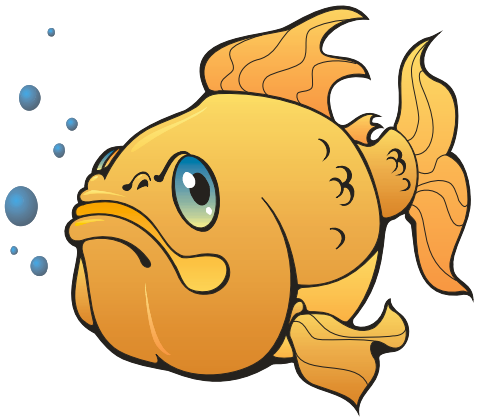
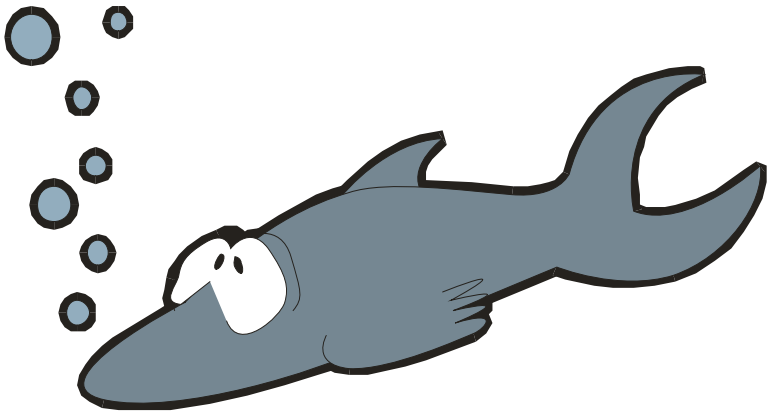
Acoustic Target Classification



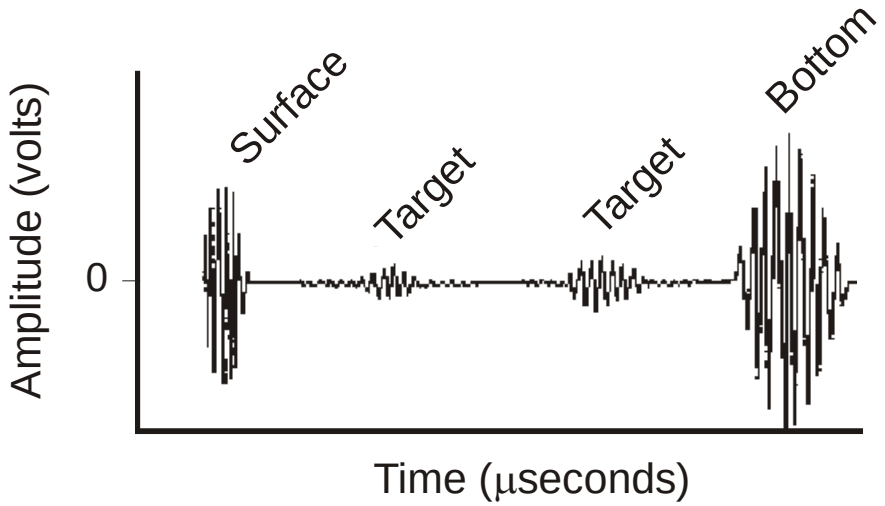
Fred



Mabel

John Horne, University of Washington

Acoustic Measurements



Measure: amplitude f(frequency), elapsed time

(everything else derived)

How do you Discriminate, Classify, and Identify targets?

D (wanted from unwanted), C categorize, I label

Acoustic Target Classification Decisions and Approaches

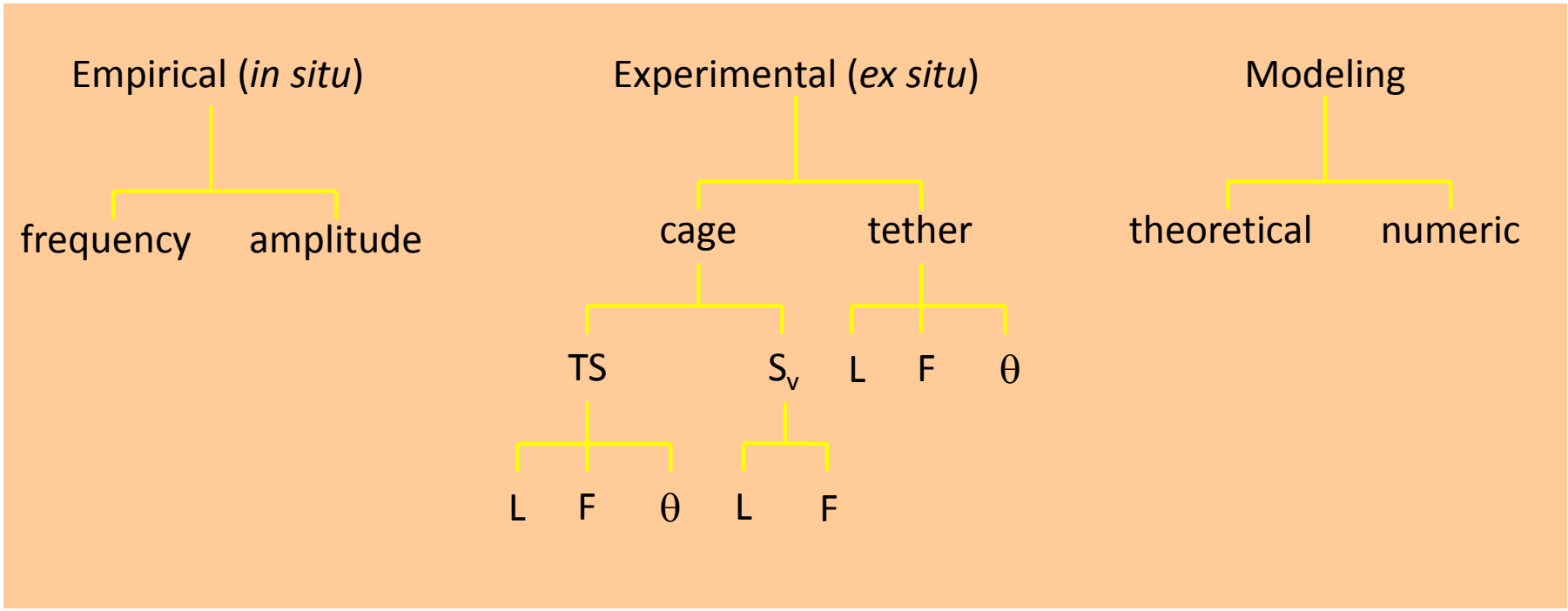
Decisions:

1. Empirical, Experimental, Modeling
2. Scattering Region: Resonance, Geometric
3. Discrete Single or Multi Frequency, Wideband
4. Single Target, Ensemble Backscatter

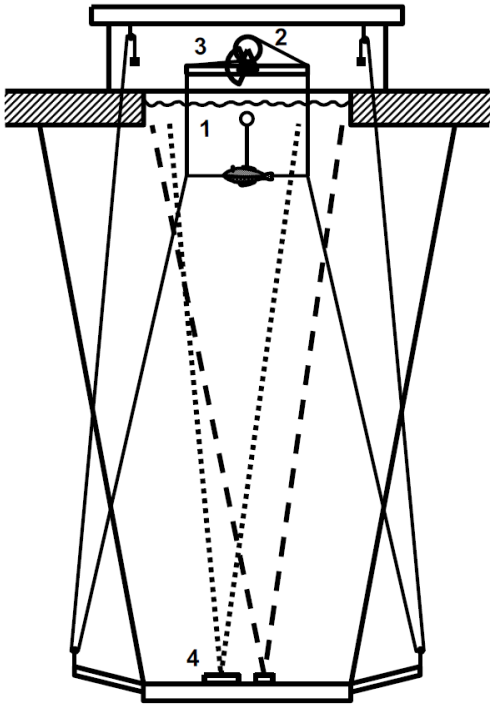
Approaches:

1. Prior Knowledge and Direct Sampling
2. Statistical Comparisons
3. Matching Models to Measures

Acoustic Classification Org Chart

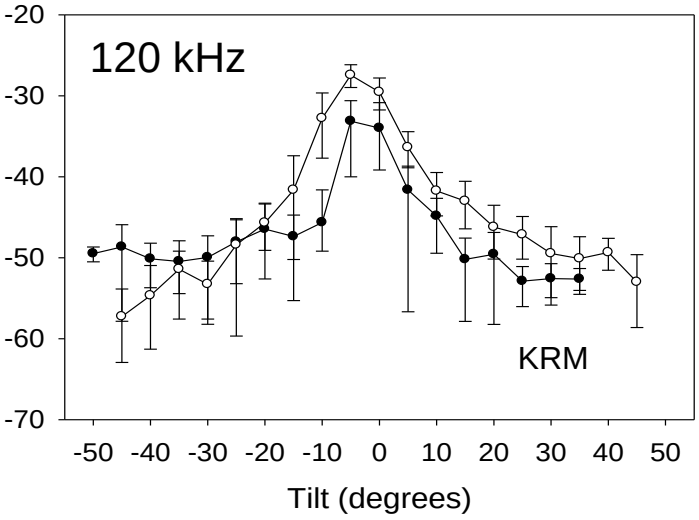


Ex Situ Target Strength Measurements

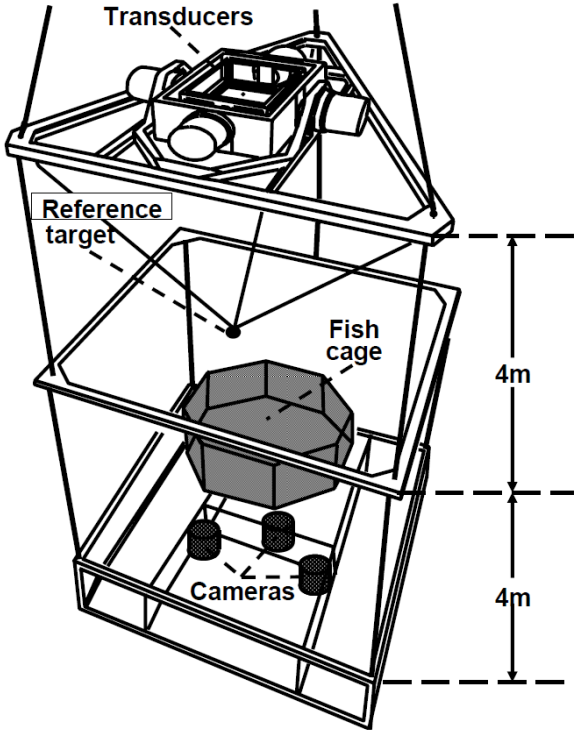


Nakken & Olsen 1977

species, length, frequency, tilt



Henderson & Horne 2007



Edwards & Armstrong 1983

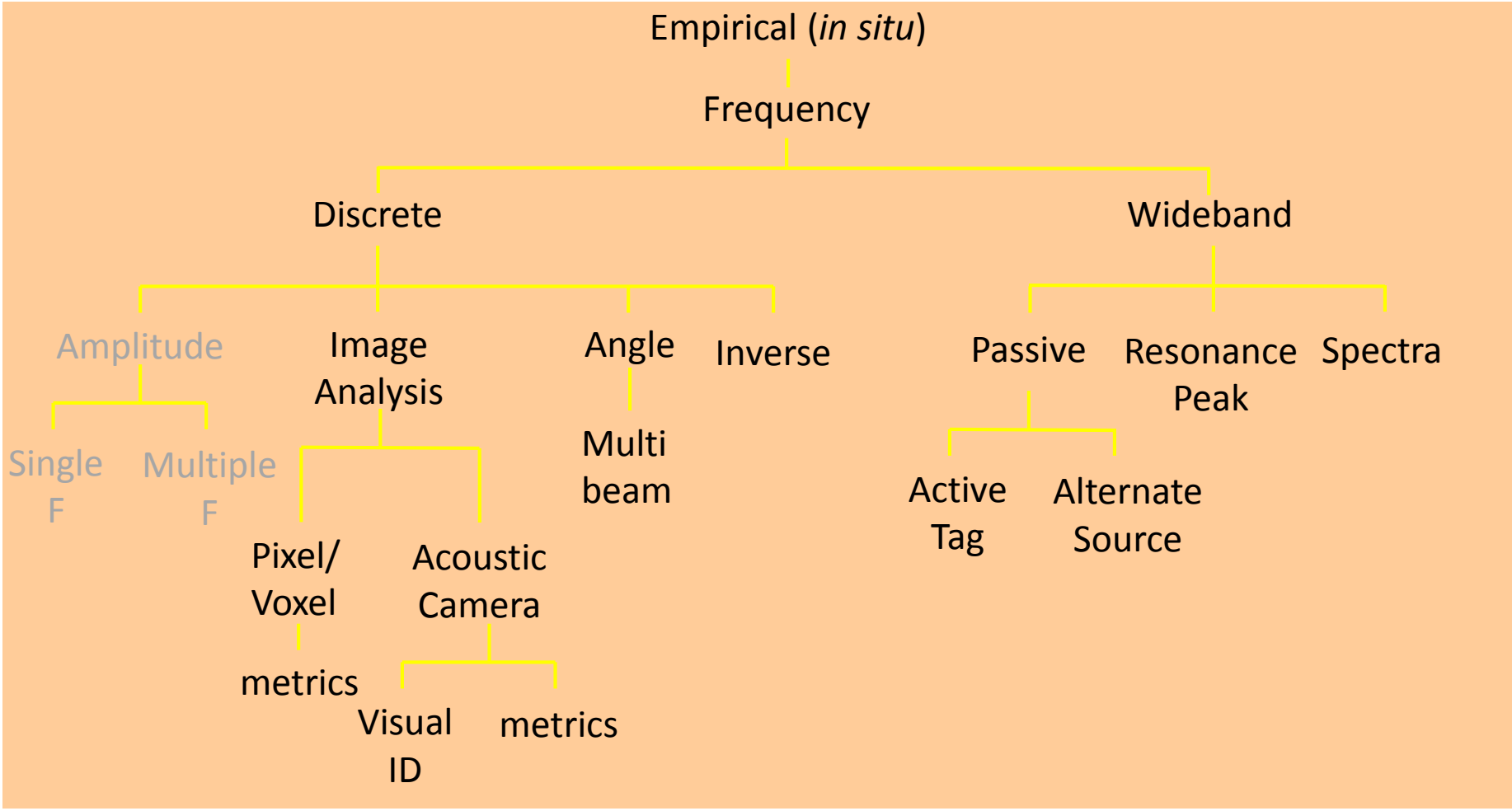
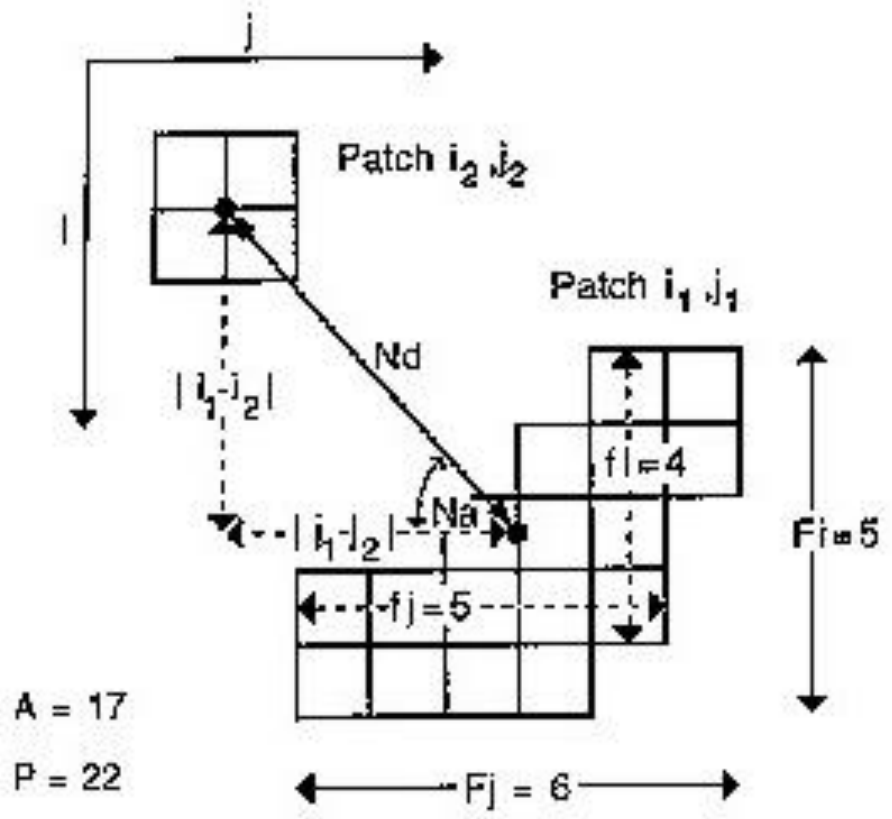

Empirical (*in situ*)
Frequency
Discrete
Wideband
Amplitude
Image Analysis
Angle
Inverse
Passive
Resonance Peak
Spectra
Single F
Multiple F
Multi beam
Active Tag
Alternate Source
Pixel/ Voxel
Acoustic Camera
metrics
Visual ID
metrics

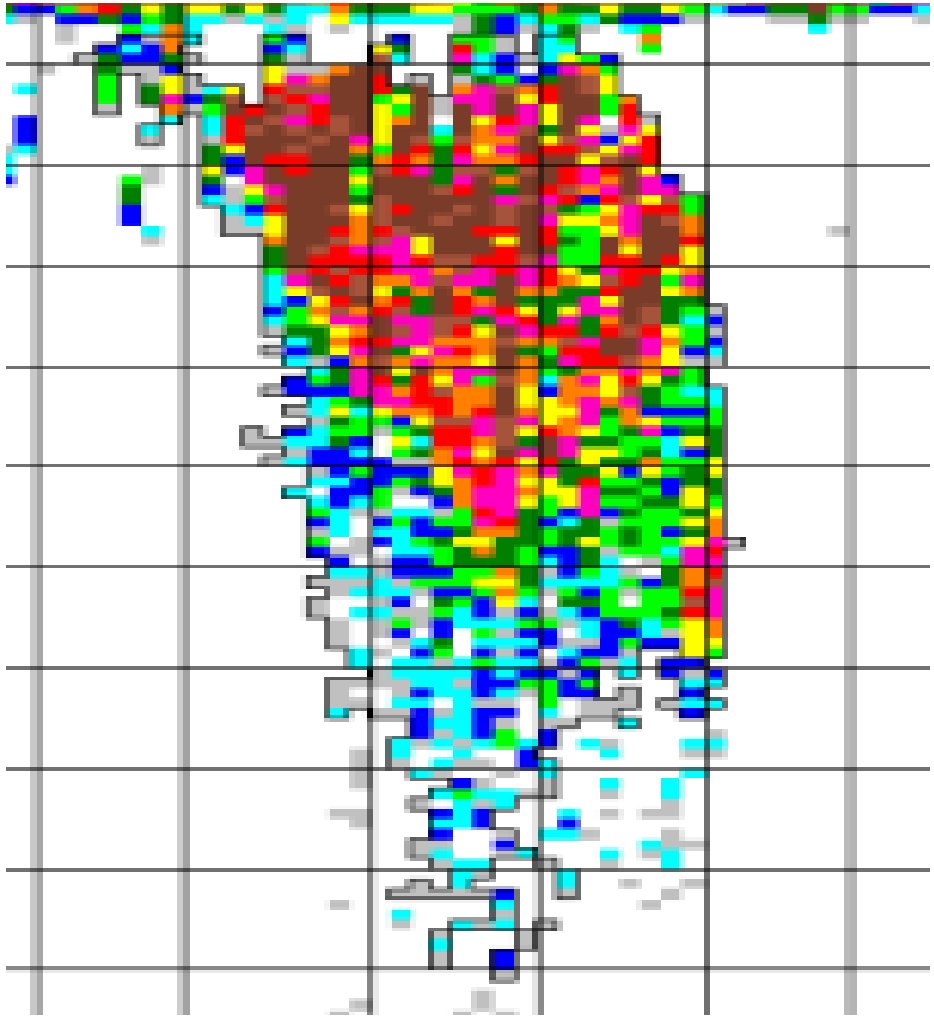
Image Analysis: Digital Echogram Metrics



- Goal: classify patches relative to environment
- tabulate patch metrics
- linear discriminant functions

Nero and Magnuson 1989

Image Analysis: Shapes algorithm

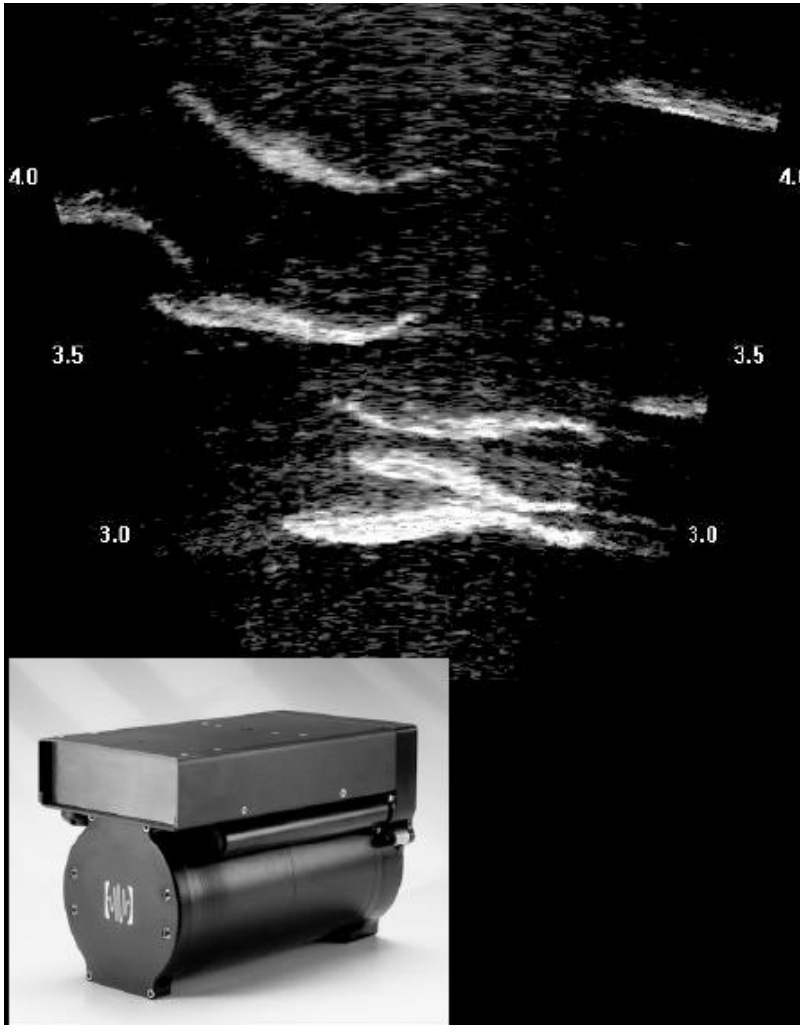


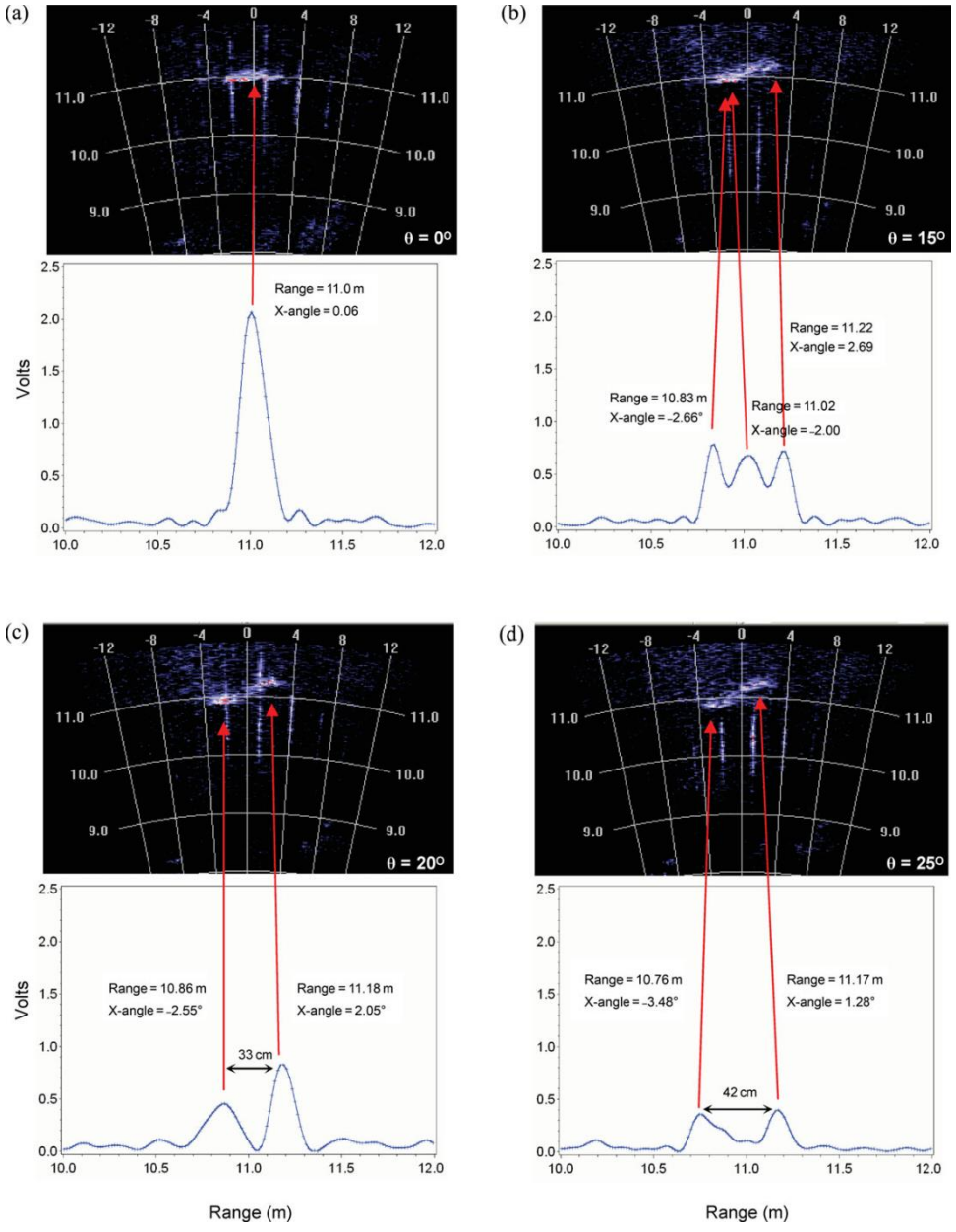
Mean Sv: -29.83
Mean sa: 1044311.18
Mean height: 23.30
Mean depth: 26.71
Max Sv threshold applied: no
Min Sv threshold applied: yes
Max Sv: -15.40
Min Sv: -56.00
Mean noise Sv: -945.58
Mean noise sa: 0.00
Mean bottom depth: 0.00
Number of samples: 1491
Number of pings: 32

- schools module in Echoview

Barange 1994

DIDSON/ARIS: Visual ID, Metrics

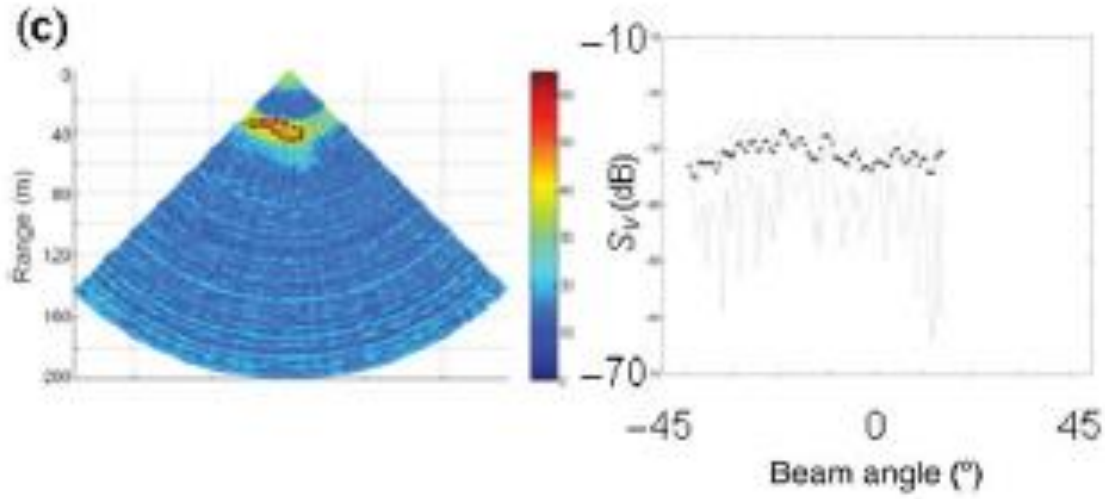




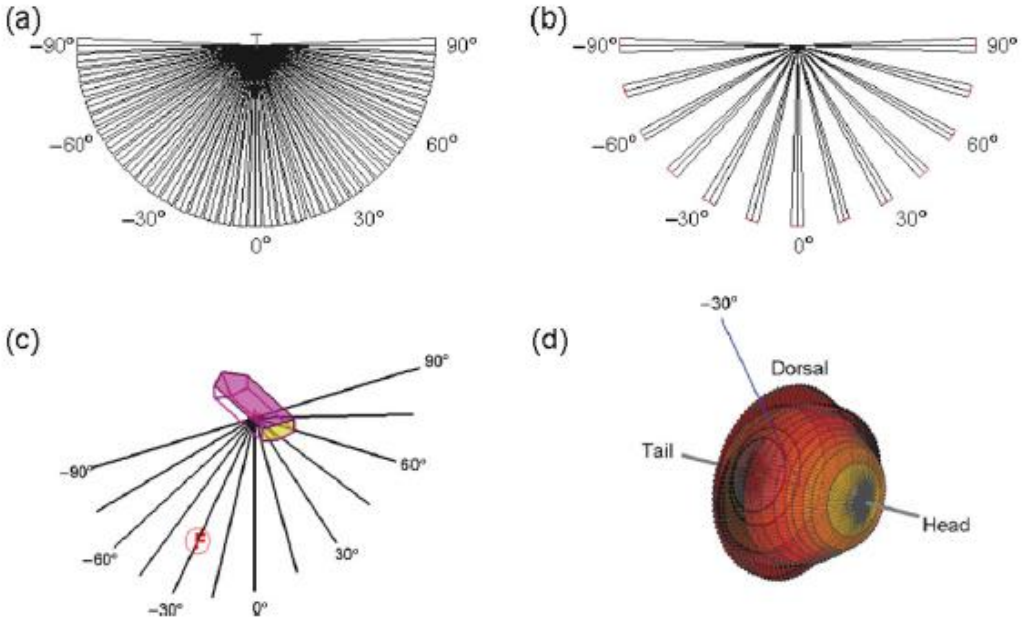
Burwen et al. 2007

Multibeam Target Strengths

Empirical measures



Backscatter models

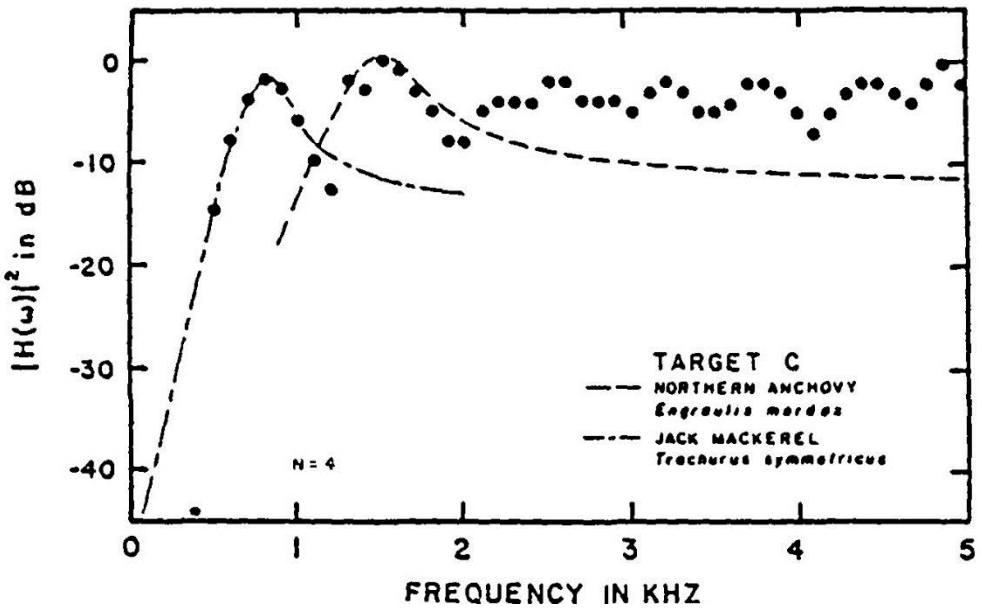


Cutter & Demer 2007

Inverse Approach

Multifrequency Measures+Inverse Algorithm+Backscatter Models

Holliday 1977



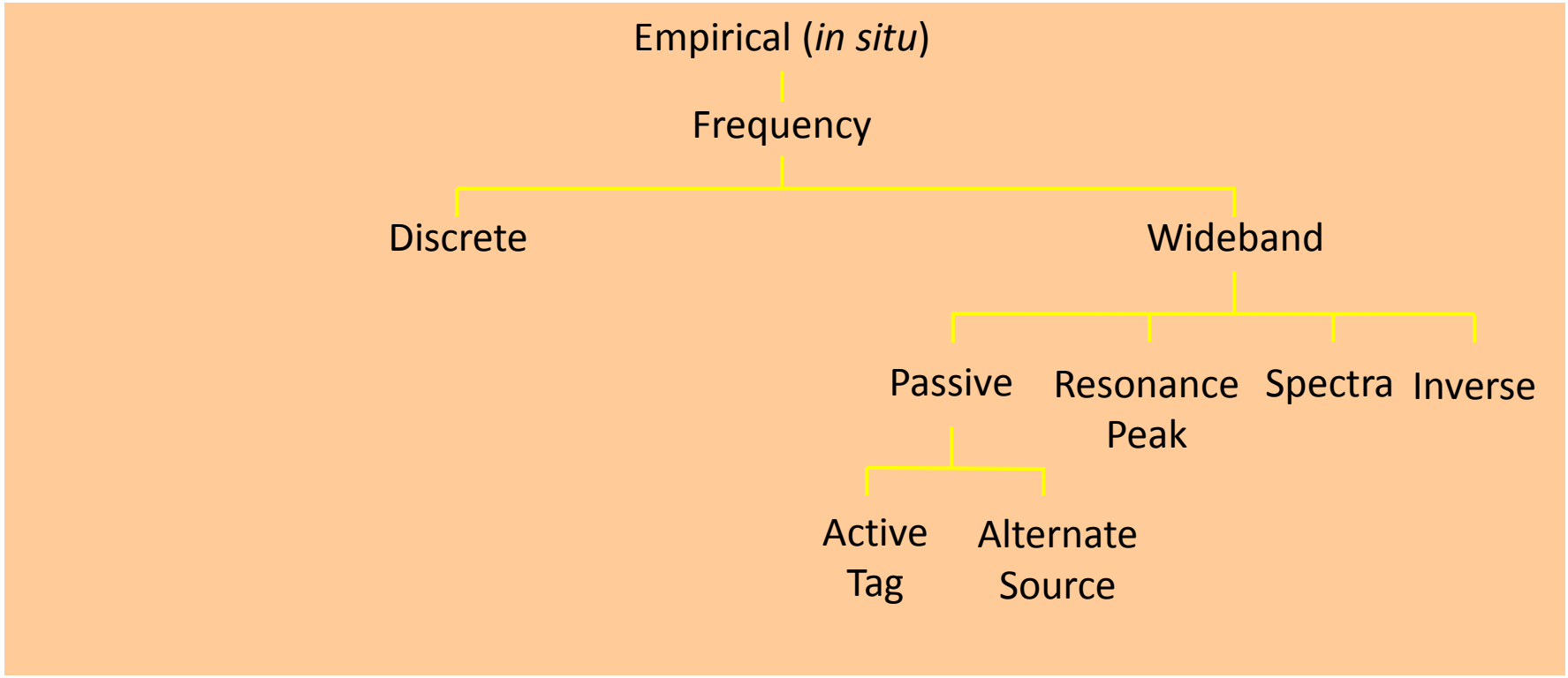
Species/Size Class Resonance Peaks

Inverse algorithm

$$S_1 = \sigma_{11} n_1 + \sigma_{12} n_2 + \sigma_{13} n_3$$
$$S_2 = \sigma_{21} n_1 + \sigma_{22} n_2 + \sigma_{23} n_3$$
$$S_3 = \sigma_{31} n_1 + \sigma_{32} n_2 + \sigma_{33} n_3$$

where S_i is backscatter vector at frequency i, σ_{ij} is backscatter at frequency i and species/size class j, and ni is number of organisms at frequency i

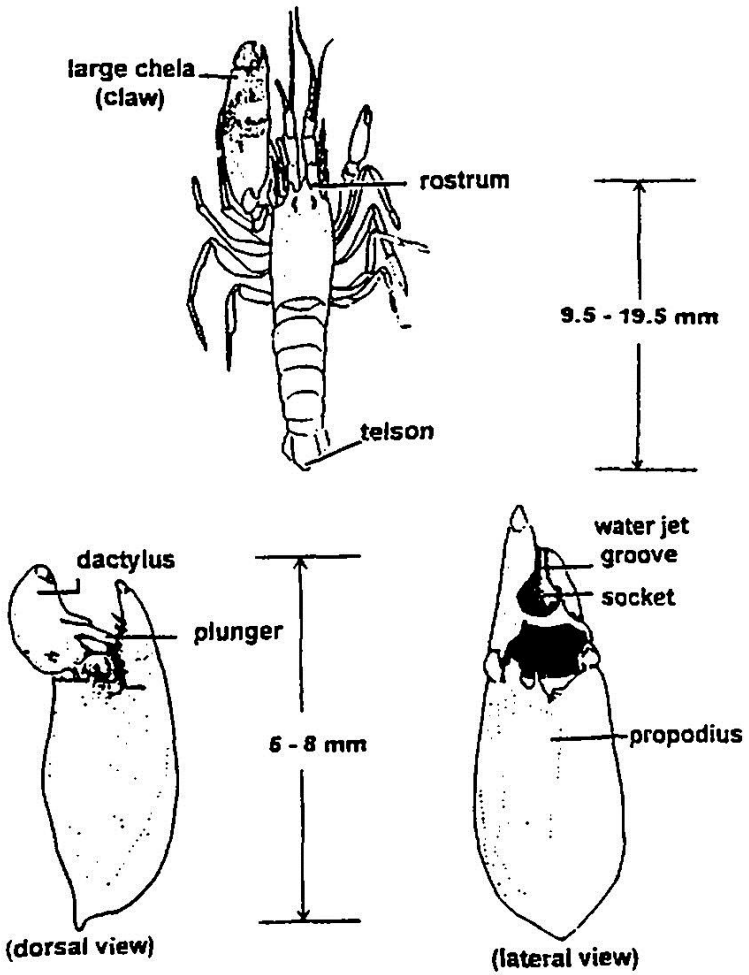
Critical needs: accurate scattering model, unique σ_{bs} for each species/size class


Empirical (*in situ*)
Frequency
Discrete
Wideband
Passive
Resonance Peak
Spectra
Inverse
Active Tag
Alternate Source

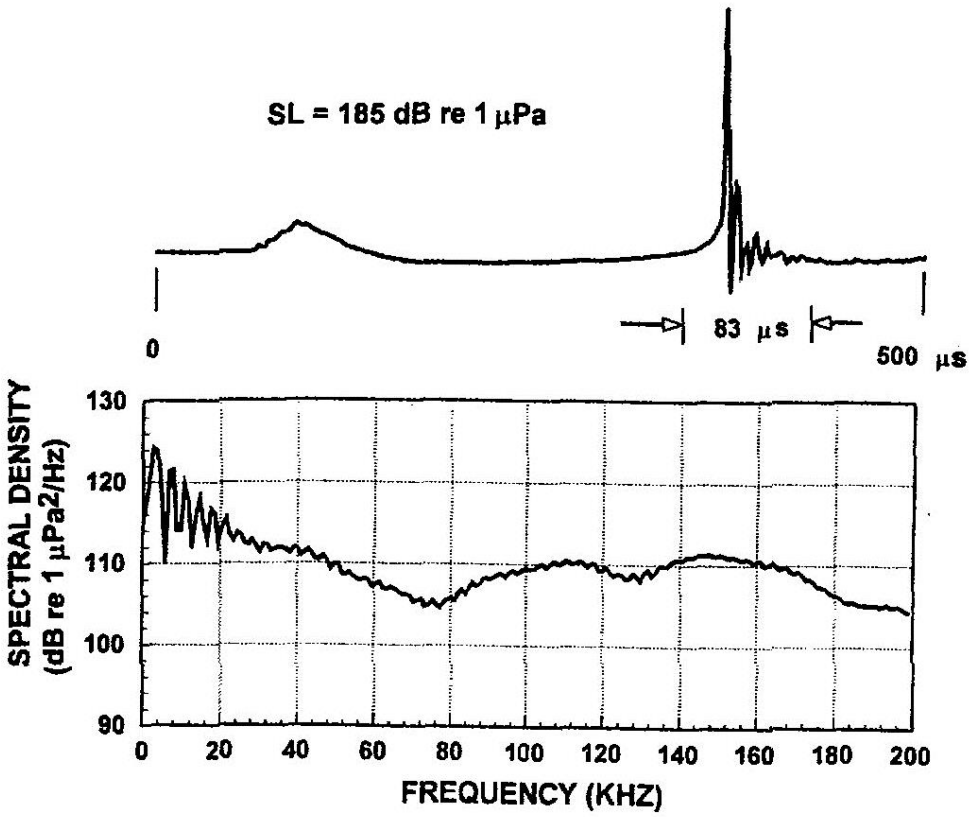
Passive Acoustics: Hydrophones

1. Crustaceans (e.g. snapping shrimp)
2. Teleost fish with swimbladders (e.g. weak, red drum)
3. Marine mammals (e.g. whales, dolphins)

Passive Acoustics: Invertebrates



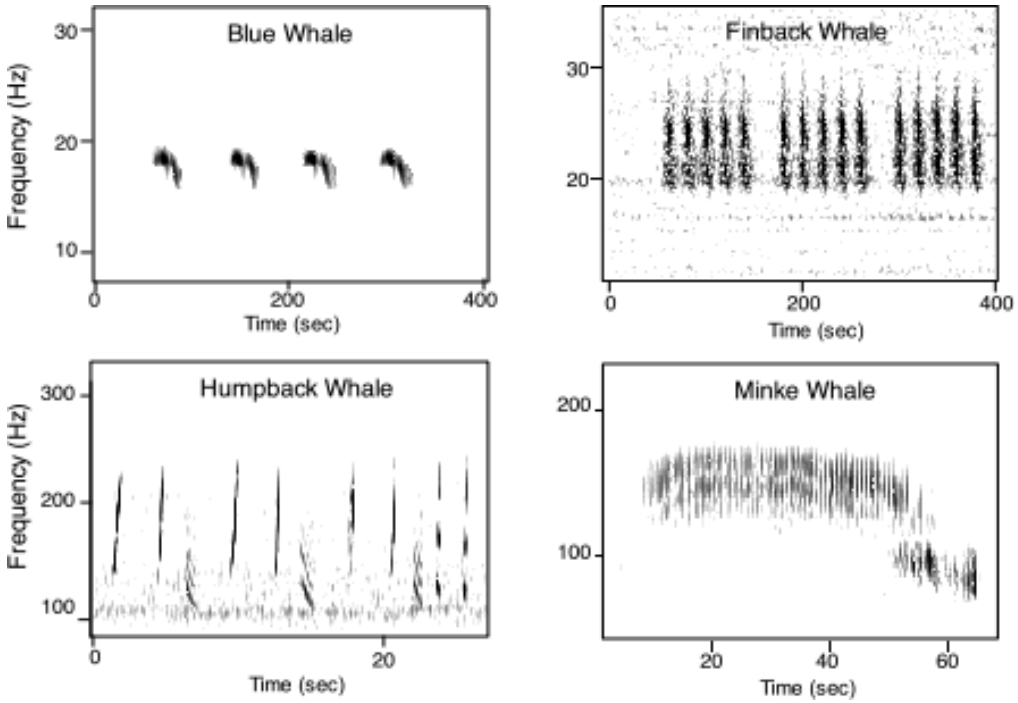
Snapping Shrimp



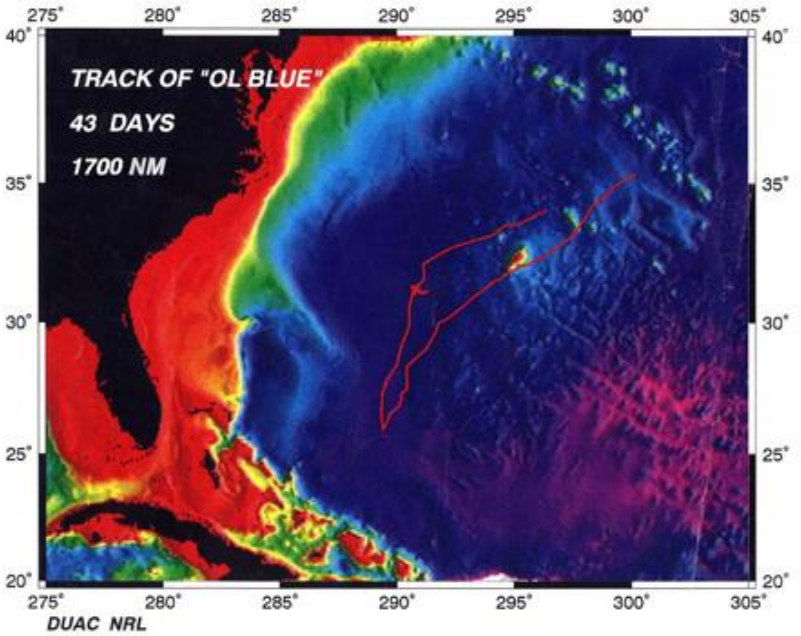
Au & Banks 1998

Passive Acoustics: Whale Tracking

Whale Spectrograms

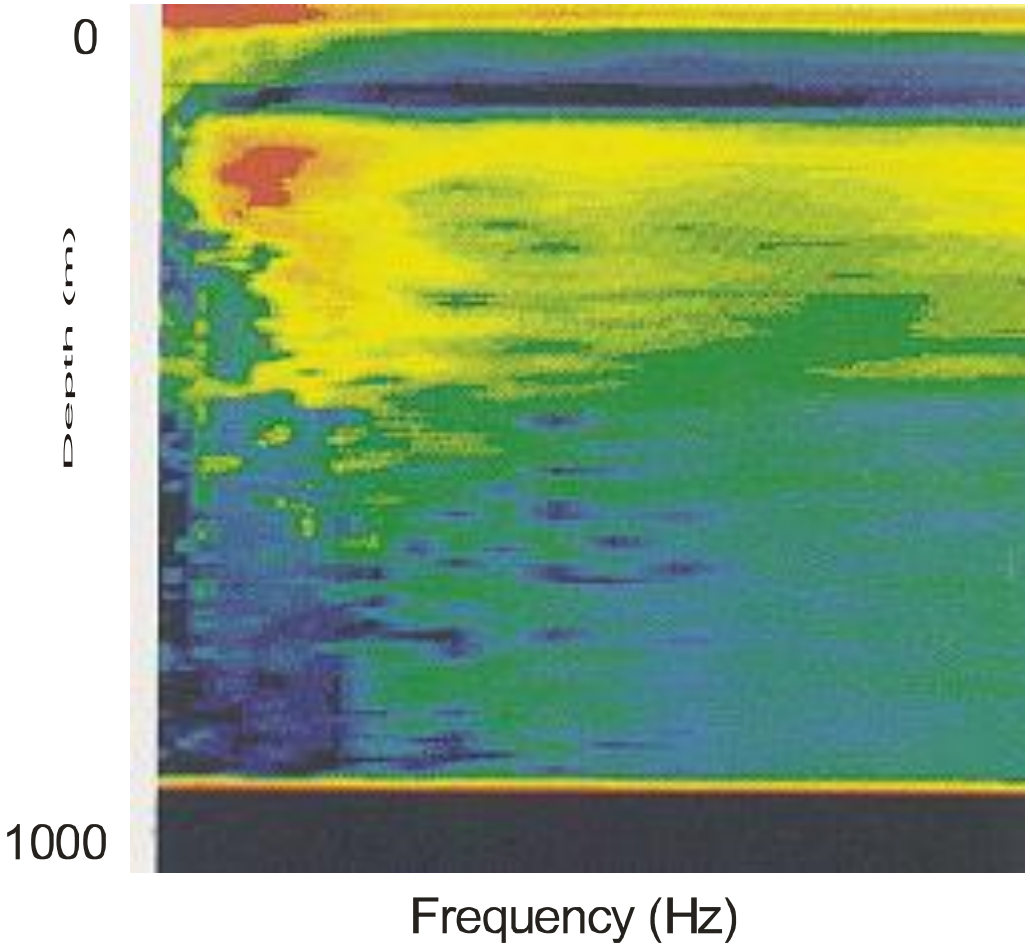


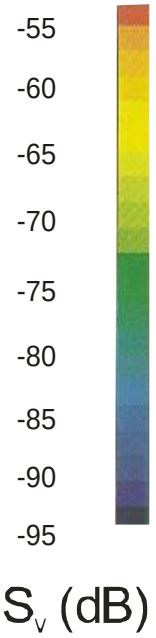
IUSS Whale Track



C. Clark, Cornell Univ

Resonance Peak Measures



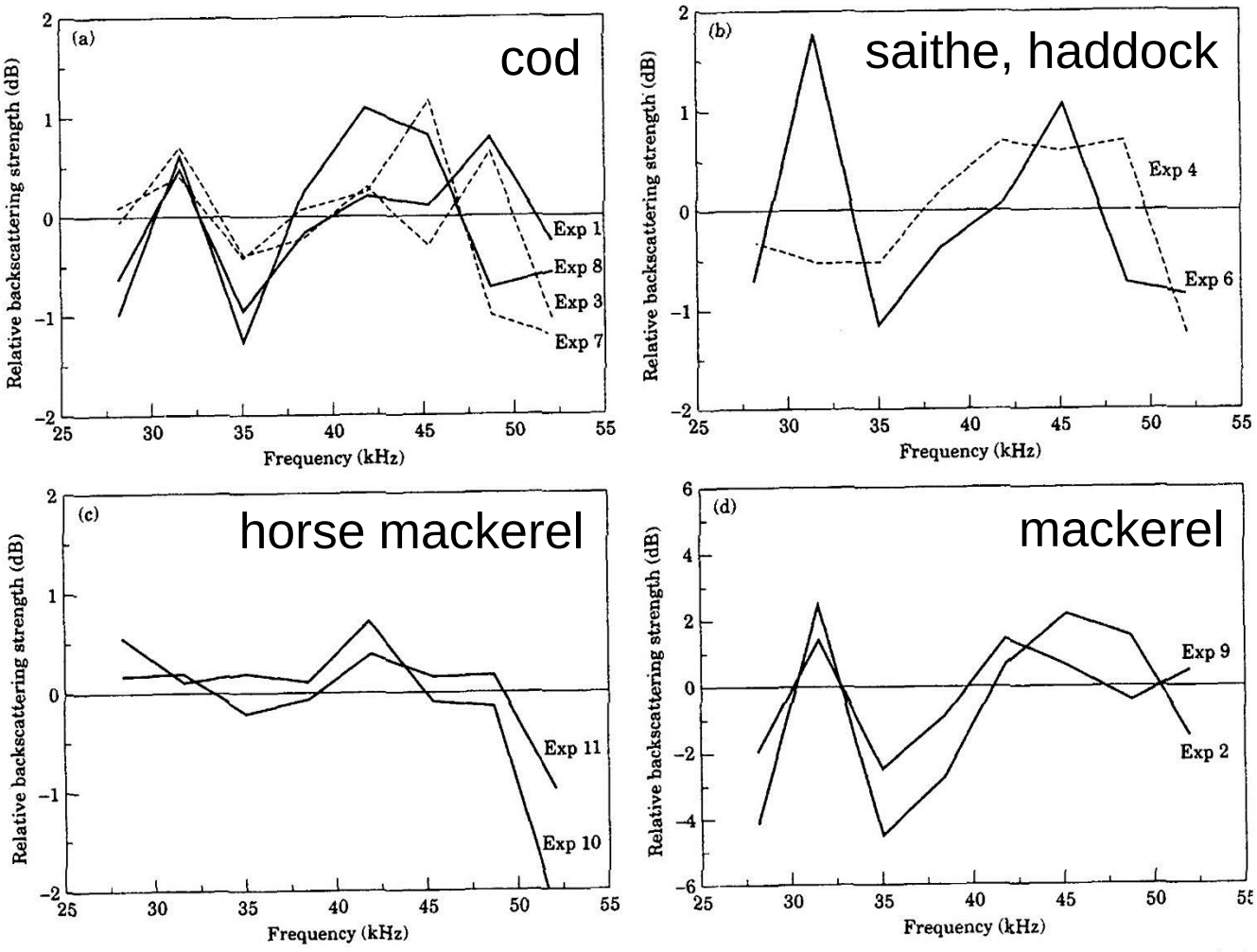


- match resonance peaks to backscatter models

Nero *et al*. 1997

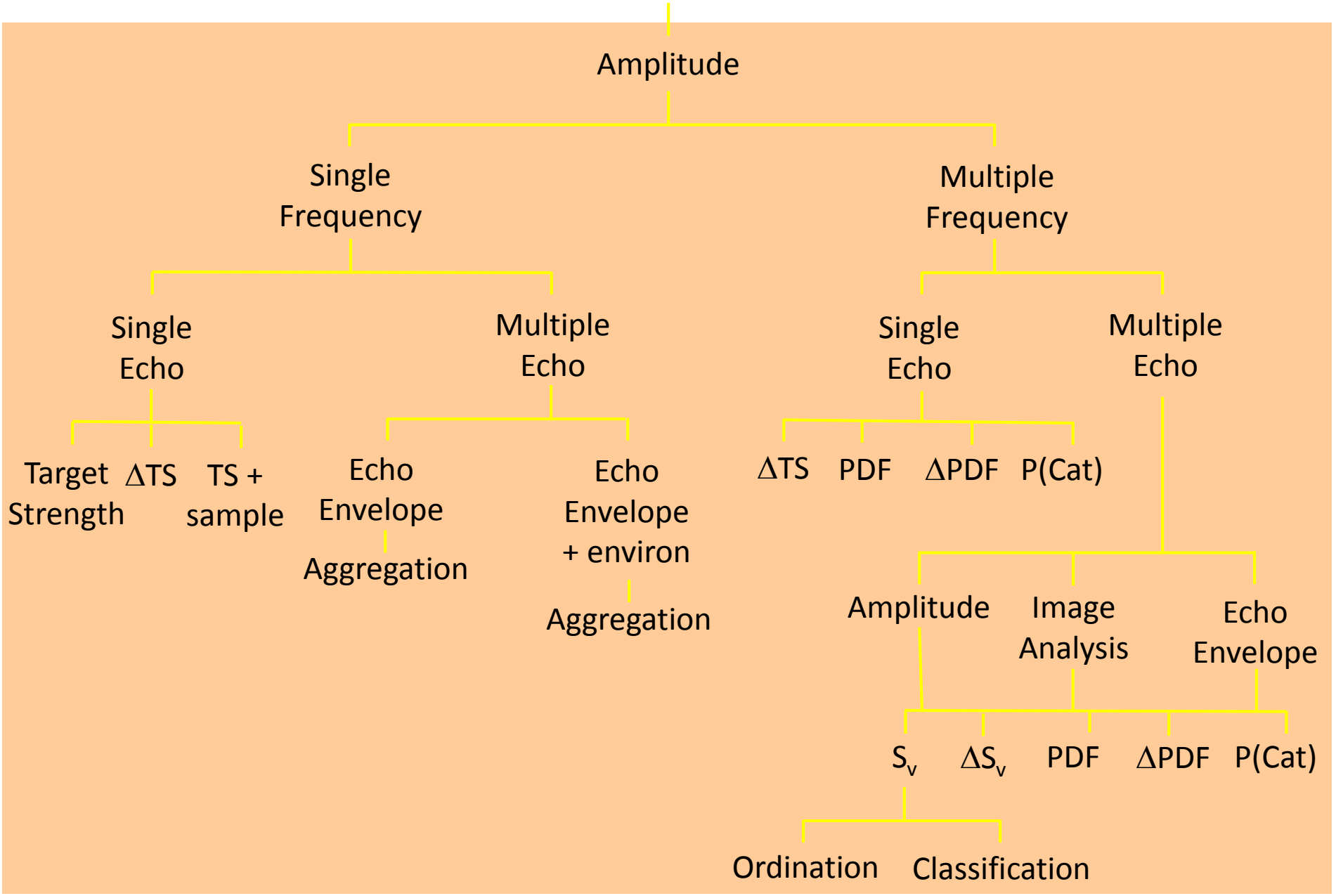
Current contributions from Stanton, Lavery, Jech

Wideband Frequency Spectra



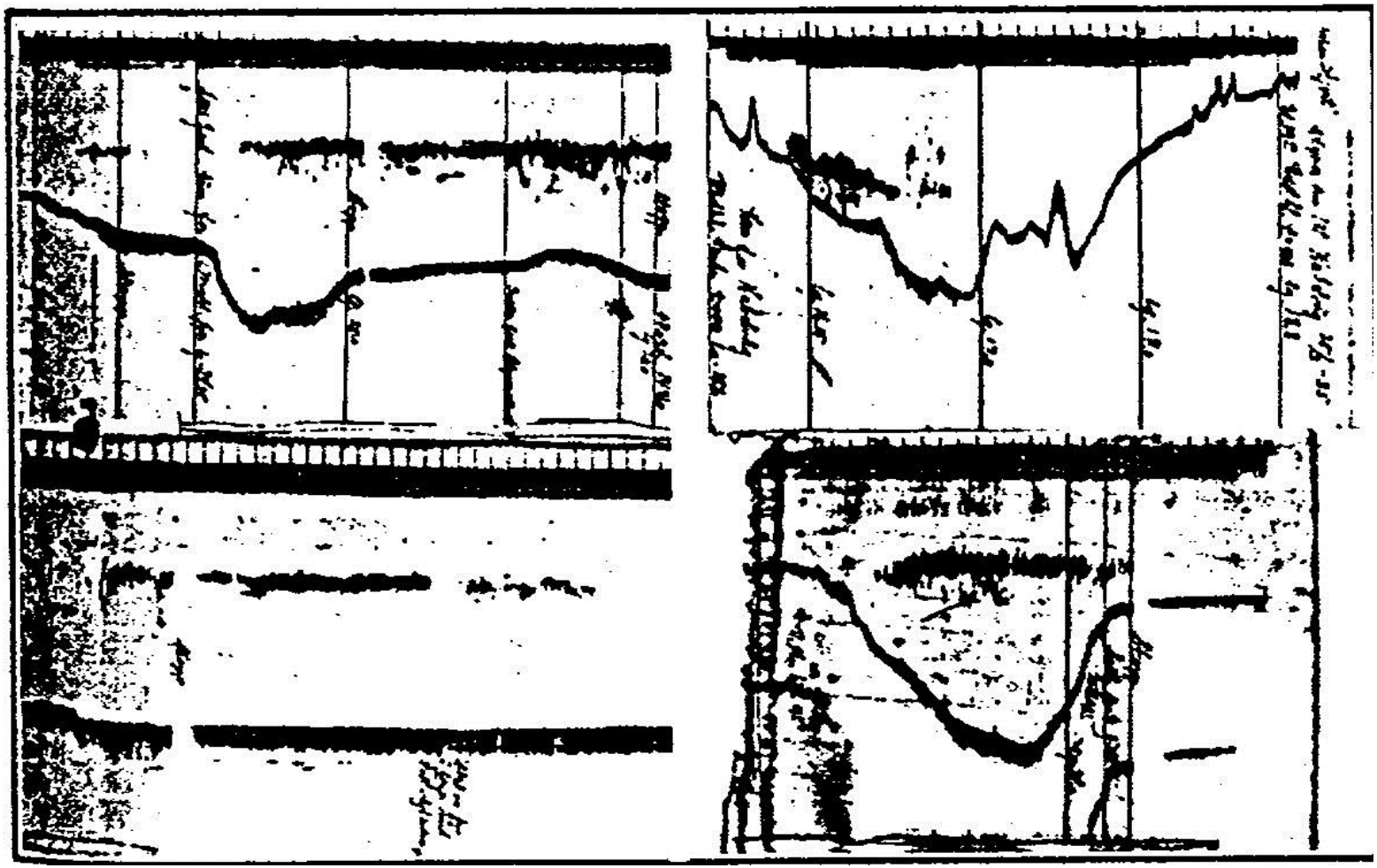
- neural network & discriminant analysis

Simmonds *et al*. 1996


Amplitude
Single Frequency
Multiple Frequency
Single Echo
Multiple Echo
Single Echo
Multiple Echo
Target Strength
ΔTS
TS + sample
Echo Envelope
Aggregation
Echo Envelope + environ
Aggregation
ΔTS
PDF
ΔPDF
P(Cat)
Amplitude
Image Analysis
Echo Envelope
S_v
ΔS_v
PDF
ΔPDF
P(Cat)
Ordination
Classification

Target Strength & Direct Sampling

Combine biological knowledge, net samples, and echogram patterns



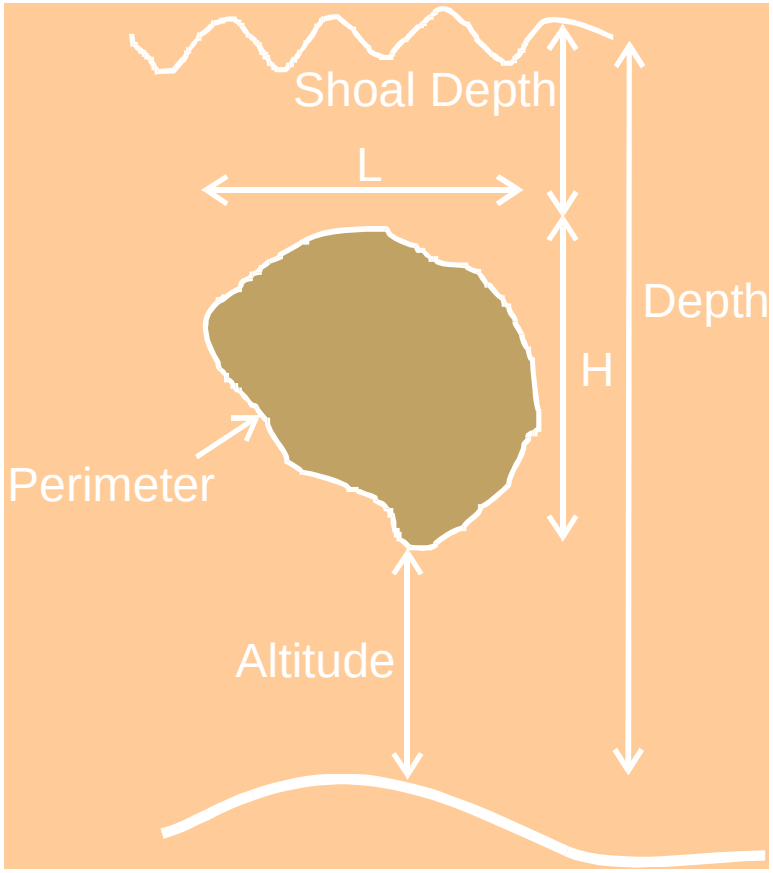
Sund 1935

Echo Envelope Metrics
Ensemble Backscatter

- linear discriminant functions

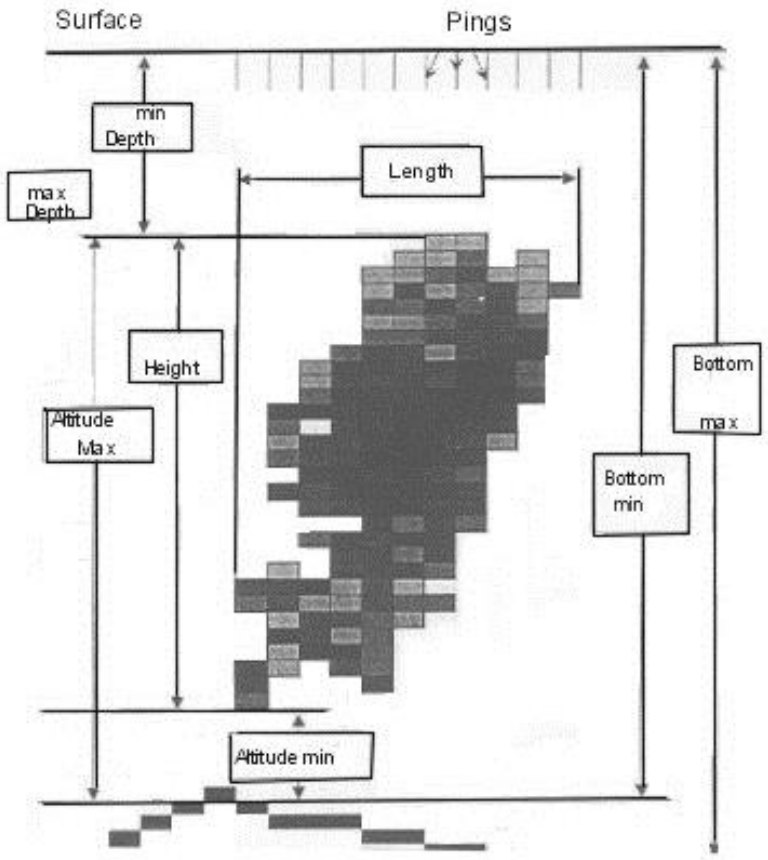
Rose & Leggett 1988

Single f, Echo Envelope, + Enviro



- discriminant functions & PCA

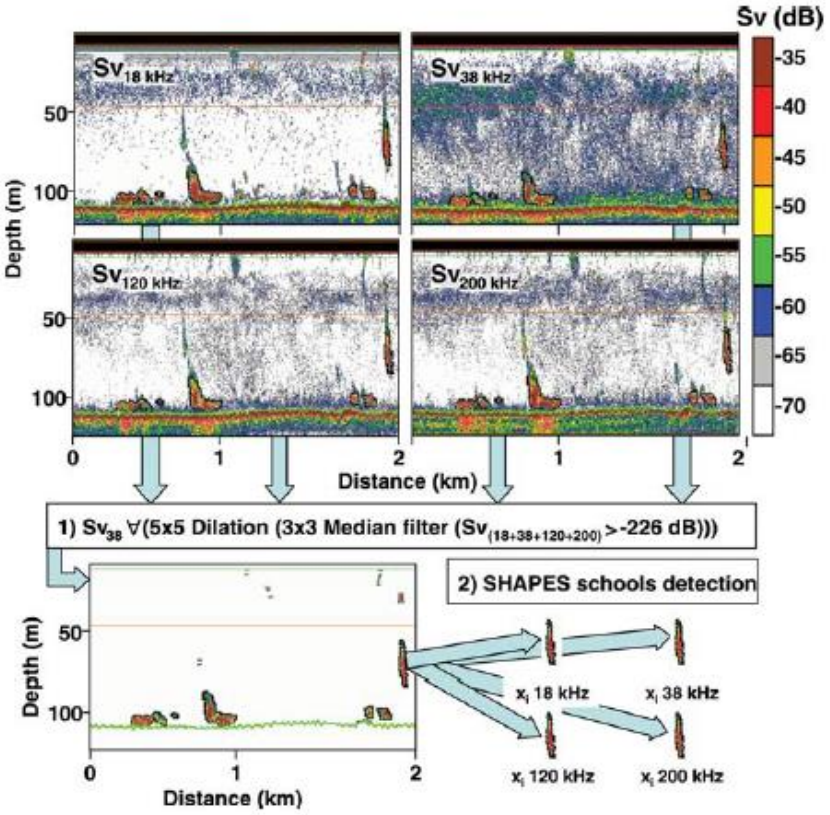
Scalabrin *et al*. 1994

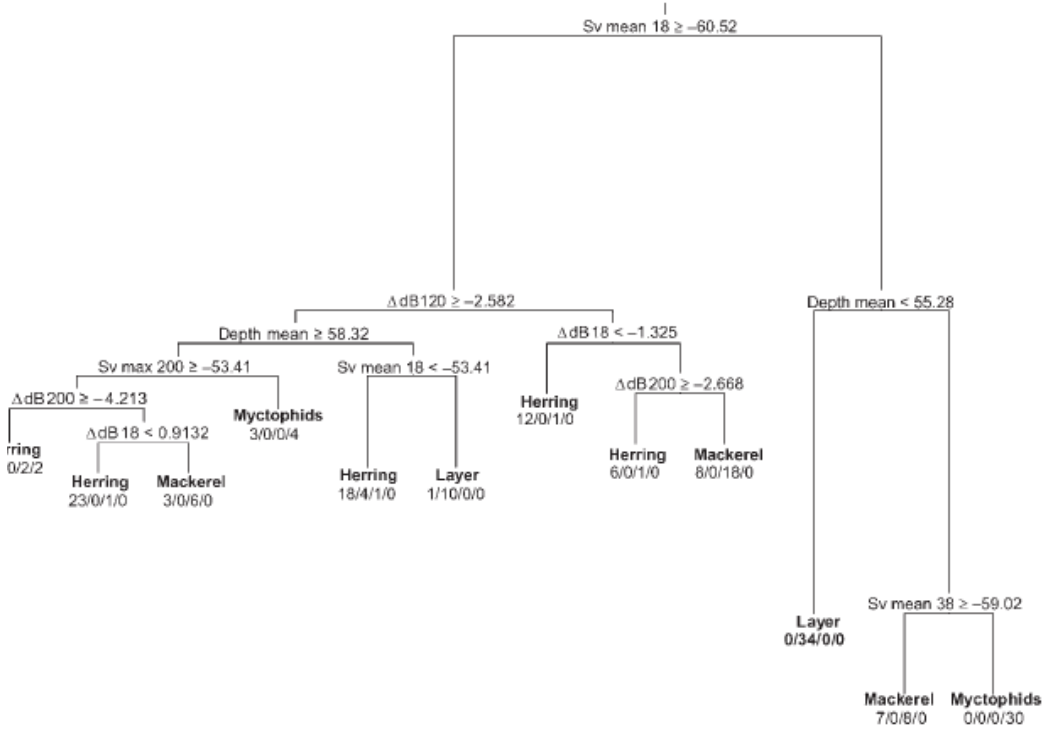


- discriminant functions & neural networks

Haralabous & Georgakarakos 1996

Multifrequency Classification & Regression Trees

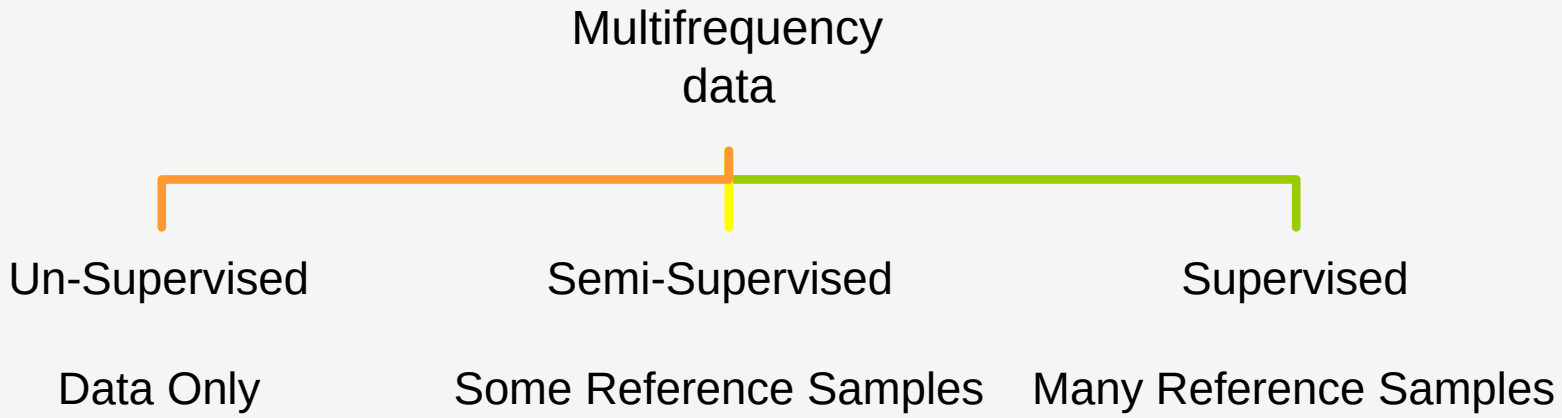




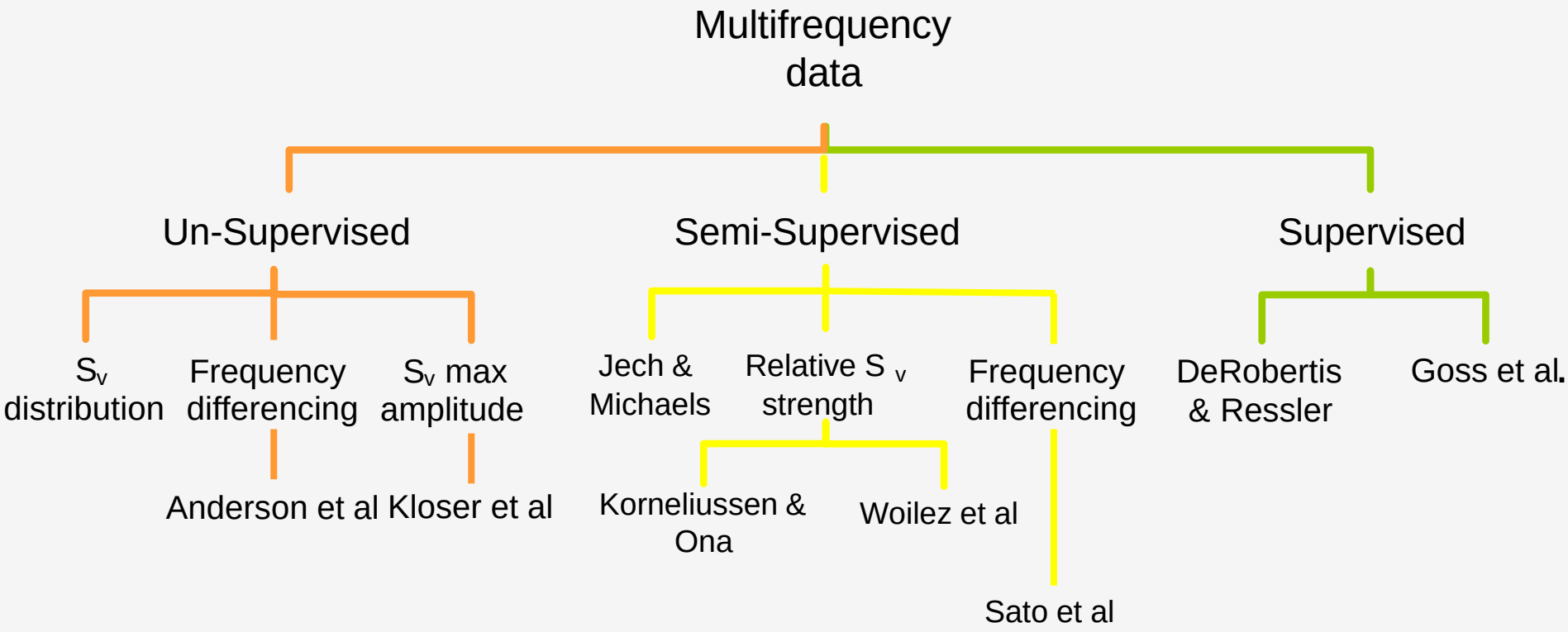
- aggregation & environmental metrics as covariates

Fernandes 2009

Multifrequency Classification

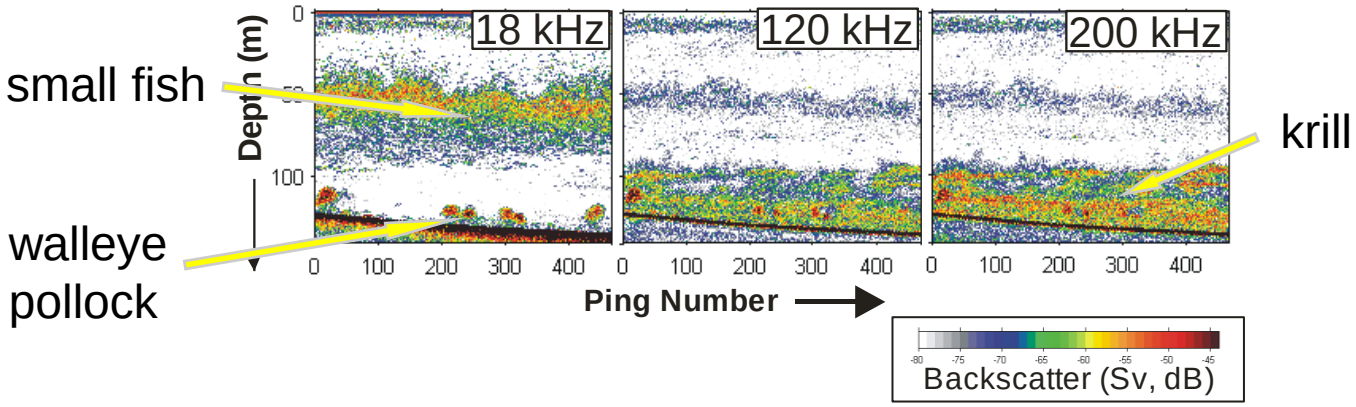


Multifrequency Classification

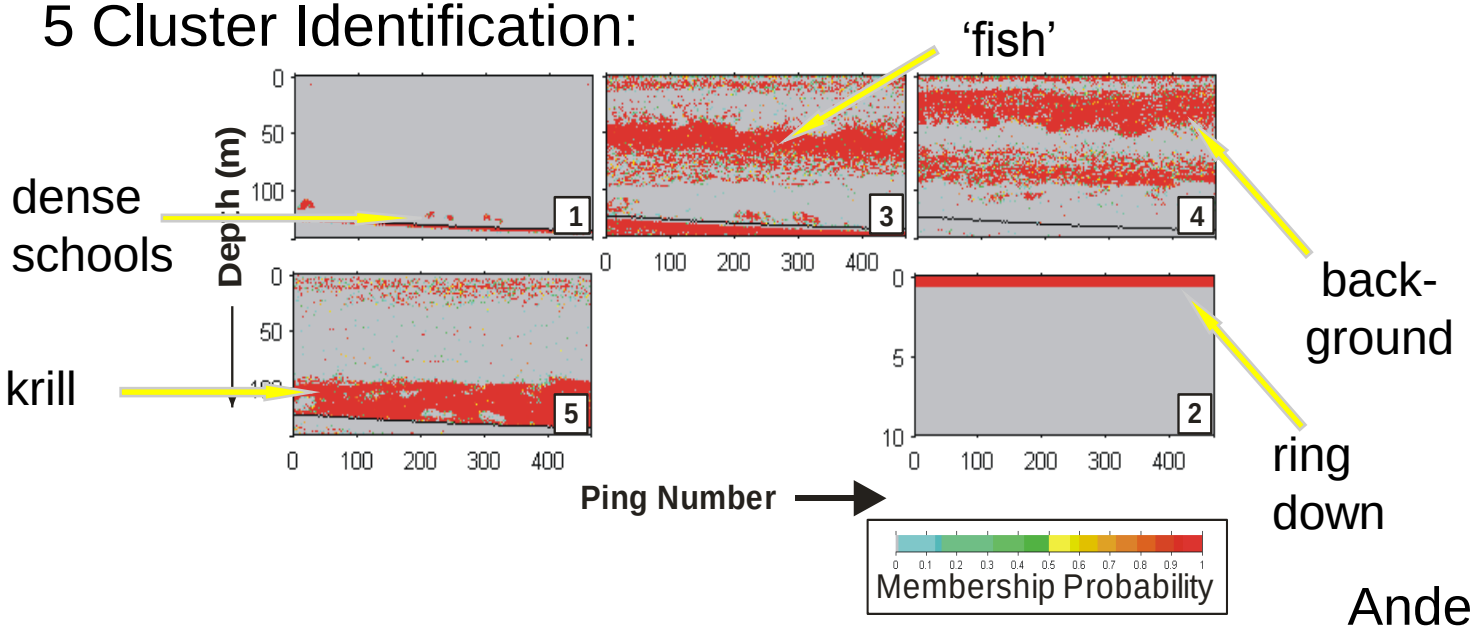


Probabilistic Backscatter Identification

3 Frequency Backscatter:



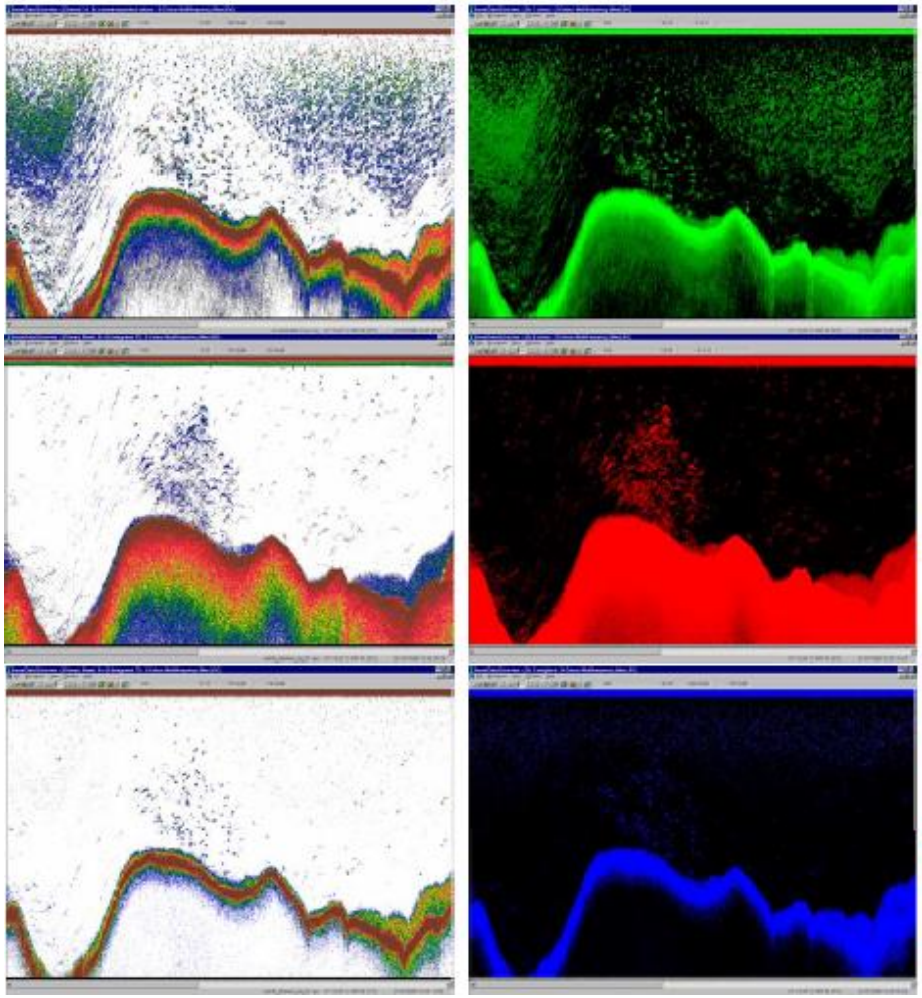
5 Cluster Identification:

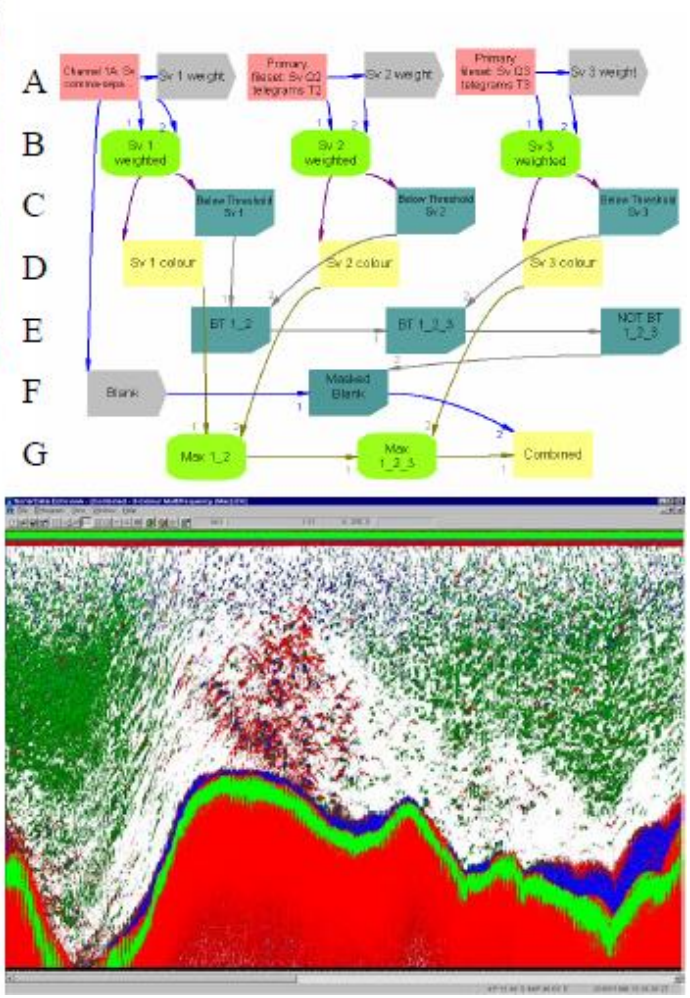


Anderson et al. 2007

Synthetic Echogram

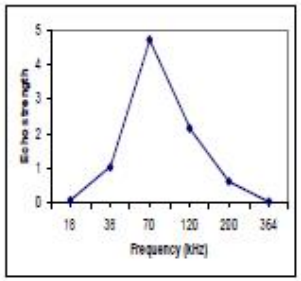
S_v maximum amplitude

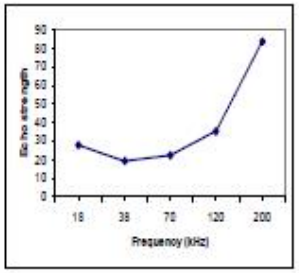


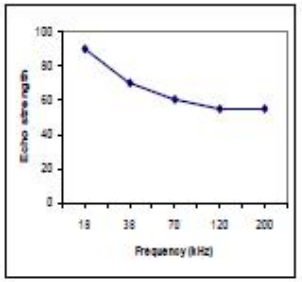


Kloser et al. 2002

Frequency Response





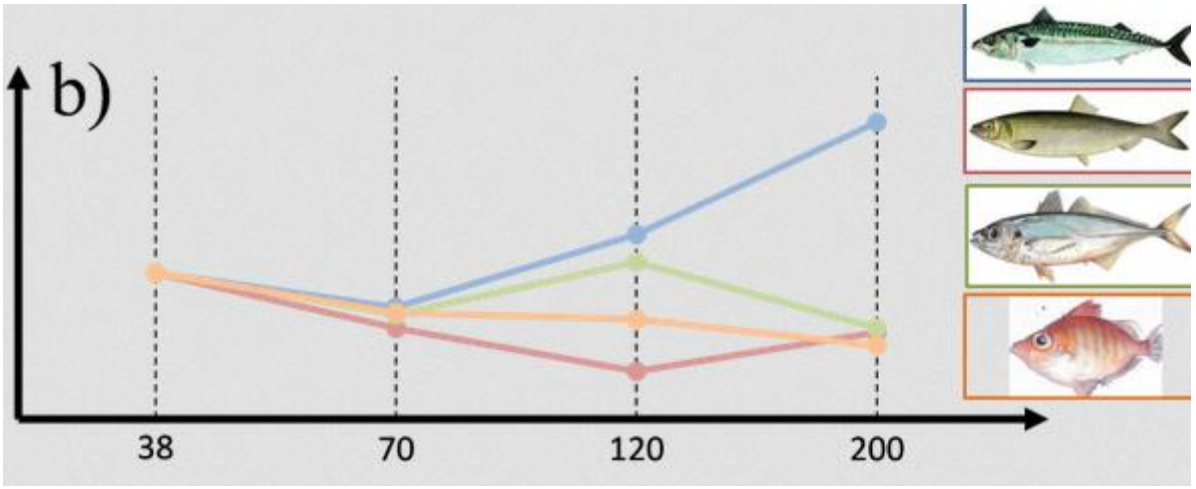


krill

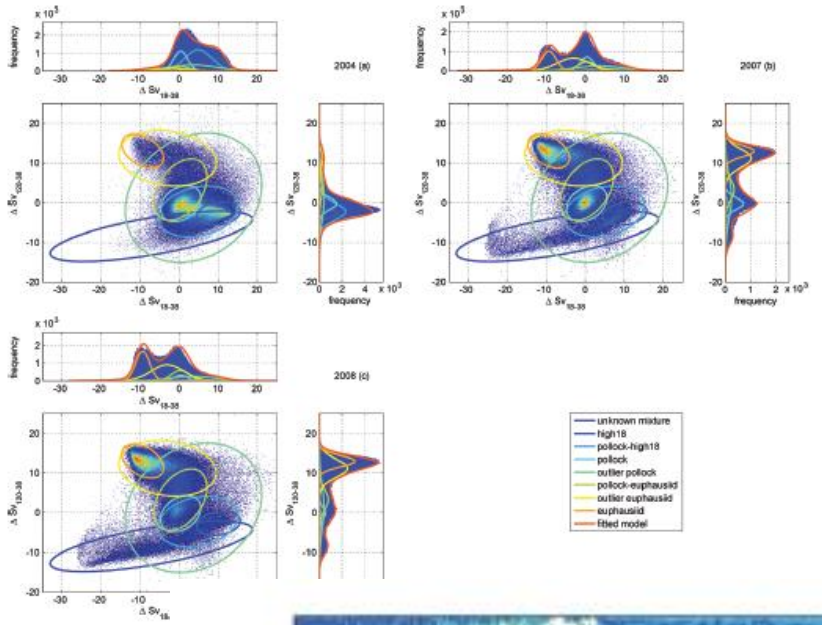
mackerel

herring

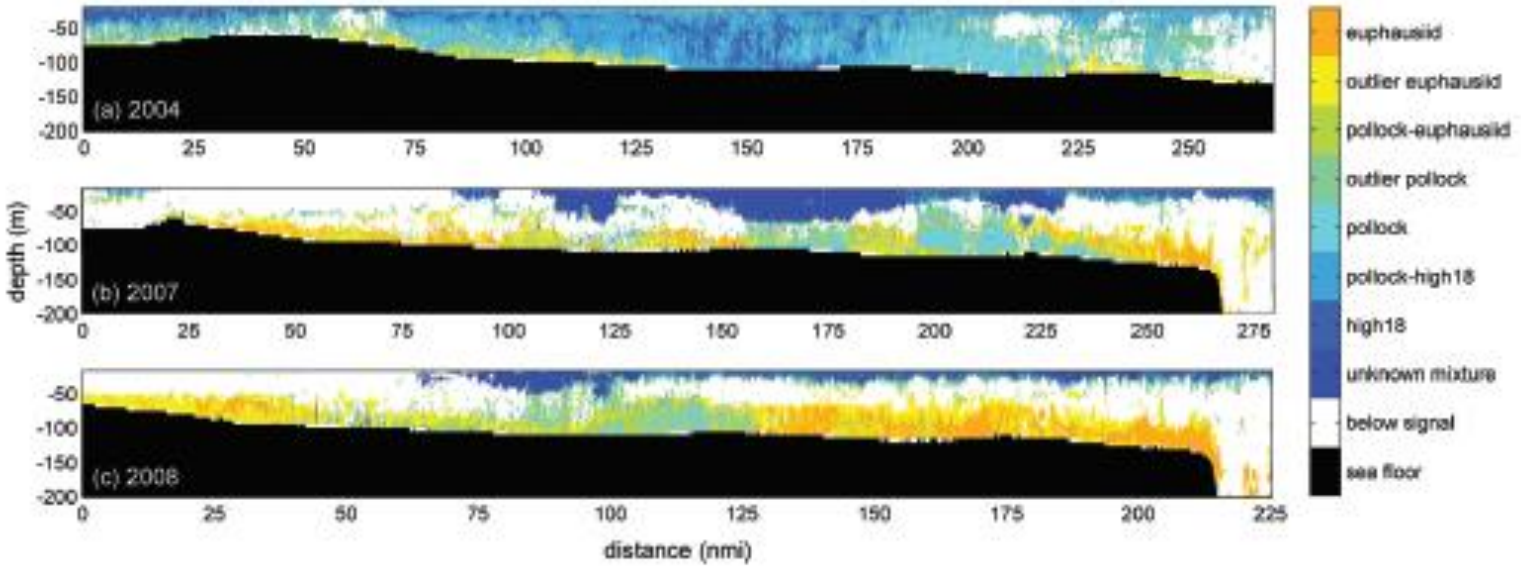
Korneiliussen and Ona (2007)



Semi-Supervised Classification

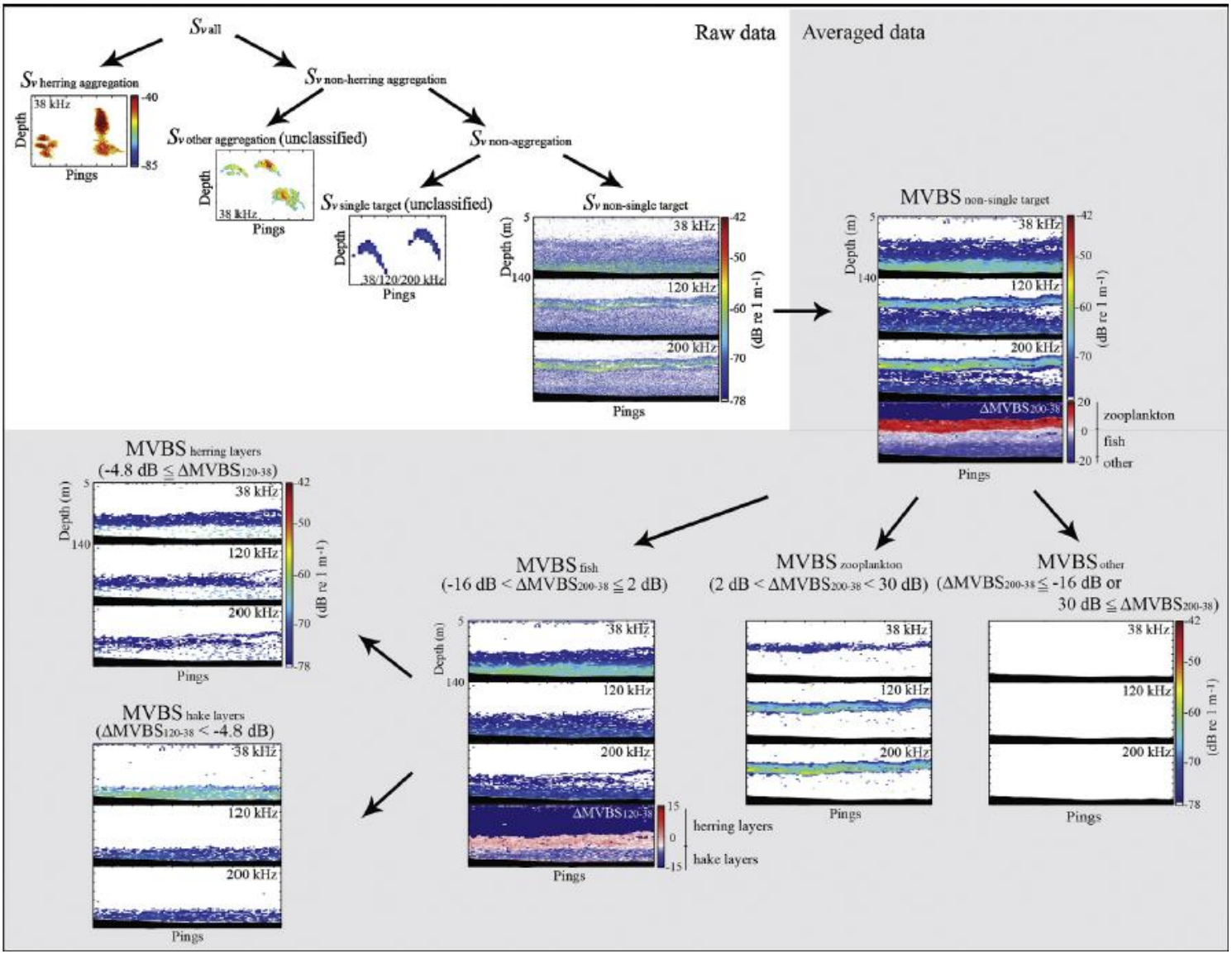


K-means Clustering



Woilez et al. 2012

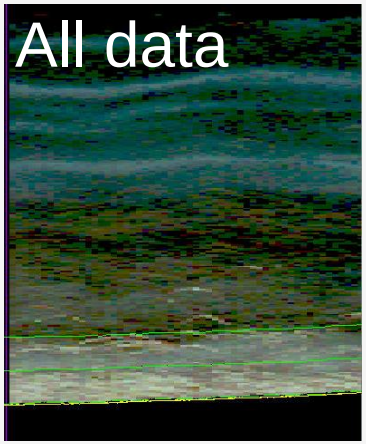
MVBS Frequency Differencing



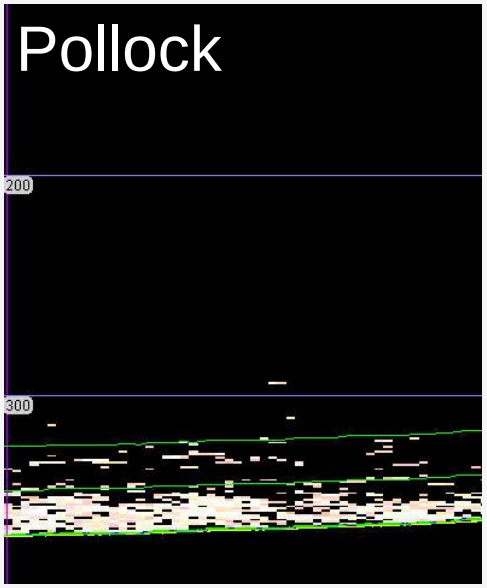
Sato et al. 2015

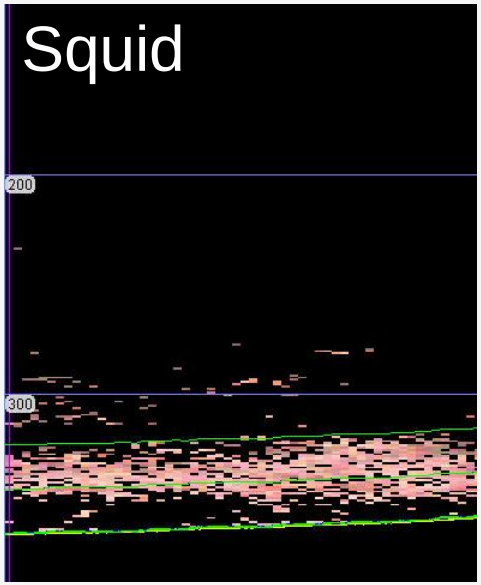
Supervised Classification

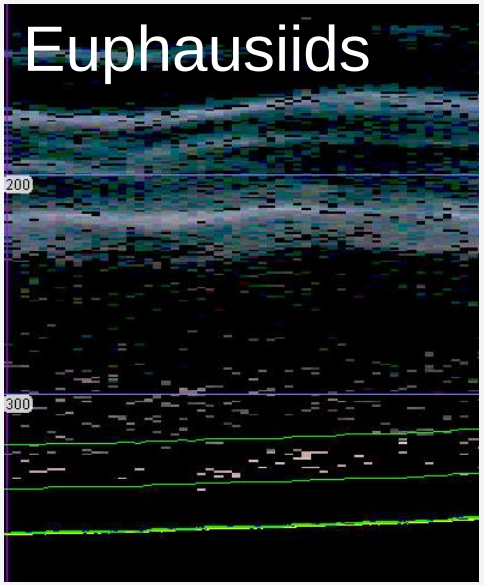
Training sets of ‘pure’ samples



Analyst-assigned categories







Current Trends... as seen in 2018

- renewed interest in resonance peaks as classifier
- renewed interest in wideband for resolution and classifier (EK-80), community standards being established but not there yet
- potential for machine learning/big data tools to become more prevalent
- alternate platforms increasing spatial and temporal ranges but acoustic classification is an ongoing challenge
- increased scrutiny from marine mammal community may constrain frequency range