Summary of lambda & Killer Whale growth rates

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Recovery Criteria for ESA listed species

- Objective, measureable criteria
  - Downlisting- determine that species/DPS no longer in danger of extinction
  - Delisting- determine that species/DPS not liekly to become endangered int eh foreseeable future
- Types of criteria
  - Biological
    - % population growth over time
    - Extinction risk (no more that 1% chance of extinction in 100 years)
    - Total abundance, abundance of sub-populations
  - Threats based

Recovery Criteria for SRKW

- Delisting Biological Criteria
  - Increasing population trend at average growth rate of 2.3 % per year for 28 years
  - Available information on social structure, calf recruitment, survival, population age structure and gender ratios consistent with increasing or stable population
    - Quantitative measures include: representation from all three pods, more than 2 reproductive age males per pod, ratio of juvenile, adult and post-reproductive females and males similar to NRKW, adequate interbirth intervals for populations growth, no significant increase in mortality for any sex or age class.

Recovery Criteria for SRKW

- Downlisting Biological Criteria
  - Increasing population trend at average growth rate of 2.3 % per year for 14 years
  - Available information on social structure and population structure consistent with increasing or stable population
    - Quantitative measures for some population parameters: representation from all three pods, at least 2 reproductive age males per pod

Data Supporting Recovery Criteria

- Past growth rates
  - 1974-1980 average growth of 2.6 % per year
  - 1984-1996 average growth of 2.3% per year
  - Comparison to NRKW growth1974-1991 3.4% per year, 1991-1997 3% per year
- Time frame to encompass variability
  - PVA for 2004 Status Review “best fit” analysis for survival had 14 year cycles with 7 years high and 7 years low survival
  - Downlisting 1 full cycle, Delisting 3 full cycles
  - Age at maturity

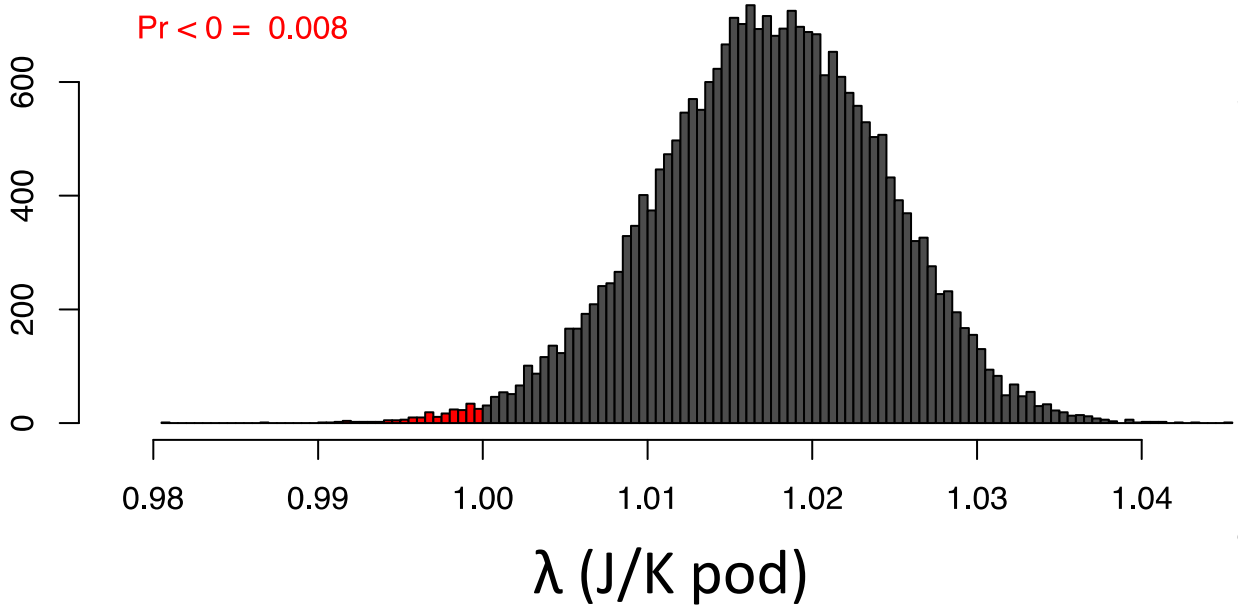
Scenarios for Meeting Recovery Criteria

- Delisting
  - 81 whales in 2001 with 2.3% avg annual growth for 28 years = 155 whales in 2029

- Downlisting
  - 81 whales in 2001 with 2.3% avg annual growth for 14 years = 113 whales in 2015

1. Estimating constant λ for SRKW

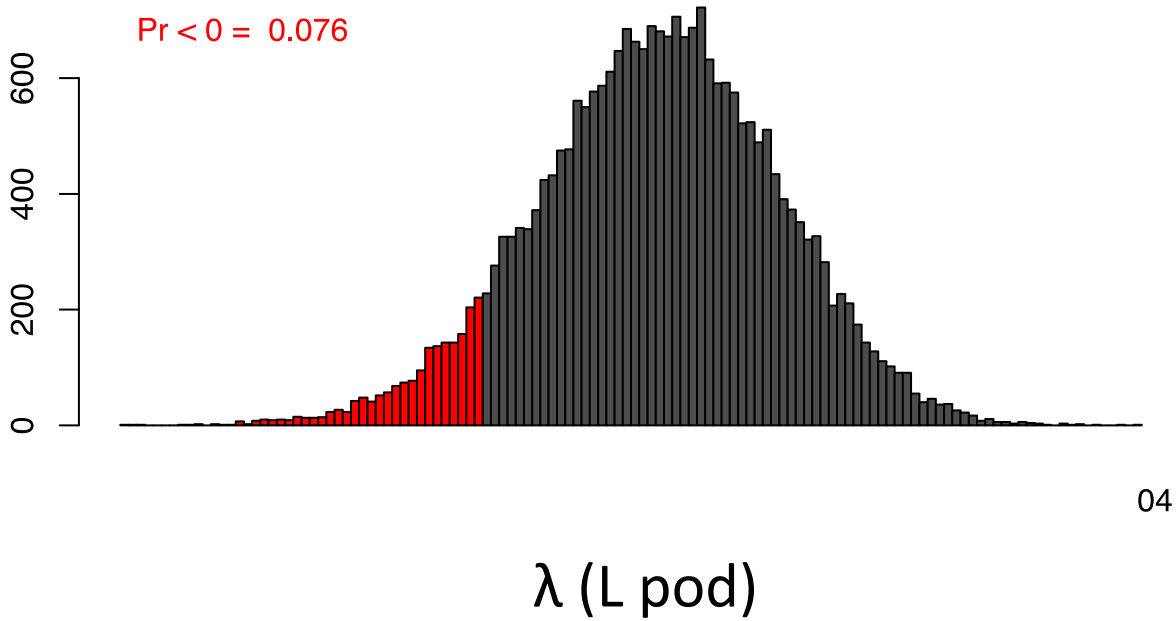
- Apply Bayesian logistic regressions to SRKW data 1974-2011 (Sharepoint)
  - Age structured fecundity
  - Stage structured survival (L pod different)
- This quantifies long term average growth rate, or “replacement of females by females”



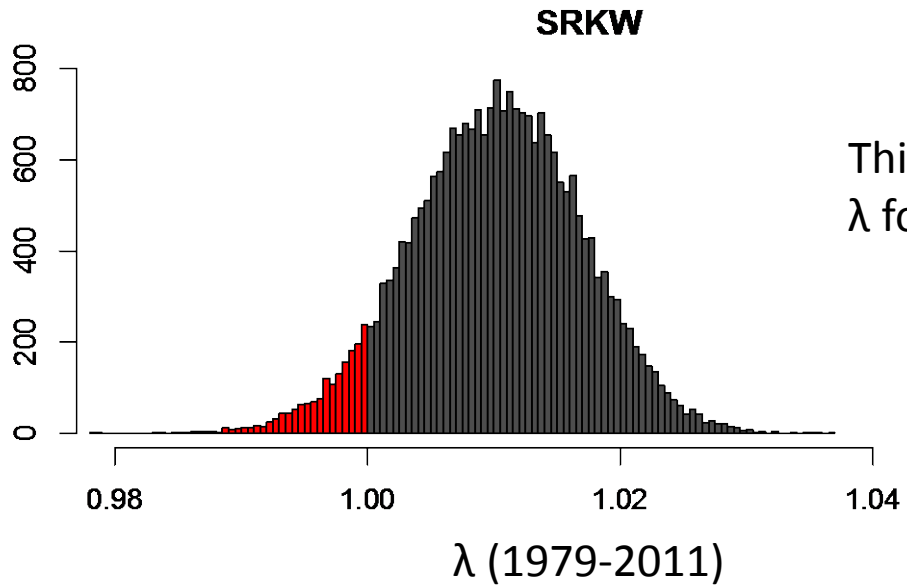
While SRKW population has declined in some years historically, estimates of λ are overwhelmingly positive

Mean λ is less than recovery goal (1.023)

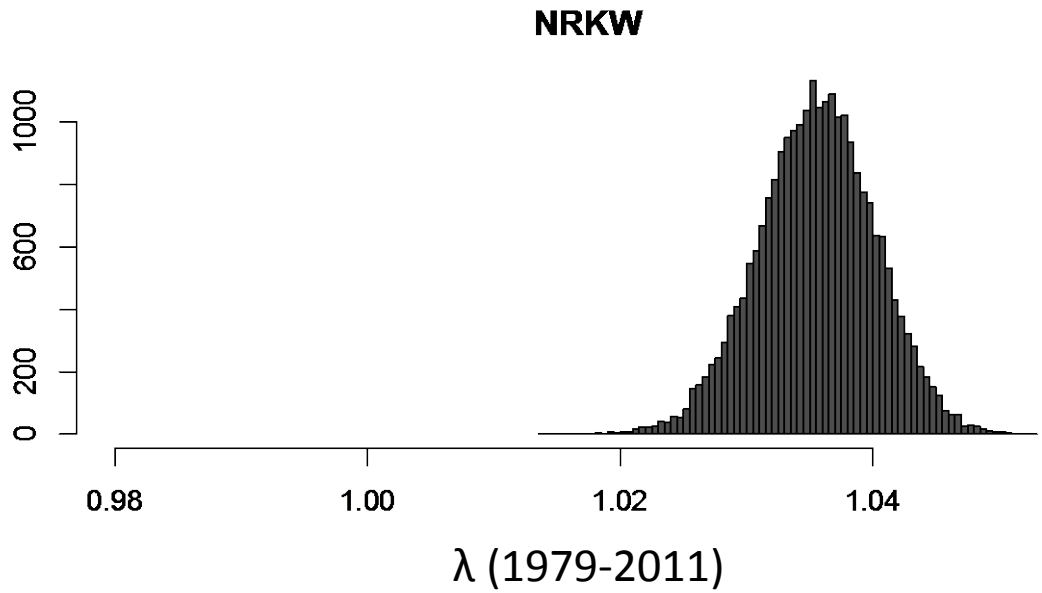
These estimates are higher than just doing a regression in log-space because this is females only



Probability distributions were calculated separately for NRKW (with J. Ford)



This represents the average of λ for J/K and L pods



Larger than Solange & Caswell (1993)

Slightly higher than Olesiuk et al. 2005 (2.8%)

2. Time varying λ

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

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

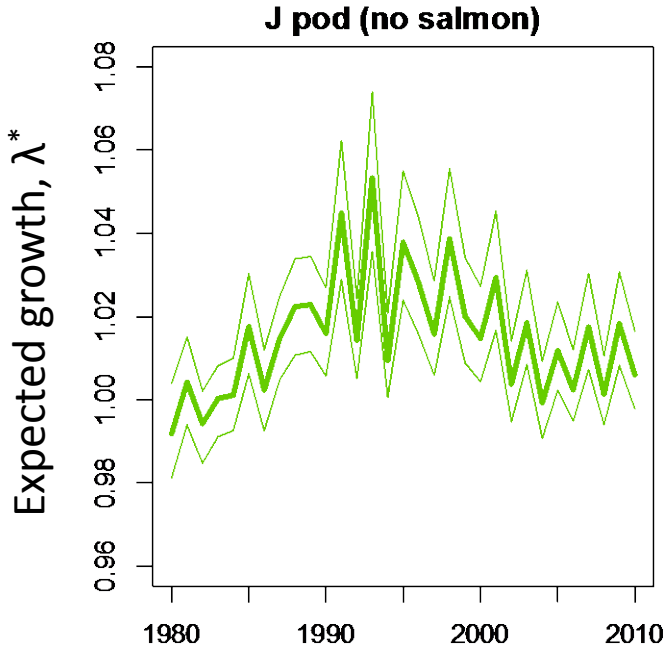
- Differs from λ, which is the expected growth rate of a population at equilibrium (stable age / sex distribution)

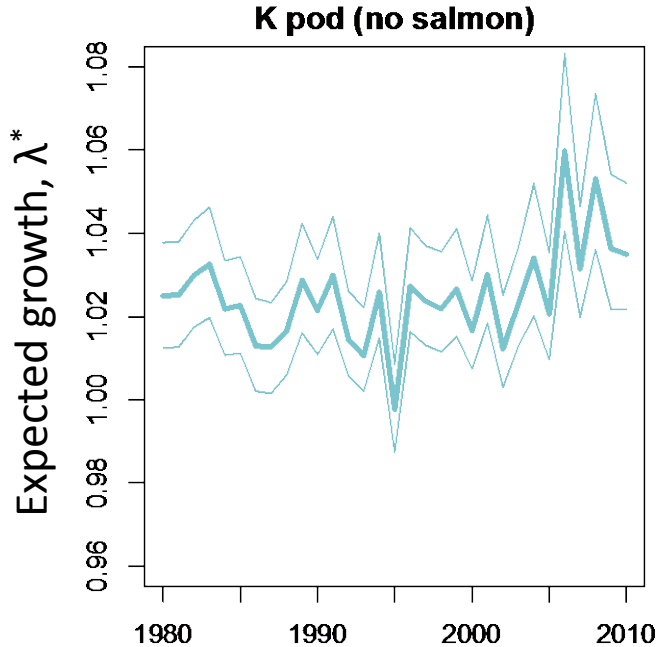
Caveats

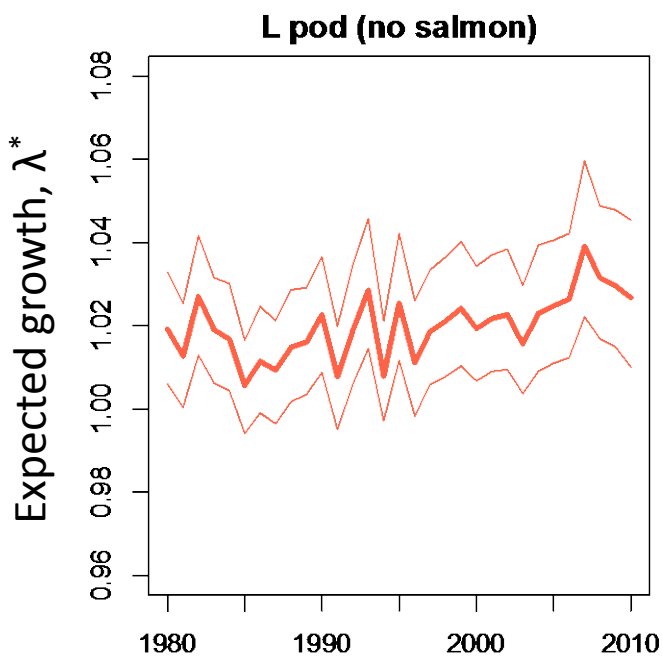
- Still females only (< 42), 3 groups:
  1. Females available to give birth
  2. Females not available to give birth
  3. Juveniles of unknown sex (fractionally assigned)

- No demographic / environmental stochasticity
  - This is a historical analysis, and we know exactly who survived (or didn't) from one year to the next
  - DO include uncertainty in sex ratio at birth

Growth by pod (no salmon in model)







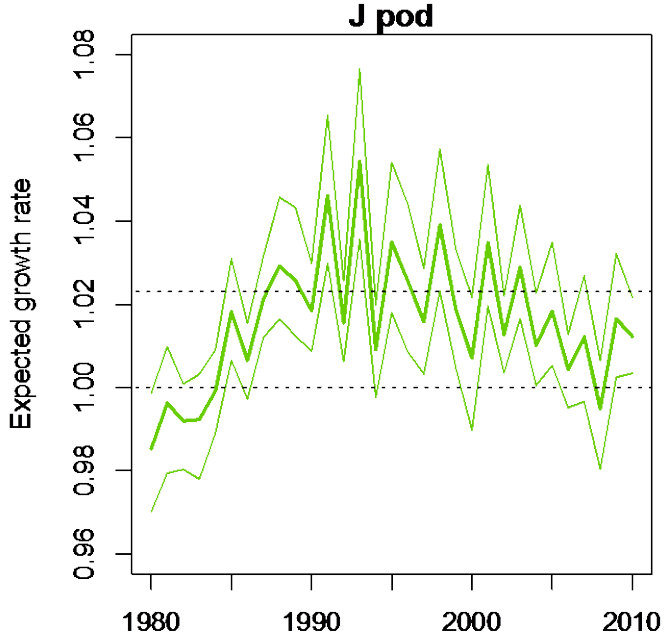
Include:

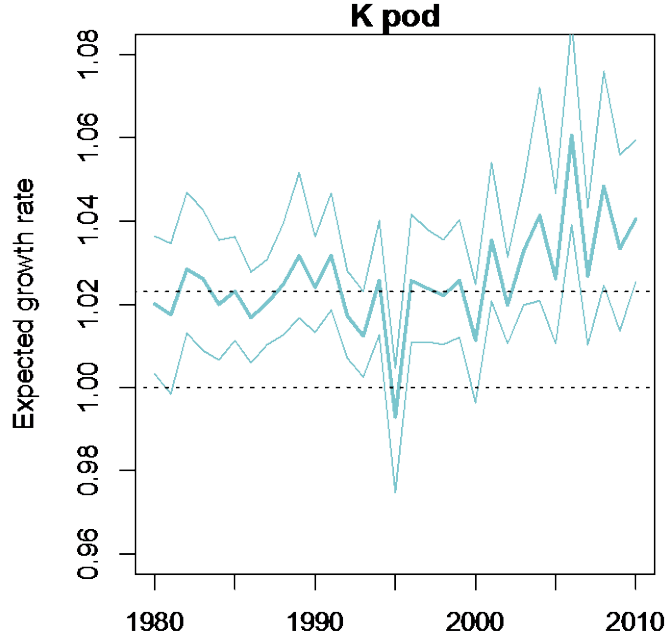
- All females < 42
- All offspring, including unknown sex
  - Fractional assignment as female

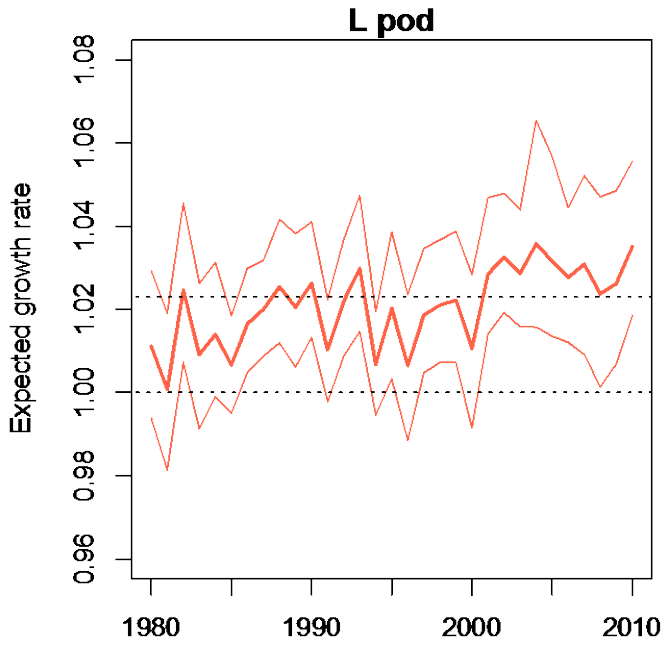
Inference:

- What this shows is decline in 1990s not due to anomolous age structure

Growth by pod with fishing (terminal run as predictor)







Include:

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

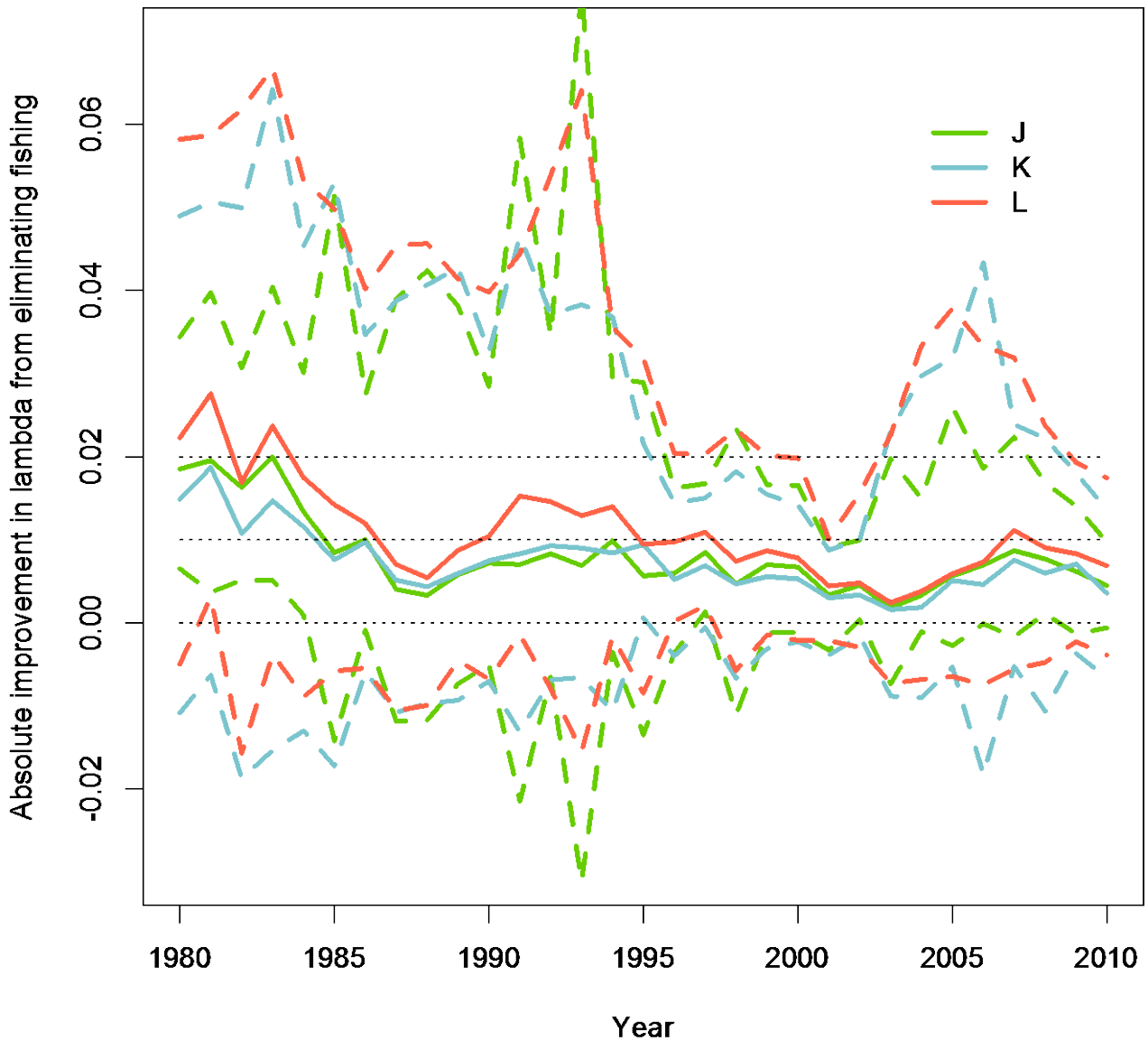
Calculate absolute improvement in λ

- Calculated λ with and without fishing impact included, as

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

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

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

How do these differ?

- Recovery goals based on total population size (fitting line through total abundance)
- 1. Lambda only includes females
  - Population assumed at stable age dist.
- 2. Time varying lambda allows lambda to vary through time, reflecting changing sex / age structure of the population
  - Allows us to manipulate covariates in each year

Advantages in considering alternatives metrics to recovery criteria

- Not all deaths equally likely
- Expected deaths changes through time
  - Age structure
  - Environment
- Not all deaths have the same impact on the population
  - e.g. older individuals

Some deaths have essentially 0 impact on current / future population growth

Year	totalDeaths	deaths > 40
1979	0	0
1980	3	0
1981	4	1
1982	3	1
1983	5	1
1984	2	1
1985	2	1
1986	1	1
1987	0	0
1988	0	0
1989	3	1
1990	0	0
1991	2	0
1992	0	0
1993	2	0
1994	4	1
1995	6	2
1996	5	4
1997	5	2
1998	7	1
1999	2	1
2000	5	1

Discussion Questions

- Based on data and uncertainties, what criteria are robust for assessing impacts of fisheries on the whales?
- What biological criteria might complement absolute growth?
  - Incorporate age structure?
  - Incorporate sex structure?
  - Include reproductive females?
  - Unique goals for each of the 3 SRKW pods?

Discussion Questions

- If the effects of prey reduction on killer whale population dynamics cannot be adequately quantified, are there alternative frameworks for evaluating the risks of a particular level of prey reduction?