Mortality Rates and Birth Rates of SRKWs and CTC Abundance Indices for Fraser Stocks of Chinook Salmon

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Evaluating the Effects of Salmon Fisheries on Southern Resident Killer Whales – Workshop 2

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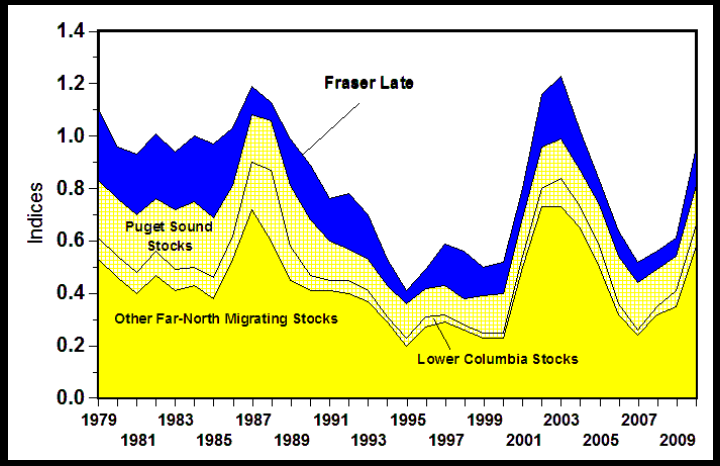
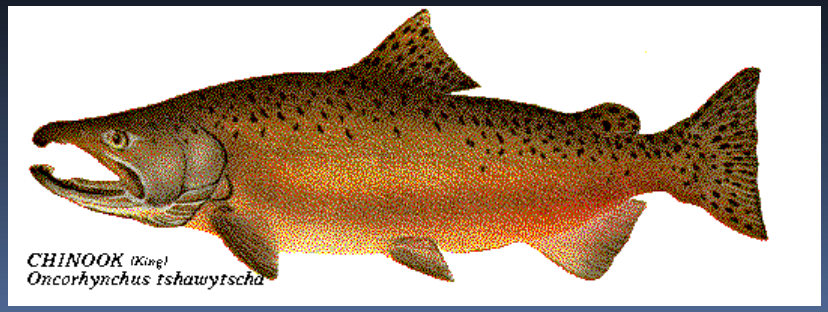




Goal

To judge the suitability of CTC abundance indices and their components for determining the possibility that abundance of Chinook salmon meaningfully affects the dynamic rates of SRKWs.

Tasks

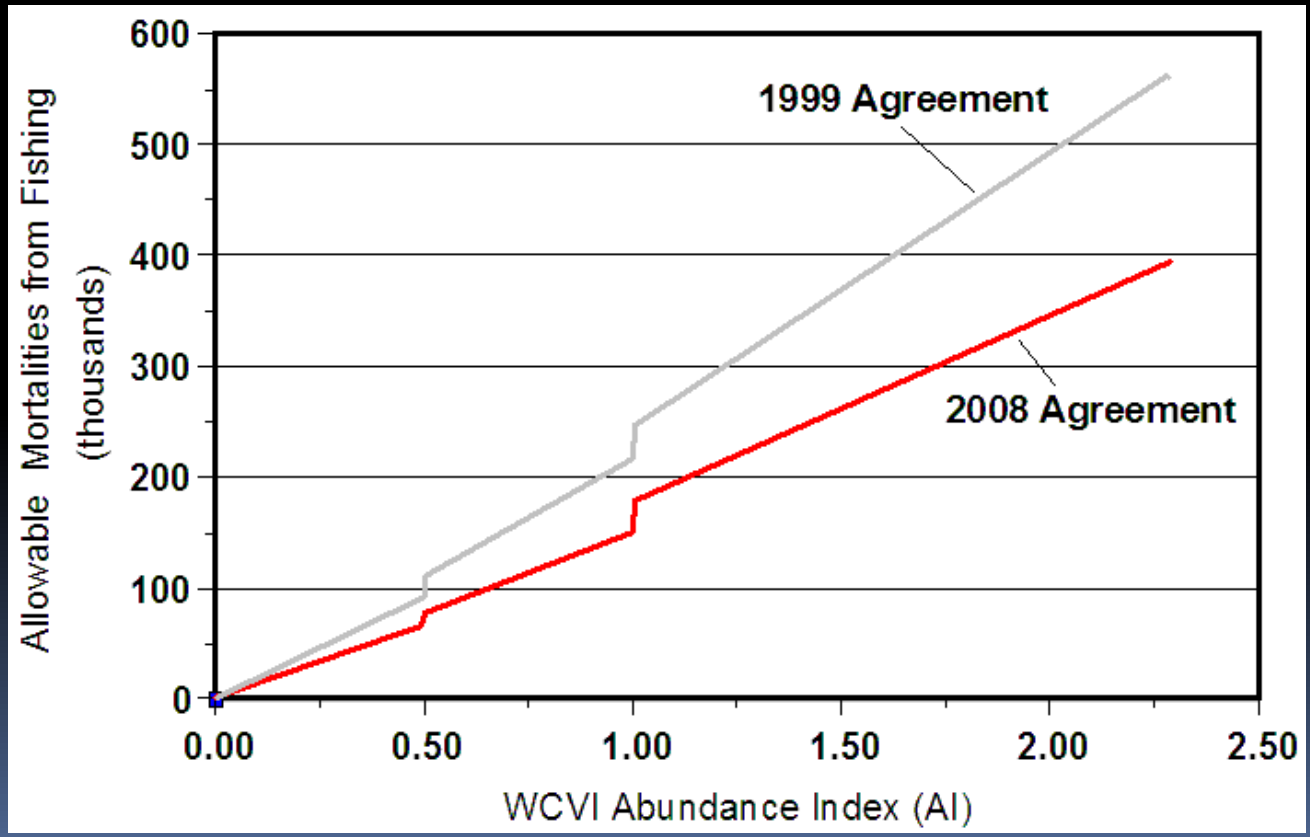
- Describe how CTC abundance indices (AIs) for Chinook salmon are calculated.
- Decompose AIs for the three AABM fisheries to correspond to what we know of the Chinook diet of SRKWs.
- Reconstruct the decomposed indices into covariates.
- Look for statistical associations that represent a biologically meaningful portion of the observed ‘variation’ in dynamic rates for SRKWs.
- Discuss findings relevant to the observational nature of the data used in the analysis.

AI Calculation: Steps to Get an Aggregate

1) Estimate exploitation rates (ERs) by age for exploitation indicator stocks from recoveries of CWTs;
2) Estimate catches in ocean (AABM) fisheries for each escapement indicator stock by expanding estimated terminal run size as a function of ERs;
3) Reconstruct the run through forward cohort analysis calibrated against estimated escapements to calculate abundance in ocean fisheries for escapement indicator stocks by stock, age, year, and fishery;
4) Predict **catches** by year, stock, age, fishery that would be expected if **ERs** from base period (1979 – 1982) **were still in effect**; and
5) Sum predictions across age and stock for a given year and fishery, then divide the sum by the average over the base period.

$$AI_{fishery,year} = \frac{\sum_{stock}\sum_{age}\left[N_{stock,age,(year-age)} \times SurvRate_{age} \times ER_{(base)fishery,stock,age} \times PortionVul_{fishery,age}\right]}{\sum_{year=1979}^{1982}\left\{\sum_{stock}\sum_{age}\left[N_{stock,age,(year-age)} \times SurvRate_{age} \times ER_{(base)fishery,stock,age} \times PortionVul_{fishery,age}\right]\right\} / 4}$$

The Only Variate Across Years



AI Decomposition

$$AI_{fishery,year} = \frac{\sum_{stock}\sum_{age}\left[N_{stock,age,(year-age)} \times SurvRate_{age} \times ER(base)_{fishery,stock,age} \times PortionVul_{fishery,age}\right]}{\sum_{year=1979}^{1982}\left\{\sum_{stock}\sum_{age}\left[N_{stock,age,(year-age)} \times SurvRate_{age} \times ER(base)_{fishery,stock,age} \times PortionVul_{fishery,age}\right]\right\} / 4}$$

$$AI_{fishery,year} = AI_{fishery,stock=1,year} + AI_{fishery,stock=2,year} + AI_{fishery,stock=3,year} + AI_{fishery,stock=4,year} + \cdots$$

Table I.1. Abundance indices (AIs) for the Southeast Alaska troll fishery by model stock and year
Numbers represent the model stock contribution to the total AI: the summation across a
the AI total for each calendar year. **(TCCHINOOK11-3 at psc.org)**

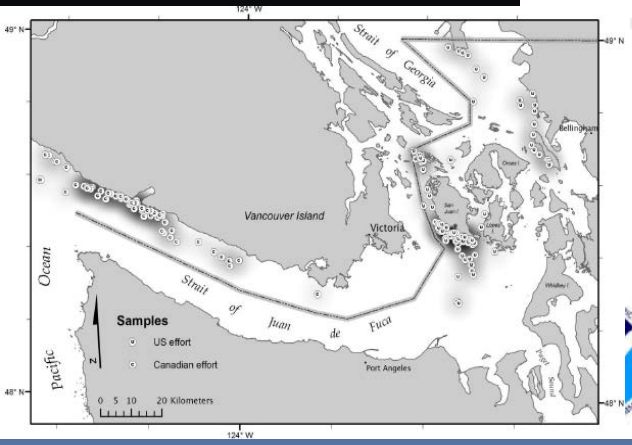
Year	Alaska South SE	North / Centr	Fraser Early	Fraser Late	WCVI Hatchery	WCVI Natural	Georgia St. Upper	Georgia St. Lwr Nat	Georgia St. Lwr Hat	Nooksack Fall	Pgt Sd Fing	Pg N
1979	0.03	0.12	0.06	0.00	0.05	0.07	0.04	0.00	0.00	0.00	0.00	0.
1980	0.03	0.13	0.05	0.00	0.10	0.15	0.05	0.00	0.00	0.00	0.00	0.
1981	0.04	0.14	0.04	0.00	0.08	0.12	0.04	0.00	0.00	0.00	0.00	0.
1982	0.05	0.14	0.04	0.00	0.19	0.21	0.04	0.00	0.00	0.00	0.00	0.
1983	0.05	0.16	0.04	0.00	0.30	0.14	0.03	0.00	0.00	0.00	0.00	0.

SRKW "Summer" Diets by Chinook Salmon Stock

From presentation by Brad Hanson Workshop 1

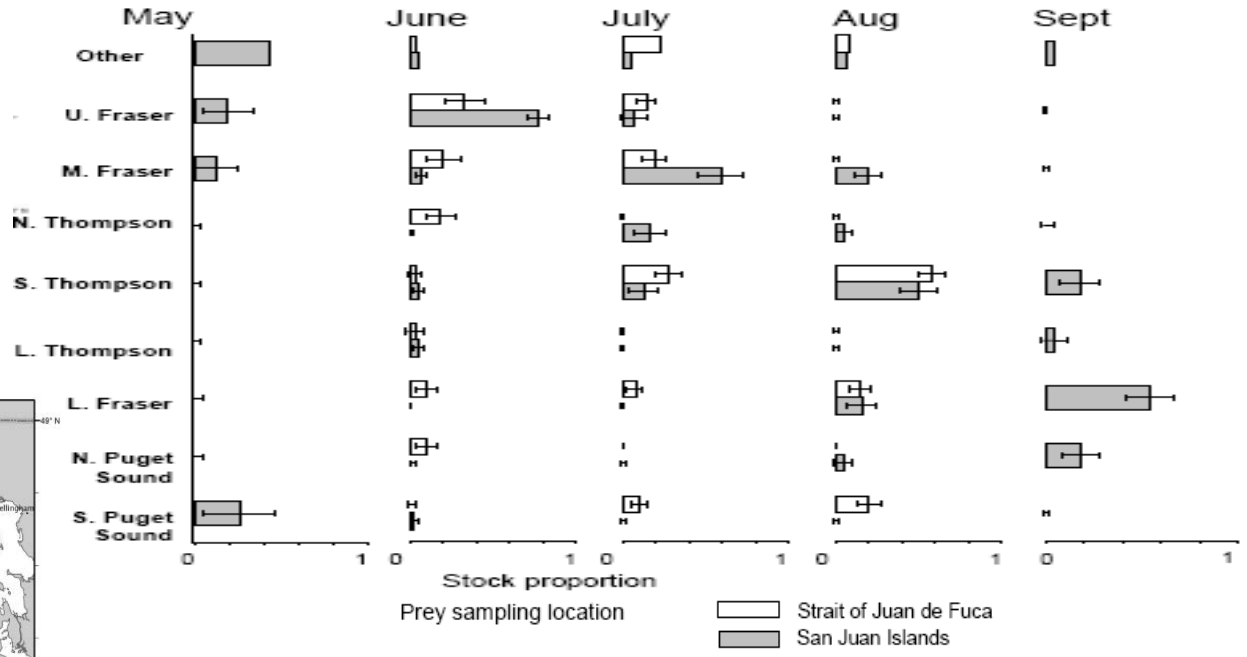
131 Samples 2004/5 - 2008

"Winter" diets of SRKWs essentially unknown



SRKW Focal Follow behavioral foraging study

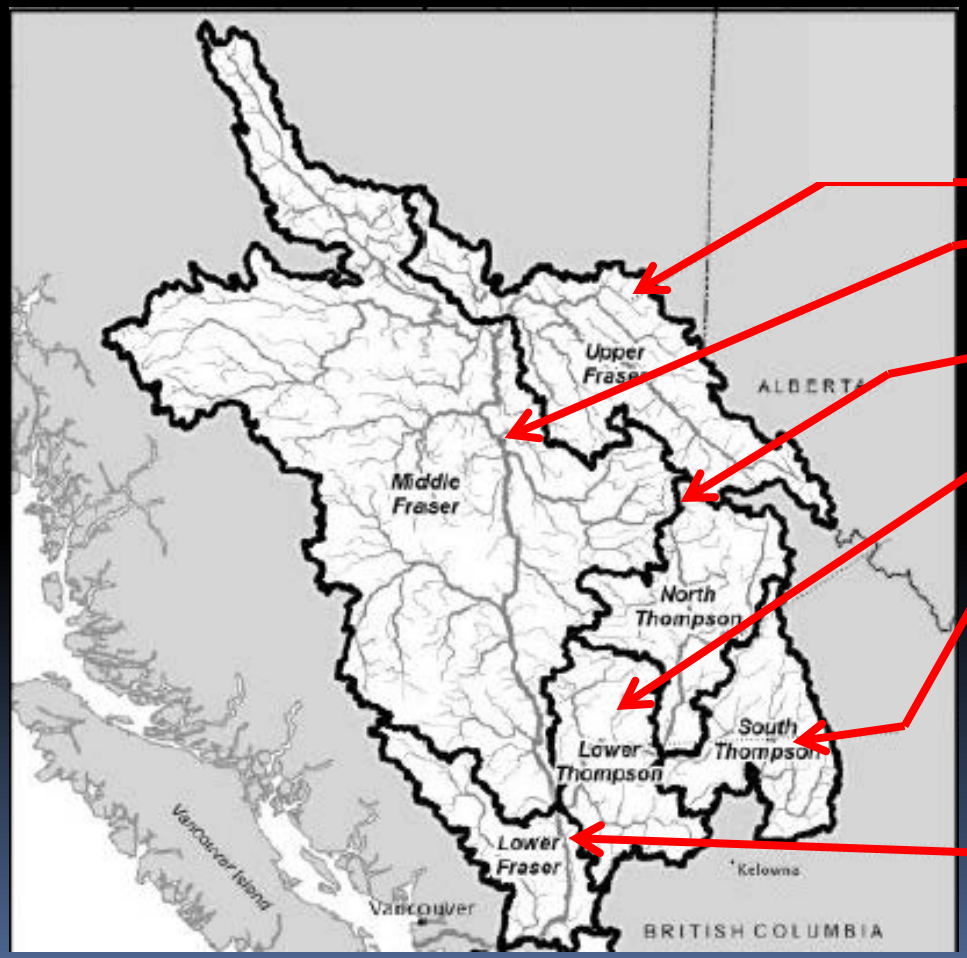
Fraser River is of primary importance



Upper, Middle, and Lower Fraser, and South Thompson are seasonally important

Northwest Fisheries Science Center

Fraser Stocks as Grouped for CTC AIs



CTC AI Fraser Early

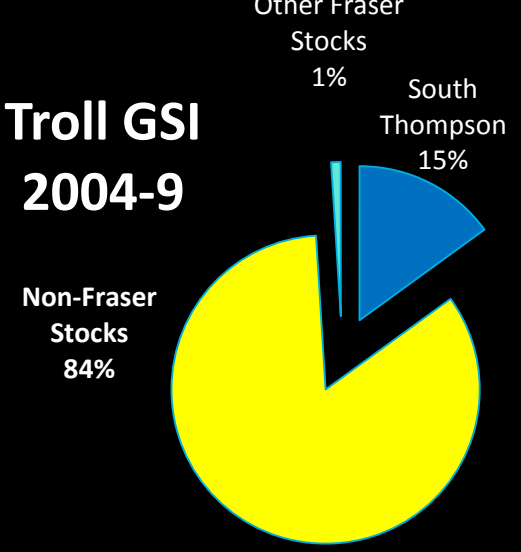
Upper Fraser
Middle Fraser

North Thompson
Lower Thompson
South Thompson

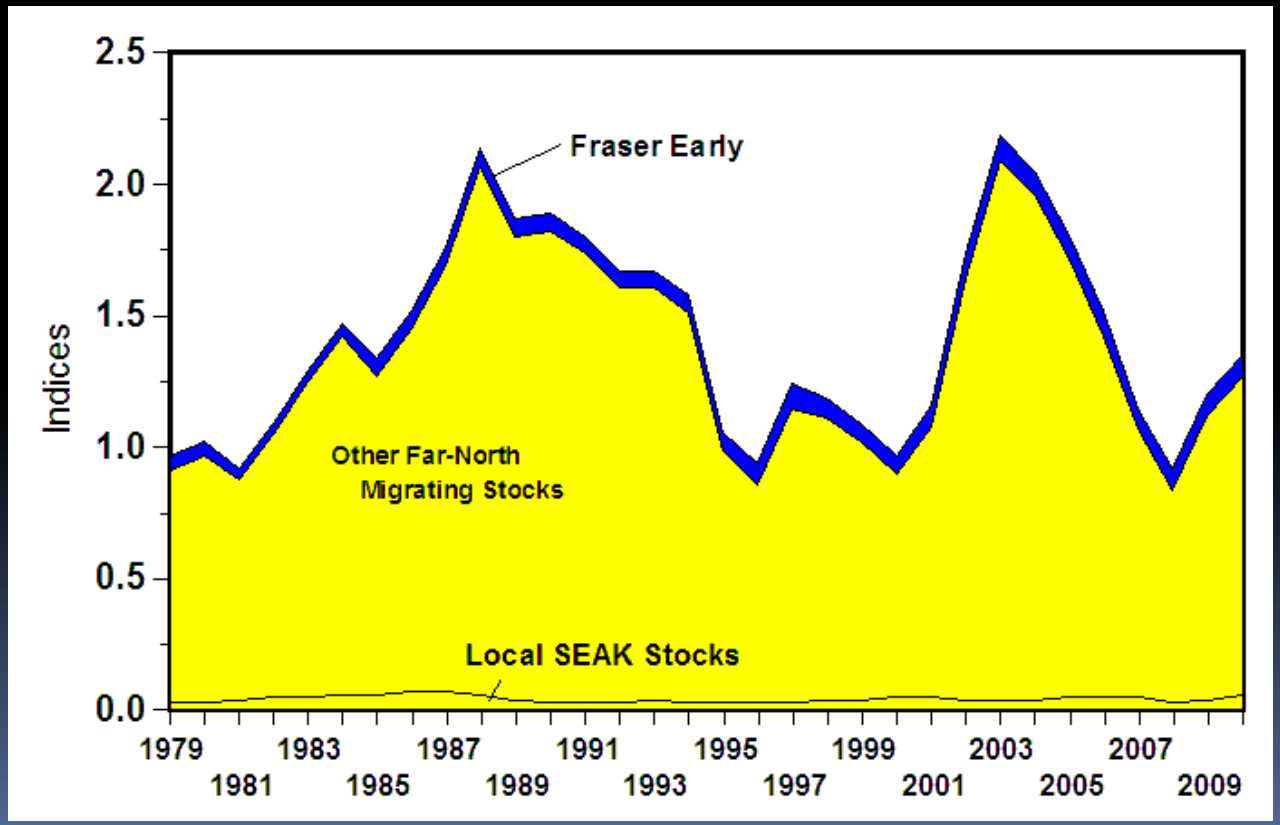
CTC AI Fraser Late

Lower Fraser (Harrison)

SEAK CTC Abundance Indices/GSI:



CTC Abundance Indices



Unavailable to SRKWs

Fraser Stocks (Available to SRKWs)

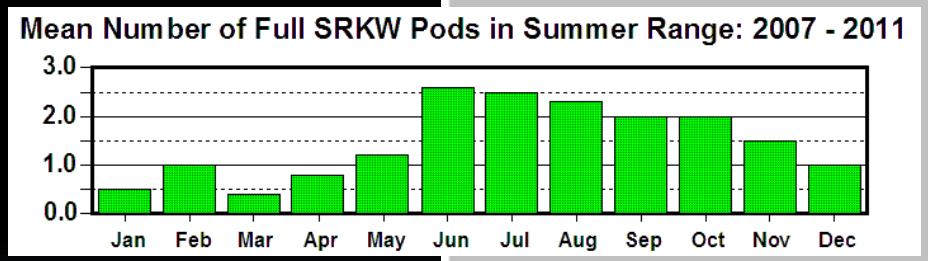
Ranges

Far-North Migrating Stocks

North Oregon Coastals
Mid Columbia
Upper Columbia
Washington Coastals
WCVI
Fraser River
Transboundary Rivers
Other BC Continental Rivers

"Local" Stocks

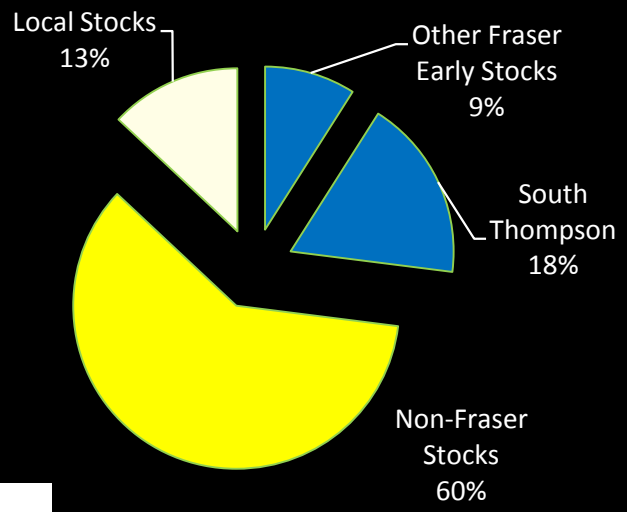
Puget Sound
Georgia Strait
Lower Columbia
Coastal Streams of BC and Alaska



Approximate distribution of far-north migrating stocks inferred from recovery of CWTs in incidental catches by trawlers.

NBC CTC Abundance Indices/GSI:

GSI Troll & Sport 2002-5



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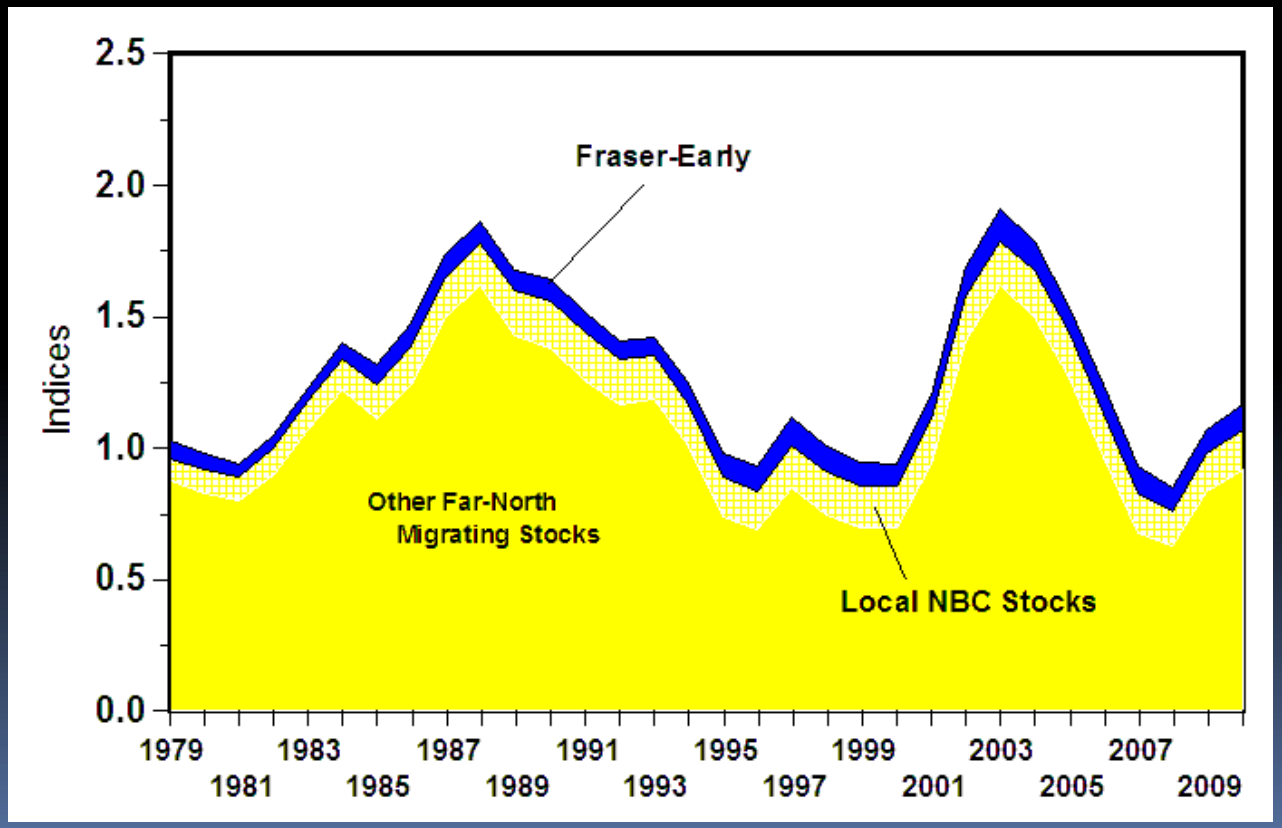
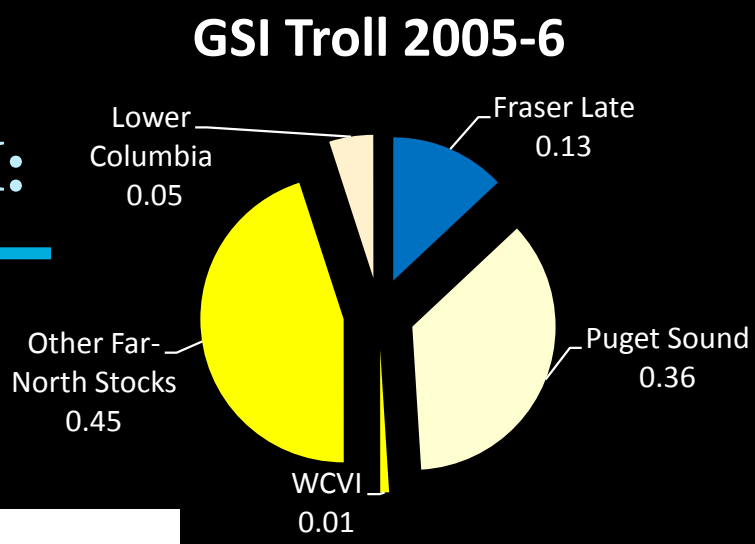


Unavailable to SRKWs

Available to SRKWs (perhaps)

Fraser Stocks (Available to SRKWs)

WCVI CTC Abundance Indices/GSI:



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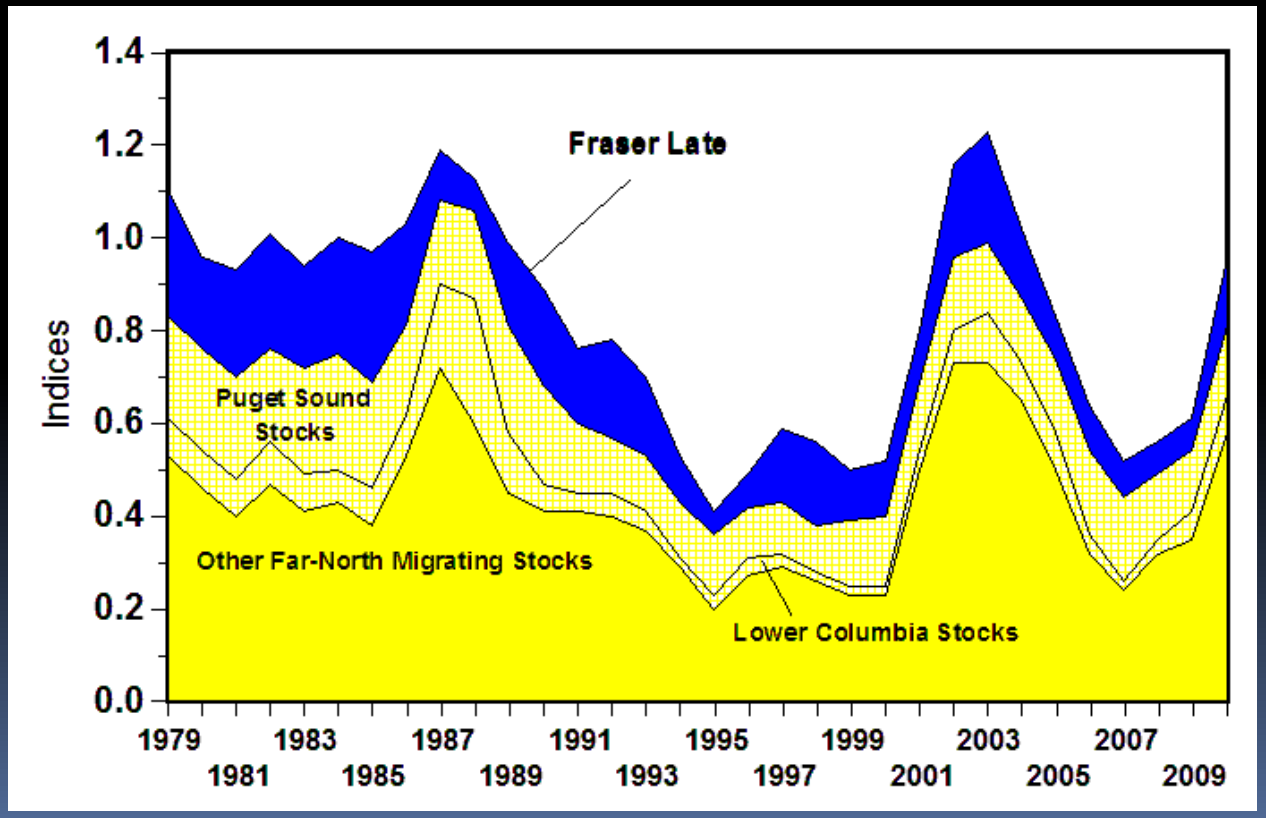

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- The majority of stocks in aggregate indices are far-north migrating stocks not from the Fraser River, stocks that are geographically and/ or temporally not, or only partially available to SRKWs.

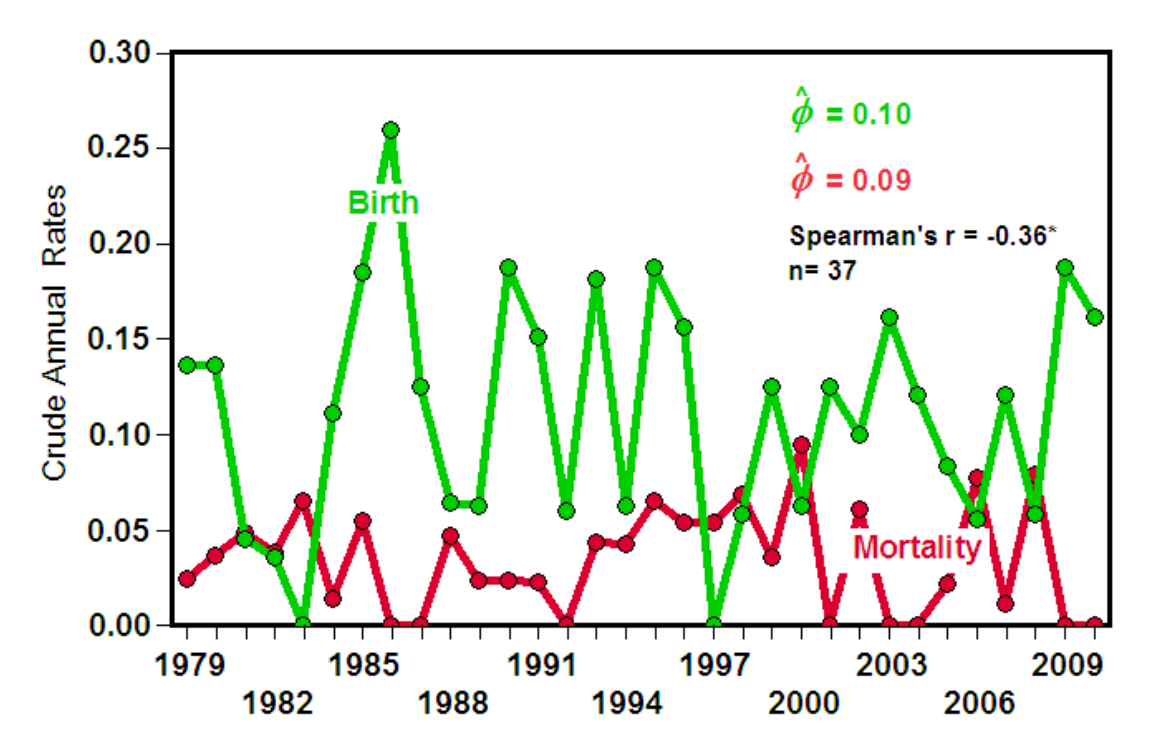
Mortality and Birth Rates of SRKWs

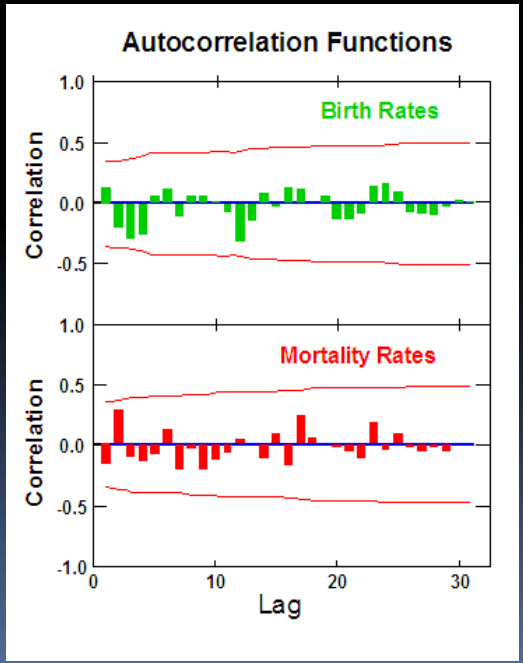
Birth Rates = # Births/ # Mature Females

Mortality Rates = # Deaths/ # in Population

No evidence for serial correlation in either series

$-1 < \phi < 1$
w/ $\phi = 0$ being a lack of serial correlation





Logistic Regression: Base Model for Birth Rates

Model	AIC
Null (no covariates)	713
Base (null + age poly-nomial as covariates)	591 (-122)

Akaike Information Criterion (deviance – 2 x number of parameters)

A "measure" of explanatory power of covariates in a single model

Covariates in a single model linked by (and)

Sign on the coefficient

Base Model

Year of Giving Birth			P-value
Age	(and)	(-)	0.000408490
Age^2	(and)	(+)	0.000824508
Age^3	(and)	(+)	0.001376552
Age^4	(and)	(-)	0.001908719
Age^5		(+)	0.002380936

$P \leq 0.05$ Statistically Significant

Non-Significance with Birth Rates

	AIC	AIC
Null Model	713	693
Base Model	591 (-122)	575 (-118)
Base + Covariates	591±1 (0)	575±2 (0)

Covariates in different models indicated by (or)

Base Model + Covariate	Year of Giving Birth P-values	Year Before Giving Birth P-values
WCVI AI (or) (+)	0.229020837	0.423101648
NBC AI (or) (+)	0.127833352	0.245819536
SEAK AI (or) (+)	0.268623804	0.342721749
WCVI Puget Sound AI (or) (+)	0.618055957	0.126495453
WCVI Fraser Late AI (and) (+)	0.329634689	0.057598804
NBC Fraser Early AI (+)	0.154452451	0.422152948

Logistic Regression: Base Model for Mortality Rates

Base Model

Year of "Death"	P-value
Age (and) (-)	0.000000000
Age^2 (and) (+)	0.000000003
Age^3 (and) (-)	0.000000117
Age^4 (and) (+)	0.000001584
Sex (1=&; 2=%; 0 = unknown)	0.016077077

Model	AIC
Null	856
Base	804
Base w/o Sex	808

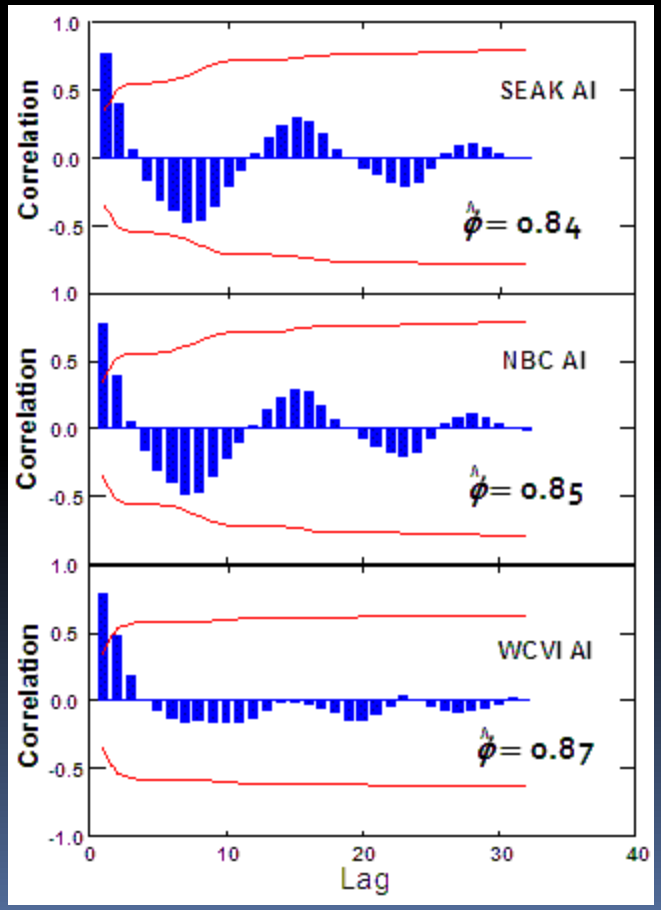
A Problem (?) with Independence

Base Model + Covariate	Year of Death P-values	Year Before Death P-values	Year AFTER Death P-values
WCVI AI (or) (-)	0.000849392	0.002413417	0.003085388
NBC AI (or) (-)	0.000857054	0.005659499	0.002155486
SEAK AI (-)	0.002748031	0.030615968	0.001982907

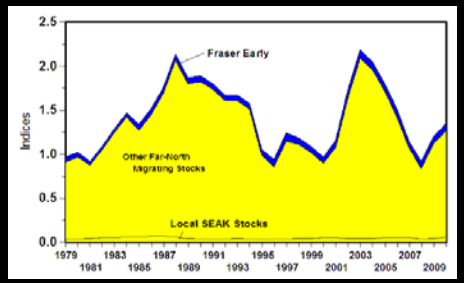
	AIC	AIC	AIC
Null Model	856	844	811
Base Model	804 (-52)	794 (-50)	758 (-52)
Base + WCVI AI	795 (-9)	787 (-7)	751 (-7)
Base + NBC AI	794 (-10)	788 (-6)	750 (-8)
Base + SEAK AI	797 (-8)	792 (-2)	750 (-8)

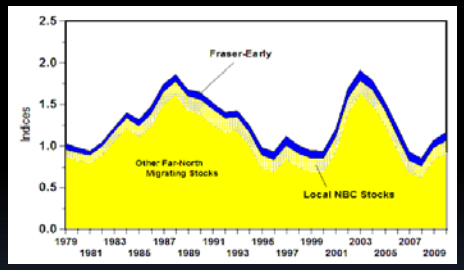
Strong Serial Correlation in the AIs

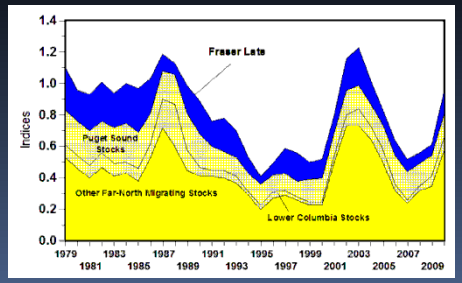
Autocorrelation Functions



AI Time Series Plots







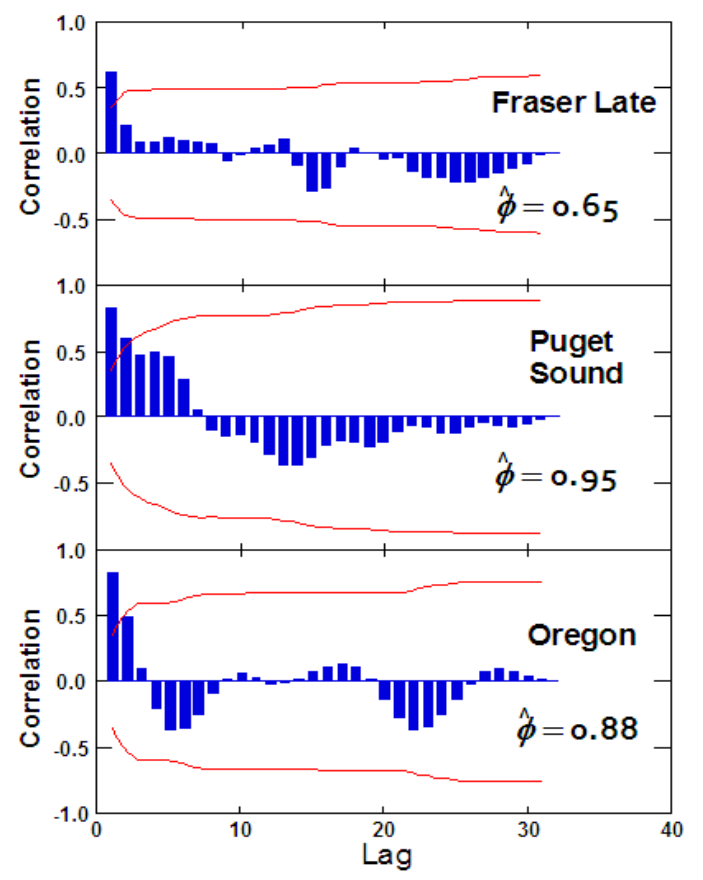
$-1 < \phi < 1$
w/ $\phi = 0$ being a lack of serial correlation

To some unknown degree, serial correlation in AIs is due to using cohort analysis to construct indices.

Lack of serial correlation in mortality and birth rates when there is strong correlation in the AIs is further evidence AIs have negligible explanatory power.

Serial Correlation and Significance: Stock-Specific AIs

Autocorrelation Functions for Stock-specific WCVI AIs



Association between Stock-specific CTC AIs and SKRW MORTALITY RATES:

- Fraser Late – NOT significant
- Puget Sound – NOT significant
- **Oregon Coastal – SIGNIFICANT**

Stock-Specific AIs and A Problem of Geography

Stock-specific AIs for stocks known to occur predominantly in the diet of SRKWs (such as Fraser River stocks) or for Puget Sound stocks are NOT statistically associated with MORTALITY RATES of SRKWs .

Instead, significant statistical associations ARE present between MORTALITY RATES for SRKWs and stock-specific AIs for other far-north migrating stocks and for the Lower Columbia River stock in the WCVI fisheries.

Base Model + Covariate			Year of Death P-values
WCVI Fraser Late AI	(and)		0.179898568
NBC Fraser Early AI	(or)		0.882751338
WCVI Puget Sound AI	(and)		0.989581957
WCVI Lower Columbia AI	**(or)**	**(-)**	**0.026540560**
WCVI Far-North AI (not Fraser)	**(or)**	**(-)**	**0.001152852**
NBC Far-North AI (not Fraser)	**(or)**	**(-)**	**0.000423422**
SEAK Far-North AI (not Fraser)	**(or)**	**(-)**	**0.002150221**

A Problem of Geography

Base Model (AIC = 804) + Covariate				Year of Death P-values
WCVI Oregon Coastal AI	(or)	(-)	ΔAIC = -8	0.001186200
WCVI Washington Coastal AI	(or)	(-)	ΔAIC = -8	0.003596483
WCVI Mid/Upper Columbia AI	(or)	(-)	ΔAIC = -5	0.009952326
WCVI WCVI AI		(-)	ΔAIC = -2	0.035123080
When all four far-north migrating stocks groups were run simultaneously [(or) replaced with (and)], no stock group had a statistically significant coefficient, and the AIC = 795				NS (P > 0.05)

While AIs above are significantly associated statistically with SRKW morality rates, they represent negligible fractions (≤1%) of 'variation' (deviance in the null model) in rates.

Ranges: Source of the Problem

CTC AI Stocks Migrating Outside the Winter and Summer Ranges of SRKWs:

North Oregon Coastals
Upper Columbia
Mid Columbia
Washington Coastals
WCVI
BC Continental Rivers

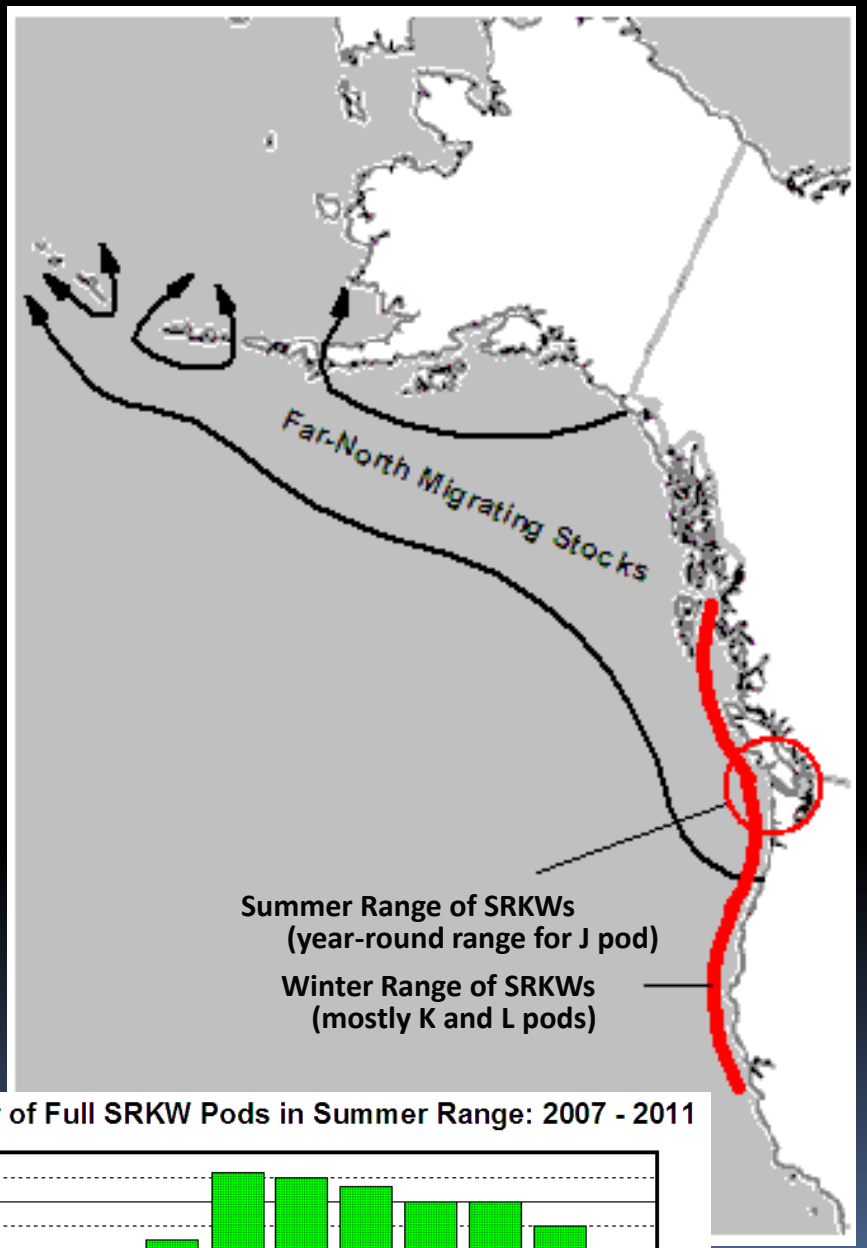
CTC AI Stocks w/ Summer Ranges that overlap the Summer Range of SRKWs:

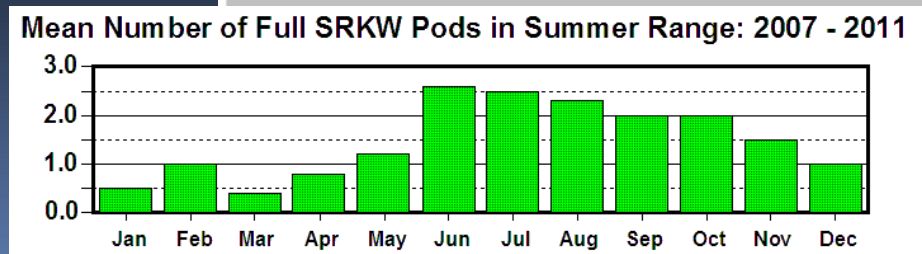
Fraser Puget Sound

CTC AI Stocks w/ Winter Ranges that overlap the Winter Range of SRKWs:

Puget Sound
Coastal Streams of BC and Alaska
Georgia Strait
Lower Columbia

Only stocks in gold have AIs with statistically significant associations with SRKW MORTALTIY RATES .





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- Statistical associations between aggregate CTC AIs and SRKW **mortality** rates WERE SIGNIFICANT; and
- In all statistically significant associations between aggregate or stock-specific AIs and SRKW **mortality** rates, the AIs had negligible explanatory power concerning variation in rates.

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- Statistical association between SRKW **mortality** rates and CTC AIs for **Puget Sound** stocks was NOT SIGNIFICANT; and
- Association between **mortality** rates and CTC AIs for the **Lower Columbia River stocks** WAS SIGNIFICANT.

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- No comprehensive knowledge of how exploitation of exploitation rate indicator stocks differ from that of escapement indicator stocks, the difference causing non-random measurement error; **(–)**
- Only the CTC AIs for the WCVI AABM fishery represent stocks likely to be frequently encountered in the SRKW winter range (**Puget Sound and Lower Columbia River**); and **(–)**

A Scientific Contradiction with CTC AIs

Statistical analyses involving CTC AIs indicated an unlikely scientific result given empirical evidence on SRKW diets and ranges:

> Chinook stocks that have statistically significant (though negligible) associations with SRKW **mortality** rates are stocks least likely encountered by the whales, while those stocks encountered the most (in the summer at least) have no discernable statistical association at all. **(–)**

A Stream Bank on the South Thompson River, 2006

Courtesy of Richard Bailey, CDFO

Acknowledgments

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