Summary of science investigating killer whale demography and Chinook relationships, 2007-2019

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WCRO: Alison Agness, Larrie LaVoy
DFO: John Ford

Northwest Fisheries Science Center

Background

History of consultations (A. Agness)

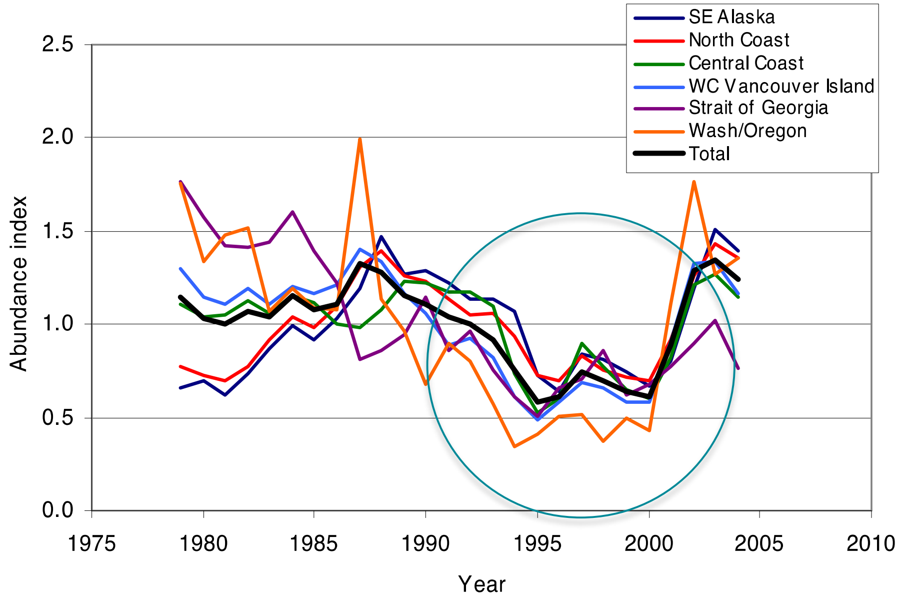
- Modeling work in 2007 and later influenced

- 2008 U.S. v. Oregon Harvest Agreement
- Pacific Salmon Treaty
- Pacific Coast Salmon Plan
- U.S. Fraser Panel Fisheries
- Puget Sound Chinook Harvest Plan

https://www.westcoast.fisheries.noaa.gov/publications/protected_species/marine_mammals/killer_whales/esa_status/agness-overview.pdf

J. Ford et al. 2005 & 2010

- Much of this relied on statistical relationships between killer whale demography and aggregate indices of Chinook abundance

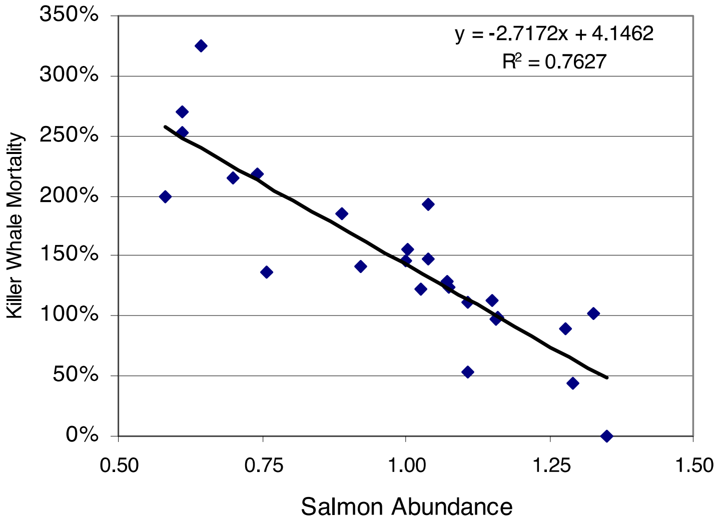


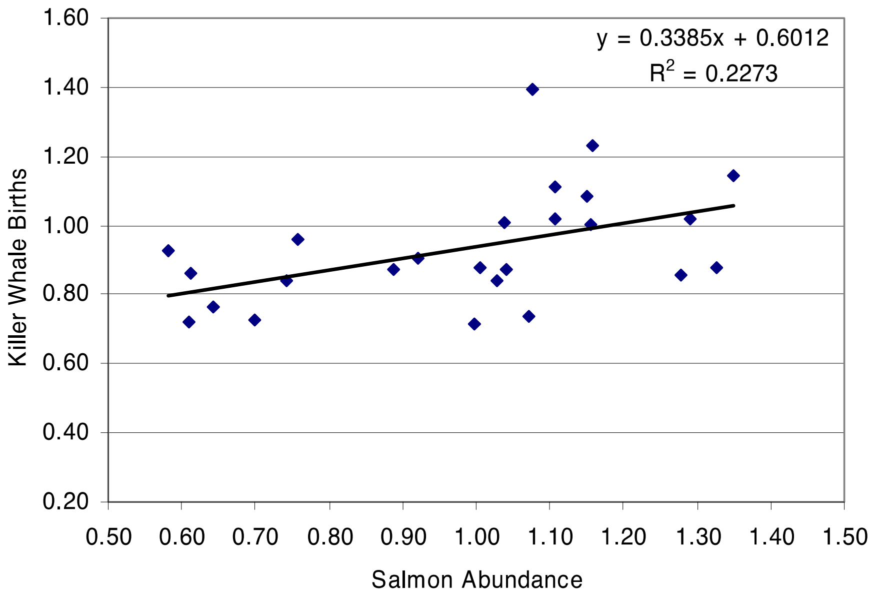
Late 1990s corresponded to SRKW downturn

Figure 9. Chinook abundance indices for the 6 west coast index regions, plus the total index for all regions combined, 1979-2004. Indices are derived from abundance estimates by the Pacific Salmon Commission Chinook Technical Committee (see text for details).

J. Ford et al. 2005 & 2010

- 3-year running avg of observed/expected births v averaged CTC indices (& spatial averaging)





Ward et al. 2009: Slightly fancier models, same result

- Goal: develop tool with WCRO for quantifying changes of Chinook abundance on killer whale pop. growth
- These models were used in 2007/08 consultations

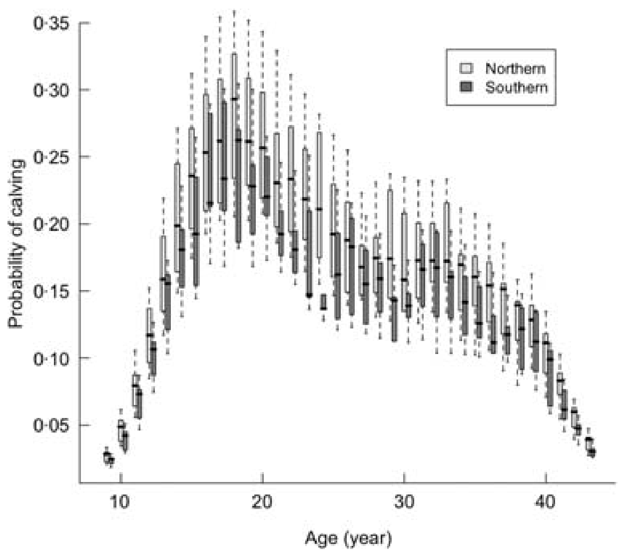


Fig. 2. The estimated effect of age on the probability of calving (estimated from the Bayesian version of Model 2, Table 1). The boxes represent the first and third quartiles around the median, and the whiskers represent the range of the variation.

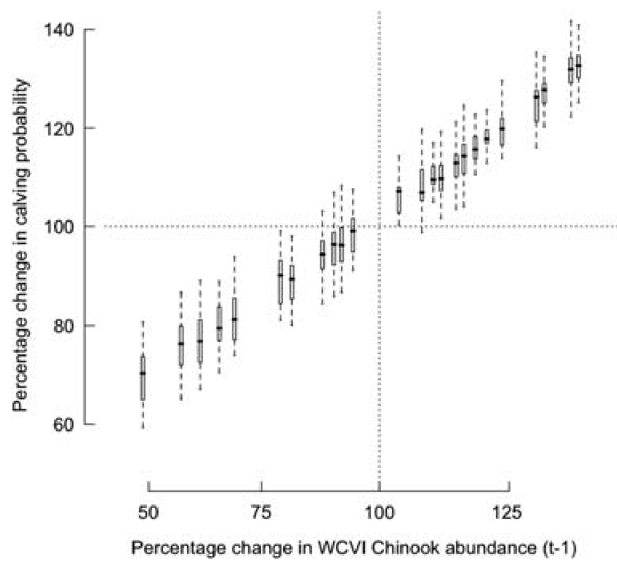


Fig. 3. Percentage deviation from the model predicted calving probability (using the Bayesian version of Model 2, Table 1) as a function of the percentage deviation in Chinook abundance relative to the 1980–2006 mean. Deviations for each variable are calculated as deviations from mean, $x_i/\bar{x}$ while the y-axis is calculated from model predictions, the x-axis is calculated from the PSC indices.

FRAM also used in consultations (L. LaVoy, A. Agness)

- FRAM separated into Inland / Coastal components
  - Motivated by Puget Sound Chinook
- Further modeling:
  - imposed selectivity curves based on NWFSC scale/age samples (Hanson 2008)
  - imposed kcal – size relationships of Chinook stocks to estimate kcal available to whales (O'Neill et al. 2014)

Evaluating impacts of fisheries

- Fisheries impacts examined by comparing status quo to 'no fishing' scenario, 20% increase in salmon
  - Coarse because of limits with killer whale data

- Used in Puget Sound RMP (NMFS 2011a) and other consultations (A. Agness)
  - Estimated impact = 0.7 whales

National Marine Fisheries Service (NMFS). 2011a. Endangered Species Act Section 7(a)(2) Biological Opinion and Magnuson-Stevens Fishery Conservation and Management Act Essential Fish Habitat Consultation on NMFS' Evaluation of the 2010-2014 Puget Sound Chinook Harvest Resource Management Plan under Limit 6 of the 4(d) Rule, Impacts of Programs Administered by the Bureau of Indian Affairs that Support Puget Sound Tribal Salmon Fisheries, Salmon Fishing Activities Authorized by the U.S. Fish and Wildlife Service in Puget Sound and NMFS' Issuance of Regulations to Give Effect to In-season Orders of the Fraser River Panel. National Marine Fisheries Service, Northwest Region. May 27. 220 pp

2007-2009: changing statistical results

- As these models were developed, and new data was collected we found results to be sensitive to:
  - Which animals / years were included
  - Whether Chinook was included as a covariate on survival or fecundity
    - Which time lag was used
  - Which Chinook index was used (CTC, FRAM, FRAM Inland/Coastal etc)

Why are things changing: asking too much of the data

- Census is totally opportunistic
- Every whale will frequent inland waters of the Salish Sea sometime in spring/summer, some more than others
  - Some groups spend nearly all their time in the Salish Sea
  - Others spend only a few weeks
- Killer whale detectability is also function of people (citizens) looking for them (unknowable)
  - Effort via social media (Facebook etc) (unknowable)
- Small sample sizes of birth/deaths per year (2-3 avg)
  - Area of parameter space where logistic/probit regression have problems
- Salmon indices are very correlated
  - Can't identify which stock is most important
  - Or what index is best supported

2011-2012 Bilateral Science Panel

Independent review by Hilborn et al. (2012)

- Review demographic modeling

- Review methods used in consultations
  - Quantifying fishery impacts
  - Selectivity curves
  - Ratios of prey available / needed

- Help identify data gaps
  - Impacts of marine mammals (other killer whales, pinnipeds)

  - Winter diet and distribution

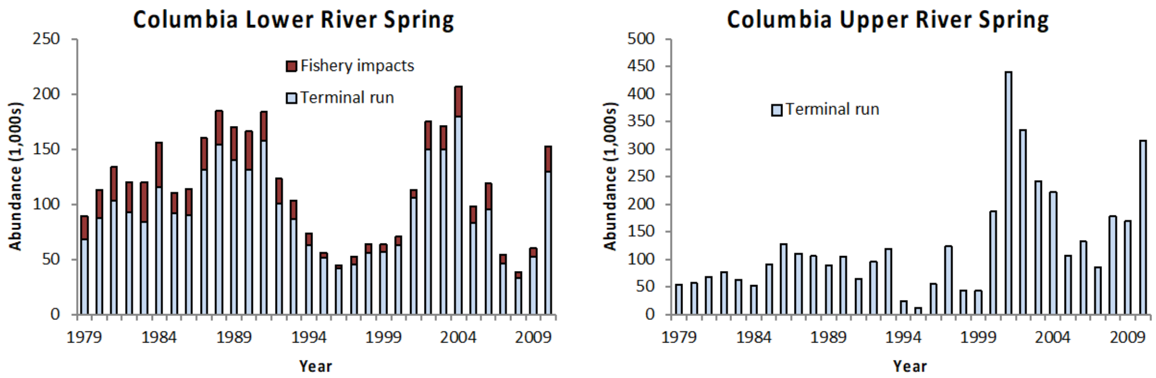
Independent review by Hilborn et al. (2012)

- Review demographic modeling
- Review methods used in consultations
  - Quantifying fishery impacts
  - ~~Selectivity curves~~ possibly biased
  - ~~Ratios of prey available / needed~~ Chasco et al. 2017
- Help identify data gaps
  - Impacts of marine mammals (other killer whales, pinnipeds)
    - Chasco et al. (2016, 2017)
  - Winter diet and distribution (more later today)

Science Panel questions

- How to quantify prey abundance for killer whales?

- 3 metrics: FRAM, CTC indices, Parken-Kope run reconstruction (Hilborn et al. 2012)



R. Kope and C. Parken, Ward et al. (2013)

Science Panel questions

- Are there Chinook stocks, or groups of stocks that are most correlated with killer whale demography?
- Are there season(s) or runs (spring v fall) that are more important?
- What are the impacts of reducing harvest
  - Analogous to increasing ‘terminal run component’ by up to 10%
- Correlation != causation, ‘most correlated’ != ‘most important’

Portfolio effect

- Tables and tables and tables of combinations of stocks, with AIC values relating them to survival / fecundity
- In the end: most support for a coastwise index of Chinook with killer whale fecundity and survival

NOAA Technical Memorandum NMFS-NWFSC-123

Estimating the Impacts of Chinook Salmon Abundance and Prey Removal by Ocean Fishing on Southern Resident Killer Whale Population Dynamics

July 2013

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Marine Fisheries Service
Northwest Fisheries Science Center

Fishery impacts

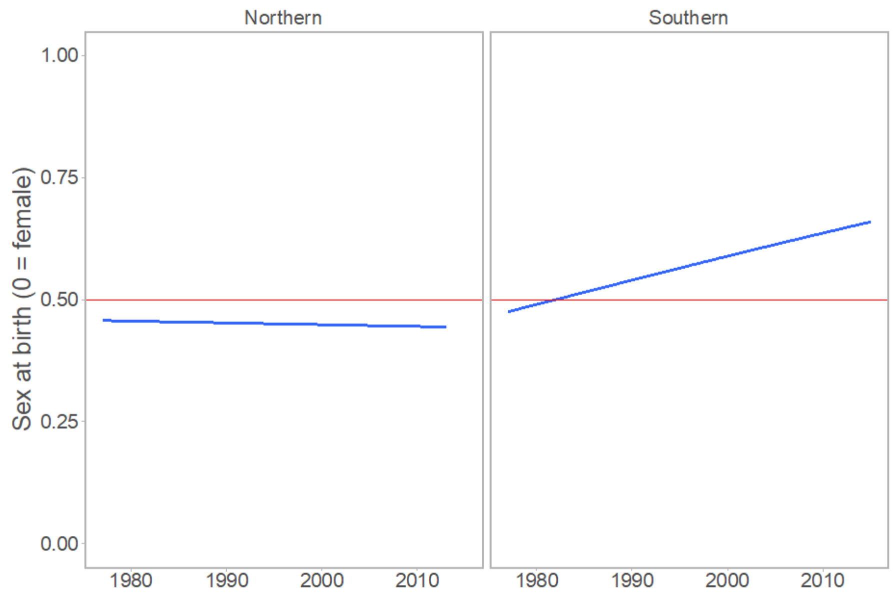
- Panel: non-mechanistic approach probably overestimates salmon that would be available in absence of fishing

Key Point:

The panel sees many potential reasons why not all foregone Chinook salmon catch would be available to SRKW, and is therefore skeptical that reduced Chinook salmon harvesting would have a large impact on the abundance of Chinook salmon available to SRKW.

Demographic comparisons

- SRKW have reduced fecundity and survival compared to other populations (Hilborn et al. 2012, Ward et al. 2013)
- SRKW also have skewed sex ratio at birth toward males



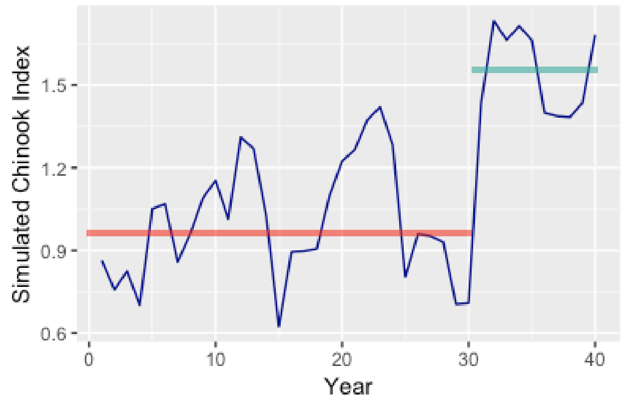
Demographic comparisons

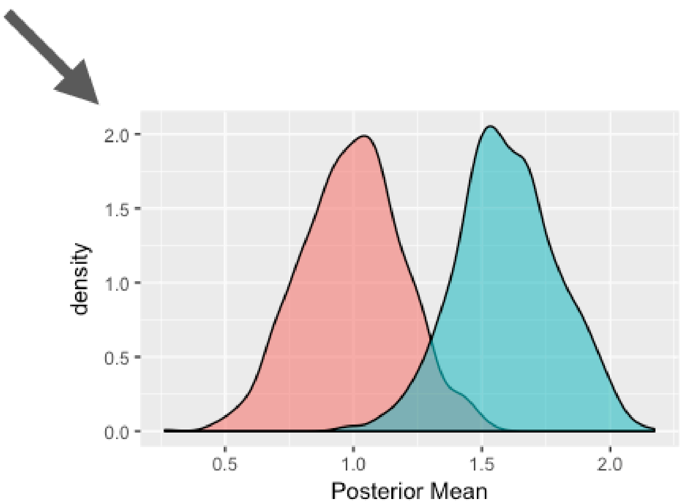
- Greyed out animals = old or haven't given birth in ~ a decade
- K pod, J22/L83/L90 underperforming through bad and good salmon years and their reproductive prime
- Reproductive potential is now very low

animal	pod	age	last	animal	pod	age	last
J17	J	40	2	L54	L	40	7
J19	J	38	12	L55	L	40	6
J22	J	32	14	L72	L	31	12
J31	J	22	1	L77	L	30	5
J35	J	19	7	L82	L	27	7
J36	J	18	2	L83	L	27	10
J37	J	16	2	L86	L	26	3
J40	J	13	NA	L90	L	24	NA
J41	J	12	2	L91	L	22	2
J42	J	10	NA	L94	L	22	2
K14	K	40	9	L103	L	14	2
K16	K	32	15				
K20	K	31	13				
K22	K	30	11				
K27	K	23	6				

Low power to detect small change in salmon

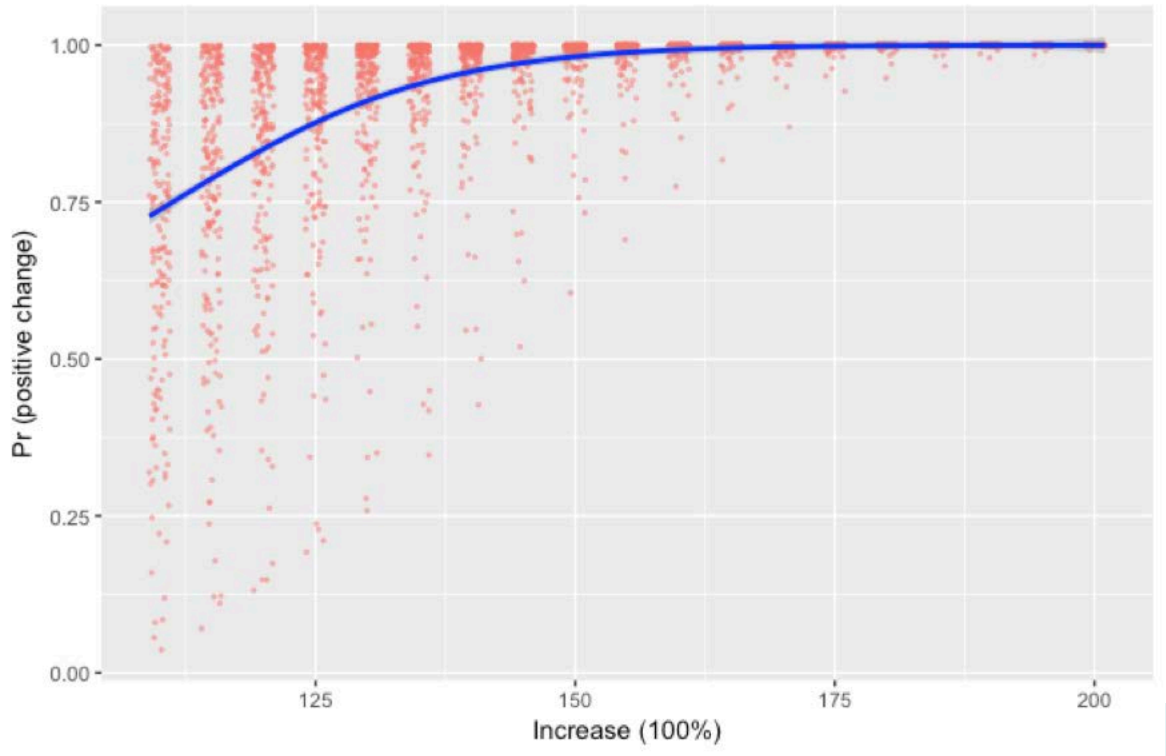
- Time series power analysis, same statistical properties as Chinook indices





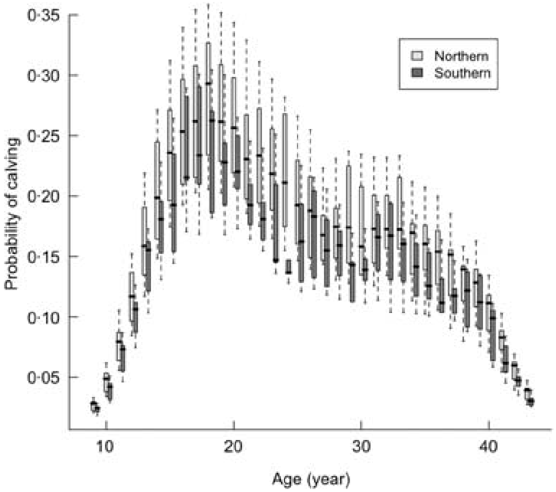
Low power to detect small change in salmon

- Being ~ 90% confident in detecting change requires large increases in Chinook indices
- Even lower power through killer whale demography



Changing correlations

- Many long term examples of changing relationships with long term data (e.g. Mantua and Hare 2002)
- Are correlations between SRKW and Chinook indices driven by years with extremes? (E.Ward + R. Kope)



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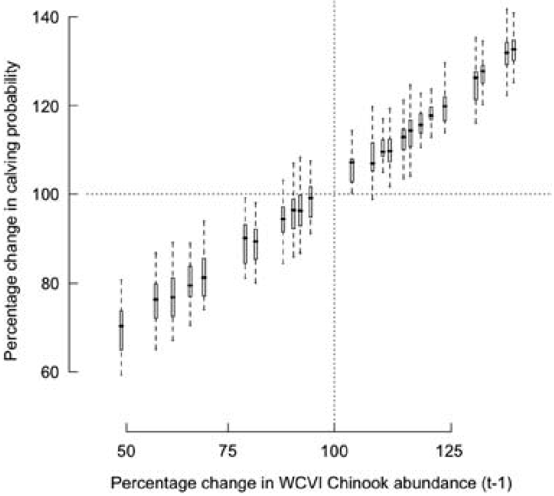

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Demographic correlations have weakened

- Bayesian updating of coefficient as new data collected

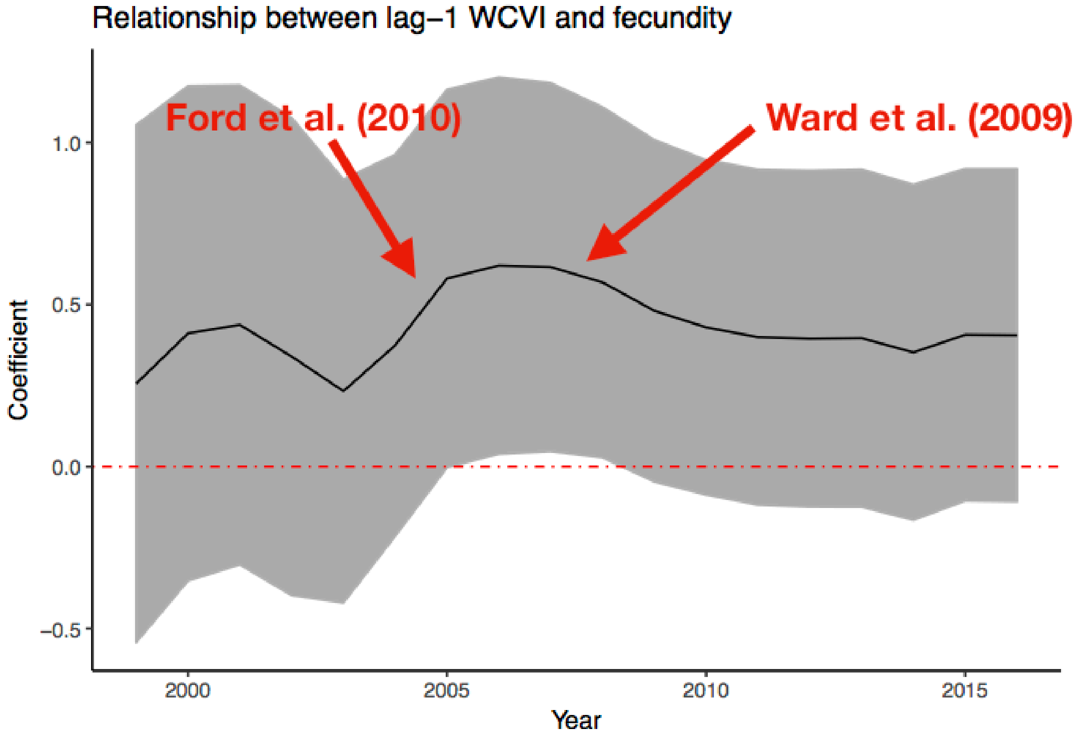


Figure 1: Estimated relationship between SRKW fecundity and WCVI salmon indices. The estimation model is identical to Ward et al. (2013) and includes NRKW data through 2010. Estimates for each year are estimated using data up to that year. The WCVI index starts in 1979.

Interpreting changing correlations

- In some ways, this is what we should expect
  - For small populations, demographic stochasticity > environmental signal (prey)
- But also could be indicative of population not responding as expected to changes in prey & role of other factors
  - Last ~ 5 years = near reproductive failure
  - Chinook slightly below avg, maybe even increasing depending on stock
- Probably not useful line of evidence for future studies

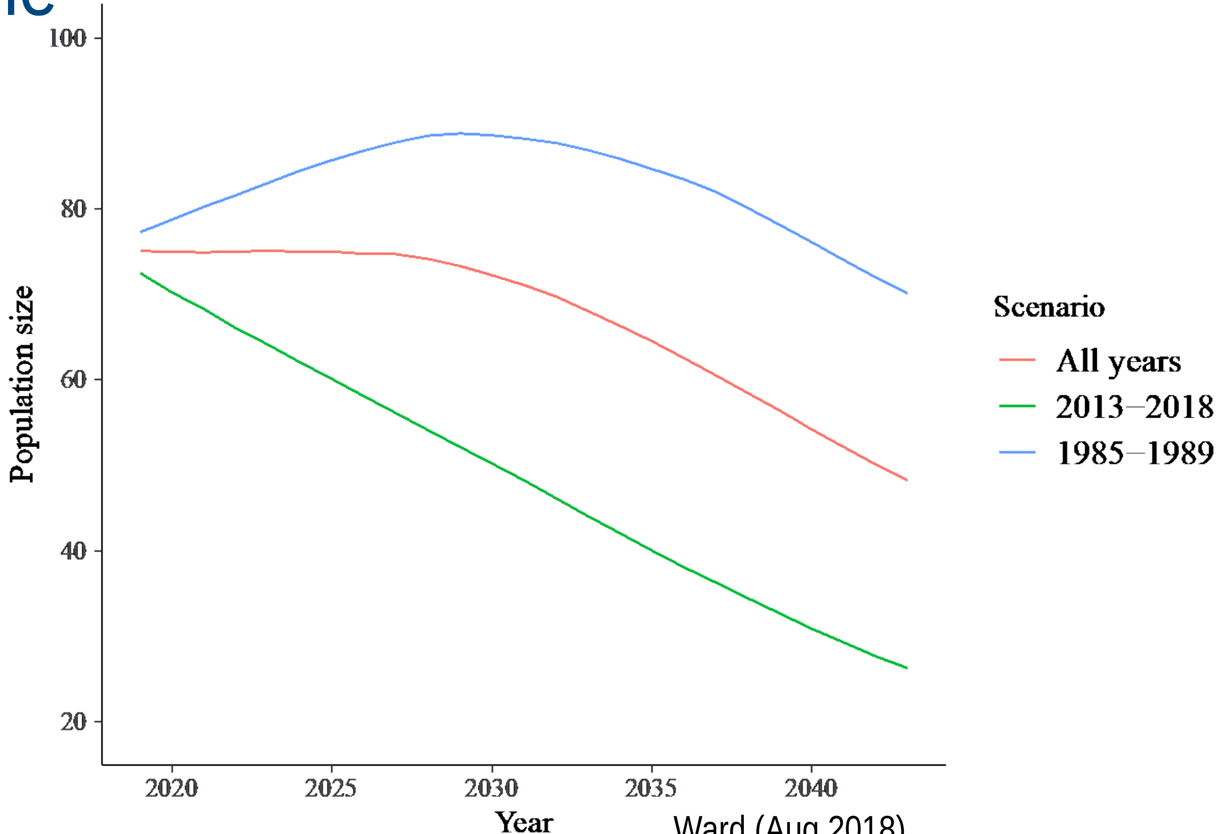
Where we are now

The known unknowns

- What are the reasons for individual deaths?
  - Most animals that disappear are not in bad condition
- Why is reproductive failure seemingly high? (Fearnbach et al. 2018, Wasser et al. 2017)
- What prey is most limiting? Which stocks?
- Which season are the animals most nutritionally stressed?
  - Ayres et al. (2012), vs photogrammetry data (Fearnbach et al. (2018))
- Which contaminants (if any) affect health, fecundity or survival?
- How does disease impact SRKW?
- Are any social behaviors, infanticide or other, affecting demographics? (Towers et al. 2018)
- How is inbreeding impacting demographic rates? (Ford et al. 2018)
- What (if anything) is causing the trend toward more males at birth? (Ward et al. 2013; Hilborn et al. 2012)
- Are SRKW just unlucky?

Rate of future decline depends on what we assume about future demographic rates

- Skewed sex ratio, older females largely driving decline



Ward (Aug 2018)

Strongest evidence of nutrition issue in some years = mid 1990s

- Low survival & fecundity, more whales in poor condition. Also bad time for NRKW (J. Ford et al. 2010), ‘correlation v causation’ discussion by Science Panel (J. Ford & others following workshop # 3)

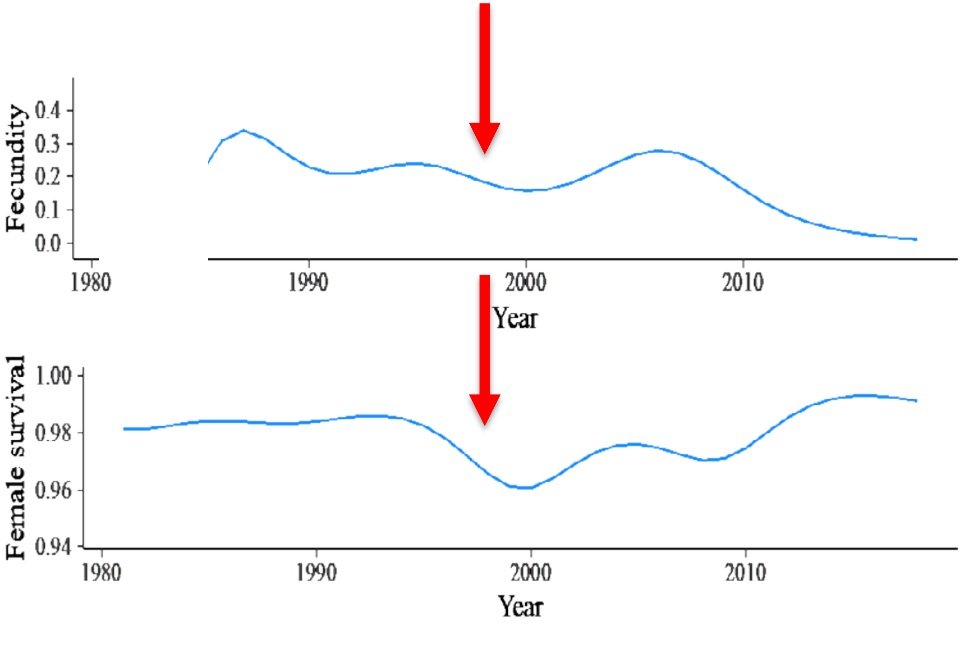
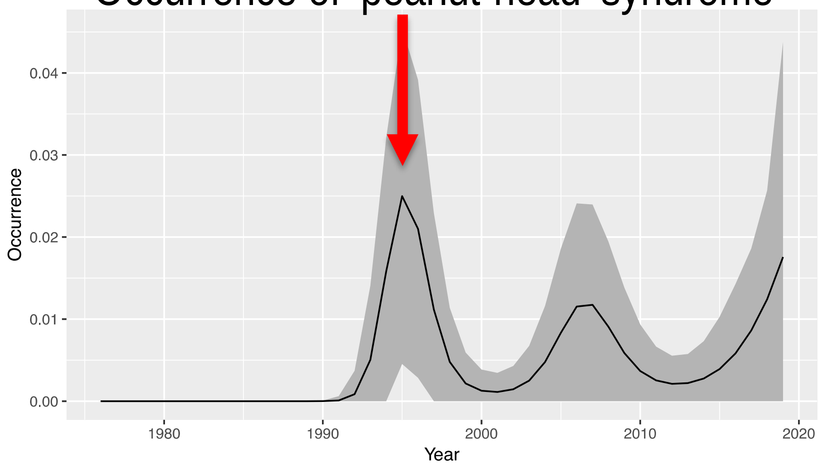


Figure 5: Time series of predicted fecundity rates for a 20-year old Southern Resident female killer whale and survival rates for a 20-year old female and male. Gray region represents +/- 2 standard errors and the black line represents the mean.

Ward (Aug 2018)

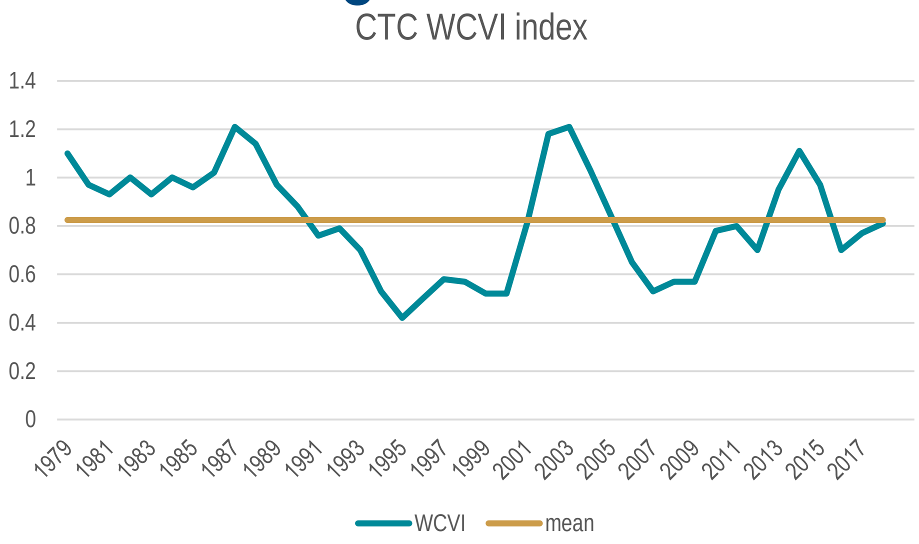
Occurrence of ‘peanut-head’ syndrome

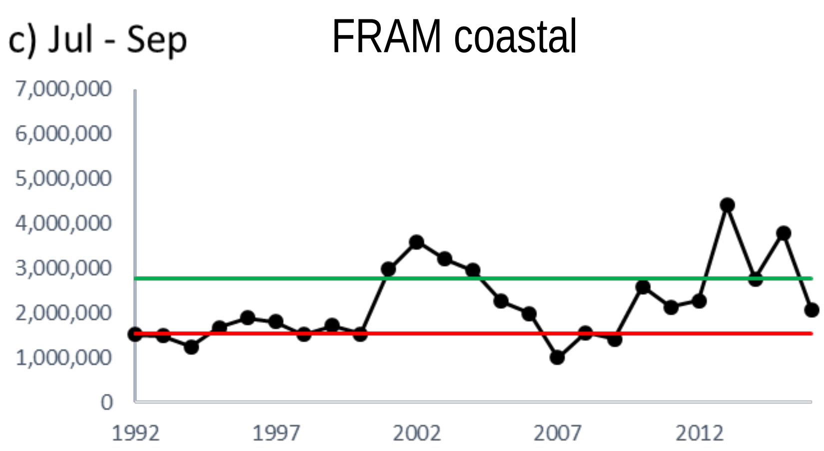


Durban et al. (2009), Durban and Ellifrit (pers. comm 2019)

Link to Chinook / fisheries for metrics like defining thresholds will depend on index used

- CTC low in mid-1990s, maybe increasing since 2007
- FRAM also increasing since 2007, but flatter through 1990s





WCRO Draft Framework