The Pathway

A program for regulatory certainty for instream tidal energy projects

Presentation

Scientific Echosounder Review for In-Stream Tidal Turbines

Principle Investigators
Dr. John Horne

August 2019

Scientific-grade echosounders are a standard tool in fisheries science and have been used for monitoring the interactions of fish with tidal energy turbines in various high flow environments around the world. Some of the physical features of the Minas Passage present unique challenges in using echosounders for monitoring in this environment (e.g., entrained air and suspended sediment in the water column), but have helped to identify hydroacoustic technologies that are better suited than others for achieving monitoring goals. John Horne's report and presentation will present a overview of echosounders and associated software that are currently available for monitoring fish in high-flow environments, and identify those that are prime candidates for monitoring tidal energy turbines in the Minas Passage.

This project is part of "The Pathway Program" – a joint initiative between the Offshore Energy Research Association of Nova Scotia (OERA) and the Fundy Ocean Research Center for Energy (FORCE) to establish a suite of environmental monitoring technologies that provide regulatory certainty for tidal energy development in Nova Scotia.

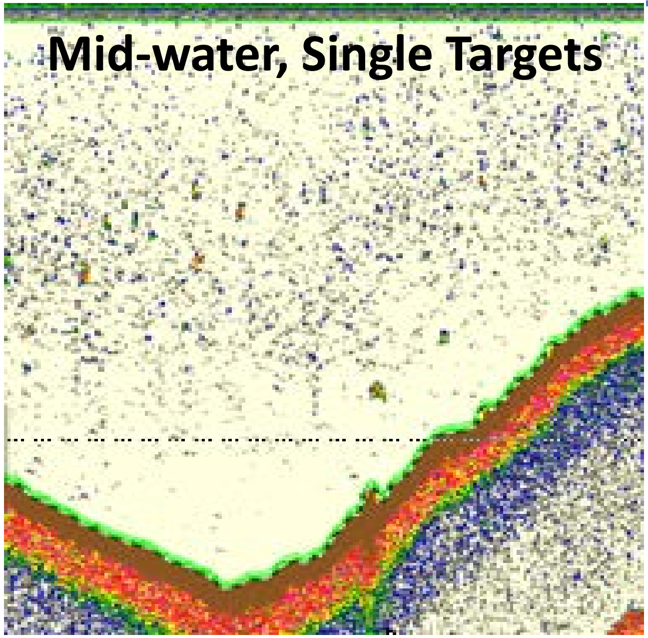
Listening in the Noise

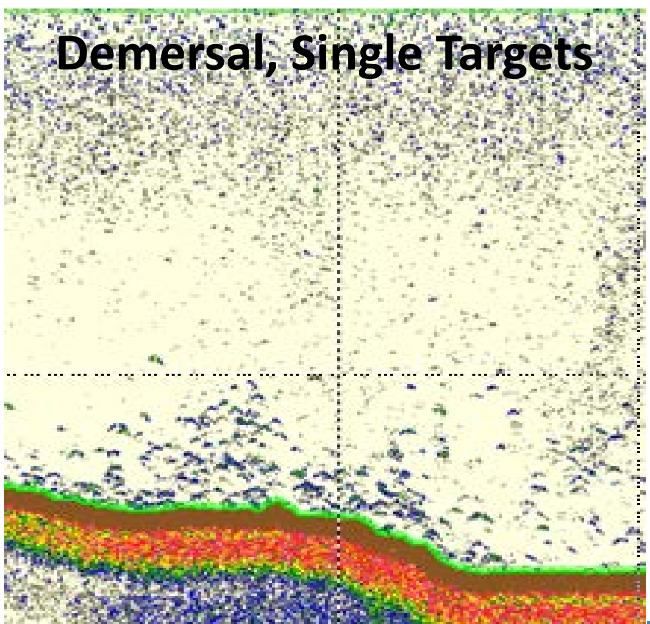
oera webinar series

John K. Horne
University of Washington

FORCE
OERA

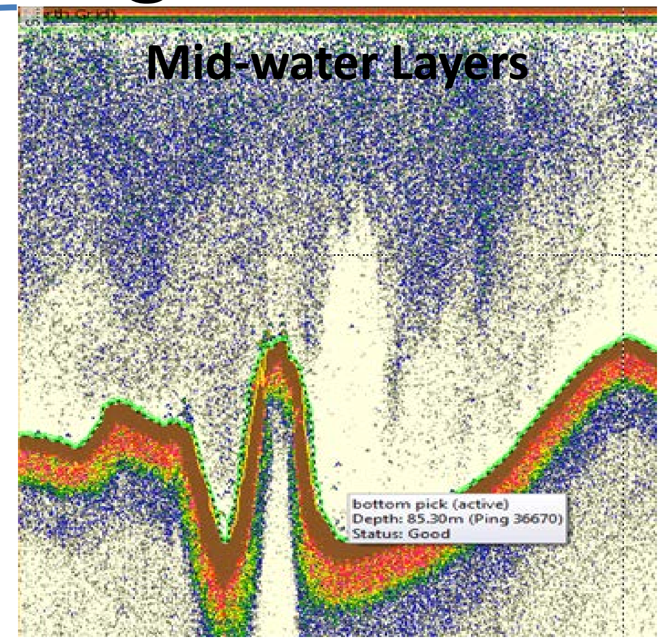
Typical Acoustic Targets

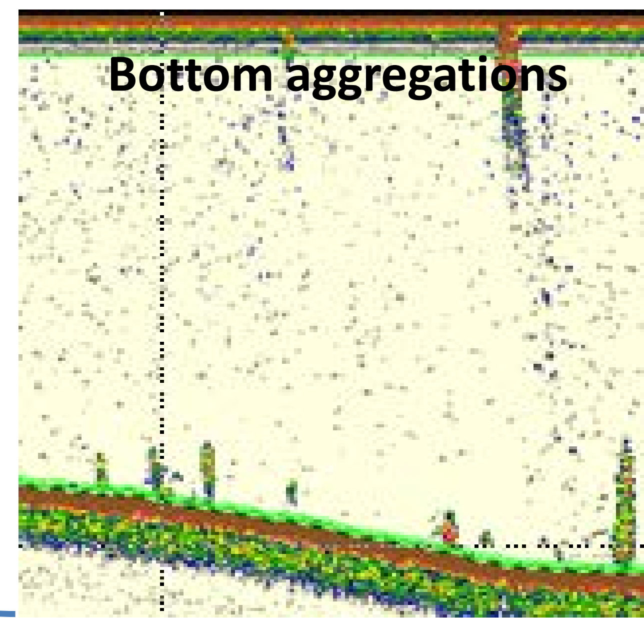




Echo Counting

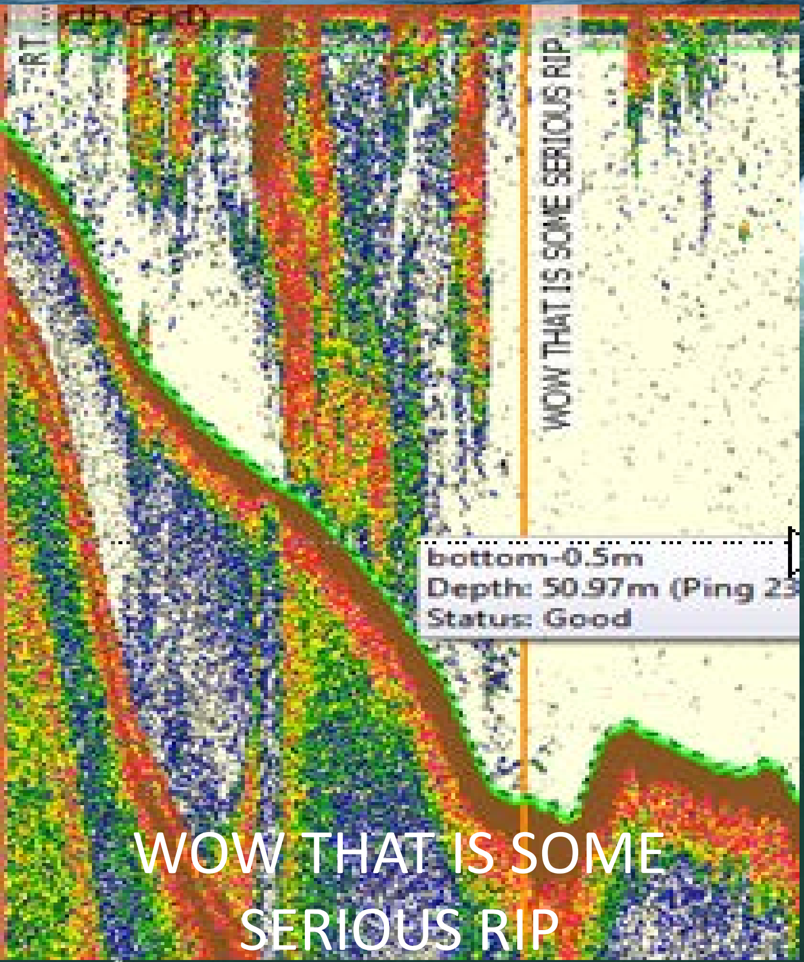
Echo Integration





Using Sound as a Sensor:

How to detect swimbladdered fish in bubbly, turbulent water?



WOW THAT IS SOME SERIOUS RIP

What is an Echo?

An acoustic impedance mismatch resulting in a reflection

Acoustic Impedance (Z) $Z = \text{density x sound speed} = \rho\ c$

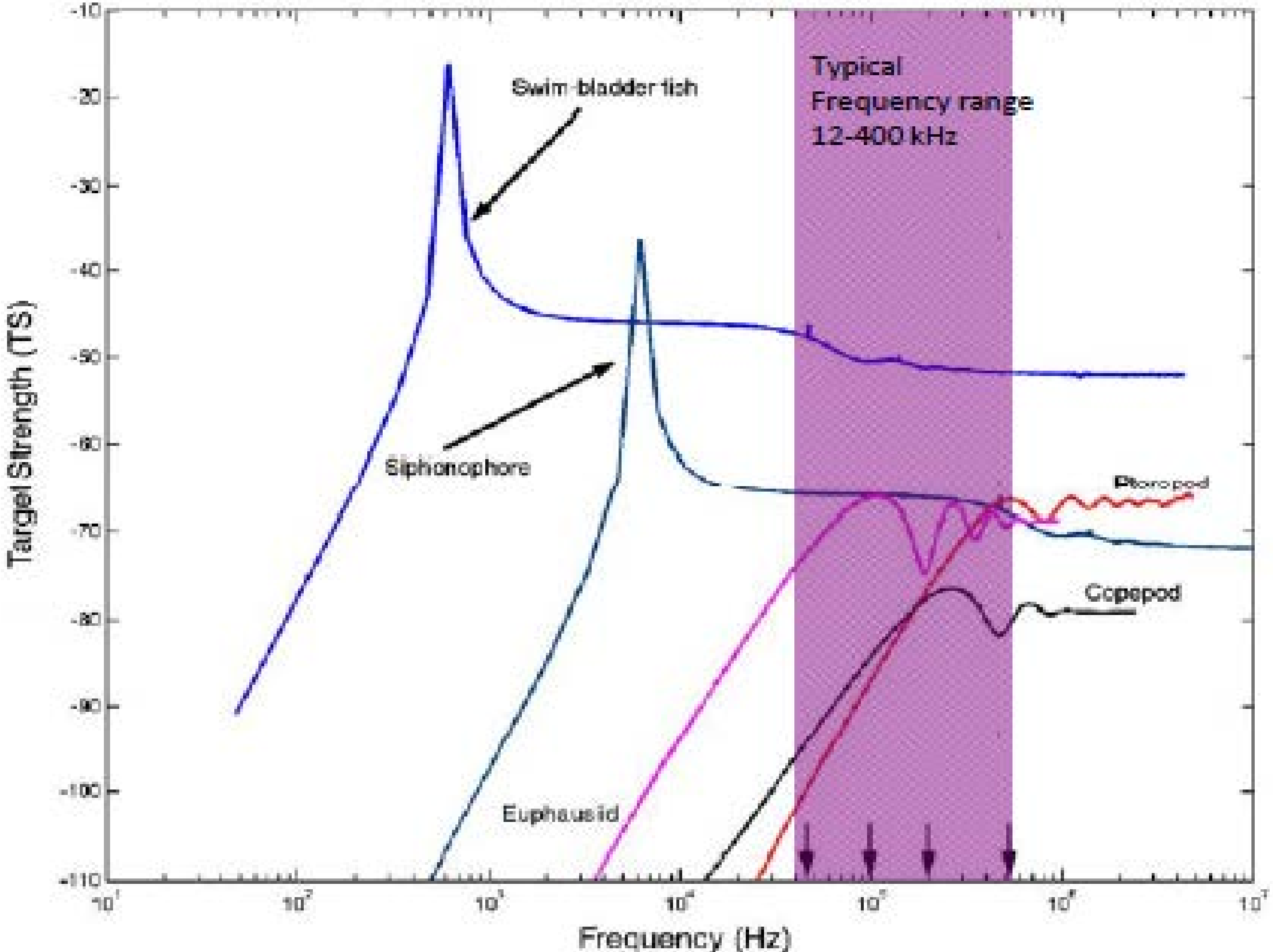
Comparing Impedance at an Interface

$g = \rho_2/\rho_1$ — density contrast

$h = c_2/c_1$ — sound speed contrast

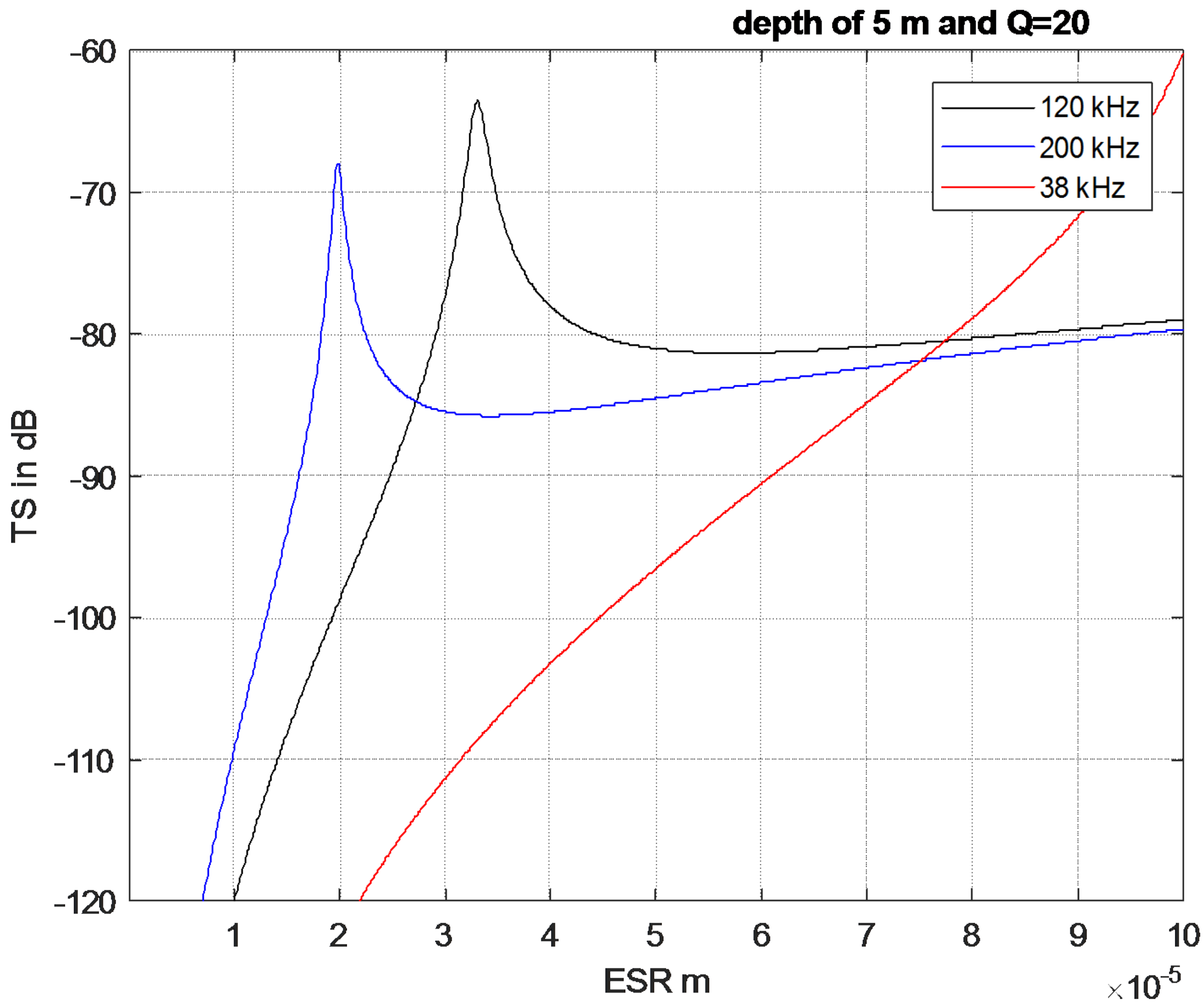
Anything with a density different than water will reflect sound

Echo Amplitudes f(Frequency)



Lavery et al. 2002

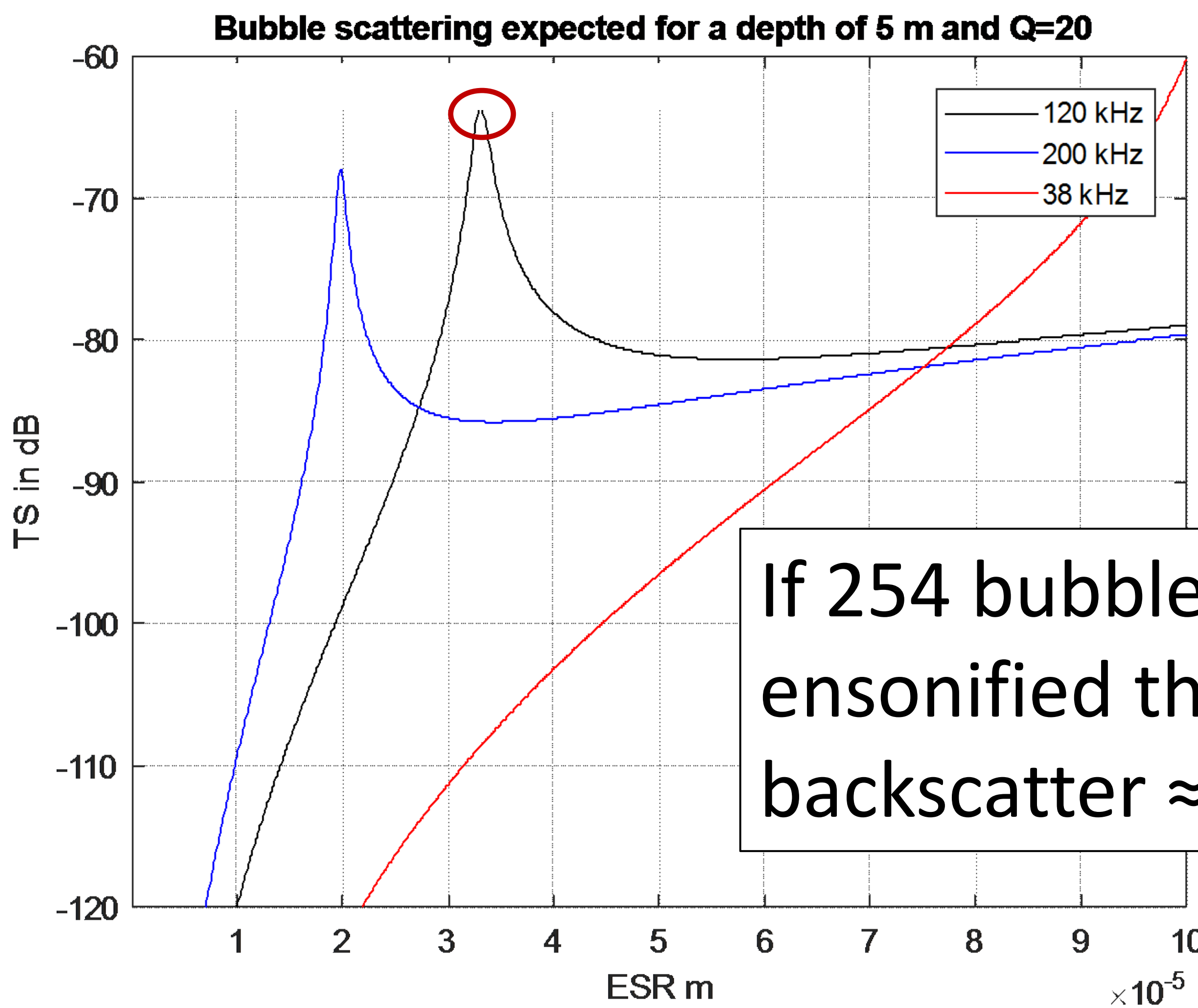
Bubble TS: Model Estimate



Courtesy of T. Ryan

Bubble Ensemble

TS of 0.06 mm bubble (width of human hair) at 120 kHz ≈-64 dB



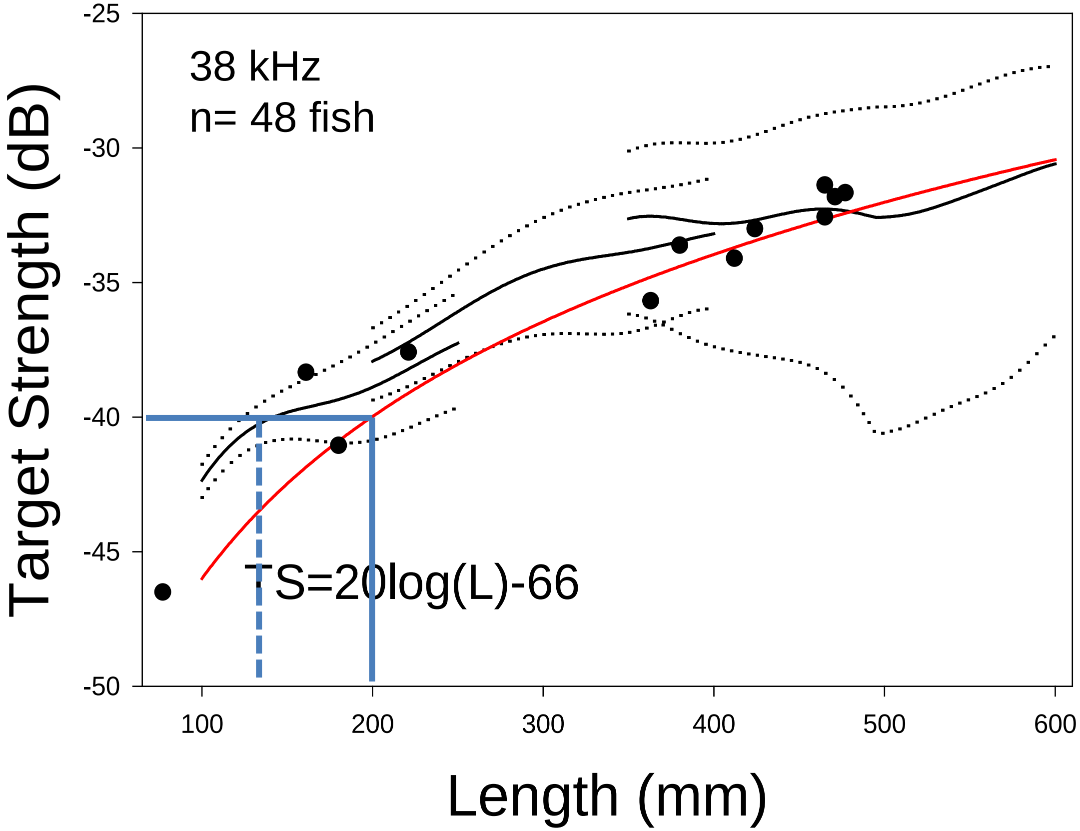
If 254 bubbles ensonified then backscatter ≈ -40 dB

Courtesy of T. Ryan

Fish Target Strengths

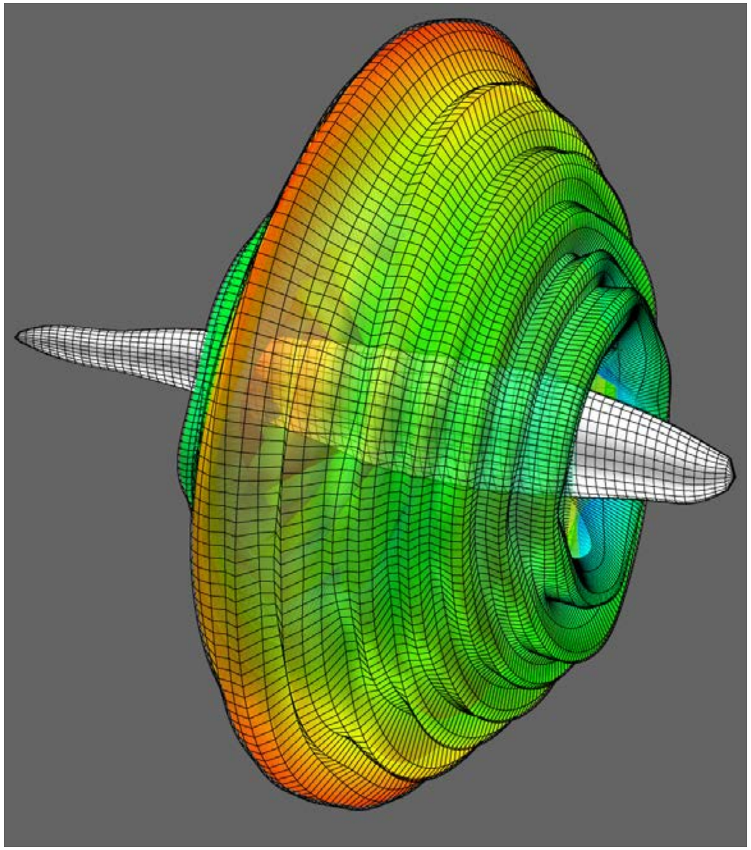
Walleye pollock (*Gadus chalcogrammus*)

comparison of backscatter to statistical model



Horne 2003

Backscatter Model Visualization



Needed Sensor Characteristics

General
Calibratable: accuracy and precision of measurements
Constant source level and TVG: accuracy and precision of measurements
Known beam pattern: accuracy and precision of measurements
Digital output: data processing and analysis

Data Processing
compatible with commercial processing software for bulk processing (Echoview, LSSS, SonarX)

MRE
Maximize SNR: CHIRP signal + matched filter for target detection
Physical footprint and packaging: 'fit' in deployment platform
Power and communications: 'fit' with deployment strategy and sample design

What Determines Echo Amplitude?

Simplified Sonar Equation

Echo Amplitude = Source Level + Target Echo + Beam Compensation – Transmission Loss

$$EL = SL + TS + 2D_i(\phi,\theta) - (40\log(r) + 2\alpha r)$$

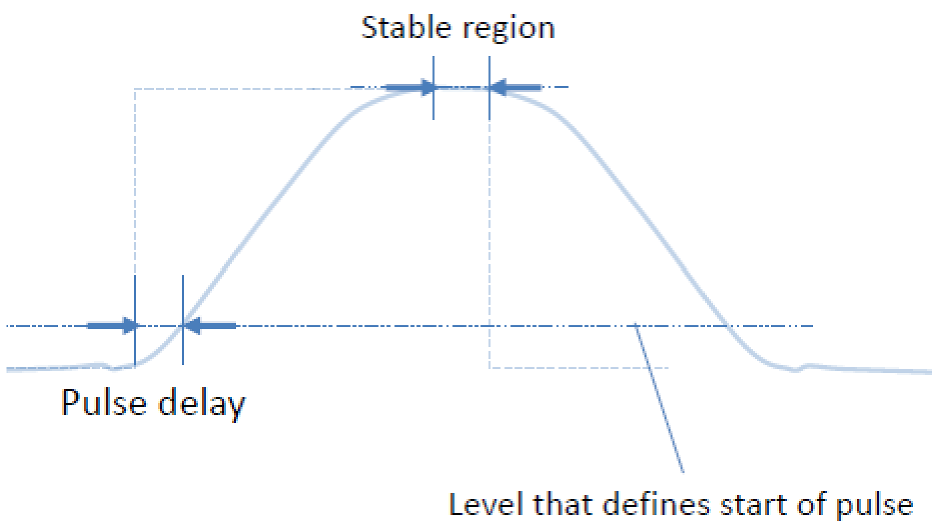
Echo Level | Source Level | Target Strength | Beam Directivity | Spreading | Absorption

How to Increase Echo Amplitude (relative to noise)?

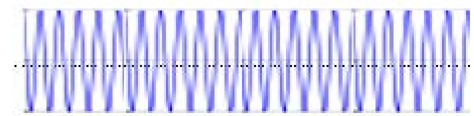
1. Increase source level (amplifies everything)
2. Reduce distance to targets (strategic deployments)
3. Increase signal-to-noise ratio (increase signal (see 1), reduce noise, change pulse type)
4. Match transmit frequency to target resonance peak (lower transmit frequency but operational and regulatory constraints)
5. Process data to remove noise (ambient noise filter, mask unwanted targets)

Transmit Pulse Types

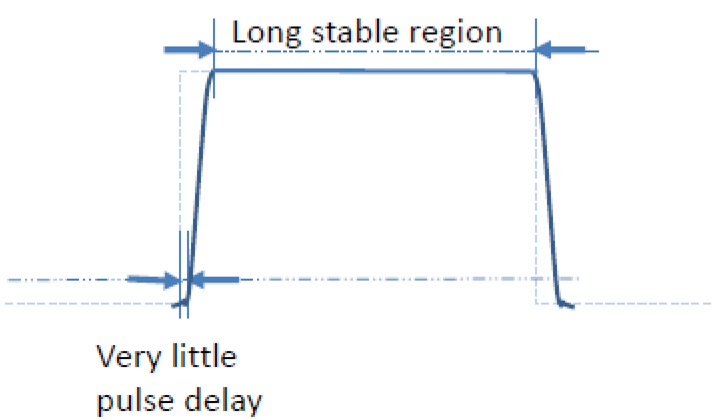
Narrowband

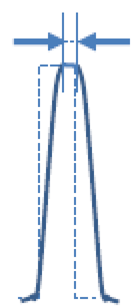


Continuous Wave (CW)

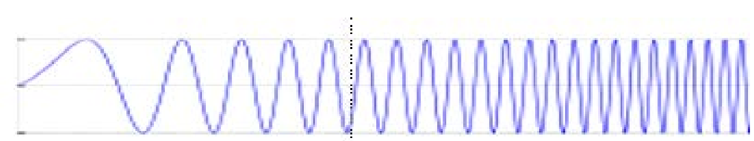


Broadband





Frequency Modulated (FM)
Linear up-sweep (CHIRP)



Broadband: very short pulses possible
=> High spatial resolution is possible

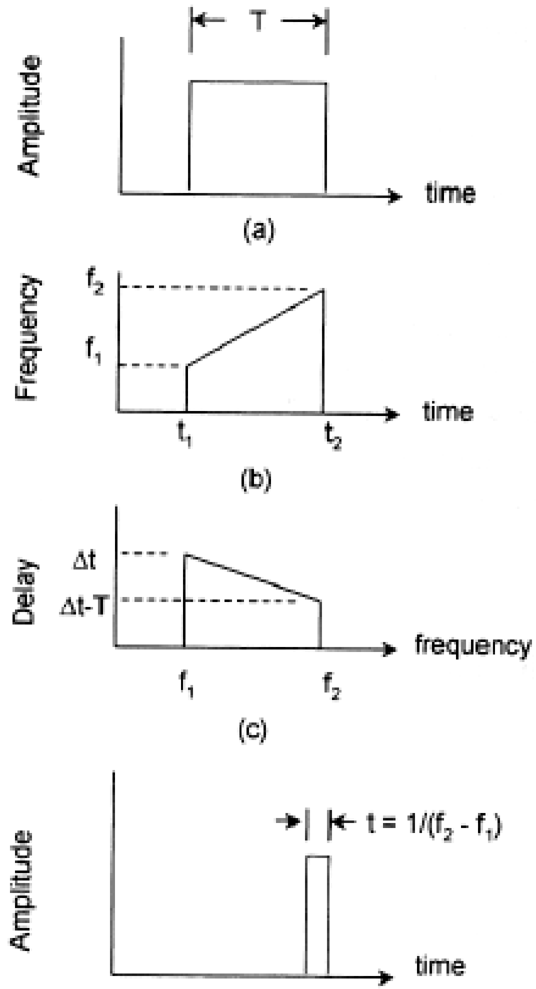
Broadband Matched Filtering

Transmit Pulse

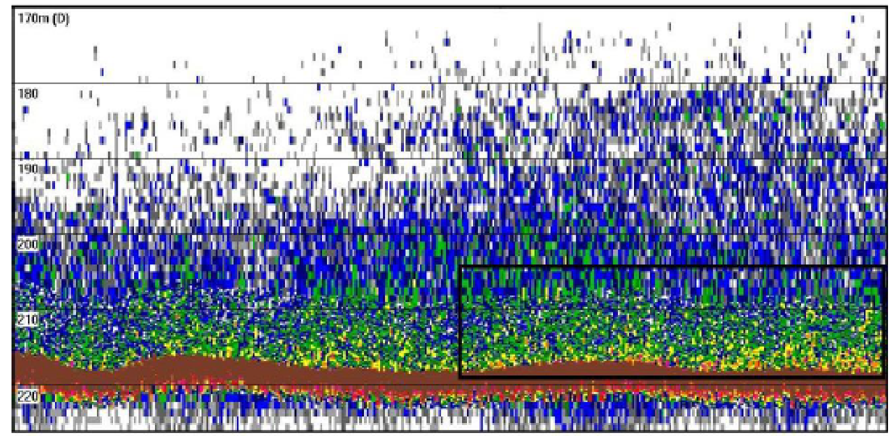
Time –dependent Frequency

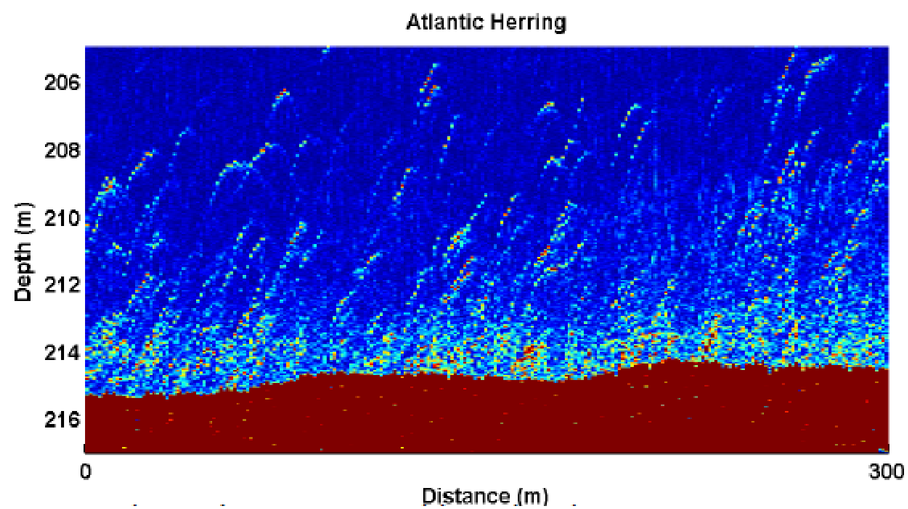
Receive Echo Delay

Receive Echo Amplitude



Ehrenberg & Torkelson 2000





Stanton 2010

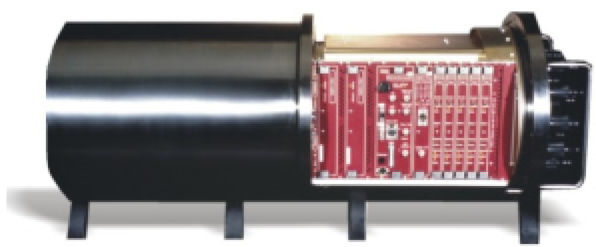
SNR increase ~ 15 dB over CW pulse (depends on pulse bandwidth)

Commercial, Scientific Echosounders

Tier I: calibrated, internationally vetted, digital output

Simrad EK80

HTI Model 244



BioSonics
DTX Extreme

Commercial, Scientific Echosounders

Tier II: calibratable, consistent TVG, international vetting underway

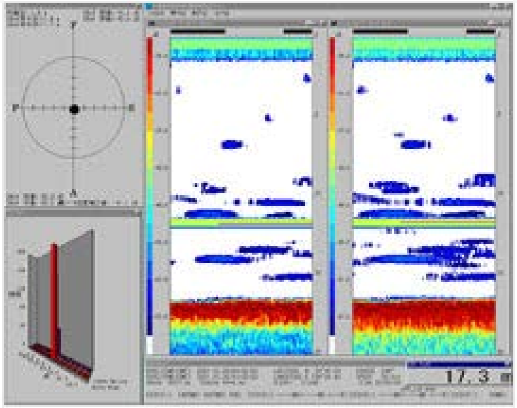
ASL AZFP

Nortek
Signature 100

Commercial, Scientific Echosounders

Tier III: not internationally vetted

Kaijo/Sonic
KFC-3000



Furuno FQ80

Imagenix 853