Estimating “other” marine mammal effects on salmon with limited data

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After workshop 2…

- Panel asked me to explore how strongly other marine mammals were correlated with SRKW demographic rates

Post workshop # 2:

- Panel and I are largely in agreement with the issue
  - Pinnipeds consume lots of salmon
  - Probably compete some in space or time with SRKW
- But we may differ slightly on how best to quantify impact
  - A. Acevedo-Gutierrez (ESSA website)
  - Correlation modeling (panel requests, E. Ward workshop 2)
  - Time series approaches (E. Ward workshop # 1)

- All seal / sea lion marine mammals have increased ~ 10-fold since the 1972 MMPA
  - Harbor seals, CA sea lions, elephant seals, Steller sea lions, fur seals
- All of these species are super-generalists
  - More so than killer whales
  - Large degree of individual specialization (A. Acevedo)
  - Capability for diet switching
  - Long distance foraging (> 200km)
- For salmon: generally favor smaller individuals (e.g. pink) but will eat both adults & juveniles
  - Greater size selectivity than kw?

- Question: how much to seals / sea lions compete with killer whales?

Best US data: harbor seal surveys (Jeffries et al. 2003)

Year	JdFuca	San Juans	E Bays	Pug Sound	Hood Canal
1978	6.03	6.75	6.63	5.82	6.60
1979					
1980					
1981					
1982					
1983	6.78	7.43	7.21		
1984	6.93	7.74	7.45		
1985	7.16	7.53	7.26	6.60	
1986	6.74	7.69	7.39		
1987	6.92	7.69	7.47		
1988	7.33	7.95	7.55		
1989	7.25	7.97	7.52		
1990	7.04	8.06			
1991	7.12	8.16	7.57	6.79	7.10
1992	7.37	8.20	7.65	6.56	6.90
1993	7.68	8.42	7.68	6.88	6.38
1994	7.31	8.42	7.67	6.75	
1995	7.73	8.49	7.63		
1996	7.59	8.58	7.83	7.02	6.88
1997	7.73	8.36	7.60	6.97	6.54
1998	7.46	8.40	7.50	6.93	6.36
1999	7.47	8.19	7.54	6.93	6.57

This table represents ln(abundance)

1. What we'd like is continuous time series without missing values
   - To be able to compare to density dependence, PDO, other effects that don't have missing values

2. Best case scenario: seal data from 1983-1999 from San Juans (about 50% of the population), after which the population is thought to have stabilized
   - But we don't have surveys, so aren't really sure

Canadian data also has gaps (CSAS SAR 2009/11)

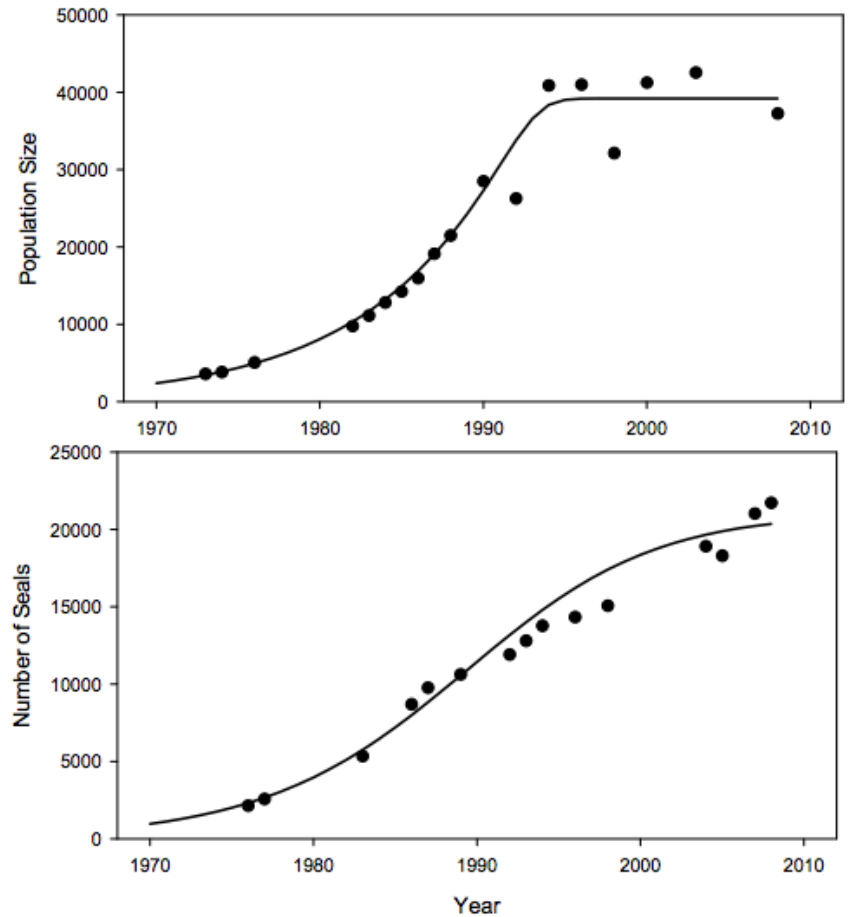
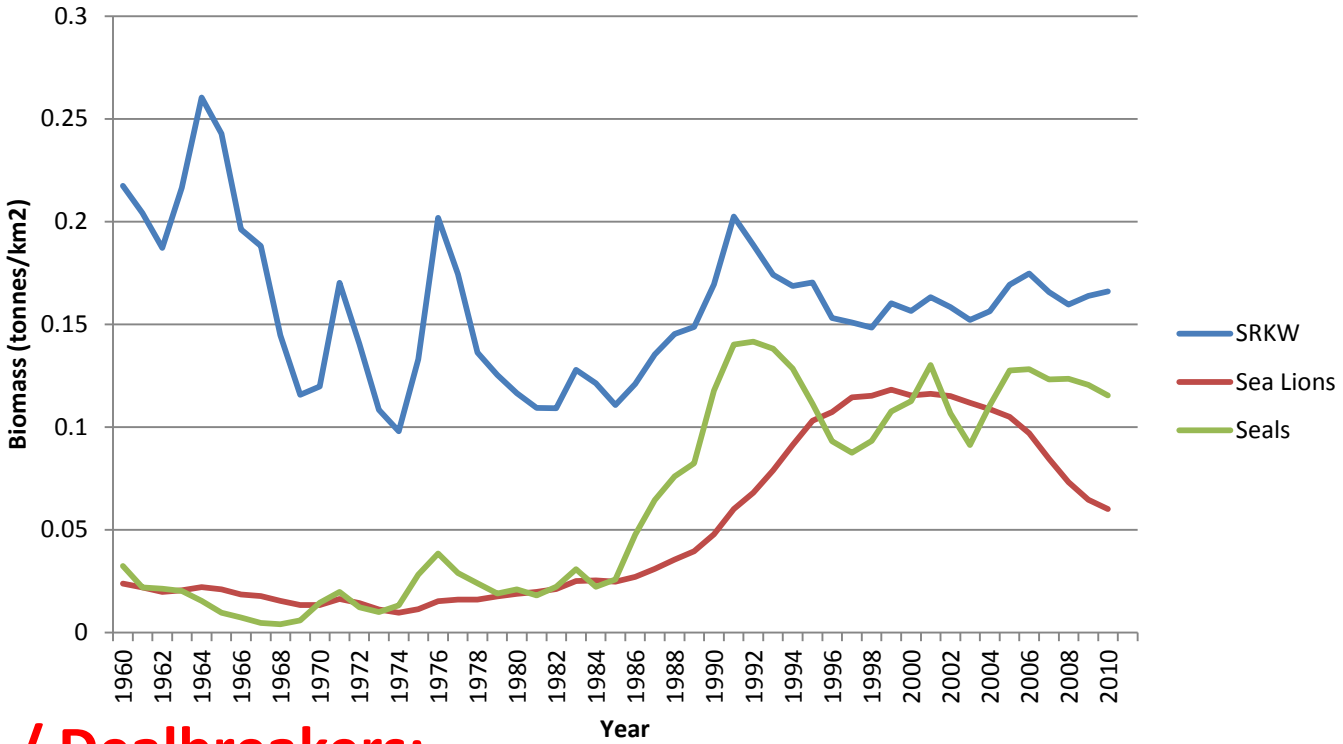


Figure 1. *Recent trends in harbour seal abundance in the Strait of Georgia (top panel) and in Index Areas outside the Strait of Georgia (bottom panel). The Index Areas are widely distributed throughout B.C. and include the lower Skeena River, most of the Queen Charlotte Islands, Queen Charlotte Strait and Broughton Archipelago, and the west coast of Vancouver Island. The trend lines represent generalized logistic curves fitted using maximum likelihood methods.*

Suggestion from panel (post wkshp 2)

- Dave Priekshot presented Ecopath modeling results (workshop 2)
  - Calibrated to biomass estimates of fish, killer whales, seals, sea lions, etc.
- Could we use his model output as “data” in logistic regressions, to correlate seal or sea lion abundance with killer whale demographics?

Priekshot's EwE output



Red Flags / Dealbreakers:

1. What causes sea lion biomass to be reduced 50% over 2000-2010 when the population is thought to be relatively stable? Over this same period, a large migration from CA -> OR / WA is thought to have occurred (ODFW)
2. Why does harbor seal biomass reach carrying capacity in 1990, but from the survey data, carrying capacity isn't reached until early 2000s? (Jeffries et al 2003, DFO 2009/011)
3. Why does seal biomass oscillate similarly to kw, but sea lions do not (and the prey base between seals/sea lions is more similar than seals / kw)

Model selection results: survival

- P-K Chinook is a better predictor than either seal / sea lion biomass alone
- Only when both are included does AIC get better
- BUT seal / sea lion effects cancel each other out

	Covariates in kw survival	AIC
1	None	18.25
2	Parken-Kope fall termsinal Chinook (+)	6.95
3	CA sea lions (-)	15.26
4	Harbor seals (+)	20.18
5	Sea lions (-)& Harbor seals (+)	10.70
6	Sea lions (-)& Harbor seals (+) & Chinook (+)	0.74

What do these results suggest?

- Not much confidence in results if EwE estimates of biomass are inconsistent with limited survey data
  - EwE may also be problematic for modeling species that only interact seasonally (salmon, killer whales; Harvey et al. 2010)
  - If results are to be believed, what's the mechanism for harbor seals having a "+" effect?
- This approach assumes seal / sea lions competing directly for adult salmon. But what about seal / sea lion impacts on juveniles?
  - 1-year time lag does no better than 0-lag
- My interpretation:
  - It's very difficult to say anything definitive about the "data" or estimated effects on SRKW

Alternative language

- “In follow-up analyses requested by the Panel after Workshop 2, some of these alternatives (e.g., marine mammals), also appear to correlate with SRKW survival”

TO

- “Pinnipeds may be competing directly with SRKW by consuming a non-negligible amount of adult and/or juvenile Chinook salmon (3-17% of diet in San Juan harbor seals). Juvenile salmon represents approximately 10% of the total estimated Chinook consumption (1030 mt / yr).”
- Cite: A. Acevedo-Gutierrez (or papers cited in his writeup on ESSA website)

Alternative approach (I discussed at workshop 1)

- Multivariate state-space modeling of time series
  - MARSS package in R (Ward et al. 2010; Holmes & Ward 2012)
- Advantages:
  - Missing observations allowed, short time series
  - Observation + process variance estimated
  - Simultaneously estimate density dependence AND interspecific interactions
- Disadvantages:
  - Ideally include time series of all major players
  - In addition to seals / sea lion time series, we need time series of their major prey groups

Historic data issues: Gadids

- Entirely fishery-dependent:
- Pacific cod CPUE (1955-1998)
  - Almost no research vessel estimates (1987-1989)
  - New fisheries have emerged since 1995 (no data)
- Pollock (through early 1990s)
  - No effort, only landings
- Hake
  - Limited spatial coverage (other than Port Susan)
- Gustafson et al. (2000)

http://www.nwfsc.noaa.gov/publications/techmemos/tm44/tm44.htm

Update: new data sets

- T. Essington & T. Quinn (SAFS, UW) have survey data dating back to the 1930s/1940s
- Can be used to construct time series, but data is messy

- Currently looking for grants to write to fund a UW grad student for 1-2 quarters to help process data
- We'll try to complete over the next ~ year

- Other approaches worth pursuing for multi-species analyses: Bob Lessard's proposal after workshop 1 (differential eqns)