Exploring sensitivity of the relationship between salmon abundance indices with killer whale demographics

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Context

- Previous analyses (Ford/Wade/Ward) reached different conclusions (p 19 Sci Panel Rept)
- Workshop 1 results (FRAM) somewhat different
- New indices (Parken-Kope) presented – how do they compare?

Checklist

- CTC / FRAM comparison [high, p 15]
- Alternative approaches to FRAM [medium high, p 18]

Recap from workshop # 1

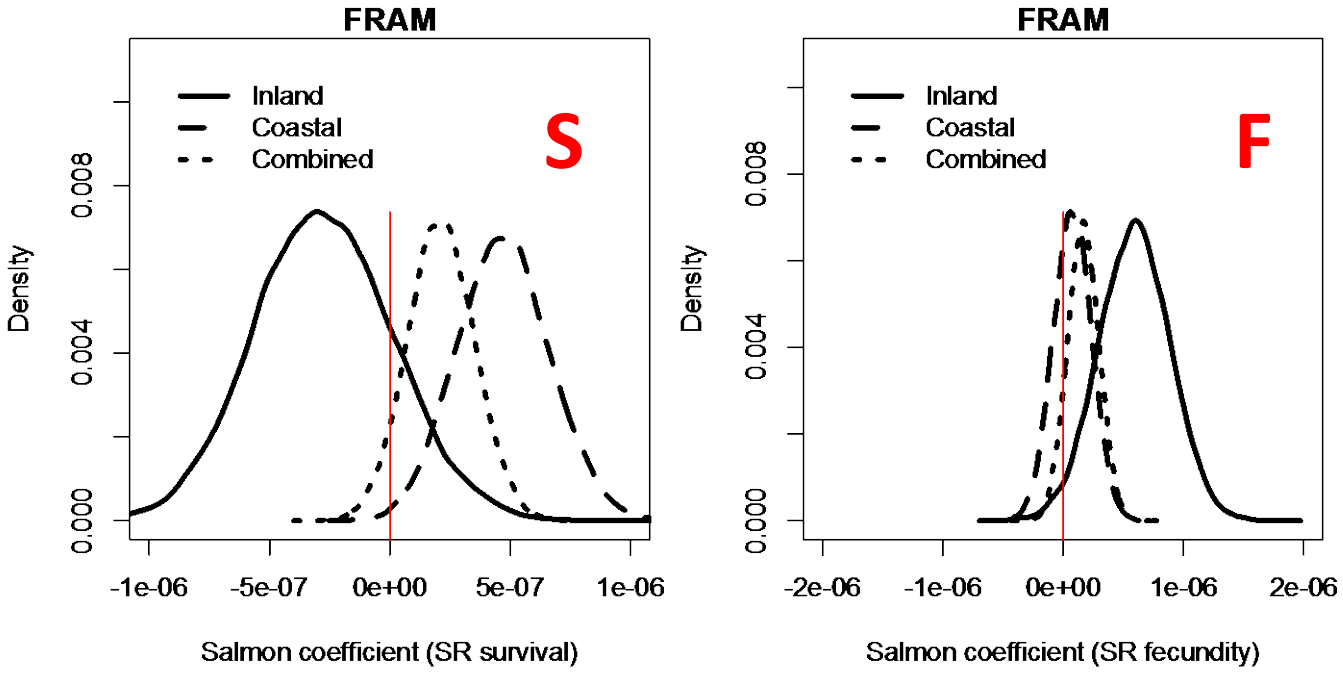
- We evaluated data support for several salmon indices correlating with killer whale fecundity / survival

- FRAM (1983-2008)
  - Inland waters abundance
  - Coastal abundance
  - Inland kcals
  - Coastal kcals
- CTC indices (1979-2010)
  - Aggregate and stratified indices
  - e.g. inland, coastal, etc (E. Ward & L. La Voy)

Results from workshop # 1

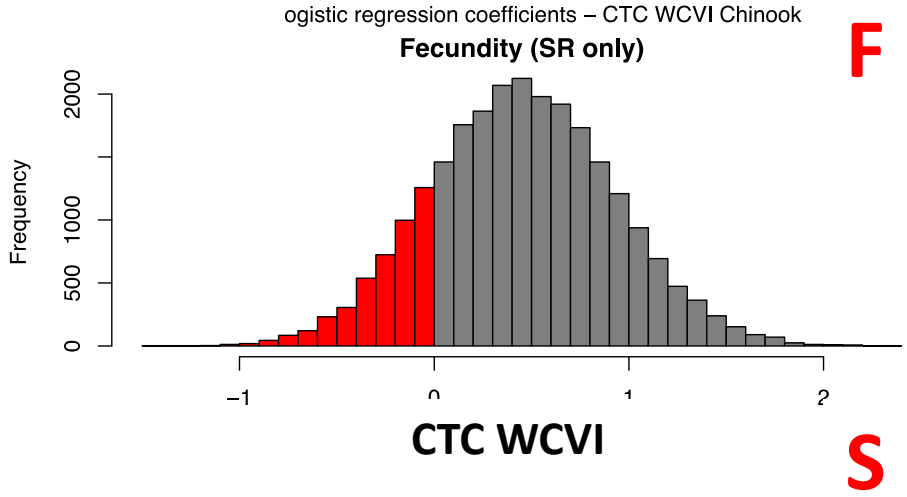
- FRAM inland abundance positively correlated with kw fecundity
- P(birth) = f(age) + f(salmon)
- FRAM model was slightly better than 'no salmon' model, model averaging used (reduces correlation)
- But negative correlation with survival
- P(live) = f(stage) + f(pod)
  - L pod has lower survival

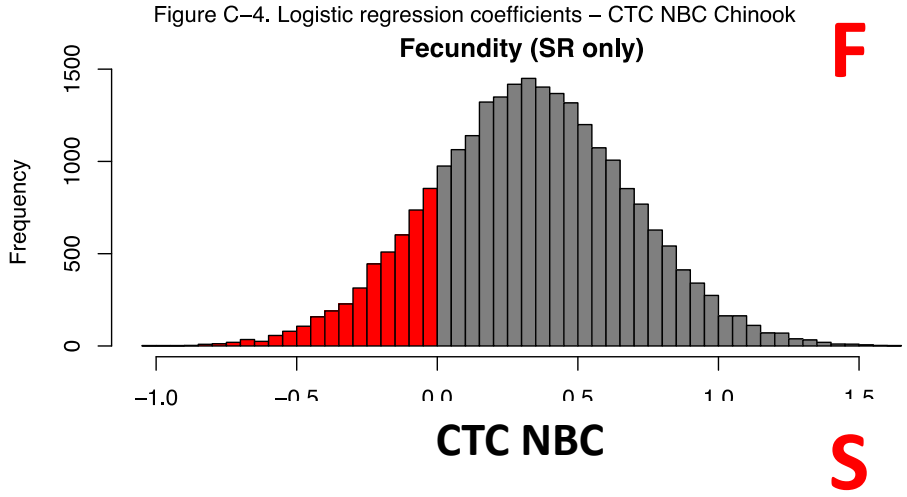
Recap of FRAM results

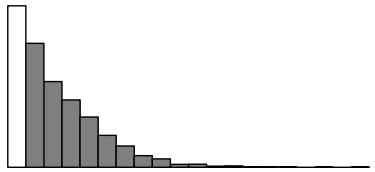


Recap of CTC results (WCVI & NBC)

Stronger correlation for survival than fecundity (opposite of inland FRAM result)







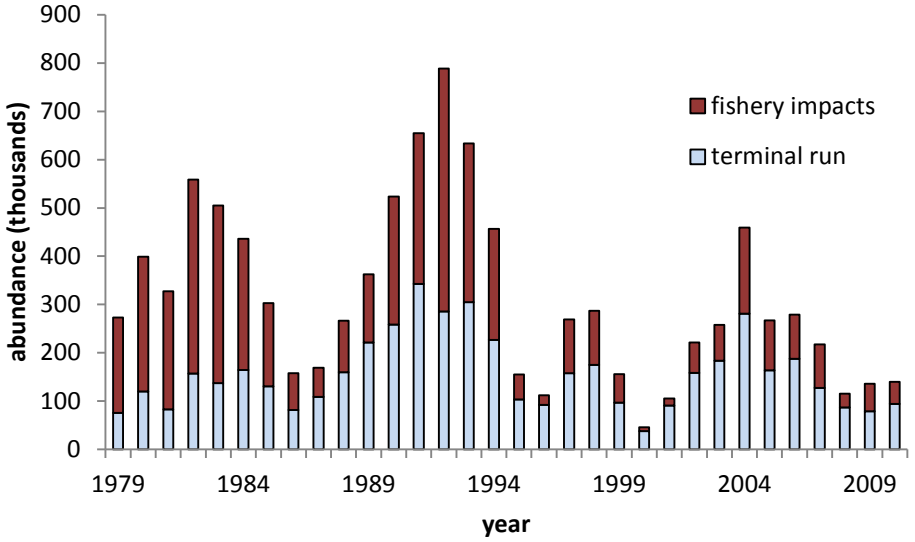
CTC WCVI

CTC NBC

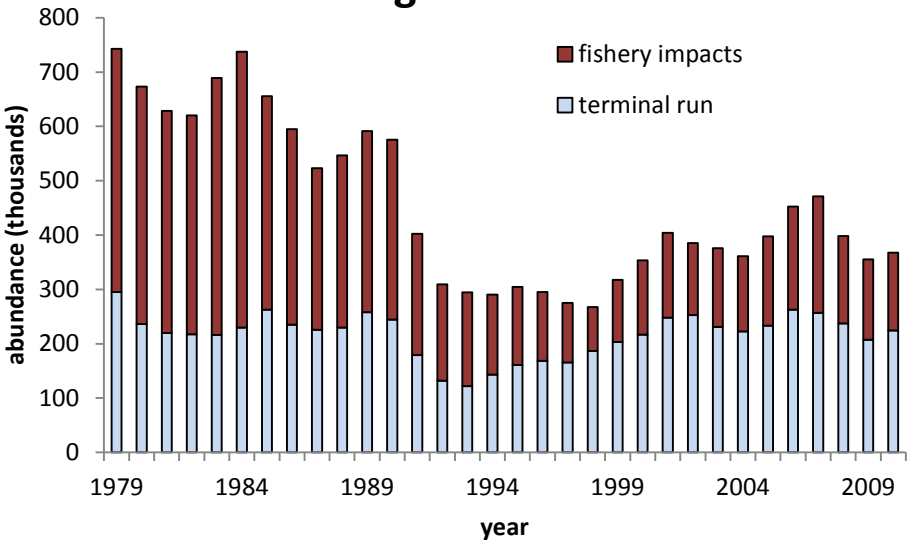
Objective for working group

- Link run reconstruction indices from workshop 1 (Parken/Kope) with kw demographic models
  - Alternative to CTC and FRAM indices
  - Less of a ‘black box’
    - Counting fish: more empirical
  - Each index is composed of a ‘terminal’ component and ‘fishery impact’ component

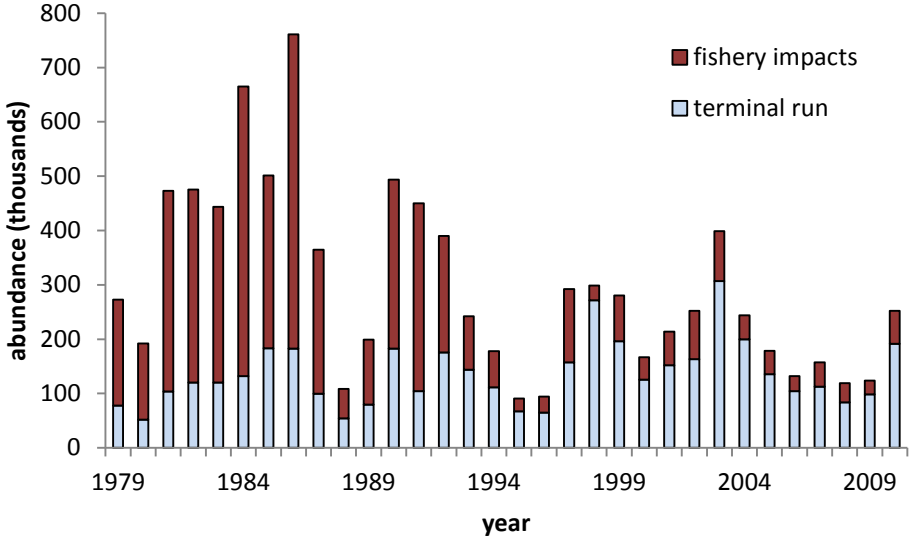
West Coast Vancouver Island



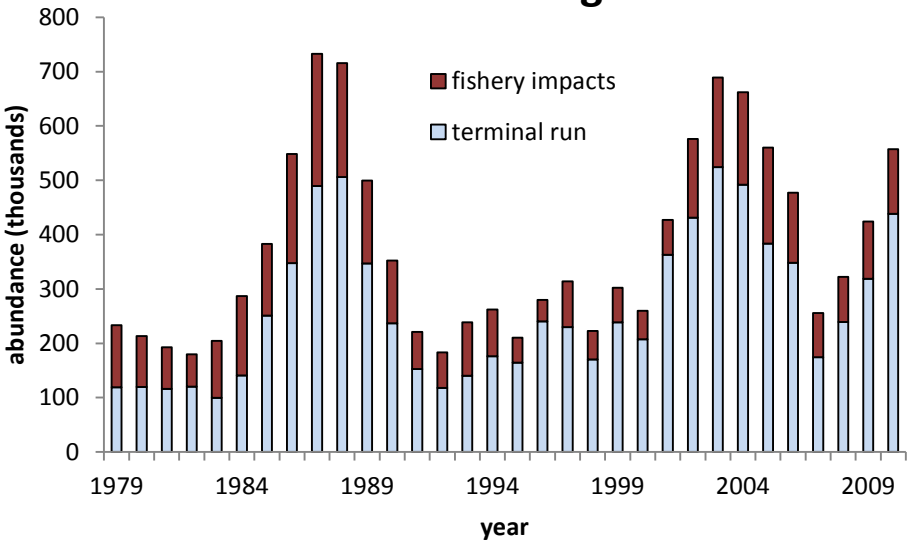
Puget Sound



Fraser Late



Columbia River Bright Fall



Hypotheses to address

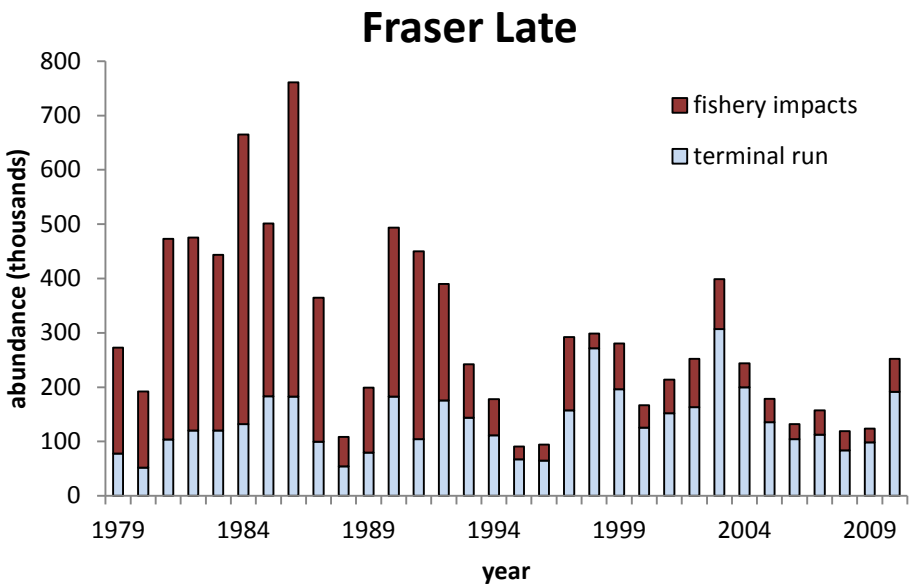
- How do new indices compare to CTC / FRAM?
- Is kw growth (survival, fecundity) more correlated with inland or ocean salmon abundance?
  - "Inner" v "Outer", like FRAM coastal v FRAM inland
- Inland abundance (after ocean fishing occurs)
  - Only exclude ocean pre-terminal catch from inland migrating stocks (Fraser, Puget Sound)
  - Ocean fishing impacts from coastal stocks included
- Ocean abundance (terminal run size + fishing impacts)

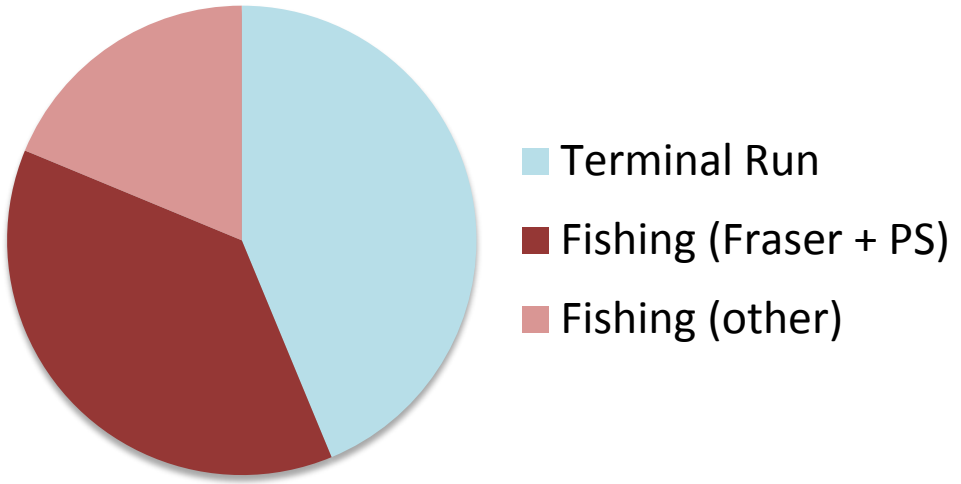
Caveats

- We have to assume that the relative importance of a group of stocks is constant over time
  - More likely this is the case than if we use individual stocks
- 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

What this comparison isn't

- This is not a comparison of fishing v no fishing
  - (next presentation: how much fishing impacts kw growth rate and ability to meet recovery criteria)
  - Fishing impacts sliced up into coastal / inland





Stratification

- 21 stocks, 2 stratification approaches considered:
- Ocean Distribution: north, central, California (south)
- Migration timing: spring, summer, summer/fall, fall

Overview of groupings for Parken-Kope time series

- For time period 1979-2010, we explored:
- 9 ocean distribution configurations
- 10 migration timing configurations

- KW Demographic models:
- SR fecundity ~ logistic regression (salmon = t-1)
- SR survival ~ logistic regression (salmon = t)

STOCK	MIGRATION TIMING	OCEAN DISTRIBUTION
Col Lower R spring	Spring	Central
Fraser Sp. 1.2	Spring	North/Central
Fraser Sp. 1.3	Spring	North/Central
SEAK	Spring	North
Upper Col R spring	Spring	Central
Areas 1-5	Summer	North
Areas 6-10	Summer	North
Col R summer	Summer	Central
Fraser Sm. 0.3	Summer	North
Fraser Sm. 1.3	Summer	North
Puget Sound	Summer/Fall	Central
Upper Georgia Strait	Summer/Fall	North
Col R Tule	Fall	Central
Col River bright fall	Fall	North
Fraser Late	Fall	Central
Lower Georgia Strait H & N	Fall	Central
Klamath fall	Fall	South
OR coast	Fall	North
Sacramento fall	Fall	South
WA coast	Fall	North
WCVI	Fall	North

Not all fishery impacts included

- Some fishing on occurs in freshwater / near mouth of Columbia
  - E.g. exclude impacts for Columbia spring

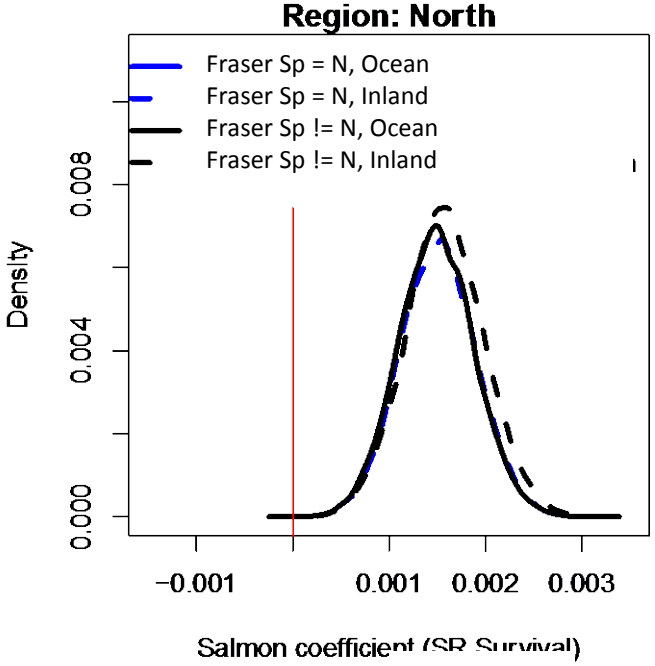
Ocean Distribution

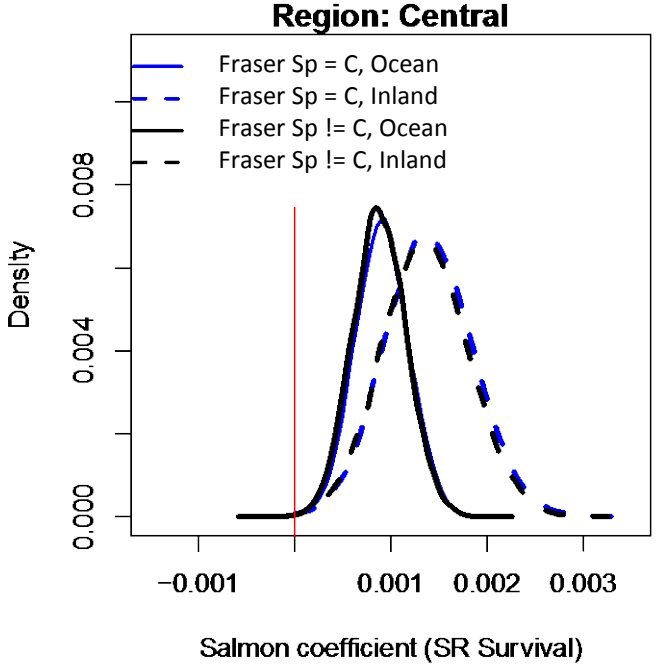
- Strata are north / central / California (south)
- Fraser spring 1.2 & 1.3 can be considered north OR central (we tried both)
- Inland pre-terminal fishery impacts (Fraser, Puget Sound) might be important or not (we tried both)

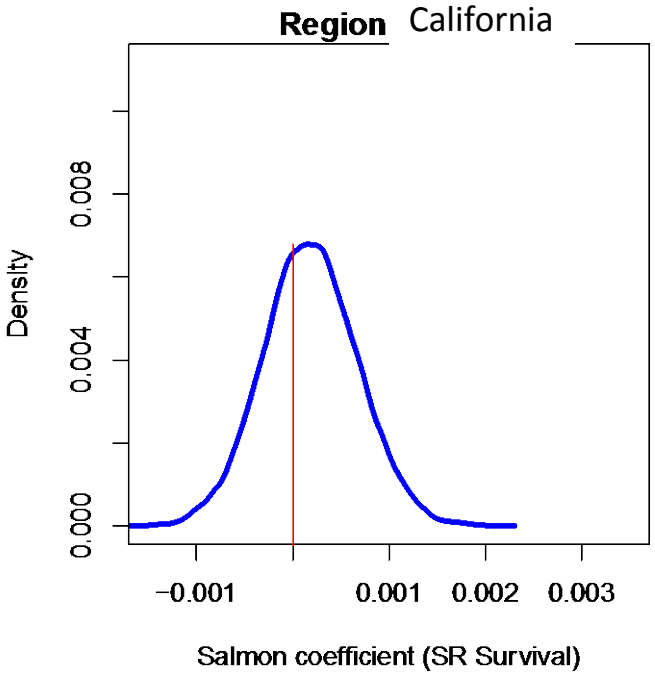
Outline for results

- Stratification by ocean distribution
  - 1. Fecundity (hidden slide)
  - 2. Survival
- Stratification by migration timing
  - 3. Fecundity (hidden slide)
  - 4. Survival

Results: SR survival, Chinook strata = ocean distribution







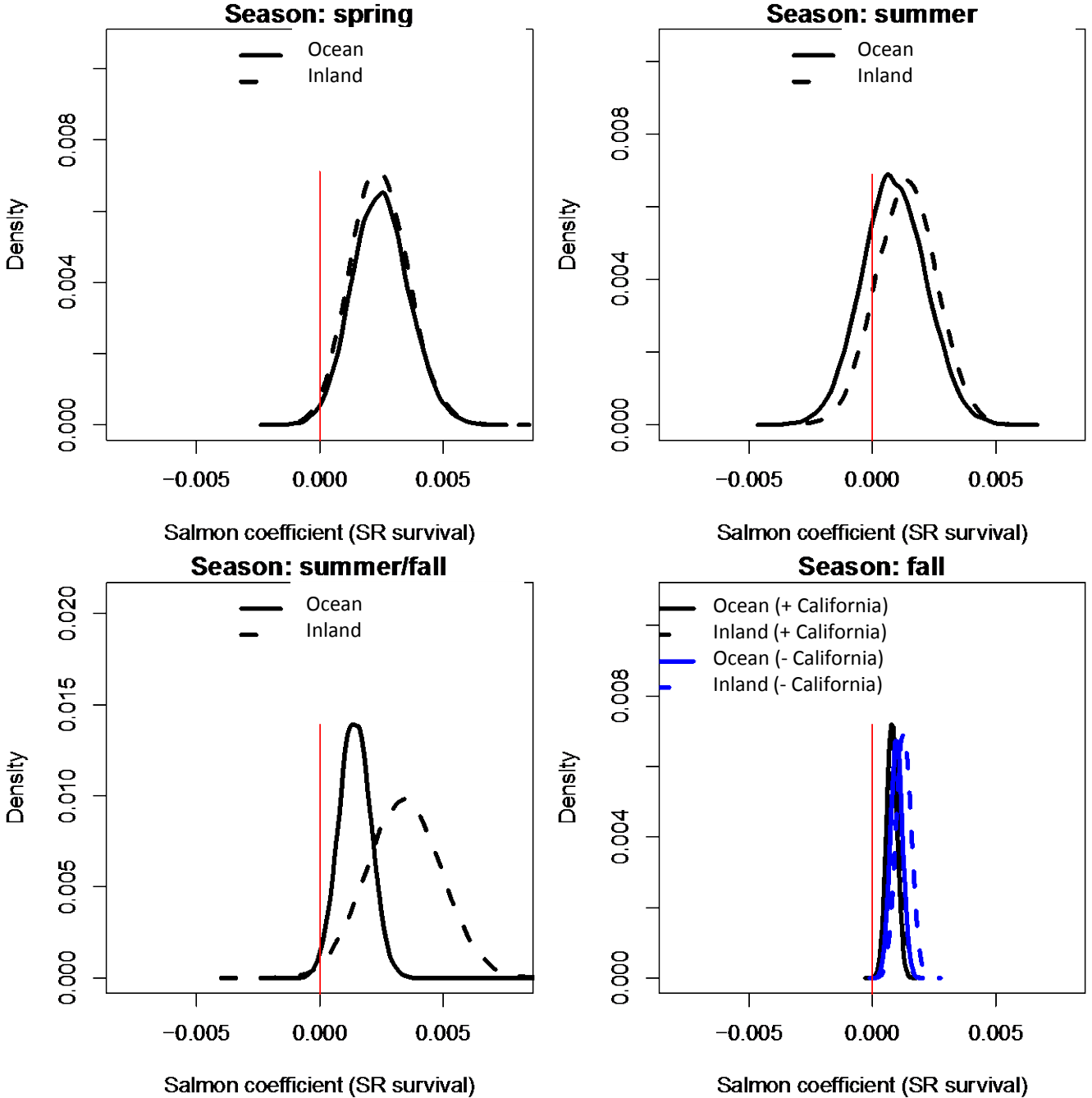
Effect slightly higher when inland fishery impacts (Fraser) not included

Migration timing

- Strata are spring, summer, summer/fall, and fall
  - Puget Sound / Upper St of Georgia = summer/fall

- Inland pre-terminal fishery impacts (Fraser, Puget Sound) might be important or not (we tried both)

Results: SR survival, Chinook strata = migration timing



Summary of stratification

- SR fecundity:
- Mostly 0, except Summer/fall (+)
- SR survival:
- North / Central (+)
- Effect of all seasons mostly (+)
- Consistency with CTC (WCVI & NBC):
- Stronger correlation for survival than fecundity, positive correlation for both

What about model selection?

- How do new indices stack up to results from workshop 1?
- Caveat: FRAM is 1983-2008, so all time series need to be shortened
- Caveat # 2: AIC values are interpreted in log-likelihood units (lower is better).
  - It's difficult to discriminate models < 2
  - Models within < 5 should still be considered good candidates
  - Models > 10 can probably be ignored or given little weight

Model selection results, 1983-2008 (SRKW)

Group	Include inland pre-terminal	delta AIC (fecundity)	delta AIC (survival)	delta AIC (total)
North (+Fraser Sp)	Y	3.4	3.8	2.1
North (+Fraser Sp)	N	5.1	**1.5**	**1.5**
North (-Fraser Sp)	Y	5.0	3.4	3.3
North (-Fraser Sp)	Y	5.1	**0.9**	**0.9**
Central (-Fraser Sp)	Y	**0.0**	6.4	**1.3**
Central (-Fraser Sp)	N	4.7	6.9	6.5
Central (+Fraser Sp)	Y	2.8	6.4	4.2
Central (+Fraser Sp)	Y	4.7	6.6	6.2
South	NA	5.4	21.7	22.0
Spring	Y	4.6	11.8	11.2
Spring	N	4.7	11.7	11.3
Summer	Y	5.3	21.4	21.7
Summer	N	5.0	18.7	18.6
Summer/fall	Y	**1.8**	16.4	13.1
Summer/fall	N	2.9	16.7	14.5
Fall (+California)	Y	5.0	3.6	3.5
Fall (+California)	N	5.3	4.4	4.5
Fall (-California)	Y	4.7	**1.3**	**0.8**
Fall (-California)	N	5.1	**0.0**	**0.0**
FRAM #s inland	NA	**1.4**	21.0	17.3
FRAM #s coast	NA	5.2	15.8	15.8
FRAM #s total	NA	3.8	19.8	18.5
FRAM kcal inland	NA	5.2	22.0	22.0
FRAM kcal coast	NA	5.4	10.7	11.0
FRAM kcal total	NA	5.4	14.1	14.4
No salmon	NA	3.4	20.0	18.3
CTC WCVI	NA	3.4	5.8	4.1
CTC NBC	NA	4.9	**1.4**	**1.2**

AIC values: “0” indicates best model, values greater than 0 indicate models that aren’t as good. Models with values > 10 can probably be ignored

AIC values for fecundity / survival can be added together for ‘total’ data support

Model selection results 1979-2010 (SRKW)

Group	Include inland pre-terminal	delta AIC (fecundity)	delta AIC (survival)	delta AIC (total)
North (+Fraser Sp)	Y	**1.7**	2.4	**0.6**
North (+Fraser Sp)	N	3.5	2.1	2.1
North (-Fraser Sp)	Y	3.4	2.1	**2.0**
North (-Fraser Sp)	N	3.5	**1.5**	**1.5**
Central (-Fraser Sp)	Y	**0.0**	7.1	3.5
Central (-Fraser Sp)	N	3.2	7.8	7.4
Central (+Fraser Sp)	Y	2.7	7.4	6.6
Central (+Fraser Sp)	N	3.2	7.9	7.6
South	NA	3.6	17.3	17.4
Spring	Y	2.6	12.6	11.7
Spring	N	2.8	13.0	12.2
Summer	Y	3.5	17.0	17.0
Summer	N	3.7	16.2	16.4
Summer/fall	Y	2.1	12.6	11.1
Summer/fall	N	**1.9**	12.3	10.6
Fall (+California)	Y	3.7	4.4	4.5
Fall (+California)	N	3.7	4.5	4.7
Fall (-California)	Y	3.6	**1.7**	**1.7**
Fall (-California)	N	3.7	**0.0**	**0.1**
No salmon	NA	**1.7**	15.4	13.6
CTC WCVI	NA	2.5	4.7	3.7
CTC NBC	NA	3.0	**0.6**	**0.0**

AIC values: “0” indicates best model, values greater than 0 indicate models that aren’t as good. Models with values > 10 can probably be ignored

*California stocks and spring / summer stocks appear to be poor predictors of survival

* North / fall migrating stocks are better predictors of Survival

* NRKW results alone give more support to fall stocks (hidden slide)

Model selection results 1979-2010 (SRKW & NRKW)

Group	Include inland pre-terminal	delta AIC (fecundity)	delta AIC (survival)	delta AIC (total)
North (+Fraser Sp)	Y	2.4	7.2	7.7
North (+Fraser Sp)	N	2.7	9.2	9.9
North (-Fraser Sp)	Y	2.1	5.4	5.6
North (-Fraser Sp)	N	2.8	7.9	8.7
Central (-Fraser Sp)	Y	3.2	18.5	19.8
Central (-Fraser Sp)	N	**0.9**	22.3	21.3
Central (+Fraser Sp)	Y	**1.6**	18.2	17.8
Central (+Fraser Sp)	N	**1.0**	22.2	21.3
South	NA	4.4	16.9	19.4
Spring	Y	3.1	15.4	16.5
Spring	N	3.1	15.1	16.3
Summer	Y	**0.7**	19.2	18.0
Summer	N	3.0	15.1	16.2
Summer/fall	Y	3.5	12.8	14.4
Summer/fall	N	3.8	19.2	21.1
Fall (+California)	Y	2.7	14.6	15.4
Fall (+California)	N	2.6	15.7	16.4
Fall (-California)	Y	2.4	2.2	2.6
Fall (-California)	N	**1.9**	**0.0**	**0.0**
No salmon	NA	2.4	20.6	21.1
CTC WCVI	NA	**0.0**	10.1	8.2
CTC NBC	NA	**1.1**	11.5	10.6

AIC values: “0” indicates best model, values greater than 0 indicate models that aren’t as good. Models with values > 10 can probably be ignored

*California stocks and spring / summer stocks appear to be poor predictors of survival

* North / fall migrating stocks are better predictors of Survival

STOCK	MIGRATION TIMING	GEOGRAPHY (Ocean)
Col Lower R spring	Spring	Central
Fraser Sp. 1.2	Spring	North/Central
Fraser Sp. 1.3	Spring	North/Central
SEAK	Spring	North
Upper Col R spring	Spring	Central
Areas 1-5	Summer	North
Areas 6-10	Summer	North
Col R summer	Summer	Central
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Fraser Sm. 1.3	Summer	North
Puget Sound	**Summer/Fall**	**Central**
Upper Georgia Strait	**Summer/Fall**	**North**
Col R Tule	**Fall**	**Central**
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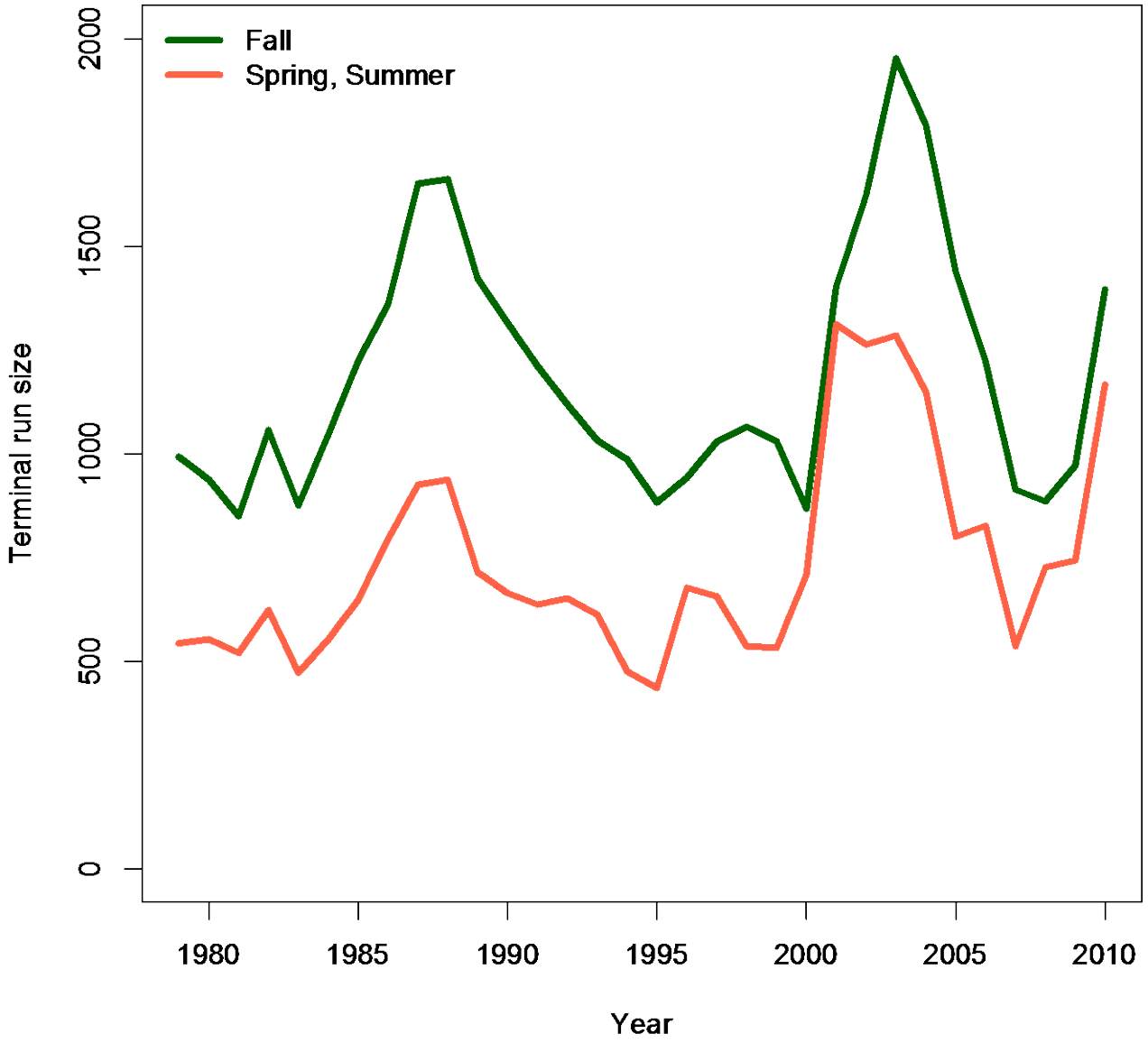
Fraser Late	**Fall**	**Central**
Lower Georgia Strait H & N	**Fall**	**Central**
Klamath fall	**Fall**	**California**
OR coast	**Fall**	**North**
Sacramento fall	**Fall**	**California**
WA coast	**Fall**	**North**
WCVI	**Fall**	**North**

What about Puget Sound, Upper G. Strait (summer / fall)?

	Pre-terminal catch	Puget Sound	Georgia St	Improvement in AIC	Improvement in AIC
Fall (-California)	N	N	N	-	-
Fall (-California)	N	Y	N	-0.09	-0.91
Fall (-California)	N	N	Y	-0.02	-0.13
Fall (-California)	**N**	**Y**	**Y**	**-0.12**	**-0.98**

More negative values indicate more improvement (reduction) in AIC value, better fit to model

Fall & Summer/Fall > 50%



What's not included in fall group?

- California stocks (Sacramento, Klamath)
- Summer stocks
- Spring stocks
  - Fattier (e.g. Columbia spring)
  - Workshop 1 result: spring stocks may be most important (Wasser, Ayres et al.)
  - Spring stocks don't seem to be supported here

Summarizing Parken-Kope indices

- Results consistent with CTC results
  - strong positive correlations with survival, less so with fecundity
- FRAM inland #s seems to be somewhat of an outlier
  - Different pattern, especially since mid 1980s
  - Science panel report, p 12-13 (Figure 1)