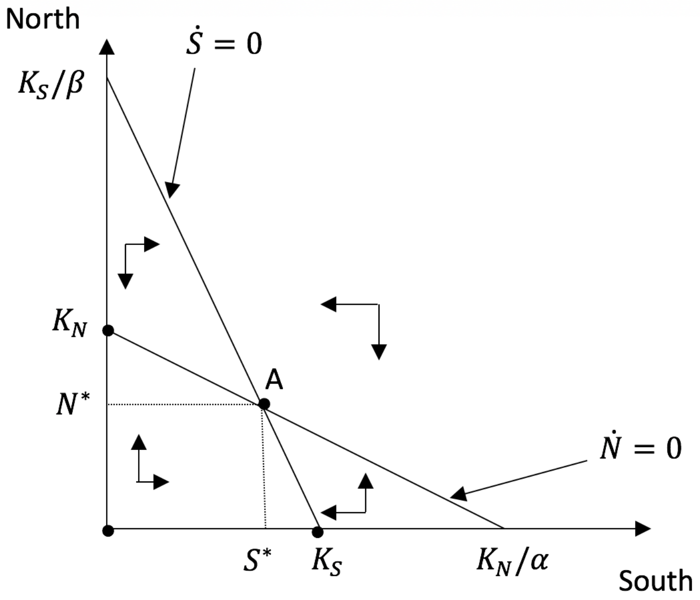
Extra Slides

Modelling Competing Species

$$\frac{dN}{dt} = rN[1 - \frac{N}{K_N} - \frac{\alpha S}{K_N}] \equiv rN[g(N, S, K_N, \alpha)] \quad (1)$$

$$\frac{dS}{dt} = rS[1 - \frac{S}{K_S} - \frac{\beta N}{K_S}] \equiv rS[G(S, N, K_S, \beta)] \quad (2)$$

- $r, \alpha, \beta, K_N, K_S$ are all positive given parameters of the system
- Initial populations are assumed to be non-negative ($N(0) \geq 0$, $S(0) \geq 0$)


North
$\dot{S} = 0$
K_S/β
K_N
A
N^*
$\dot{N} = 0$
S^*
K_S
K_N/α
South

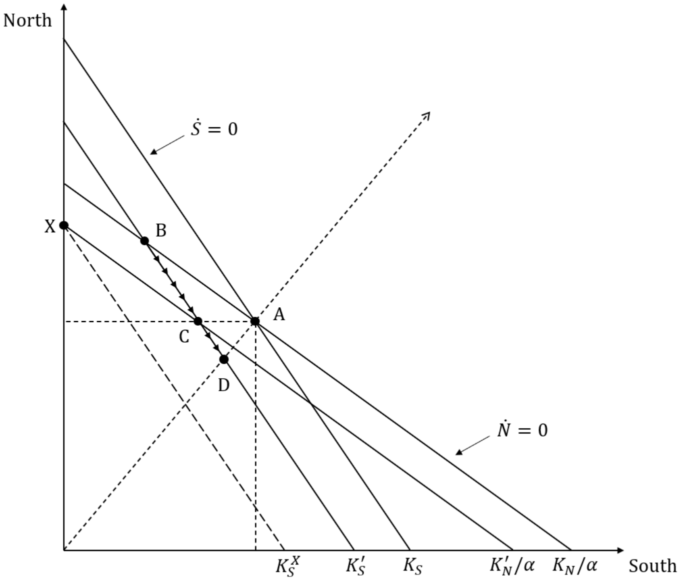
The Interior Steady State

$$\frac{1}{\beta} > \frac{K_N}{K_S} > \alpha \tag{3}$$

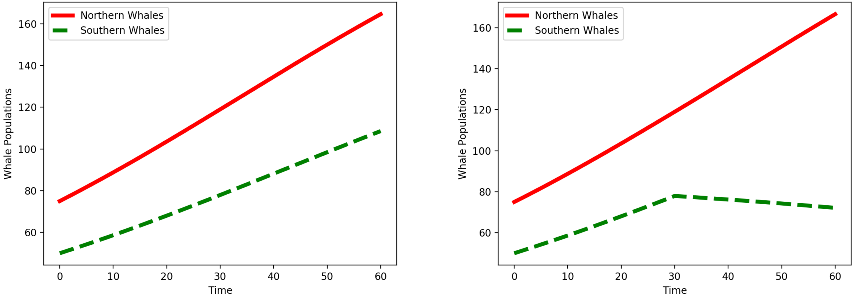
$$N^* = \frac{K_N - \alpha K_S}{[1 - \alpha\beta]} > 0 \tag{4}$$

$$S^* = \frac{K_S - \beta K_N}{[1 - \alpha\beta]} > 0 \tag{5}$$

The Competitive Exclusion Principle



Transition Paths: Baseline plus Shock to Southern Habitat



Conclusion from Theory

- Common shocks lead to common responses (Salmon availability)
- Asymmetric shocks lead to very different, and magnified, NRKW or SRKW responses.
- Correlated shocks create correlated responses that differ in magnitudes.
- One path to SRKW extinction is correlated shocks magnified by competitive exclusion.

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Vessel Arithmetic

Vessel Trips and Walras' Law

$$I_t = \sum_{i \notin u_c} \sum_{j \in u_c} X_{ijt} \tag{6}$$

- Incoming Trips

$$W_t = \sum_{i \in u_c} \sum_{j \in u_c} X_{ijt} \tag{7}$$

- Within Trips

Vessel Arithmetic

Vessel Trips and Walras' Law

$$O_t = \sum_{i \in u_c} \sum_{j \notin u_c} X_{ijt} \tag{8}$$

- Outgoing Trips

$$P_t = \sum_{i \in u_p} \sum_{j \in u_p} X_{ijt} \tag{9}$$

- Pass Through Trips

Vessel Arithmetic

Walras' Law

$$VL_t = I_t + W_t \tag{10}$$

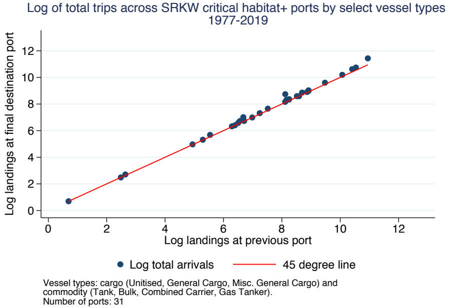
- Landings are either Incoming or Within; Exits must equal Entries; Foreign Vessel Outgoing Trips are residual needed to balance budget

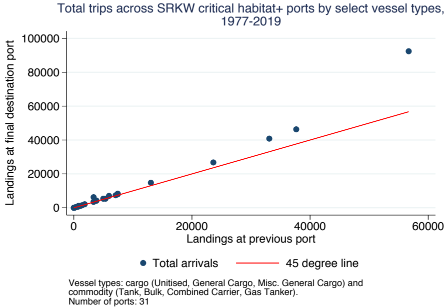
$$\begin{aligned} VL_t &= VE_t \\ VE_t &= O_t + W_t \end{aligned} \tag{11}$$

$$I_t = O_t \tag{12}$$

$$I_t = \sum_{i \in u_c} \sum_{j \in \underline{u}} X_{ijt} + \sum_{i \in u_c} \sum_{\substack{j \notin u_c \\ j \in \bar{u}}} X_{ijt} \tag{13}$$

Evaluating Vessel In - Vessel out assumption





◂ Back to Vessel Arithmetic

Back to Malthus

Births

Figure: Percentage of females with births by age in the pooled RKW populations, 1979-2019

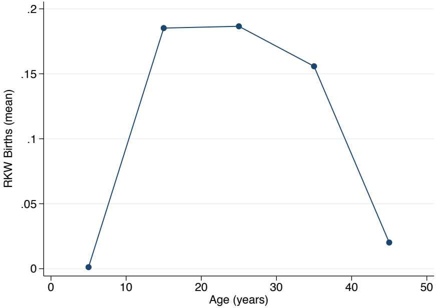
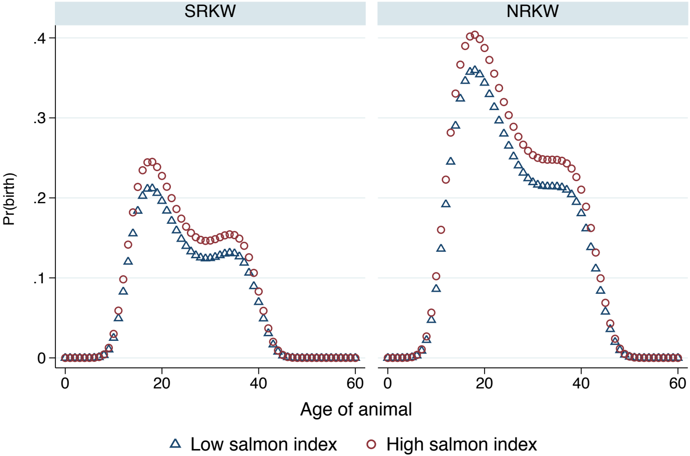


Table: Births in the pooled RKW populations by age, 1979-2019

		Birth		
Age group	*n*	without	with	Mean
0 – 9	1645	1643	2	0.001
10 – 19	1215	990	225	0.185
20 – 29	922	750	172	0.187
30 – 39	751	634	117	0.156
40 –	1288	1262	26	0.020
Total	5821	5279	542	0.093

Predicted Probabilities of Birth



Within Population Graphs differ by Salmon Availability

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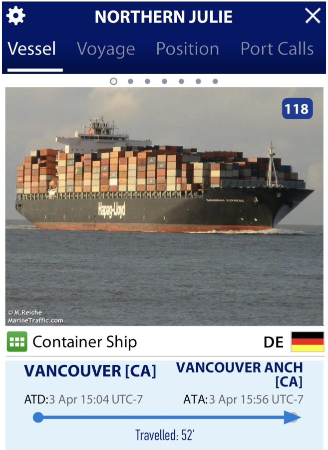
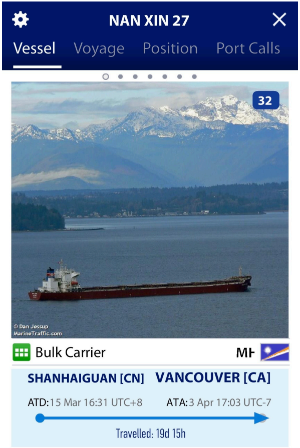
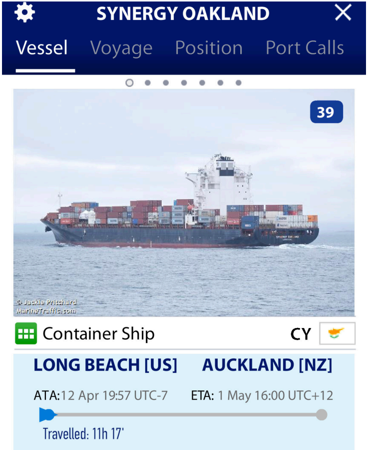
Vessel Types Container & Tanker



Vessel Types Bulk & General Cargo





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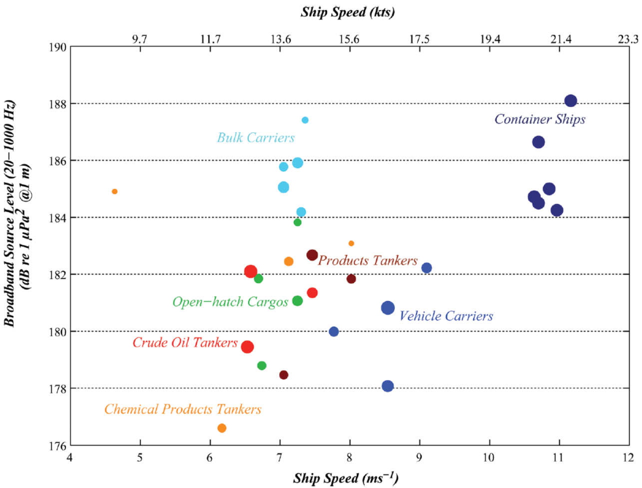
Vessel Noise vs Type



Source: Figure 5. in McKenna et. al (2012) Back

The NRKW Critical Habitat

Northern Resident Killer Whale Critical Habitat

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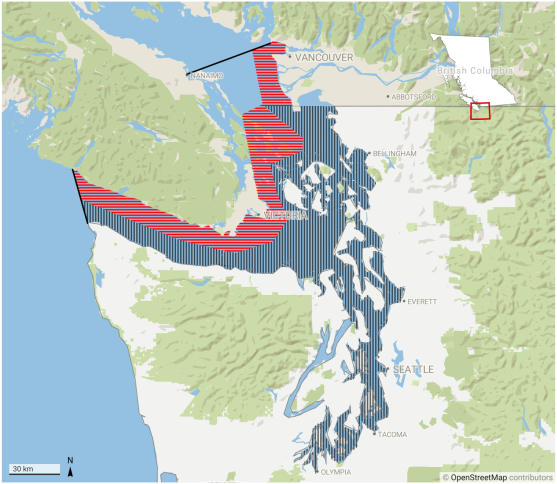
The SRKW Critical Habitat

SRKW Critical Habitat



Limit of Critical Habitat Area — SRKW Critical Habitat (CAN) — SRKW Critical Habitat (USA)

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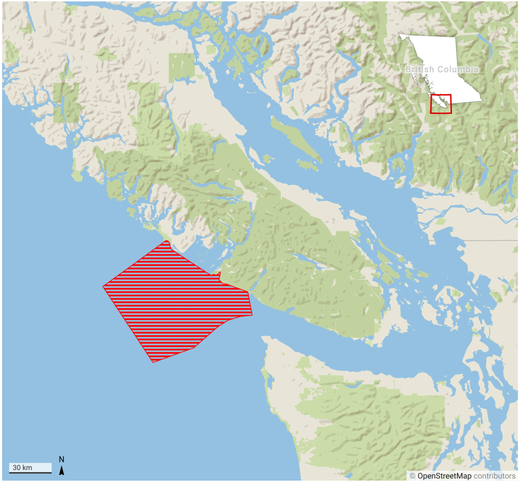
The New (2018) Shared Critical Habitat

New Killer Whale Critical Habitat



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Policy

Incomplete - in fact totally back of the envelope calculation!

- Slower speeds mean lower decibels generated by vessels. Some estimates imply 1 decibel reduction for 1 knot lower speeds
- Halving current speeds of Container and Bulk ships adds .4 to .3 of a day over longest inbound transit
- Estimates of this cost of delay (Hummels and Schaur (2013, AER,: Time as a Trade Barrier) suggest this amounts to less than a 1% ad valorem tariff on goods. There is however about 100 billion annually of exports/imports shipped via container ships through Vancouver-Fraser River ports alone.
- Dam breaching, fishing moratoriums, etc. may prove to be more costly ways to improve the marine habitat. Back