

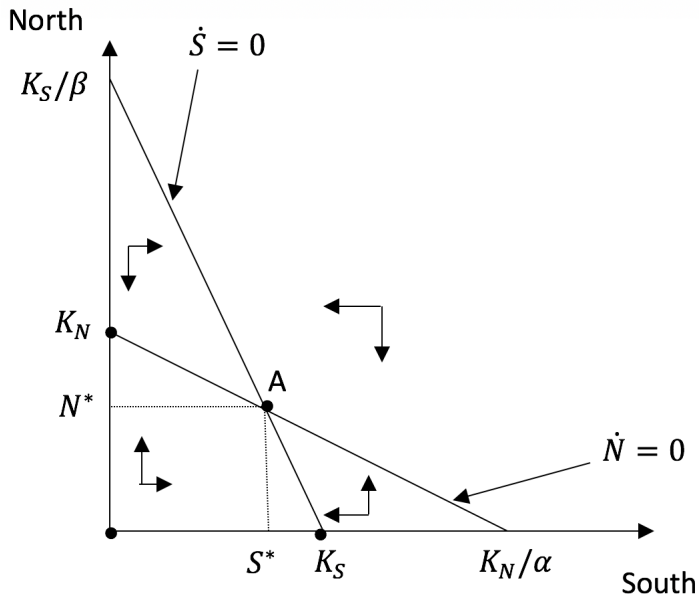
Extra Slides

Modelling Competing Species

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

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

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



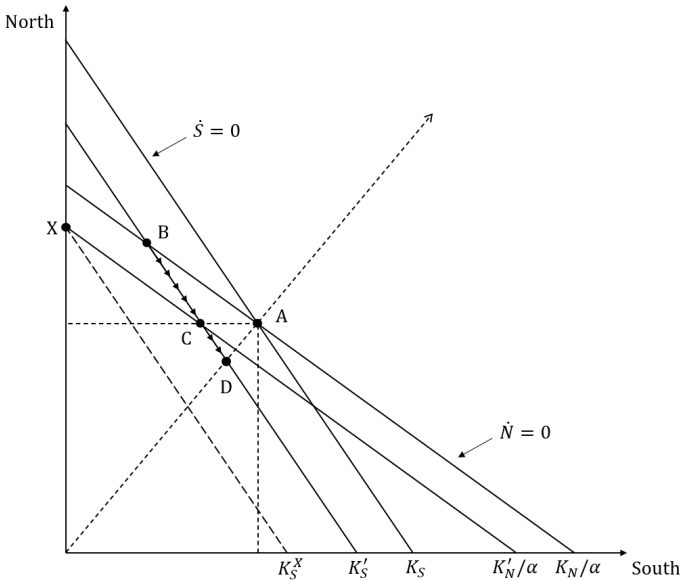
The Interior Steady State

$$\frac{1}{\beta} > \frac{K_N}{K_S} > \alpha \quad (3)$$

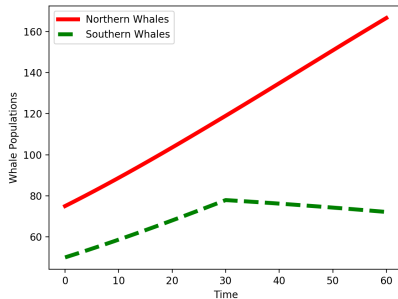
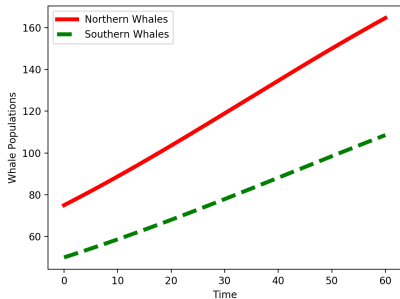
$$N^* = \frac{K_N - \alpha K_S}{[1 - \alpha\beta]} > 0 \quad (4)$$

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

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

$$I_t = \sum_{i \notin u_c} \sum_{j \in u_c} X_{ijt} \quad (6)$$

- Incoming Trips

$$W_t = \sum_{i \in u_c} \sum_{j \in u_c} X_{ijt} \quad (7)$$

- Within Trips

Vessel Arithmetic

Vessel Trips and Walras' Law

$$O_t = \sum_{i \in u_c} \sum_{j \notin u_c} X_{ijt} \quad (8)$$

- Outgoing Trips

$$P_t = \sum_{i \in u_p} \sum_{j \in u_p} X_{ijt} \quad (9)$$

- Pass Through Trips

Vessel Arithmetic

Walras' Law

$$VL_t = I_t + W_t \quad (10)$$

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

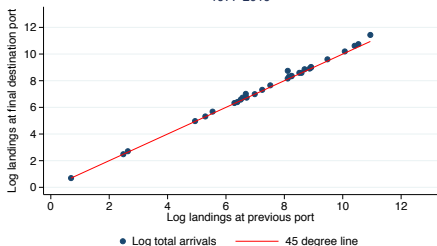
$$\begin{aligned} VL_t &= VE_t \\ VE_t &= O_t + W_t \end{aligned} \quad (11)$$

$$I_t = O_t \quad (12)$$

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

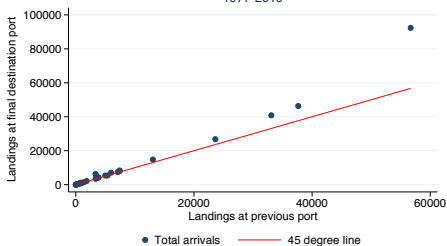
Evaluating Vessel In - Vessel out assumption

Log of total trips across SRKW critical habitat+ ports by select vessel types
1977-2019



Vessel types: cargo (Unitised, General Cargo, Misc. General Cargo) and commodity (Tank, Bulk, Combined Carrier, Gas Tanker).
Number of ports: 31

Total trips across SRKW critical habitat+ ports by select vessel types,
1977-2019



Vessel types: cargo (Unitised, General Cargo, Misc. General Cargo) and commodity (Tank, Bulk, Combined Carrier, Gas Tanker).
Number of ports: 31

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Back to Malthus

Births

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

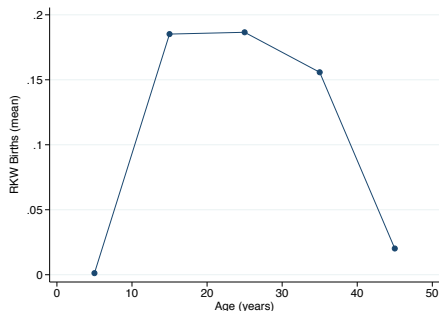
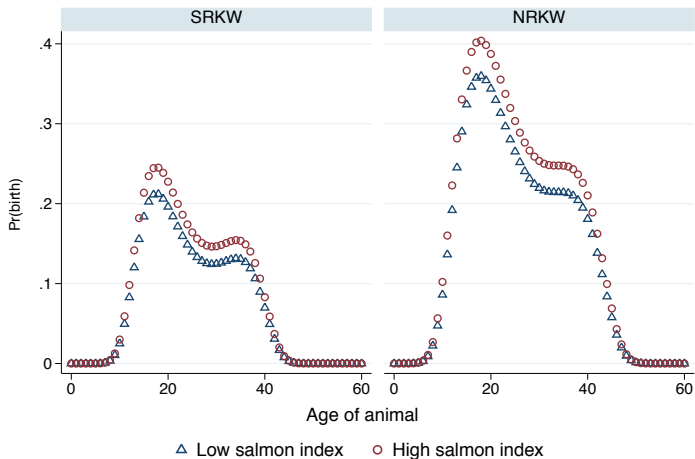


Table: Births in the pooled RKW populations by age, 1979-2019

Age group	n	Birth		Mean
		without	with	
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


Vessel Types Container & Tanker

⚙️
✕

NORTHERN JULIE

Vessel
Voyage
Position
Port Calls

118



© M. Resche
MarineTraffic.com

📦
Container Ship
DE

VANCOUVER [CA]	VANCOUVER ANCH [CA]
ATD: 3 Apr 15:04 UTC-7	ATA: 3 Apr 15:56 UTC-7

⚙️
✕

KISO

Vessel
Voyage
Position
Port Calls

96



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MarineTraffic.com

🔥
Oil/Chemical Tanker
PA

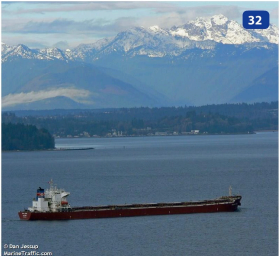
VANCOUVER [CA]	VANCOUVER ANCH [CA]
ATD: 1 Apr 23:44 UTC-7	ATA: 2 Apr 00:20 UTC-7

Vessel Types Bulk & General Cargo


NAN XIN 27 ✕

Vessel Voyage Position Port Calls

32



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marinetraffic.com

Bulk Carrier MF 

SHANHAIGUAN [CN] VANCOUVER [CA]


ATD: 15 Mar 16:31 UTC+8 ATA: 3 Apr 17:03 UTC-7

Travelled: 19d 15h


SYNERGY OAKLAND ✕

Vessel Voyage Position Port Calls

39



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Marinetraffic.com

Container Ship CY 

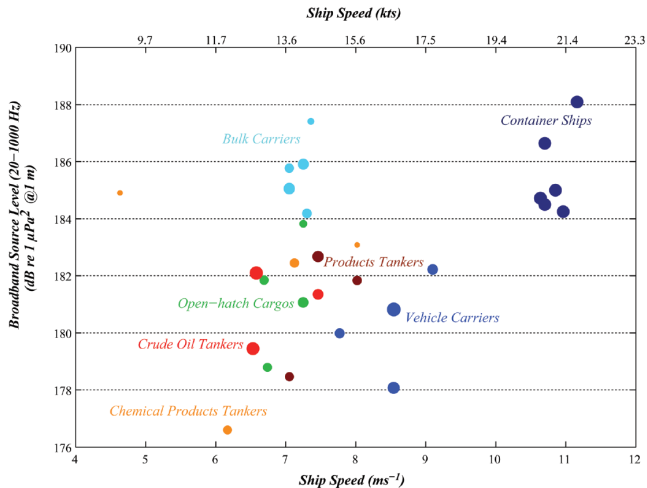
LONG BEACH [US] AUCKLAND [NZ]

ATA: 12 Apr 19:57 UTC-7 ETA: 1 May 16:00 UTC+12

Travelled: 11h 17'

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Vessel Noise vs Type



Source: Figure 5. in McKenna et. al (2012) [◀ Back](#)

The NRKW Critical Habitat

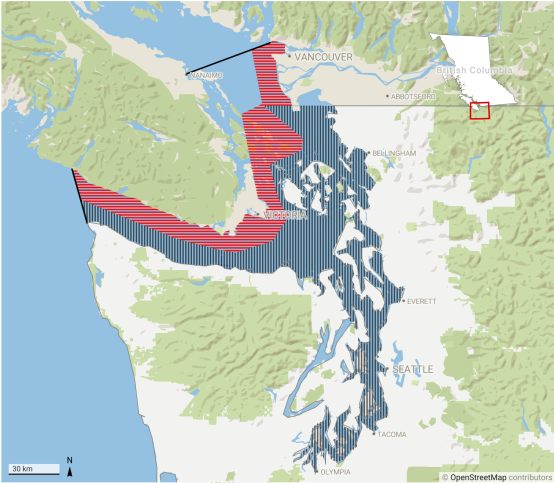
Northern Resident Killer Whale Critical Habitat



Created with Datawrapper

The SRKW Critical Habitat

SRKW Critical Habitat

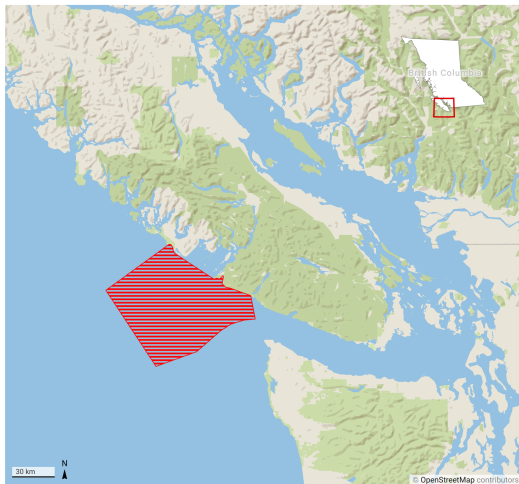


— Limit of Critical Habitat Area ■ SRKW Critical Habitat (CAN) ▨ SRKW Critical Habitat (USA)

Created with Datawrapper

The New (2018) Shared Critical Habitat

New Killer Whale Critical Habitat



Created with Datawrapper

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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](#)