Role of ocean and terminal run abundance of Chinook salmon on Resident Killer Whale population growth

(Preliminary results)

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Current evidence regarding RKW diet

- SRKW's diet from May - Sept mainly Chinook from Fraser Early (++), Fraser Late (+), & Puget Sound (-) stocks (Hanson et al. 2010)

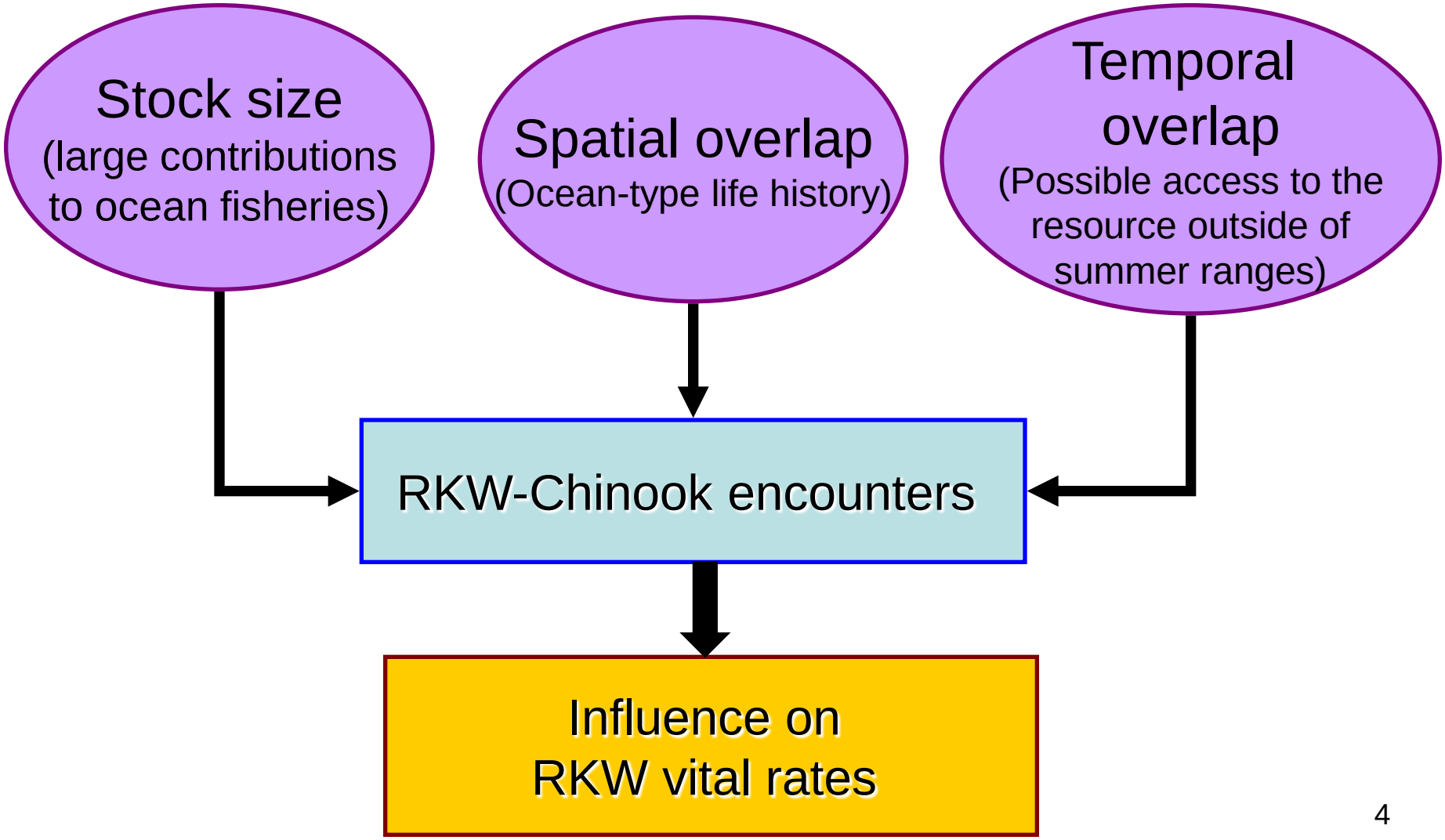
- NRKW's diet from May - Sept is broader than SRKW and mainly Chinook from Fraser Early (++), Georgia Strait (+), Columbia River (-), Puget Sound (-), and North/Central BC (-) stocks (Ford and Ellis 2006, Ford et al. 2010)

Main hypotheses regarding RKW-Chinook salmon interactions

- Hypothesis 1a (based on current evidence):
  - SRKW growth influenced by terminal run size of Fraser Early, Fraser Late, and Puget Sound Chinook

- Hypothesis 1b (based on current evidence):
  - NRKW growth influenced by
    - terminal run size of Northern BC, Central BC, WCVI, and Georgia Strait Chinook salmon stocks
    - ocean (pre-terminal) abundance of Fraser Early, Puget Sound, and Upper Columbia Chinook stocks

Criteria for **additional Hypotheses** regarding RKW-Chinook salmon interactions: assuming Chinook remains an important diet component year-round



Additional hypotheses regarding RKW-Chinook salmon interactions

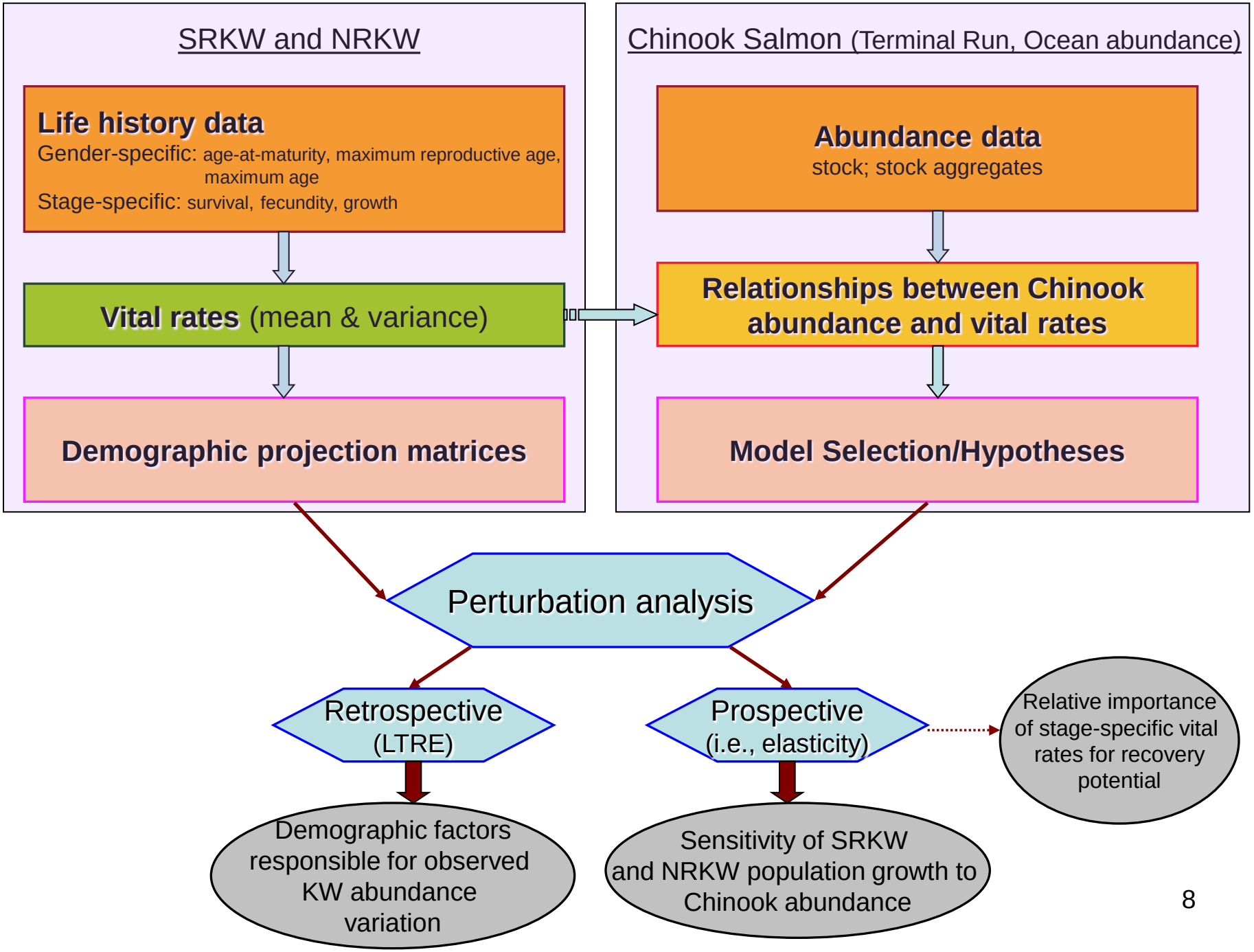
- <u>Hypothesis 2a</u> (assumes Chinook are important diet component year-round):
  - SRKW growth influenced by terminal run size of abundant stocks
  - SRKW growth influenced by ocean (pre-terminal) abundance of ocean-type stocks with large contributions to ocean fisheries

Additional Hypotheses regarding RKW-Chinook salmon interactions (contd.)

- Hypothesis 2b (assuming Chinook salmon remains an important diet component throughout the year and outside identified critical habitats):
  - NRKW growth influenced by terminal run size of abundant stocks
  - NRKW growth influenced by ocean (pre-terminal) abundance of ocean-type stocks with large contributions to ocean fisheries

The approach

- Perturbation analysis (prospective and retrospective)


SRKW and NRKW
Life history data
Gender-specific: age-at-maturity, maximum reproductive age, maximum age
Stage-specific: survival, fecundity, growth
Vital rates (mean & variance)
Demographic projection matrices
Chinook Salmon (Terminal Run, Ocean abundance)
Abundance data
stock; stock aggregates
Relationships between Chinook abundance and vital rates
Model Selection/Hypotheses
Perturbation analysis
Retrospective
(LTRE)
Prospective
(i.e., elasticity)
Relative importance of stage-specific vital rates for recovery potential
Demographic factors responsible for observed KW abundance variation
Sensitivity of SRKW and NRKW population growth to Chinook abundance

Data, metrics, and regression models

- RKW abundance & vital rate time series: 1987 – 2011
- Chinook Terminal Run size: Run Reconstruction Indices for stocks or stock aggregates (Kope-Parken, Workshop 1)
- Chinook Ocean (pre-terminal) Abundance: CTC Cohort Abundance Indices from stocks or stock aggregates (individual components of fishery indices)
- Simple & multiple linear regression models between RKW vital rates & Chinook abundance with lags 0 & 1 for survival and lags 0, 1, & 2 for fecundity
- Note: significant linkages not based exclusively on statistical significance but also on their influence on observed and potential population growth rates

Results

SRKW-Chinook regression models

Summary of significant regressions (p < 0.10)

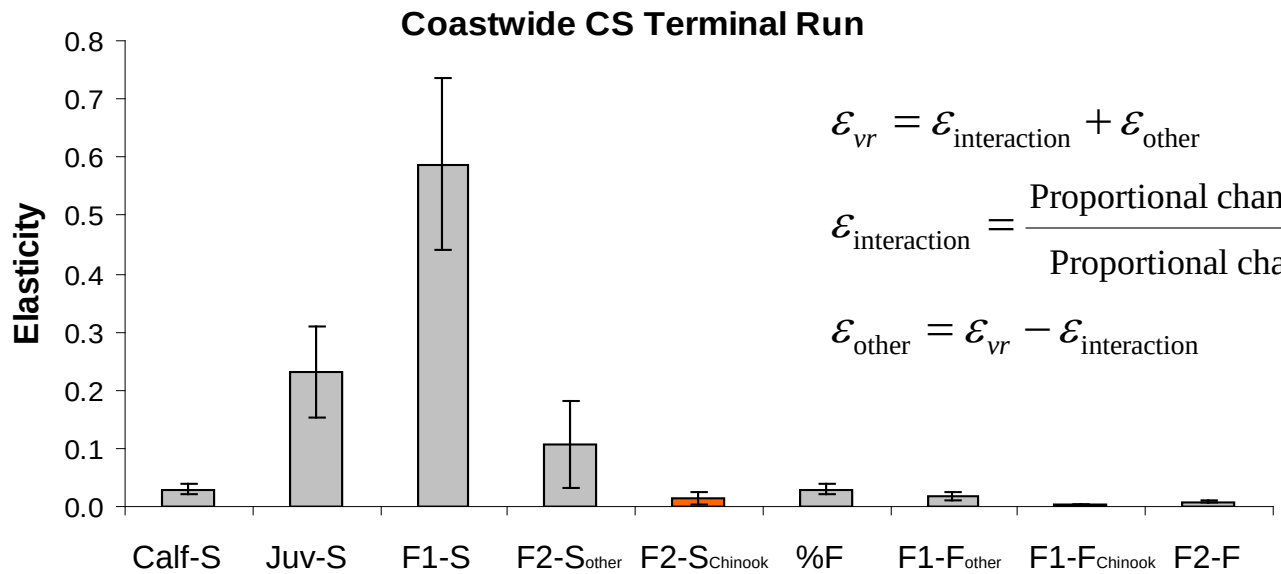
	Vital Rate	Stock or stock aggregate	Lag(s)	Adj. R2	P-value
Run-reconstruction Index	Fecundity (Female 2)	FE + PS Terminal Run	2	0.132	0.0452
	Fecundity (Female 2)	FE (excluding Spr. 1.2) Terminal Run	1	0.085	0.0906
	Survival (Male 1)	FE (Summer) Terminal Run	1	0.107	0.0652
	Fecundity (Female 2)	FE (Summer) Terminal Run	2	0.109	0.0637
	Survival (Male 1)	Fraser Late Terminal Run	0	0.109	0.0639
	Survival (Female 2)	UpRiver Brights Terminal Run	1	0.153	0.0335
	Survival (Female 2)	WCVI Terminal Run	0	0.168	0.0267
	Survival (Female 2)	WCVI Terminal Run	0, 1	0.259	0.0165
	Survival (Female 2)	Coastwide Terminal Run	1	0.119	0.0545
	Survival (Male 2)	Coastwide Terminal Run	1	0.095	0.0778
	Fecundity (Female 1)	Coastwide Terminal Run	0, 1, 2	0.156	0.0967
CTC Cohort Abundance Index	Survival (Female 2)	Fraser Late Ocean Abundance	0	0.112	0.0613
	Survival (Female 3)	Fraser Late Ocean Abundance	1	0.147	0.0367
	Survival (Male 1)	Fraser Late Ocean Abundance	0	0.126	0.0495
	Survival (Female 2)	UpRiver Brights Ocean Abundance	0	0.0805	0.0901
	Survival (Female 2)	Oregon Coastal Ocean Abundance	0	0.173	0.0245
	Survival (Female 2)	Oregon Coastal Ocean Abundance	1	0.081	0.0962
	Survival (Female 2)	Oregon Coastal Ocean Abundance	0, 1	0.142	0.0769
	Survival (Female 1)	Puget Sound Ocean Abundance	1	0.086	0.0888
	Survival (Female 2)	Puget Sound Ocean Abundance	1	0.216	0.0127
	Survival (Female 2)	Puget Sound Ocean Abundance	0, 1	0.19	0.0419
	Survival (Female 2)	WCVI Ocean Abundance	0	0.146	0.037
	Survival (Female 2)	WCVI Ocean Abundance	0, 1	0.300	0.009
	Survival (Female 2)	WCVI+FL+URB+OC+PS Ocean Abundance	0	0.340	0.0016
	Survival (Female 2)	Coastwide Ocean Abundance	0	0.357	0.0012
	Survival (Female 2)	Coastwide Ocean Abundance	1	0.194	0.0179
	Survival (Male 2)	Coastwide Ocean Abundance	0	0.081	0.0956
	Survival (Male 2)	Coastwide Ocean Abundance	1	0.302	0.0032

Example

Hypothesis 1a

Hypothesis 2a

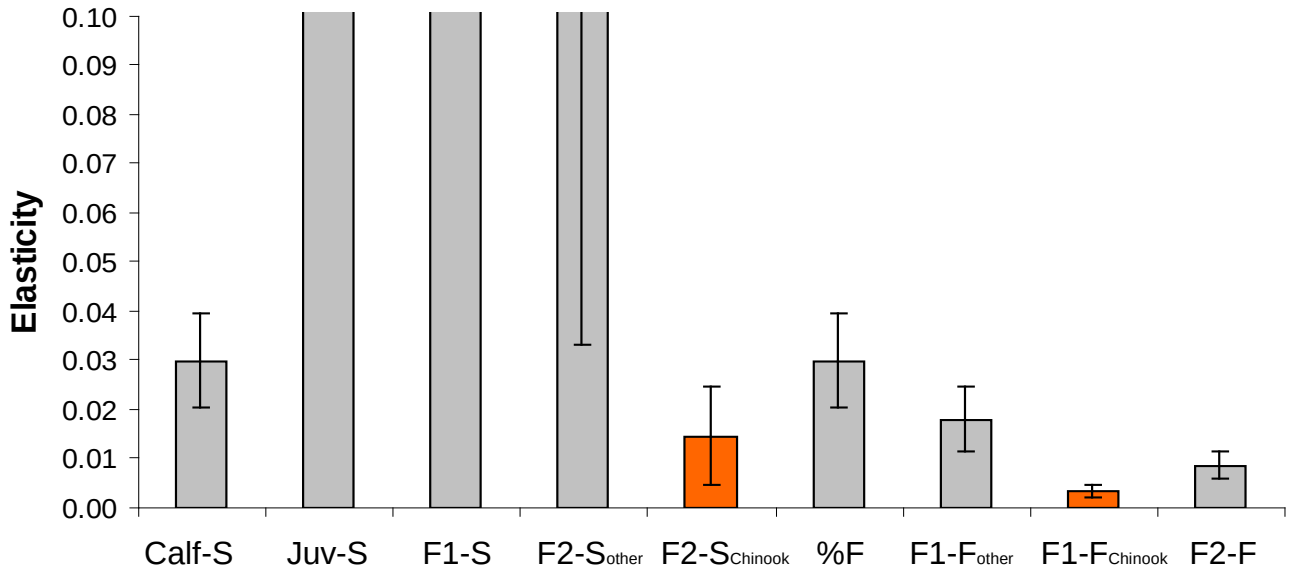
Example: SRKW - Coastwide Chinook Terminal Run



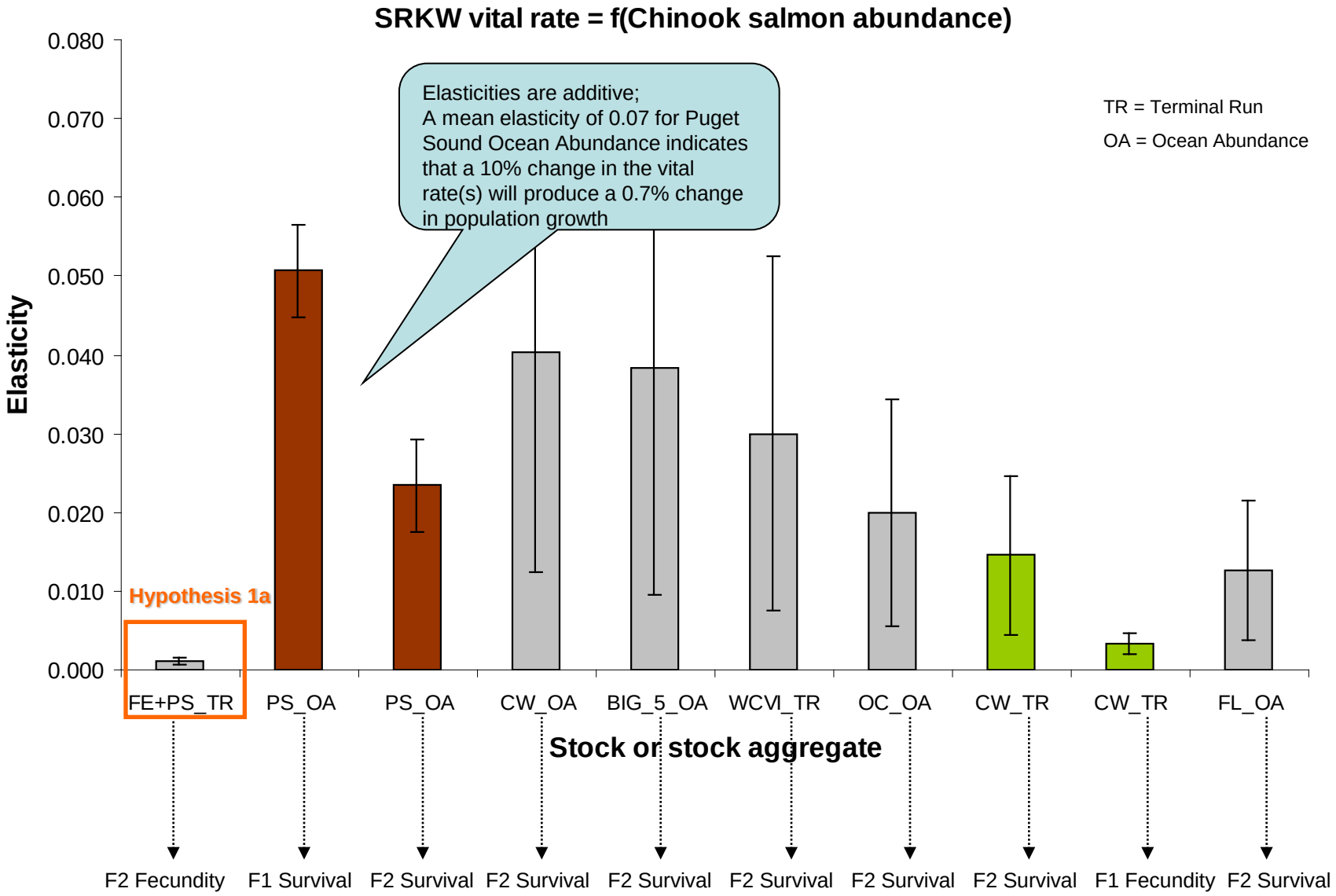
$$\varepsilon_{vr} = \varepsilon_{\text{interaction}} + \varepsilon_{\text{other}}$$

$$\varepsilon_{\text{interaction}} = \frac{\text{Proportional change in population growth rate}}{\text{Proportional change in Chinook abundance}}$$

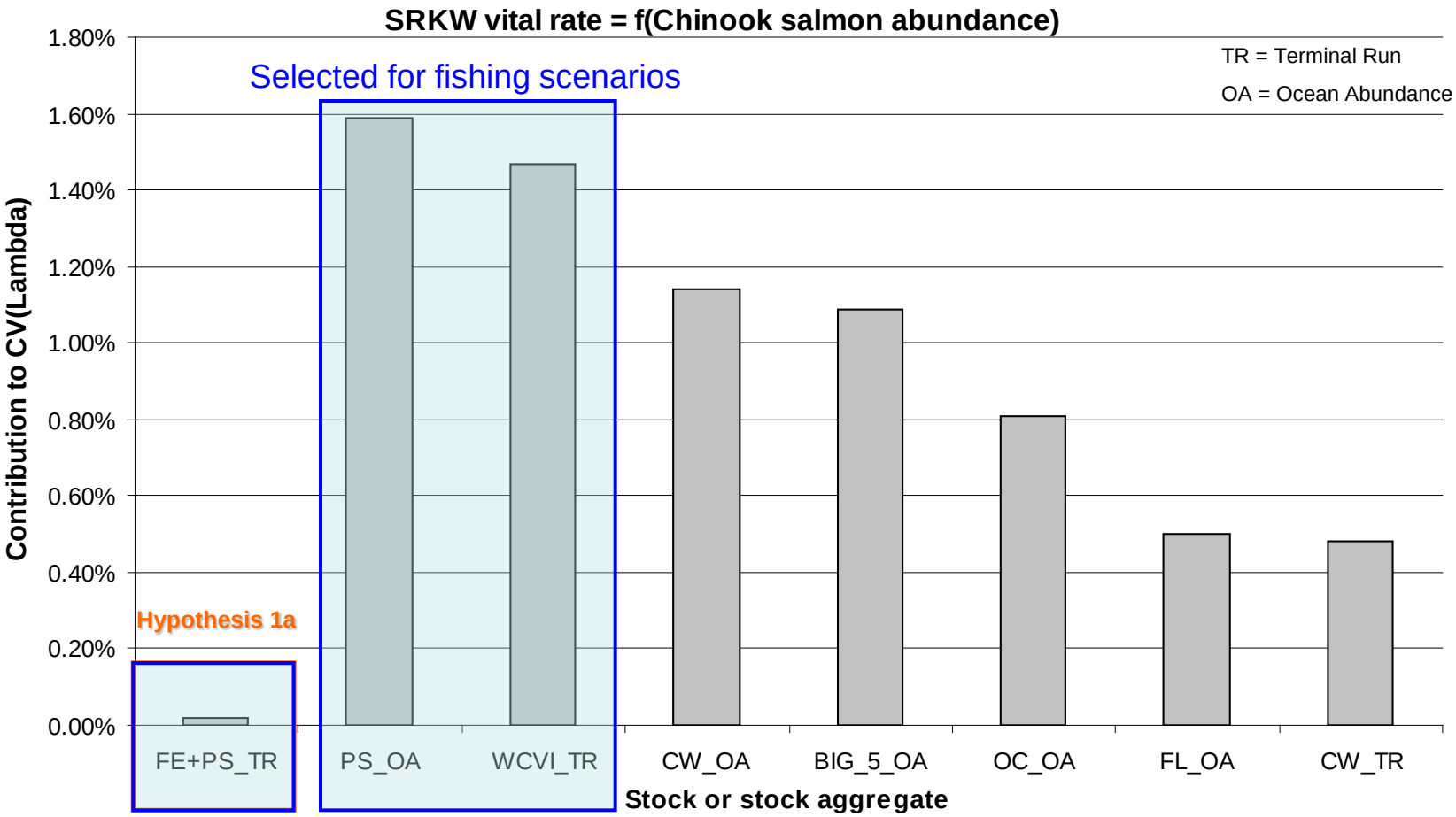
$$\varepsilon_{\text{other}} = \varepsilon_{vr} - \varepsilon_{\text{interaction}}$$



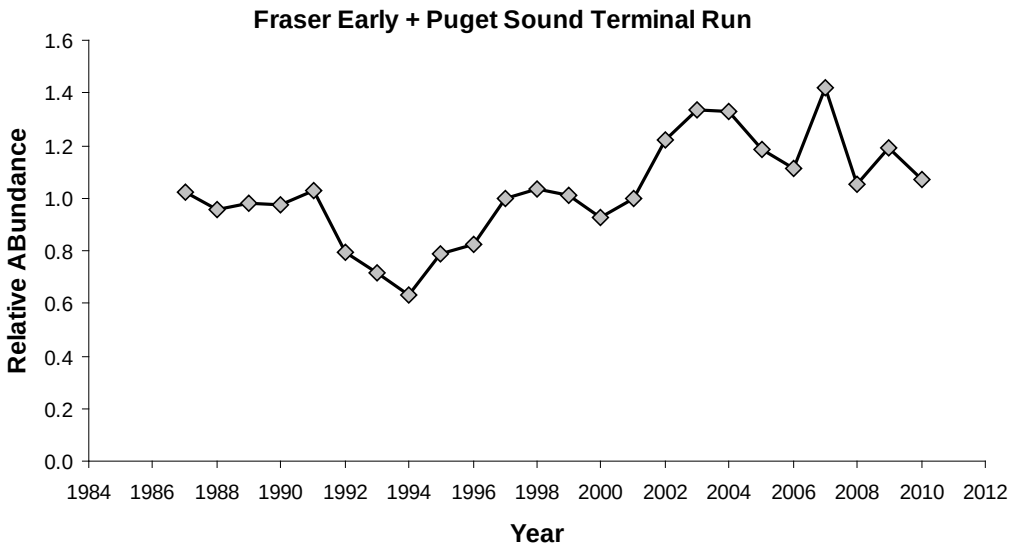
Elasticities of interactions between SRKW vital rates and Chinook salmon abundance (prospective)



Contribution of interactions between vital rates and Chinook salmon abundance to variation in SRKW population growth (retrospective)

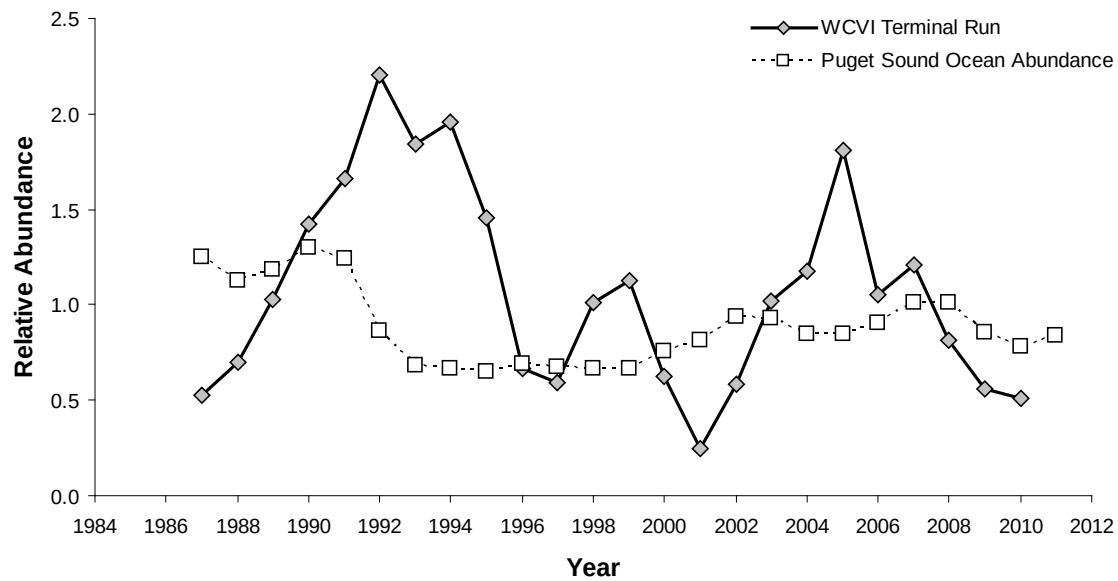


Chinook abundance trends concerning SRKW



Hypothesis 1a

Hypothesis 2a



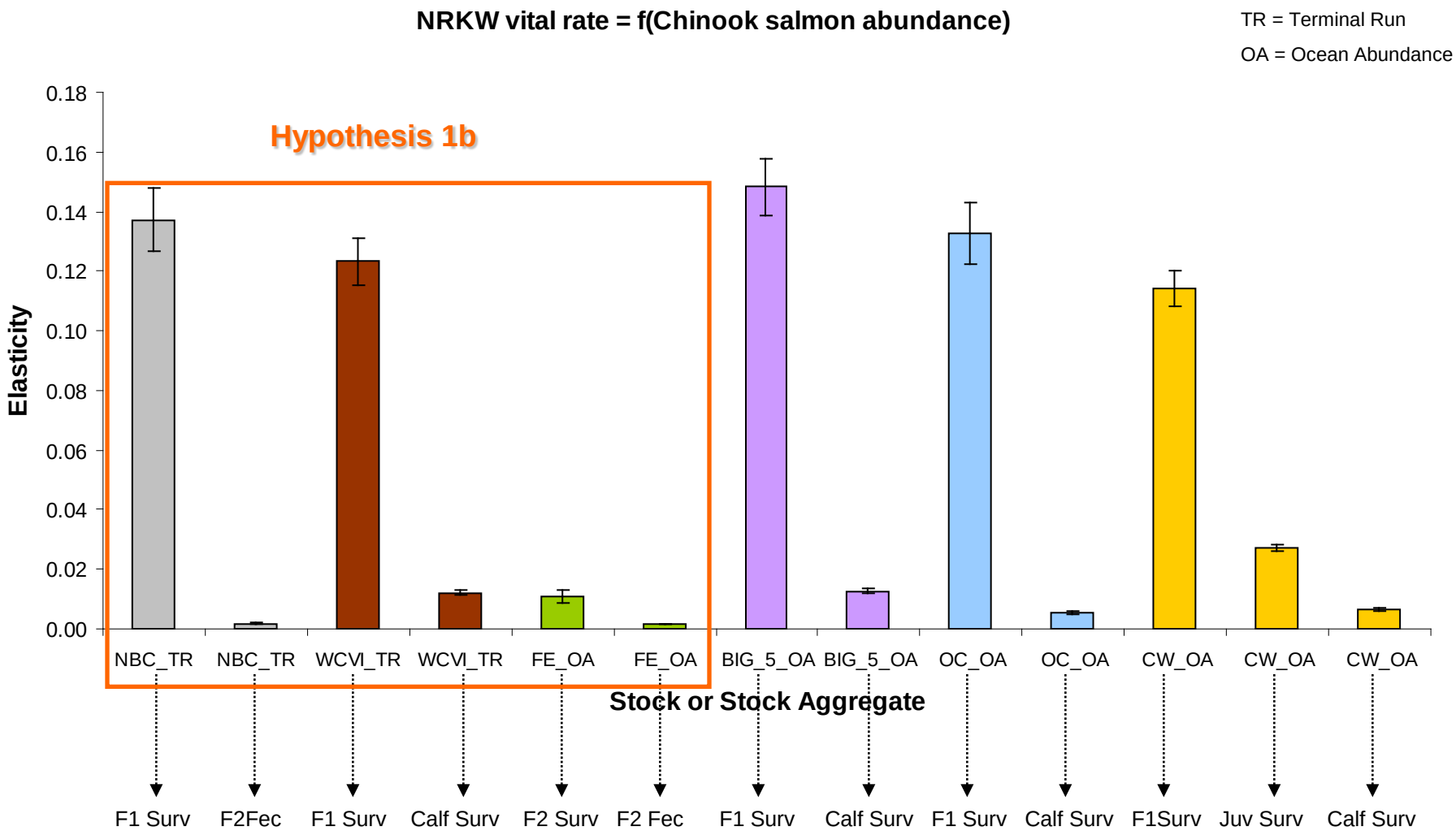
Summary of significant regressions (p < 0.10)				
Vital Rate	**Stock or stock aggregate**	**Lag(s)**	**Adj. R2**	**P-value**
Survival (Calf)	WCVI Terminal Run	0	0.275	0.005
Survival (Female1)	WCVI Terminal Run	0,1	0.233	0.0236
Survival (Male2)	WCVI Terminal Run	0	0.129	0.0474
Survival (Female2)	Georgia Strait Terminal Run	0	0.114	0.0589
Survival (Male1)	Georgia Strait Terminal Run	0,1	0.252	0.0182
Fecundity (Female2)	Georgia Strait Terminal Run	2	0.105	0.0675
Survival (Female1)	Northern BC Terminal Run	1	0.256	0.0068
Fecundity (Female2)	Northern BC Terminal Run	0,1	0.16	0.0617
Fecundity (Female2)	Central BC Terminal Run	1,2	0.142	0.077
Survival (Female2)	Fraser Early Ocean Abundance	0	0.091	0.0832
Survival (Female3)	Fraser Early Ocean Abundance	0,1	0.134	0.0853
Fecundity (Female2)	Fraser Early Ocean Abundance	2	0.148	0.0326
Survival (Juvenile)	UpRiver Brights Ocean Abundance	0	0.107	0.0655
Survival (Male1)	UpRiver Brights Ocean Abundance	0	0.096	0.0775
Survival (Male2)	UpRiver Brights Ocean Abundance	1	0.28	0.0046
Survival (Juvenile)	Puget Sound Ocean Abundance	1	0.296	0.0035
Survival (Male2)	Puget Sound Ocean Abundance	1	0.09	0.0839
Survival (Female2)	Fraser Early Terminal Run	1	0.086	0.0885
Fecundity (Female2)	Fraser Early Terminal Run	2	0.149	0.0351
Survival (Juvenile)	Puget Sound Terminal Run	1	0.19	0.019
Fecundity (Female2)	Puget Sound Terminal Run	1	0.097	0.0758
Fecundity (Female2)	FE+PS Terminal Run	2	0.183	0.0214
Survival (Calf)	Fraser Late Terminal Run	0	0.097	0.0755
Fecundity (Female2)	Fraser Late Terminal Run	1	0.13	0.047
Survival (Juvenile)	UpRiver Brights Terminal Run	0	0.124	0.0515
Survival (Male2)	UpRiver Brights Terminal Run	1	0.14	0.0403
Survival (Male2)	Coastwide Terminal Run	1	0.135	0.0433
Fecundity (Female2)	Coastwide Terminal Run	2	0.142	0.039
Survival (Calf)	Fraser Late Ocean Abundance	1	0.275	0.005
Survival (Female3)	Fraser Late Ocean Abundance	0,1	0.127	0.0923
Survival (Calf)	Oregon Coast Ocean Abundance	0	0.126	0.0498
Survival (Female1)	Oregon Coast Ocean Abundance	0,1	0.252	0.0183
Survival (Male1)	Oregon Coast Ocean Abundance	0	0.192	0.0186
Survival (Male2)	Oregon Coast Ocean Abundance	1	0.385	0.0007
Survival (Calf)	WCVI Ocean Abundance	0	0.254	0.0071
Survival (Female1)	WCVI Ocean Abundance	0	0.182	0.0216
Survival (Female3)	WCVI Ocean Abundance	0, 1	0.133	0.0863
Fecundity (Female2)	WCVI Ocean Abundance	0, 1, 2	0.274	0.0207
Survival (Calf)	WCVI+FL+URB+OC+PS Ocean Abundance	0	0.289	0.004
Survival (Female1)	WCVI+FL+URB+OC+PS Ocean Abundance	0	0.281	0.0045
Survival (Calf)	Coastwide Ocean Abundance	1	0.147	0.0366
Survival (Juvenile)	Coastwide Ocean Abundance	0	0.103	0.0696
Survival (Female1)	Coastwide Ocean Abundance	0	0.216	0.0128
Survival (Male2)	Coastwide Ocean Abundance	1	0.365	0.0011

Hypothesis 1b

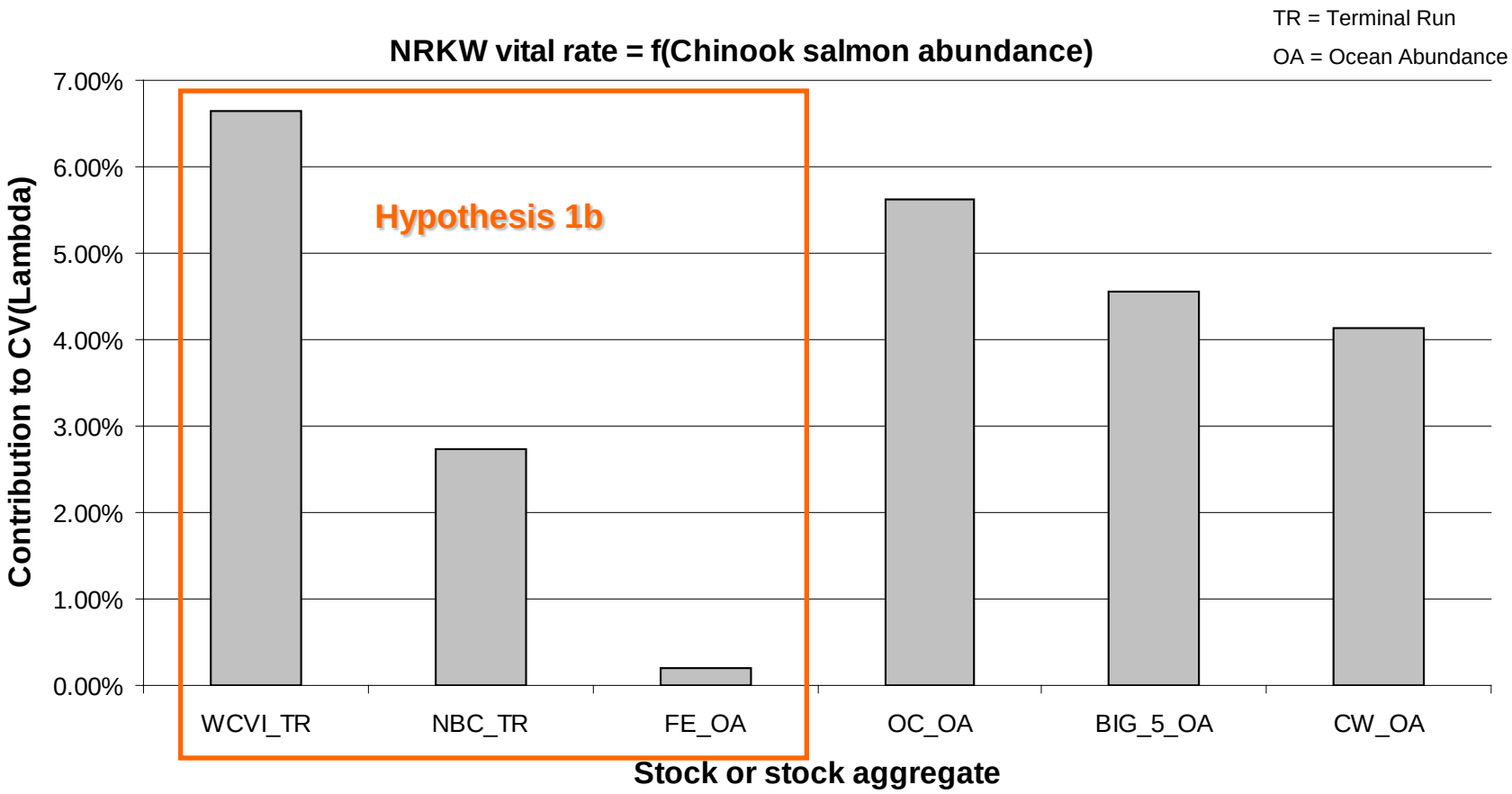
NRKW – Chinook regression models

Hypothesis 2b

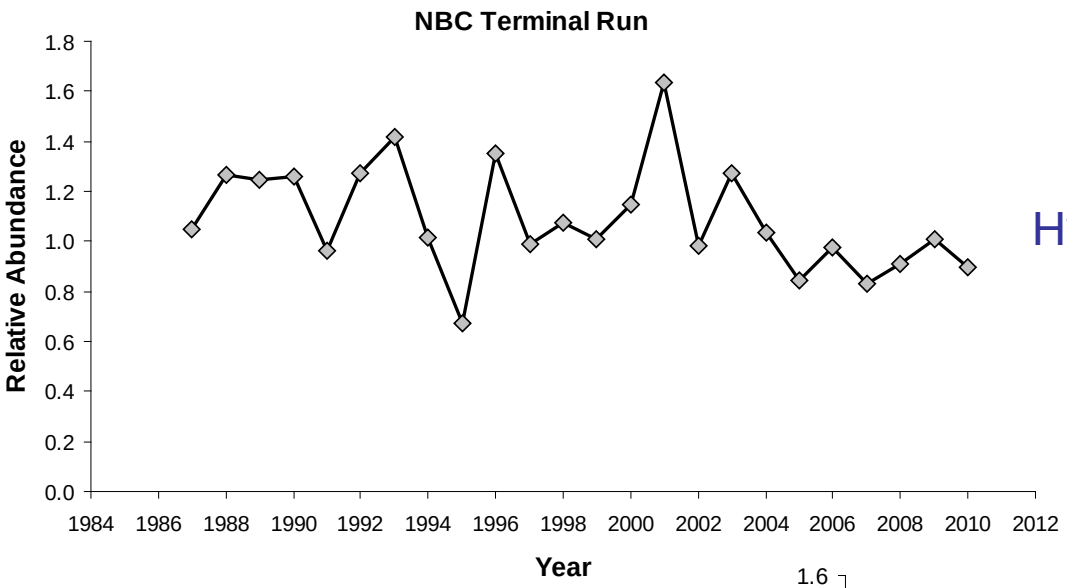
Elasticities of interactions between NRKW vital rates and Chinook salmon abundance



Contribution of interactions between vital rates and Chinook salmon abundance to variation in NRKW population growth

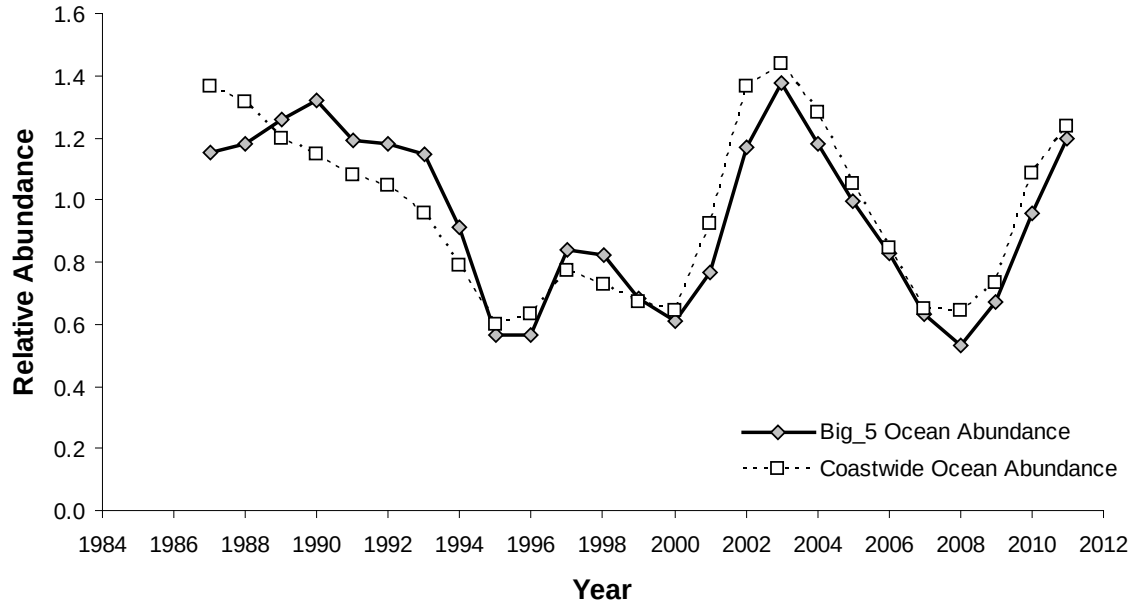


Chinook abundance trends concerning NRKW



Hypothesis 1b

Hypothesis 2b



SRKW-Chinook salmon interactions (Hypothesis 1a)

- Small portion of variability (13%) in fecundity of old reproductive females explained by the terminal run of Fraser Early & Puget Sound Chinook stocks

- Influence on observed & potential population growth is small
  - 0.02% contribution to the observed CV in population growth
  - elasticity = 0.001

SRKW-Chinook salmon interactions (Hypothesis 2a)

- **Maximum** effect on observed and potential population growth
  - Interaction between Puget Sound ocean abundance & survival of young and old reproductive females
    - contributed 1.59% to the observed CV in population growth
    - elasticity = 0.074

NRKW-Chinook salmon interactions (Hypothesis 1b)

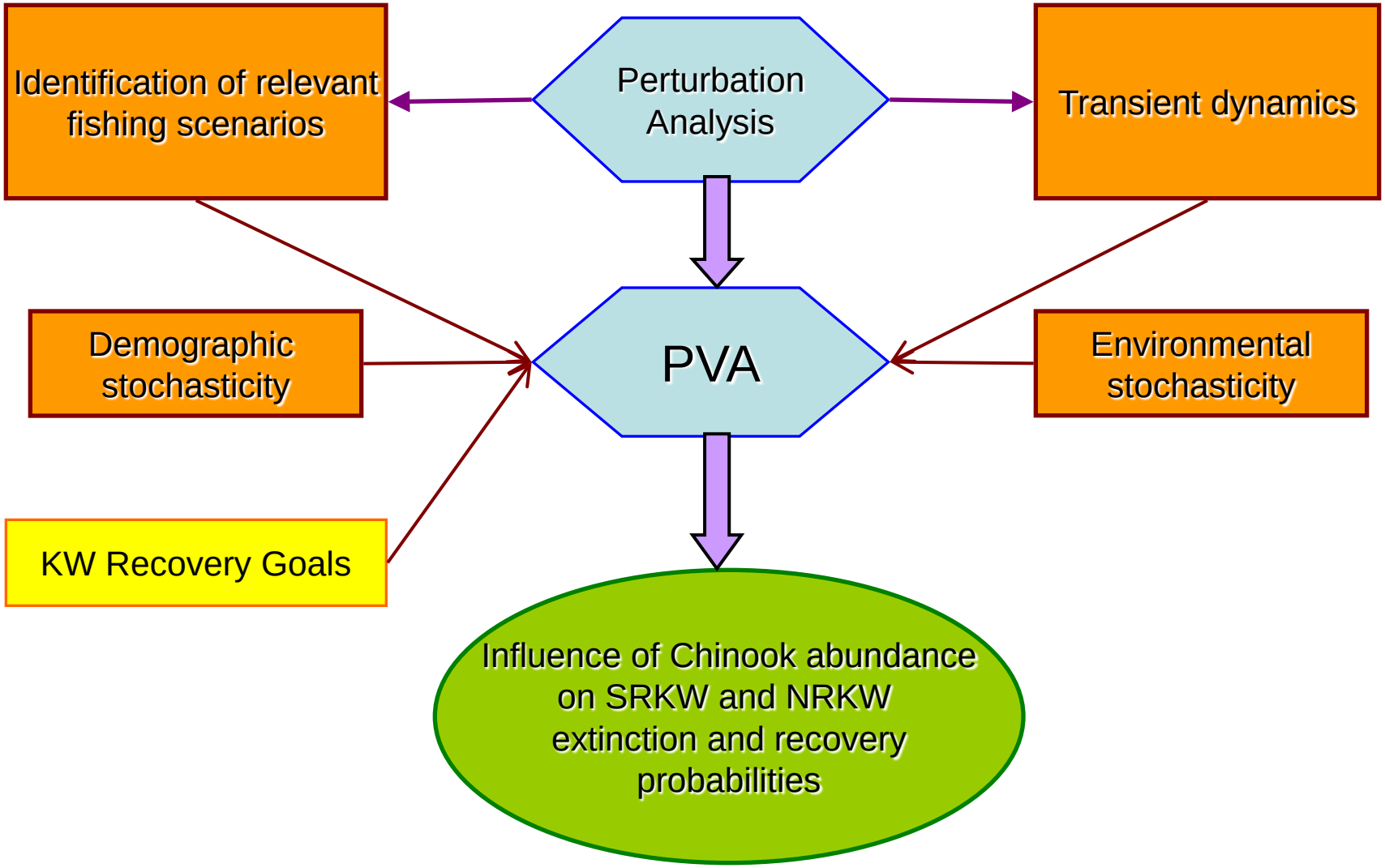
- Interactions between NRKW vital rates & Chinook abundance
  - **terminal runs** of WCVI, NBC, Central BC, & Georgia Strait
  - **ocean abundance** of Fraser Early, Columbia Upriver Brights, & Puget Sound

- Strongest interaction: NBC terminal run & survival of young reproductive females & fecundity of old reproductive females
  - Contribution to population growth = 2.74%
  - Elasticity = 0.139

NRKW-Chinook salmon interactions (Hypothesis 2b)

- Interaction between Coastwide ocean abundance & survival of calves, juveniles, and young reproductive females
  - contributed 4.1% to the observed CV in population growth
  - elasticity = 0.148

Next


Identification of relevant fishing scenarios
Perturbation Analysis
Transient dynamics
Demographic stochasticity
PVA
Environmental stochasticity
KW Recovery Goals
Influence of Chinook abundance on SRKW and NRKW extinction and recovery probabilities