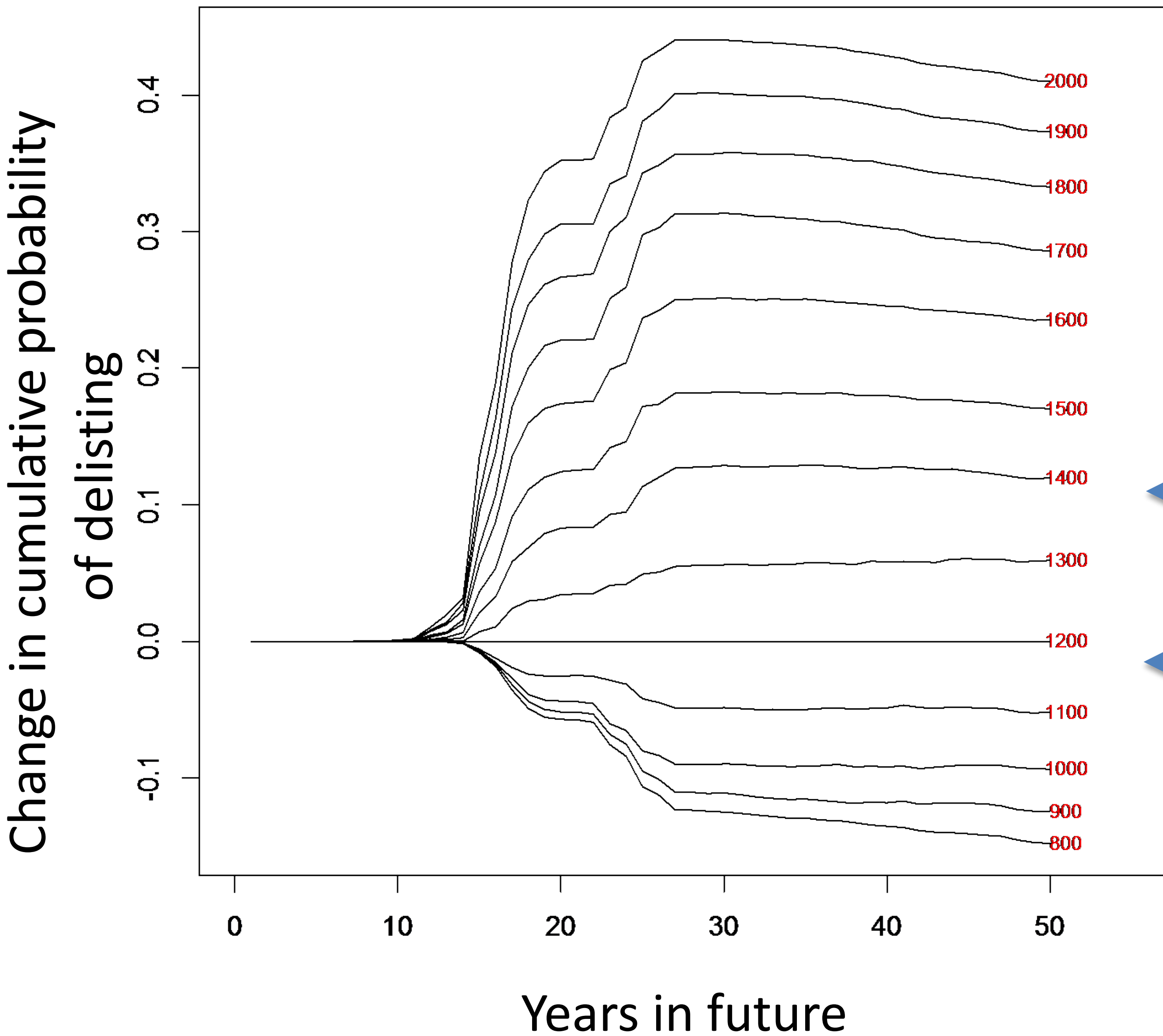


<u>Delisting</u>:
2.3% growth for 28 years

Mean ~ 1200

Effect of 20% increase in Chinook

Case 2: Low salmon variability

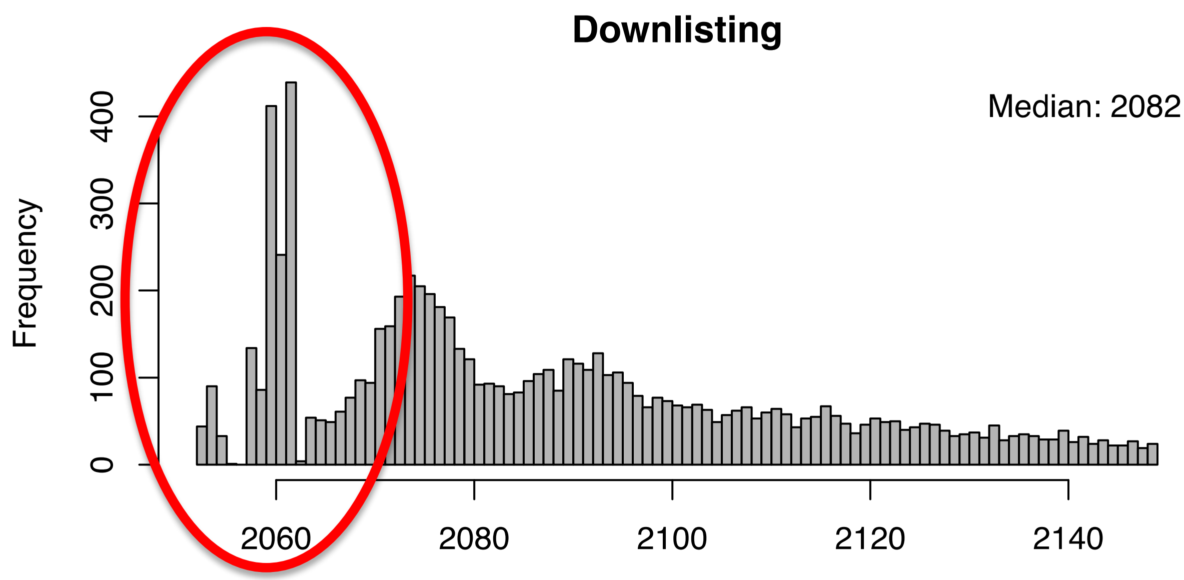


Delisting:
2.3% growth for 28 years

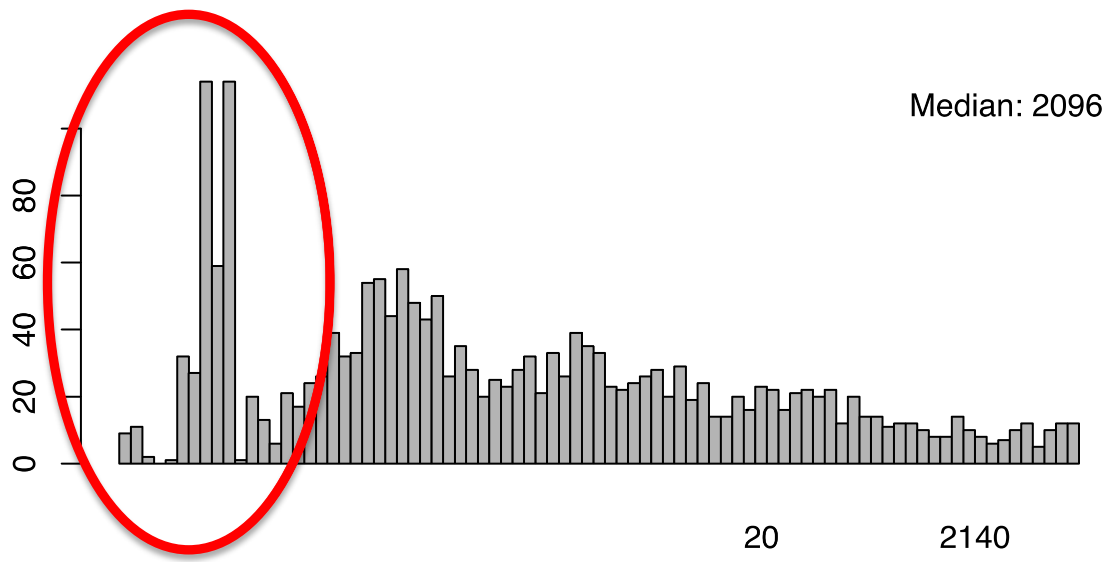
Mean ~ 1200

Effect of 20% increase in Chinook

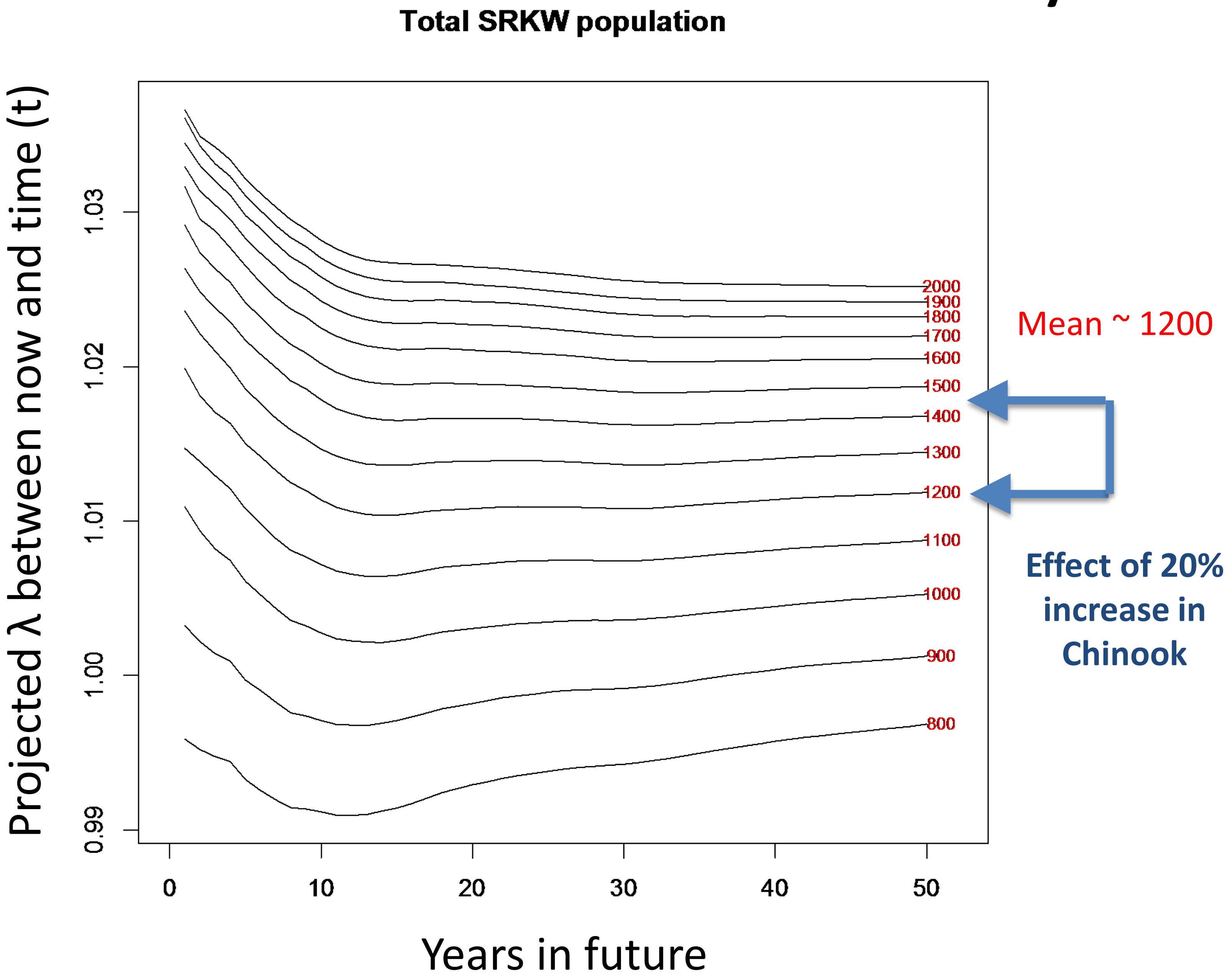
Distribution of recovery: current conditions



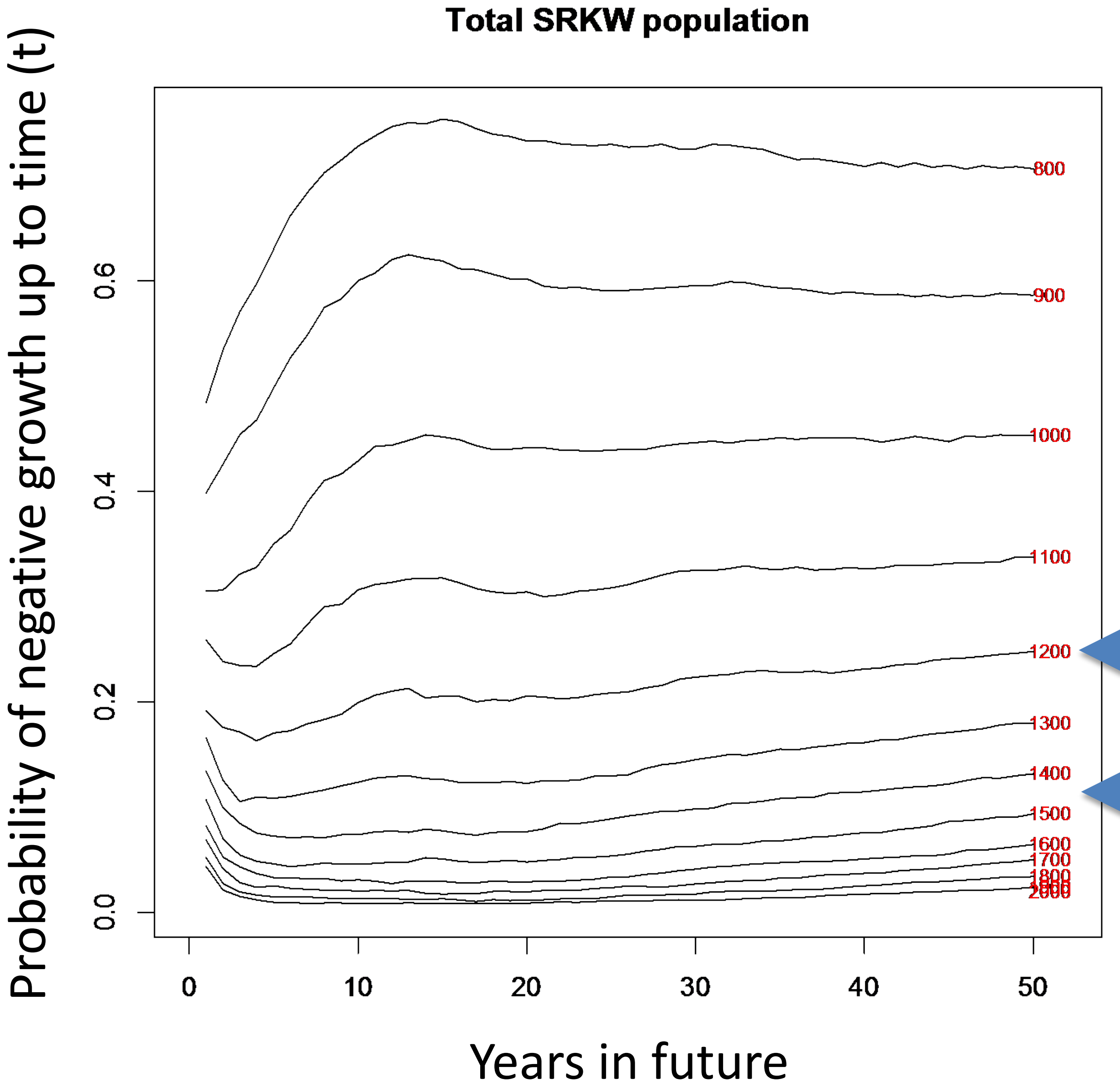
Recovery more likely with small population sizes (easier to maintain 2.3%)



Case 2: Low salmon variability



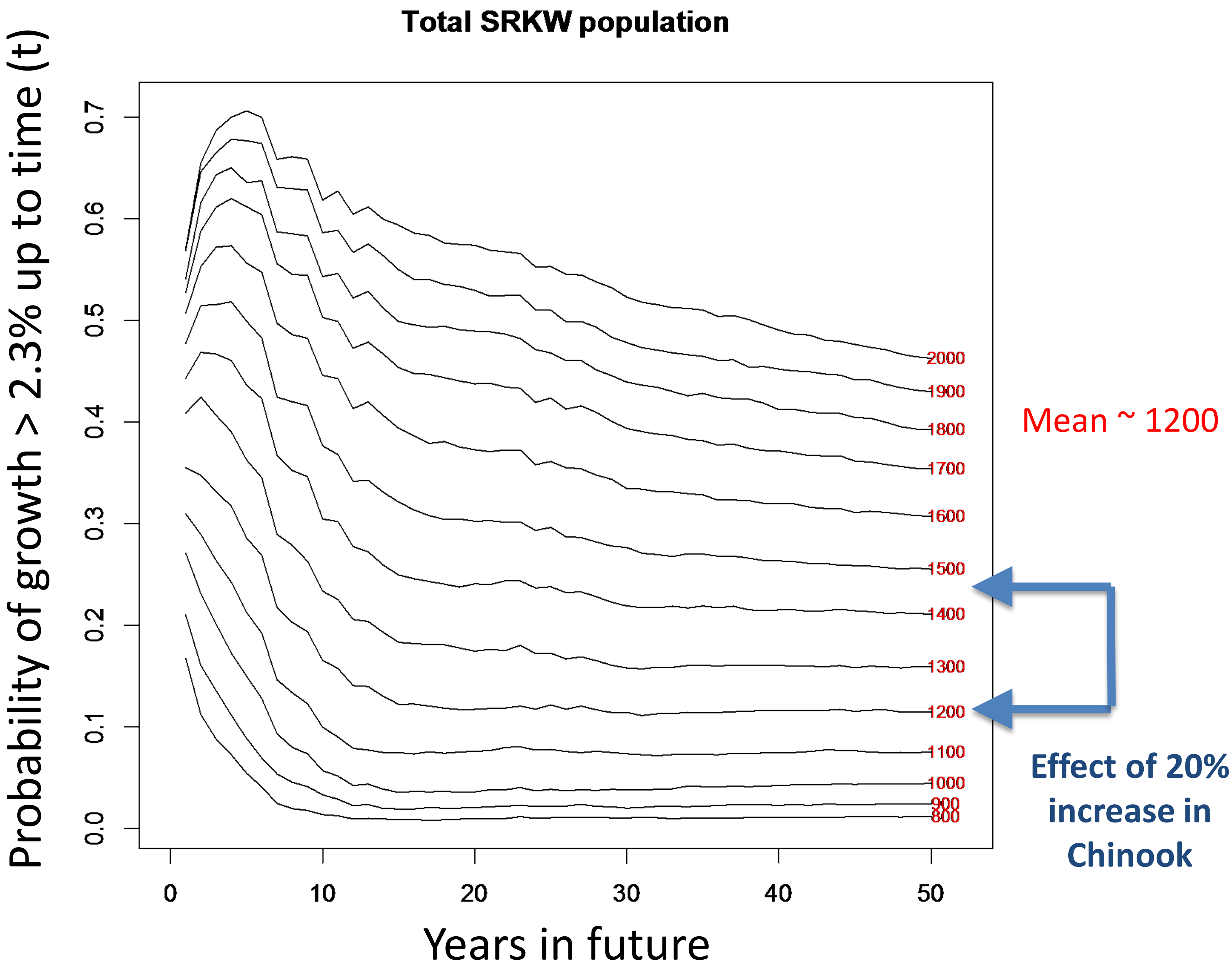
Case 2: Low salmon variability



Mean ~ 1200

Effect of 20% increase in Chinook

Case 2: Low salmon variability



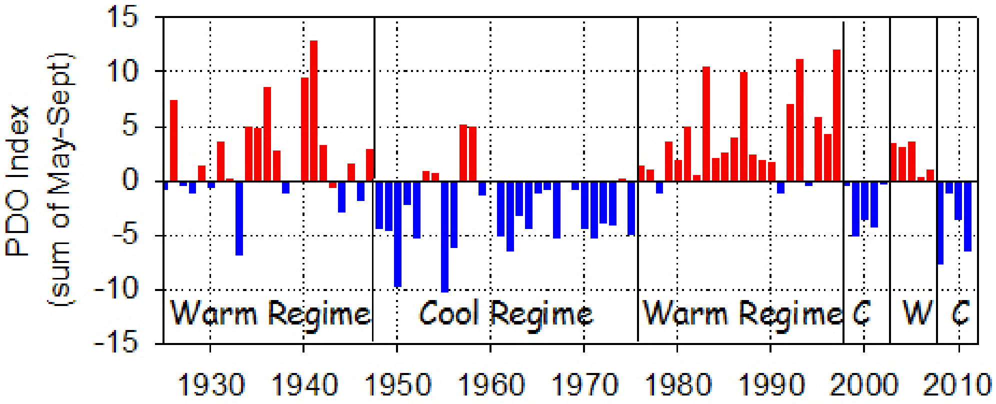
Effects of more variability (case 3): scenarios blend together with high var

- Allows much higher growth rates (many unrealistic) > 15%
- Much more difficult to assess how different levels of salmon might affect growth

- Tradeoff: short projections with realistic CVs OR long projections with low variability?
  - Metrics like extinction risk sensitive to this choice, metrics like mean population size are less so

Forecasting salmon is challenging because forecasting climate is challenging

- 7 year model may be good over period 1979-2010
- Different stocks may be affected by different processes (inverse production hypothesis)



- Most ENSO forecasts work on a time scale of 6 months – 2 years

Summary (conditions don't change)

- Pr(downlisting) ~ 31%
- Pr(delisting) ~ 18%
- λ ~ 1.5% / year
  - J growth > K growth > L growth
- Pr(λ < 0) ~ 20%
- Most likely scenario: slow growth, no delisting or downlisting or extinction