Ship noise underwater in Haro Strait

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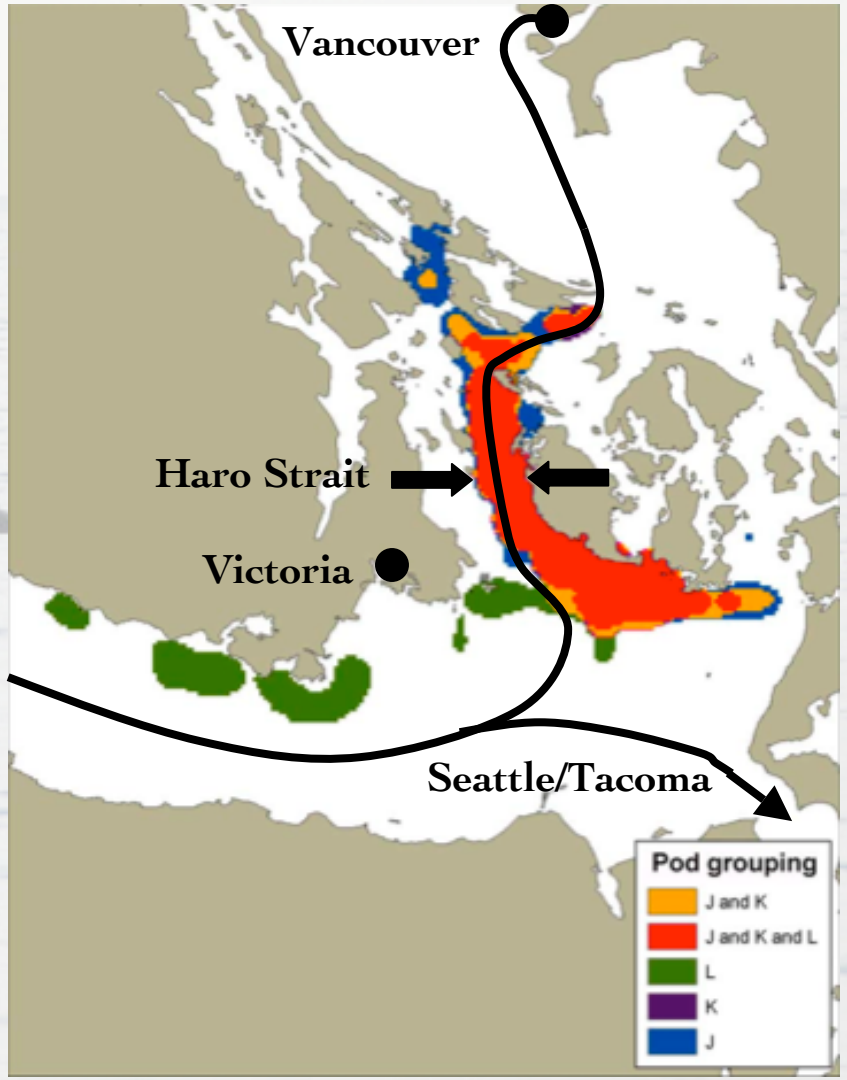
Ships and sound in orca habitat

- Vessels frequent core summer range
  - Ships (>65')
  - Boats (commercial, private)
- Orcas use sound to survive
  - Calls, clicks, whistles
- Ships dominate in the "Puget Soundscape"
  (Brett Becker, 2005)

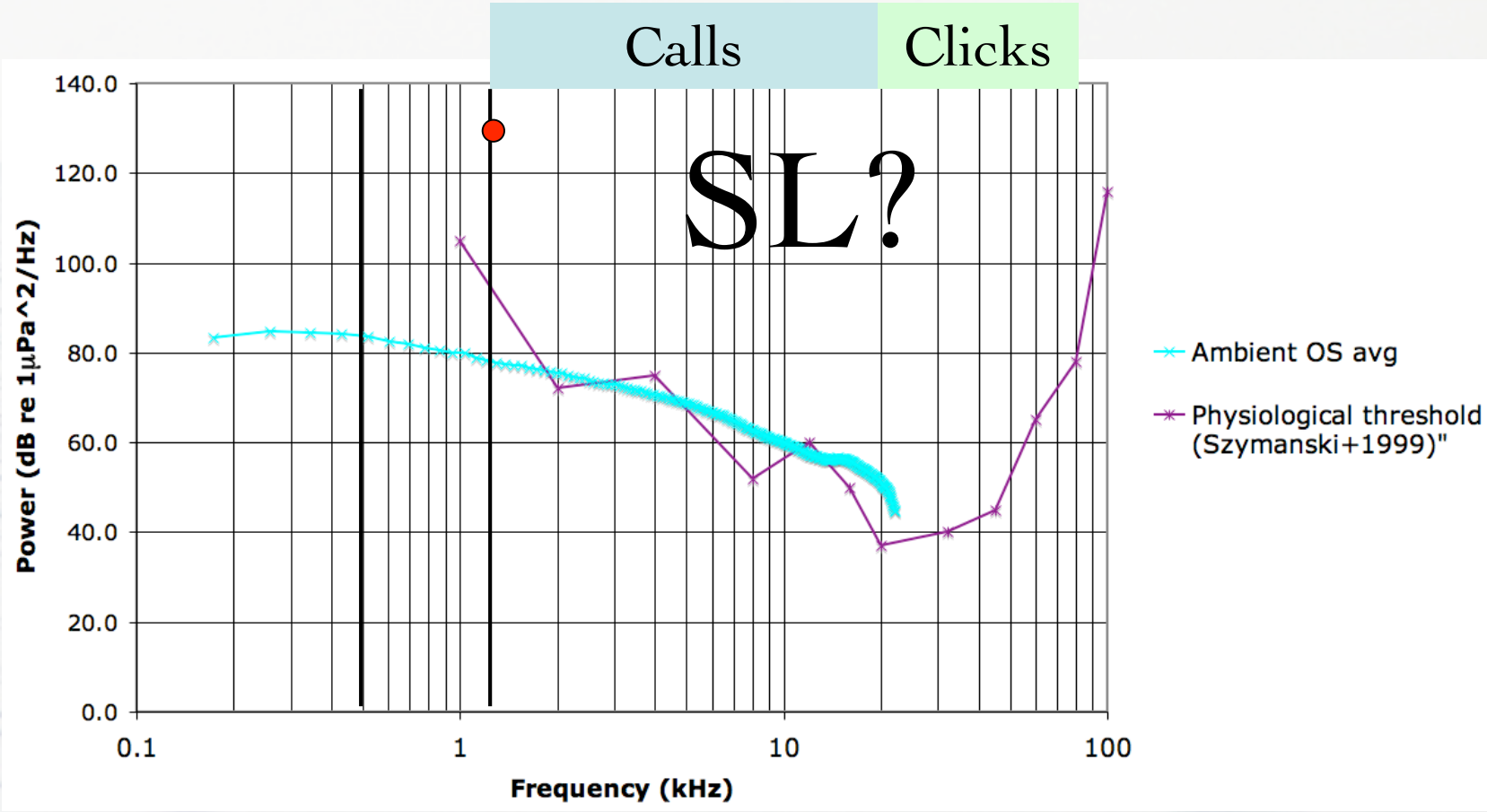


Basemap courtesy D. Hauser

Ships dominate the noise budget

- In 100Hz-20kHz, +25dB for ships (and boats)
- Duration ~30 min (vs 3 min for boats)
- ~15 ships/day or 30% of day

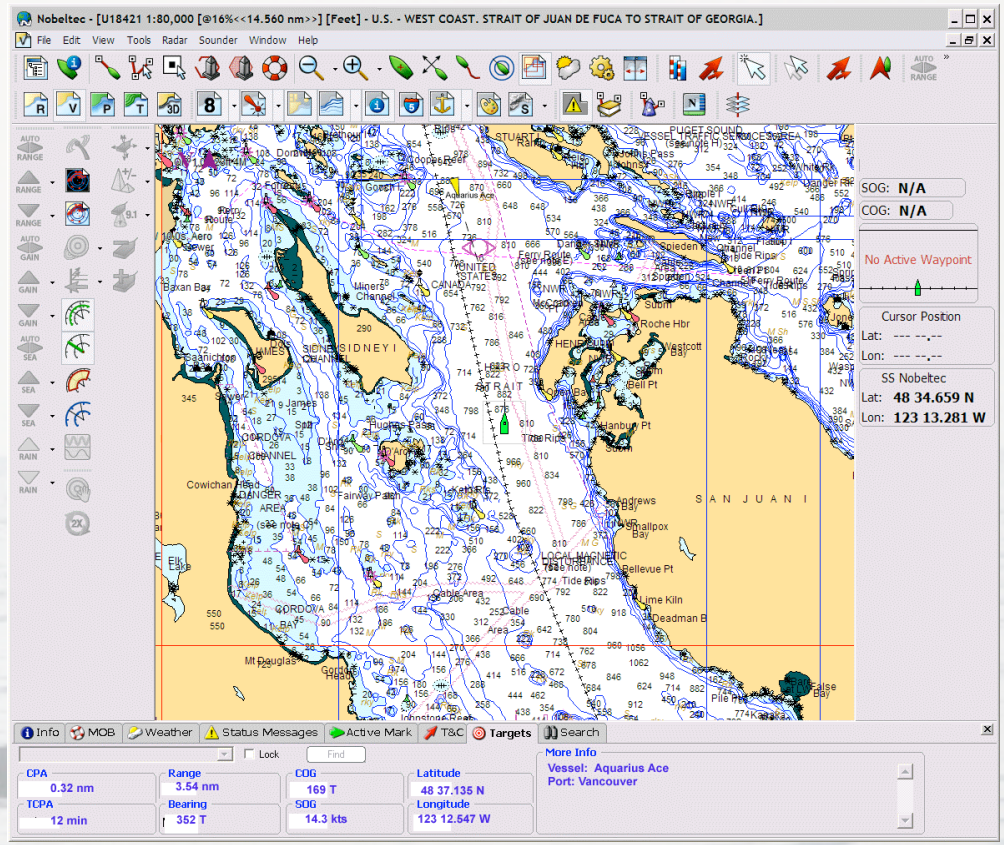
Does ship noise matter?



- Recovery Plan mentions potential ship noise impacts at <500 Hz
- Merchant ship SL ~130 dB re 1 $\mu Pa^2/Hz$ at 1200 Hz (Wales, 2004)
- Masking in Haro Strait has only been assessed for (whale watching) boats (Erbe, 2002)

Methods

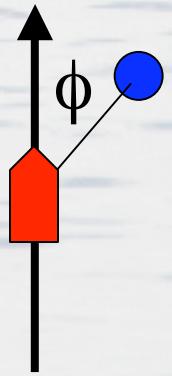
- SL = RL + m log(R)
  [all re 1 μPa @ 1 m]



- R: (0.5-5km) from AIS:
- RL: from Interocean calibrated hydrophone
  - Deployed at ~10m depth to minimize flow and surface noise
  - 44.1kHz A-D via iMike line input or Marantz PMD660
  - 1V rms calibration tone, ~30s sample duration
- m: theory & experiment

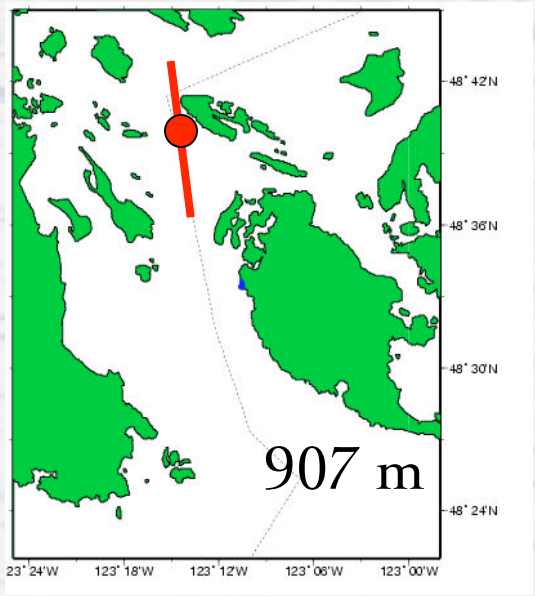
Analysis

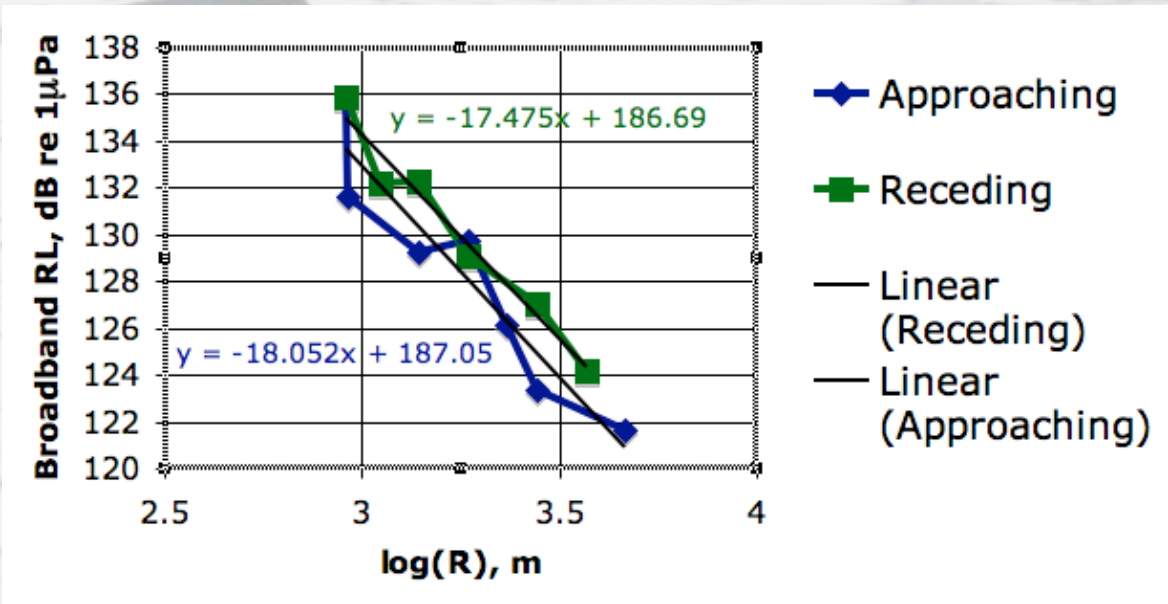
- RL
  - Compute V_{RMS} for ~3 second sub-sample
  - Spectra (1024 sample FFT, Hamming window)
  - no background subtraction (signal usually >+3dB)
- R
  - Noted from AIS to nearest 0.1 nm (185 m)
- m (spreading rate)
  - Spherical assumed for closest approach
  - Measure slope in RL vs log(R) plot
- Compute SL (as function of bearing ϕ)



High SL container vessel (VE)

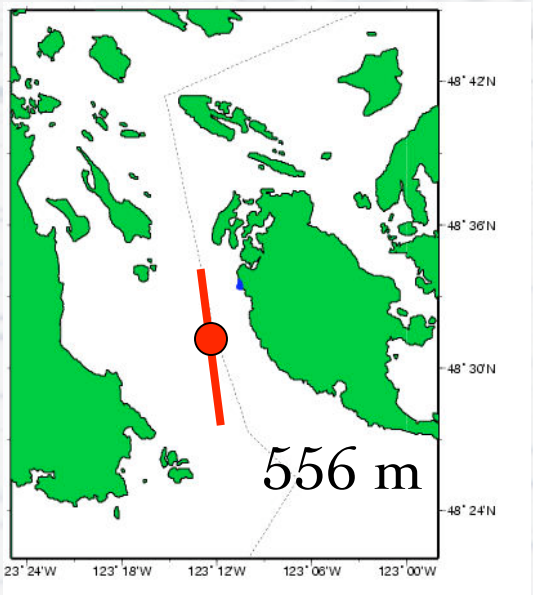
SL spherical	SL empirical
195 dB re 1µPa	187

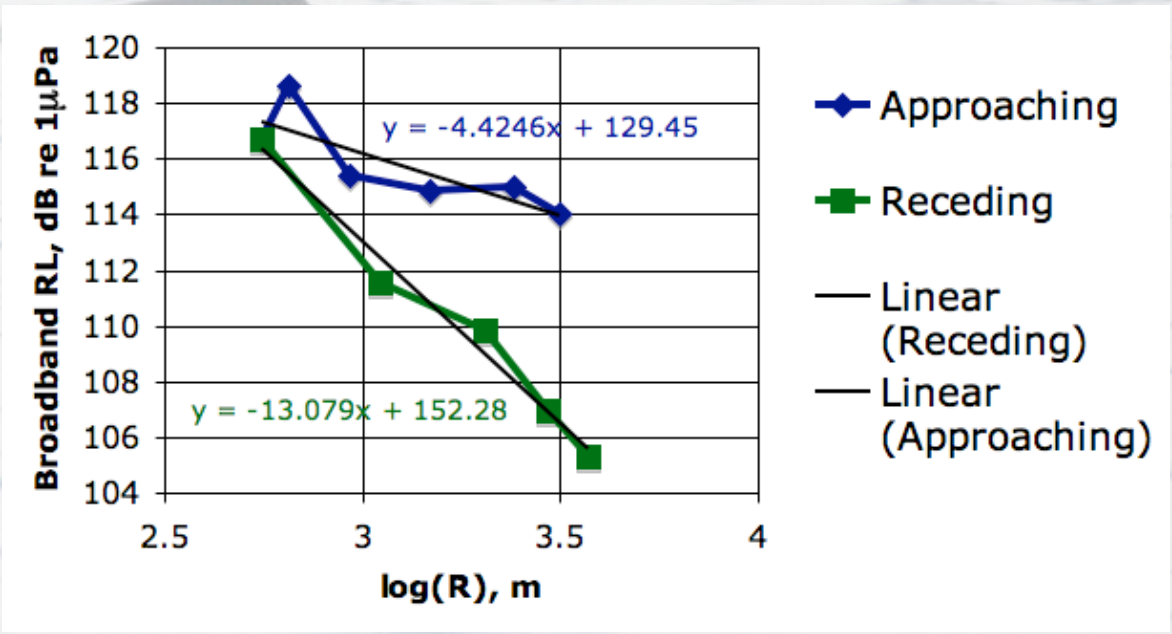




Low SL container vessel (WR)

SL spherical	SL empirical
172 dB re 1µPa	141



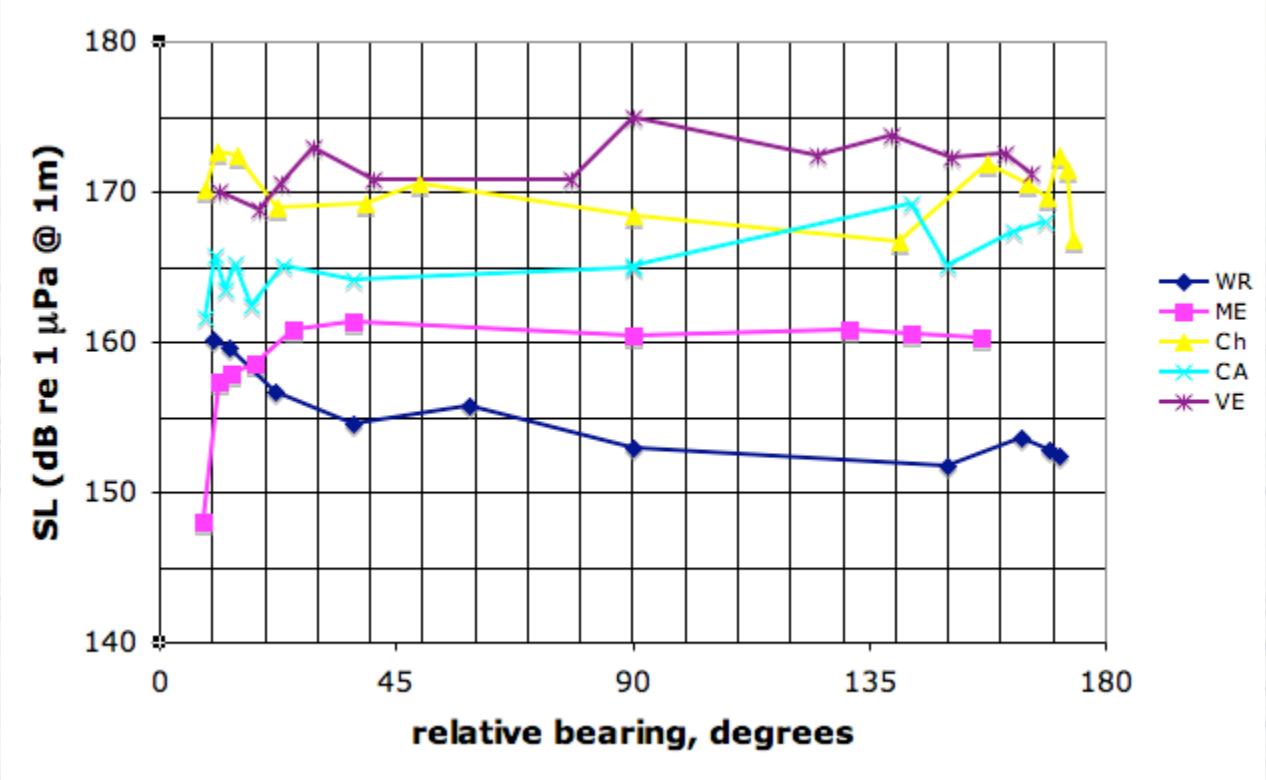


Spreading and overall SL

- Measured with ships (5)
  - –Mean: -13.2 dB/decade; standard error of mean: 1.2
  - –Approaching mean: -13.1; receding mean: -13.4
- Average of 5 characteristic ships:

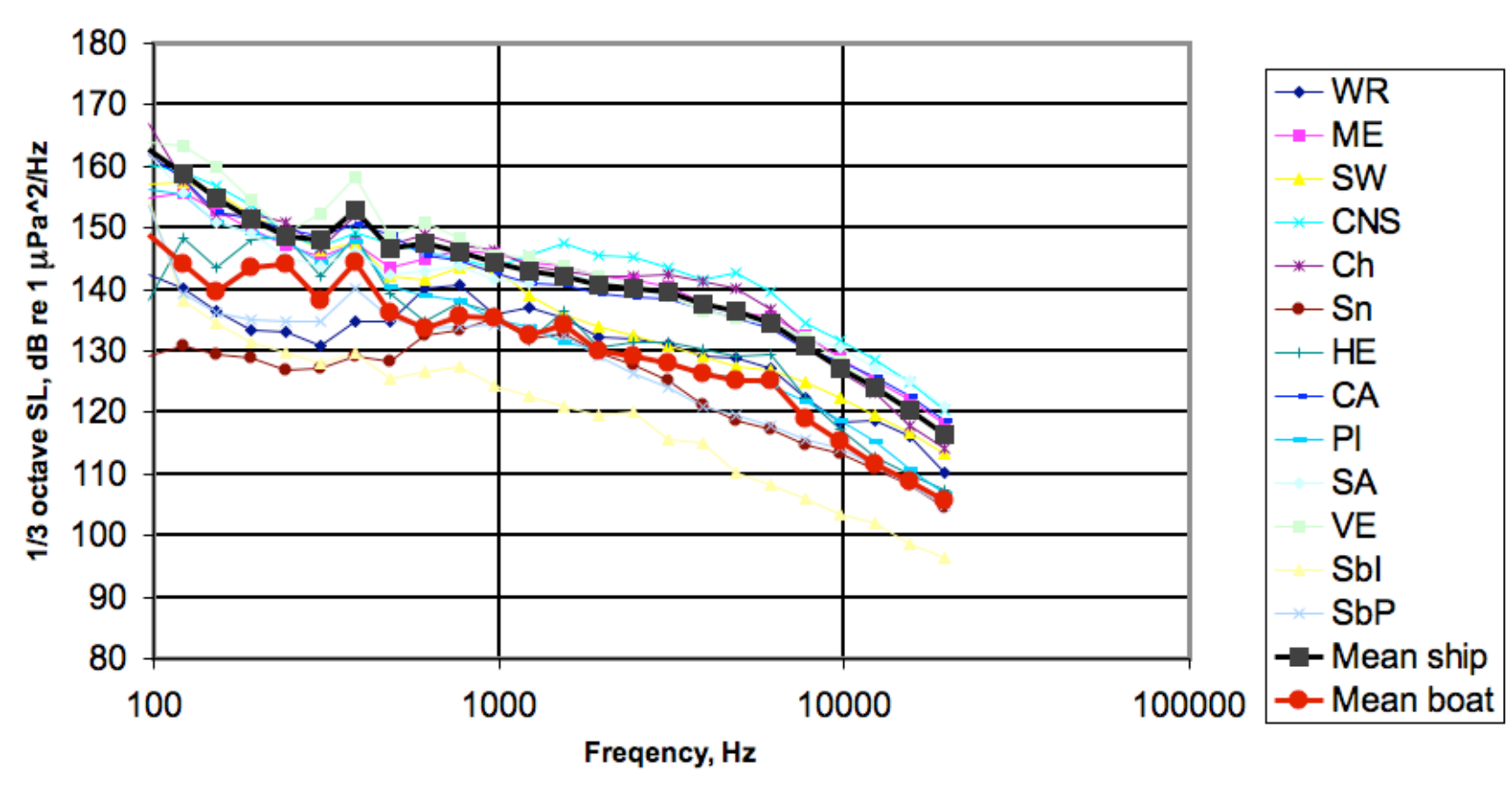
SL spherical	SL empirical
189 dB re 1μPa @ 1m	165 dB re 1μPa @ 1m

Angular distribution of broadband source levels



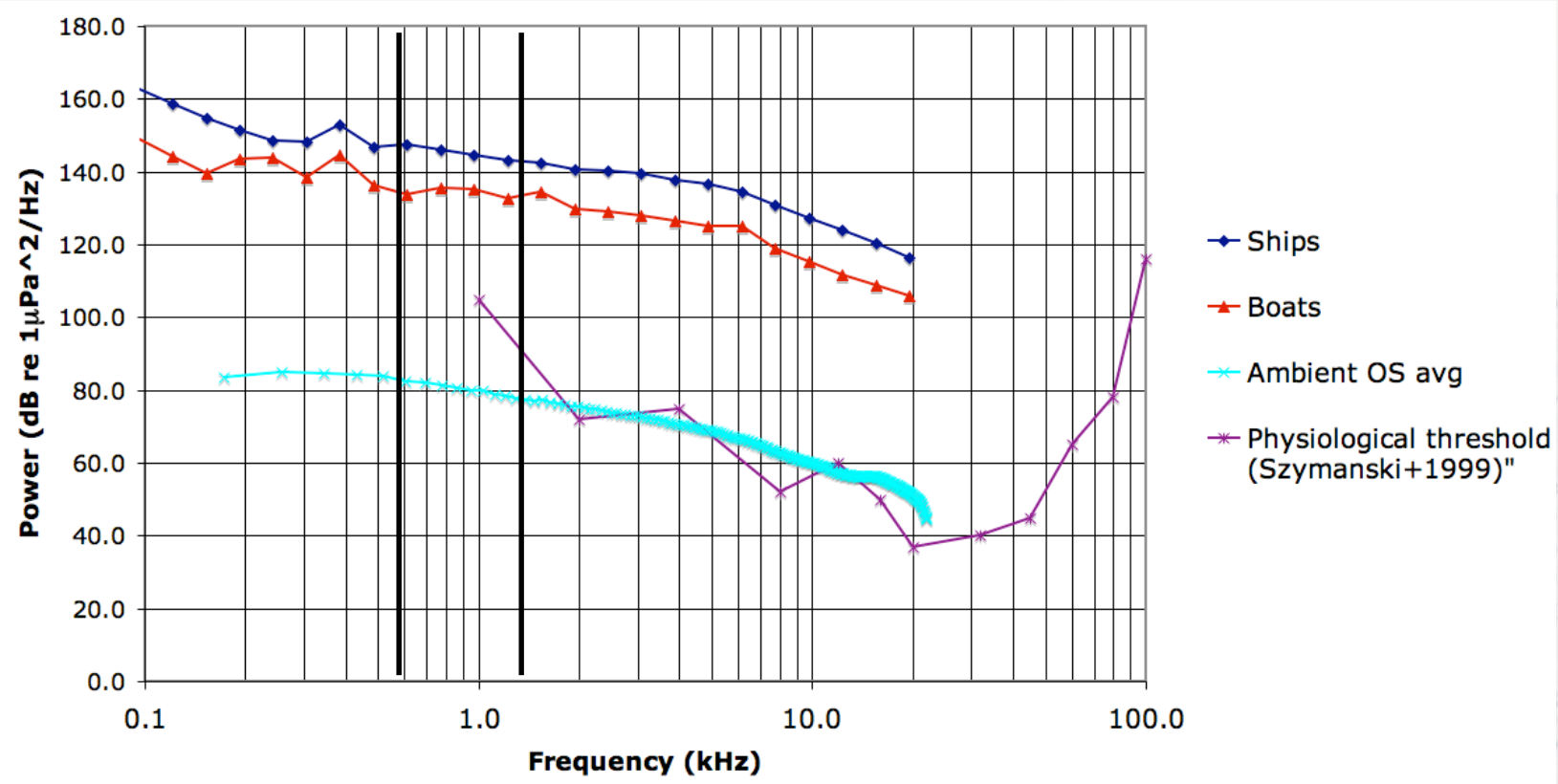
- m = 13.2 dB/decade
- Source levels vary by 20 dB: max 175, min 153

Spectral source levels



- Mean ship SL is about 10 dB above boat SL at all f

Implications



- Ships do matter: they emit ~120 dB at most sensitive f (~20kHz)
- Orcas can likely perceive a ship anywhere in Haro Strait
  - (inaudible only after 70 dB of TL)

Conclusions

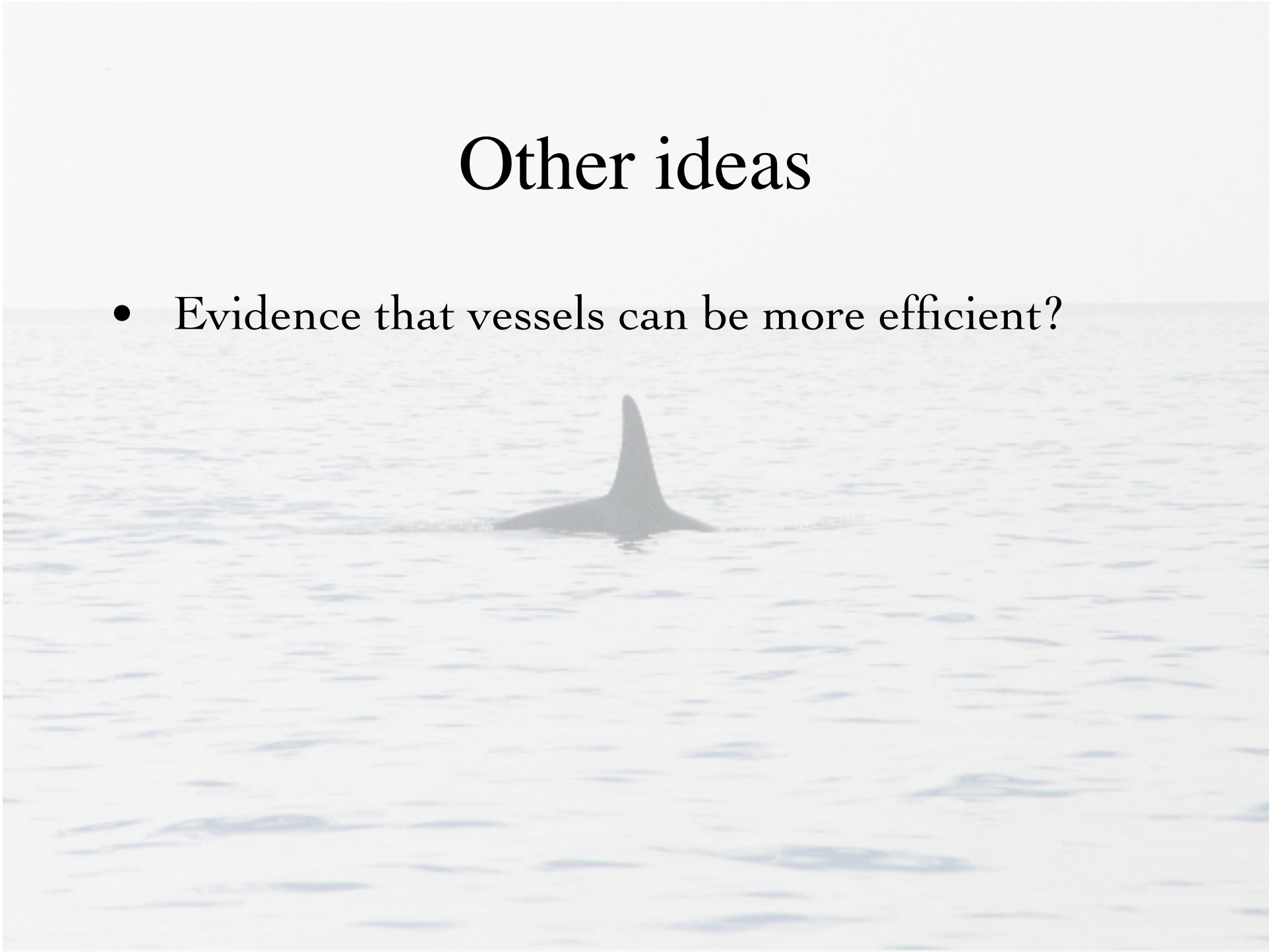
- From 0.1-20kHz, ship SL dominate

  Spherical ~ 190 dB re 1 μPa @ 1 m

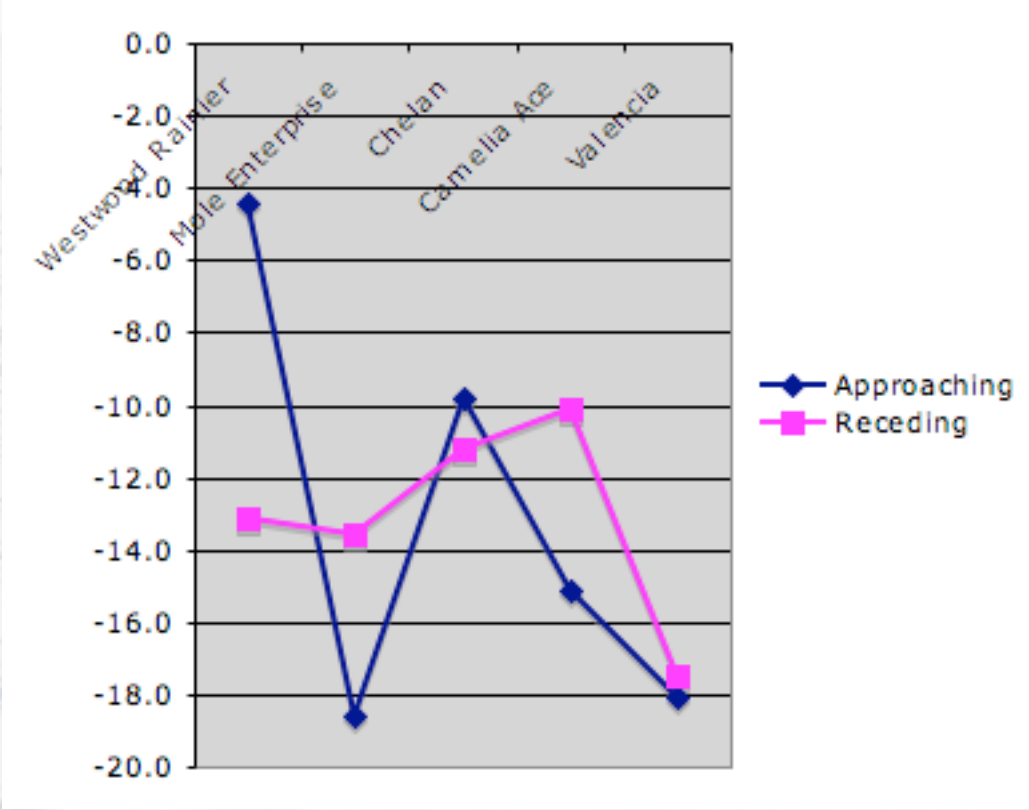
  Empirical ~ 165 dB re 1 μPa @ 1 m
- SL independent of relative bearing
- Spreading varies by location
- Source levels and spectra vary between ships
  - Some ships are much louder than others
  - Outliers with extraordinary power at orca sensitivity may be most important

Other ideas

- Evidence that vessels can be more efficient?

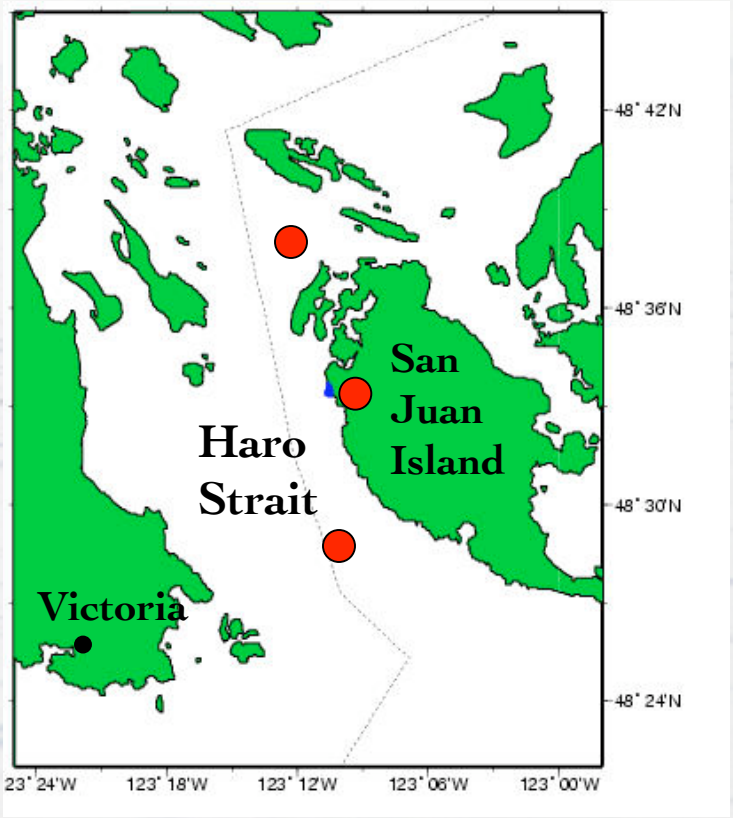


Spreading variability

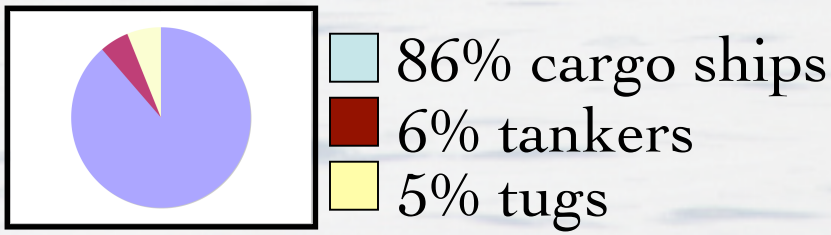


Study site and environment

- Fixed array
- Boat-based deployments
- Bathymetry
- Sound speed profile



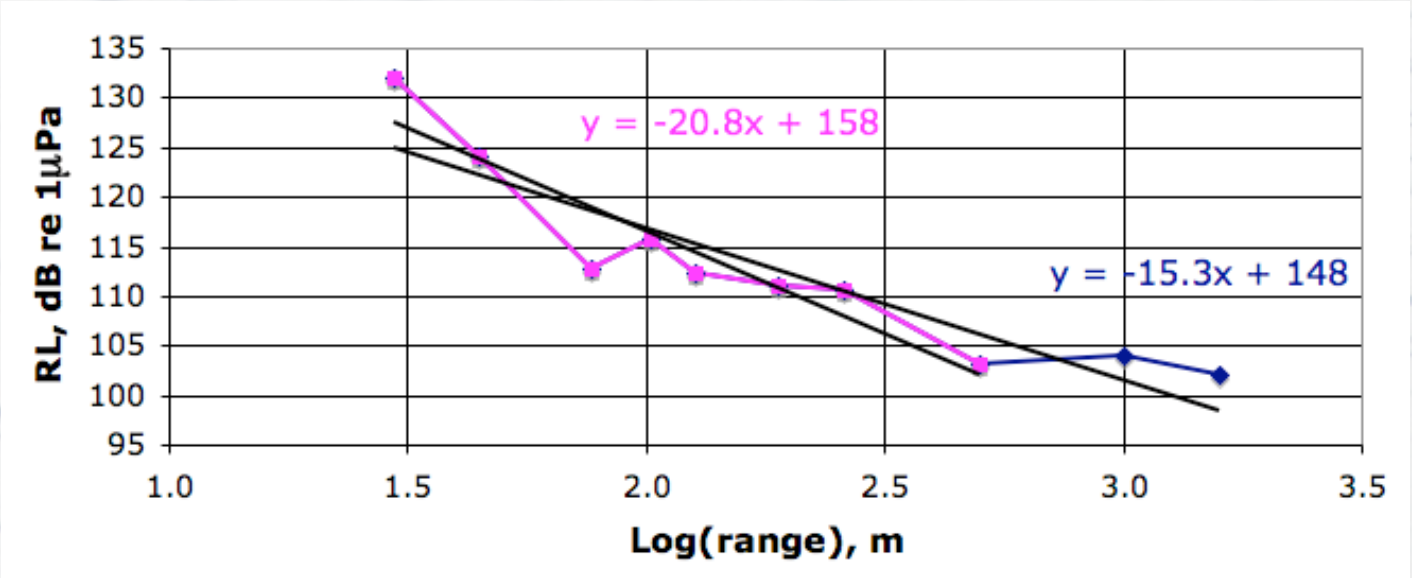
- We focused on ships



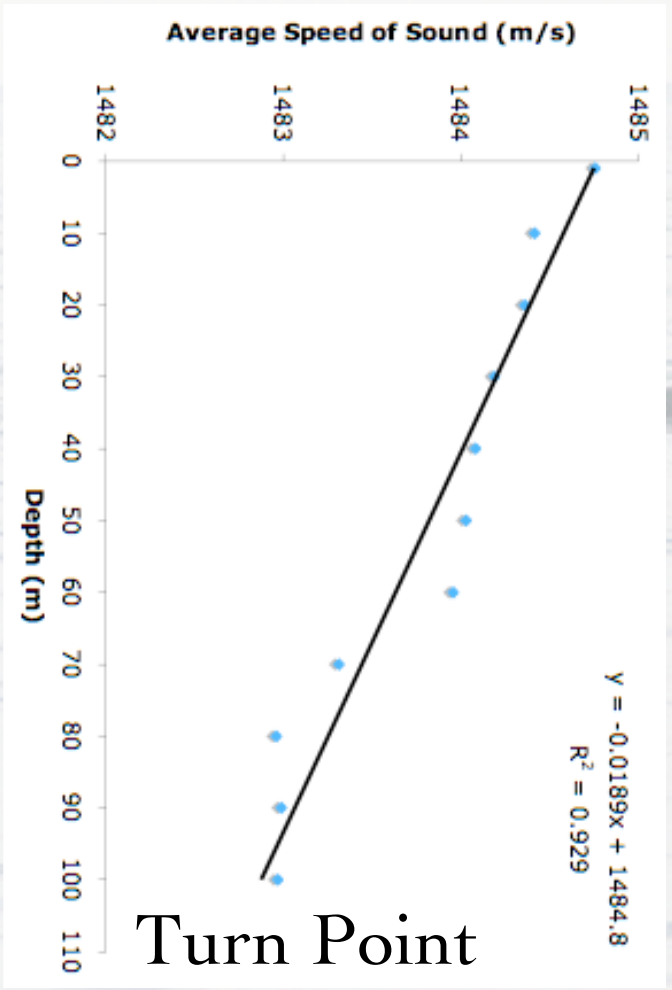
Mintz and Filadelfo 2004a+b

Spreading pings

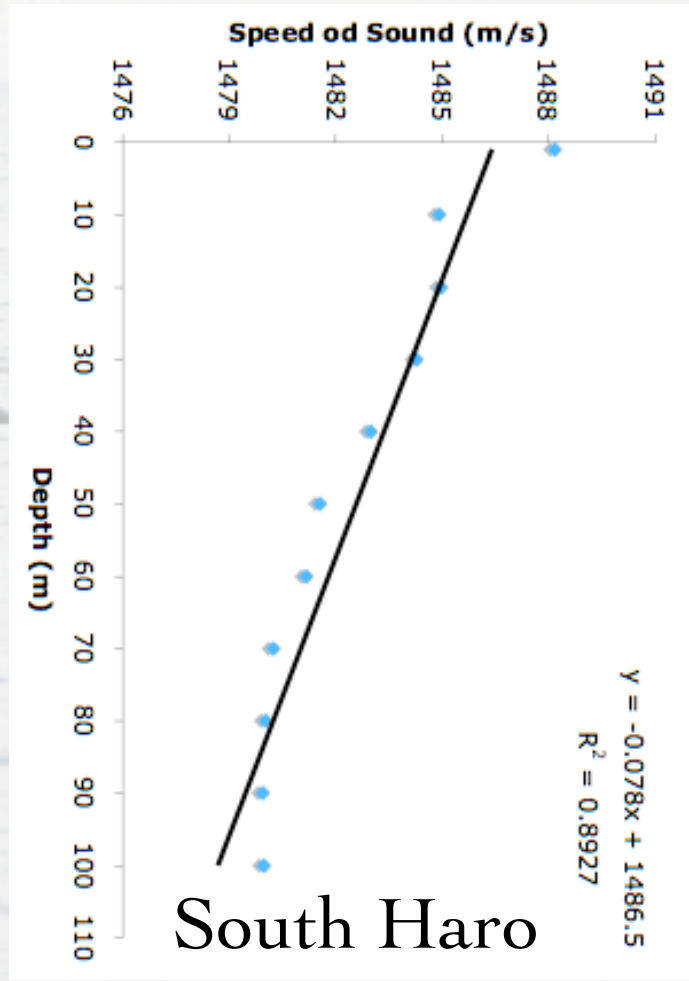
- Spherical spreading
  - Z~200m; R~500m-5km
  - <75m: -20dB/decade
- Measured with ships (5)
  - –Mean: -13.2 dB/decade
  - –Standard error of mean: 1.2
  - –Approaching mean: -13.1
  - –Receding mean: -13.4



Sound speed profiles

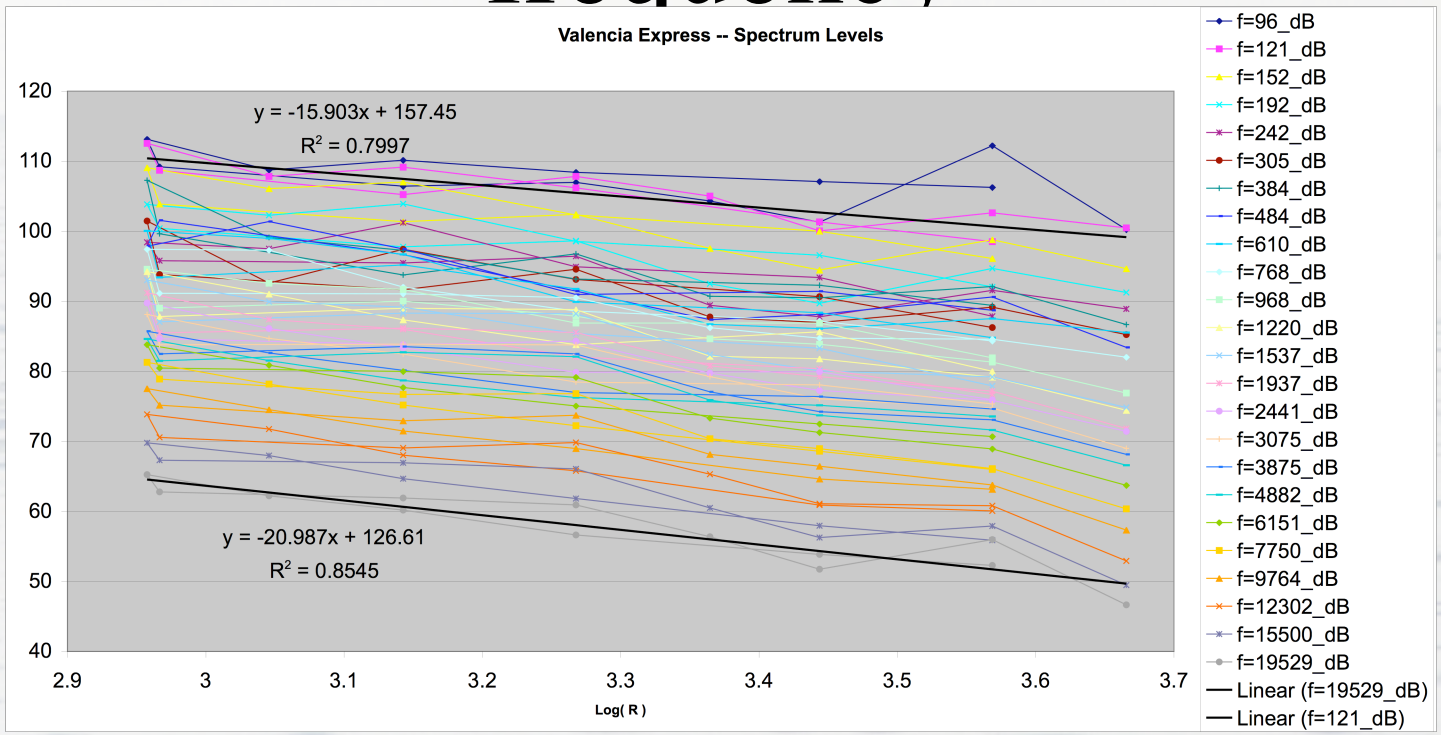


Turn Point



South Haro

Spreading as a function of frequency



- Spherical at hi f; -15 dB/decade at low f
- Same results for CA (-22.3,-14.2)

Puget Soundscape

Explore via link at http://beamreach.org/051/