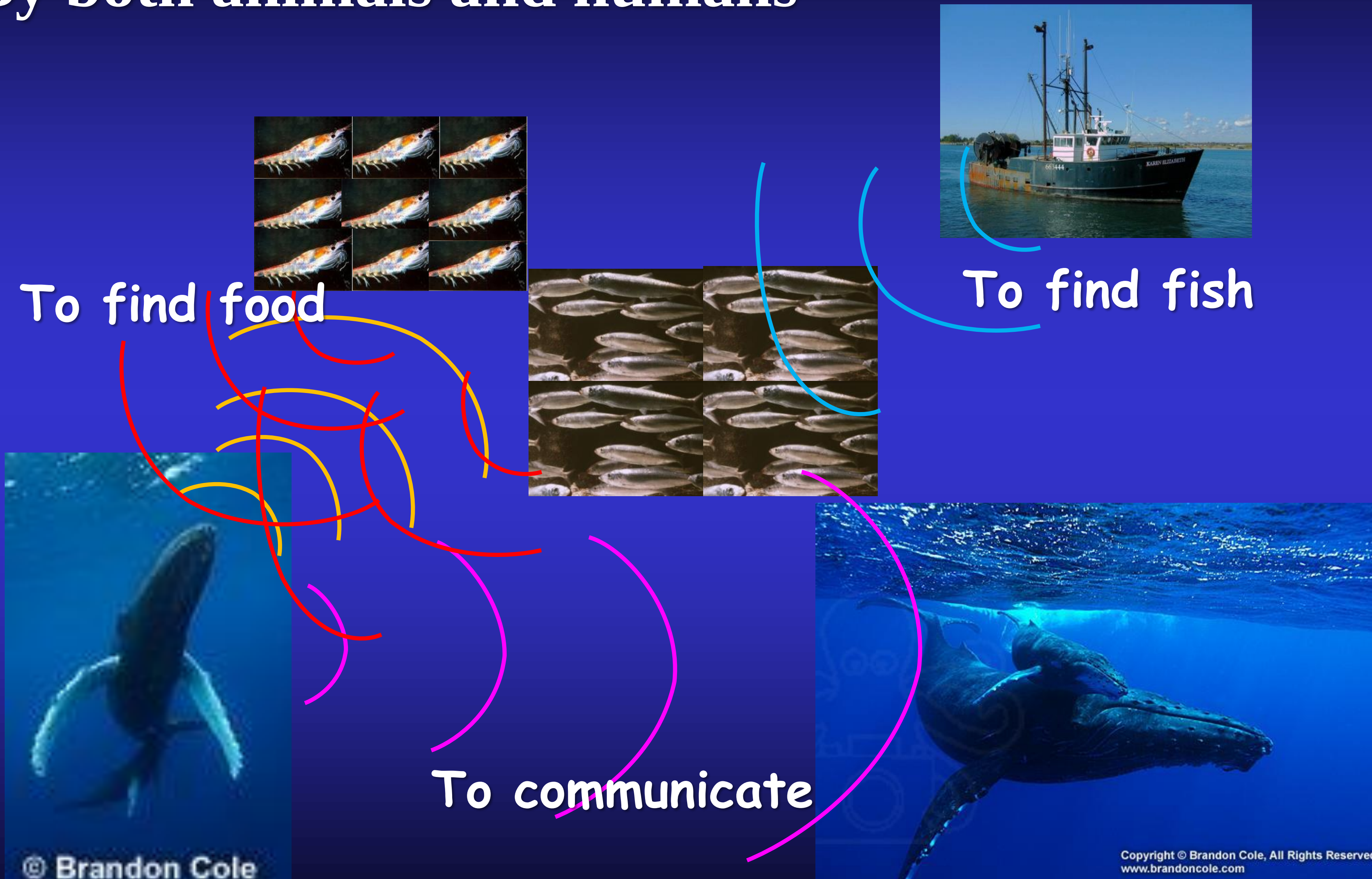
Role of Acoustics in U.S. science/management

Michael Jech, NOAA Northeast Fisheries Science Center
Woods Hole, MA
michael.jech@noaa.gov

Sound is used A LOT in the water!!
By both animals and humans



Fisher men/women know their echosounders

What we as scientists try to do is quantify what is viewed on the echogram, and one way to do that is to “pick the brain” of the fishing community.

Other ways are to incorporate *in situ* measurements, *ex situ* experiments, and theoretical models to assist us in interpreting the acoustic signal.

Role of active acoustics in U.S. fisheries management

Active acoustic methods are used widely throughout the world for surveying and assessing pelagic fish stocks.

Active acoustic methods have found limited utility in U.S. fisheries management (especially on the east coast of *North America*). Exception is walleye pollock fishery in Alaska, where acoustic data are the primary data source since the 1970s.

Why? Short answer is I don’t know, but maybe:

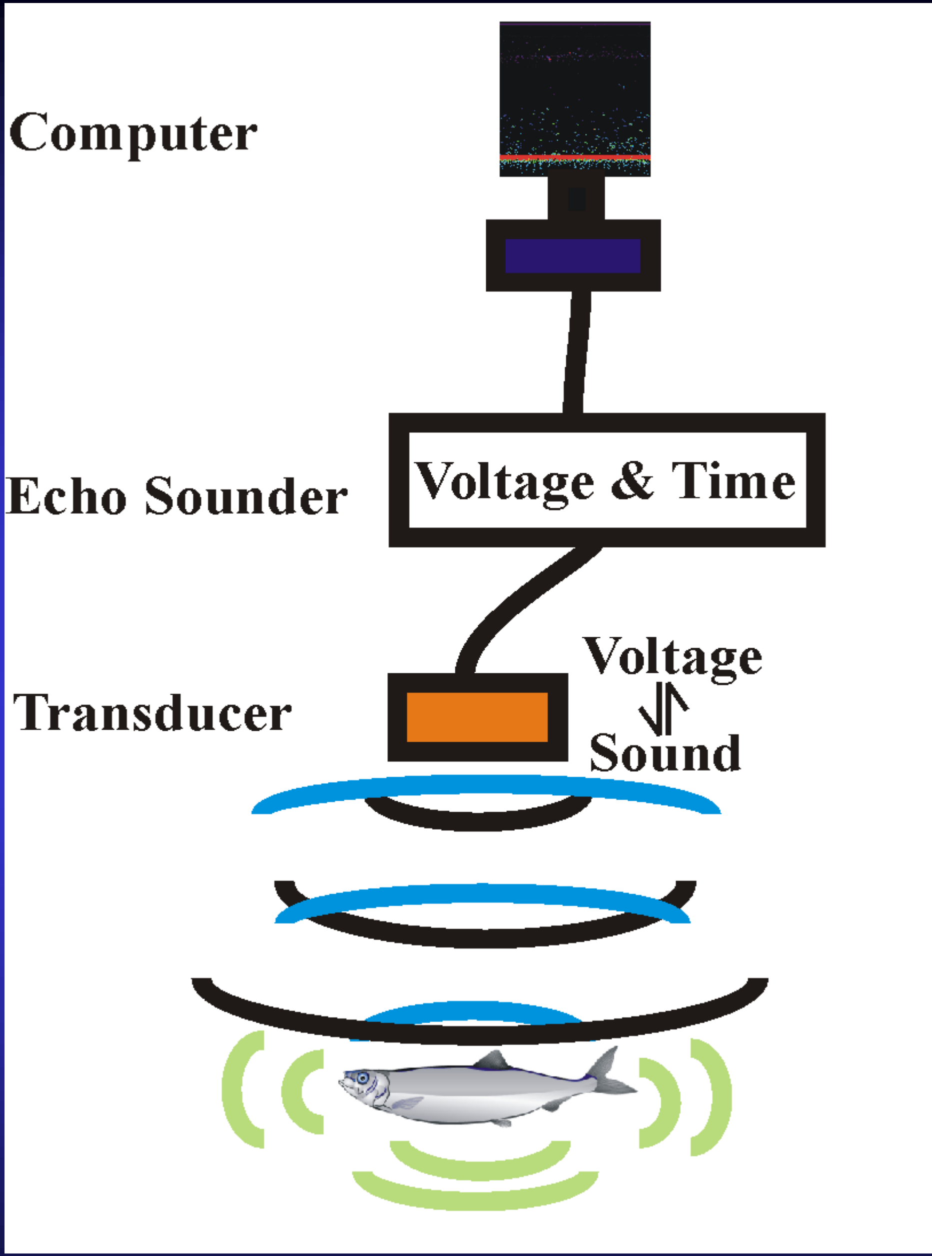
Historical precedence. Bottom trawl surveys have been conducted for decades, and for indices or trends, it is very difficult to develop a new index unless it matches the historical trend.

Ground fish are “king”. Regional and local economies were strongly coupled with ground fish (e.g., cod) and secondarily on pelagics.

Role of active acoustics in U.S. fisheries management

Active acoustics is a type of remote sensing. We don't pull up a net and see and feel fish (well, we do, but I'll get into that). Assessments need measures of age, length, maturity, and diet, which active acoustics can not directly provide. So we need to trawl.

Data are good for relative indices/trends, but I think the biggest impediments to "management quality" data are species ID and scaling from relative to absolute.



Active acoustics puts sound in the water and listens for echoes – it's a type of remote sensing.

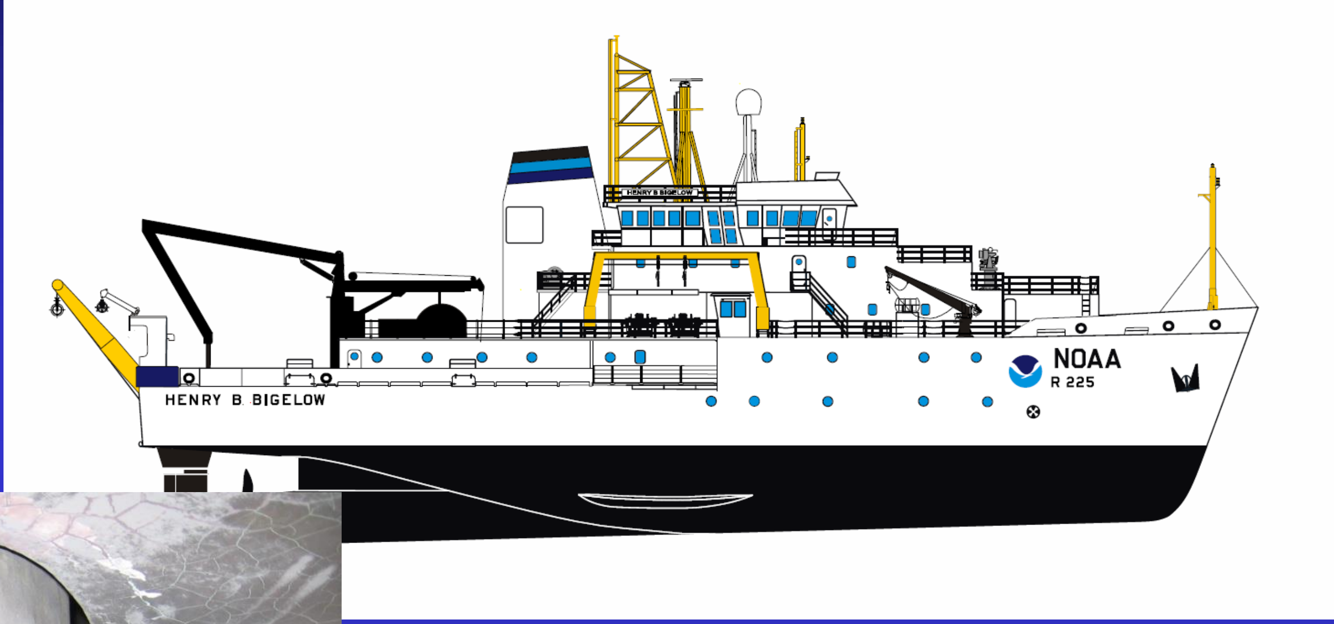
Raw signal is voltage and time. Everything else is derived or inferred.

Because we can't see the data, we must use computer visualization to display the data and results of analyses.

NOAA Ship Henry B. Bigelow

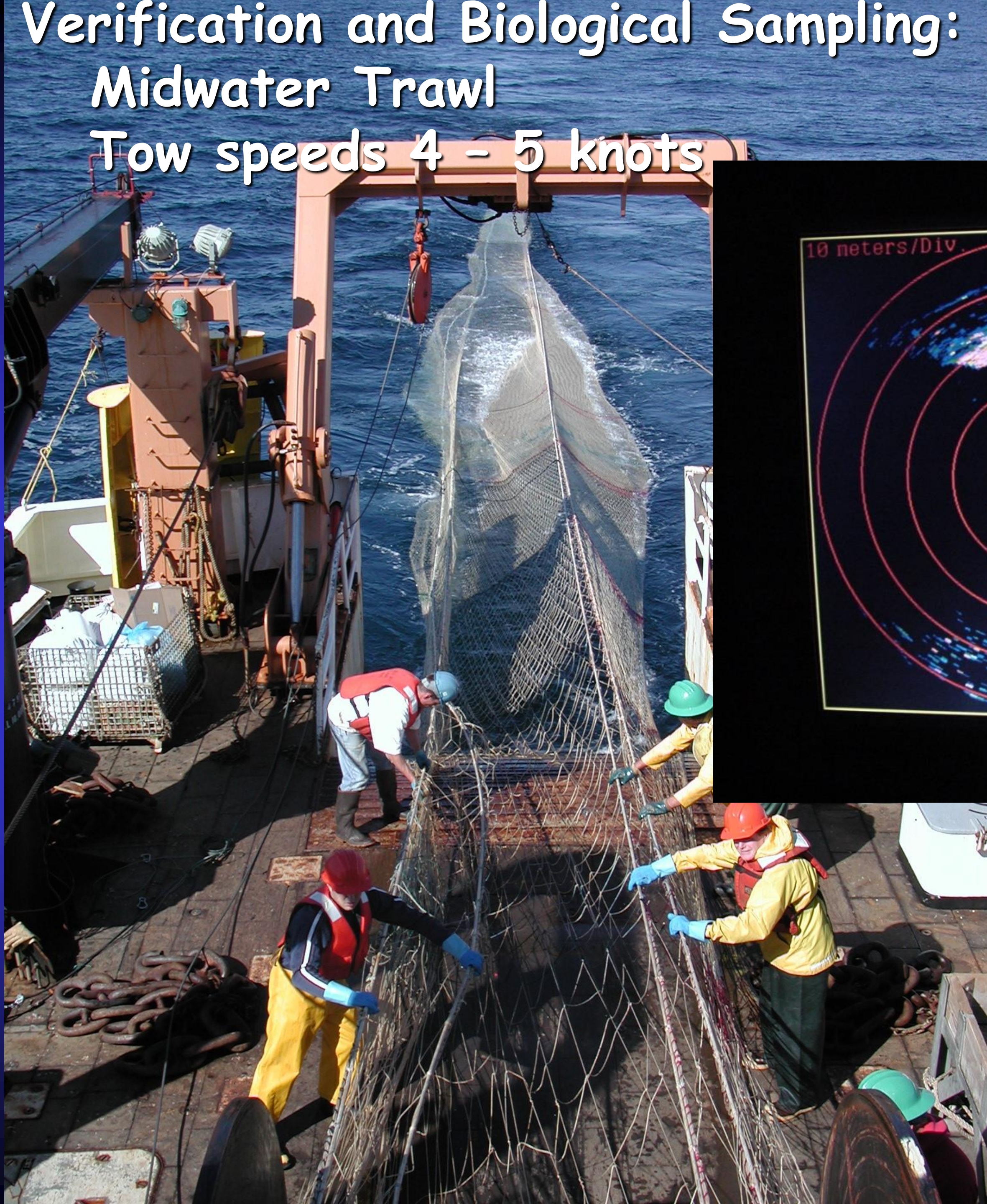
Simrad EK60 Scientific Echosounder for Fisheries Research

- 5 Frequencies: 18, 38, 70, 120 and 200 kHz. Configured as Split Beams



- Center-Board Mounted, Extends 3.4m Below Keel

Verification and Biological Sampling:
Midwater Trawl
Tow speeds 4 - 5 knots



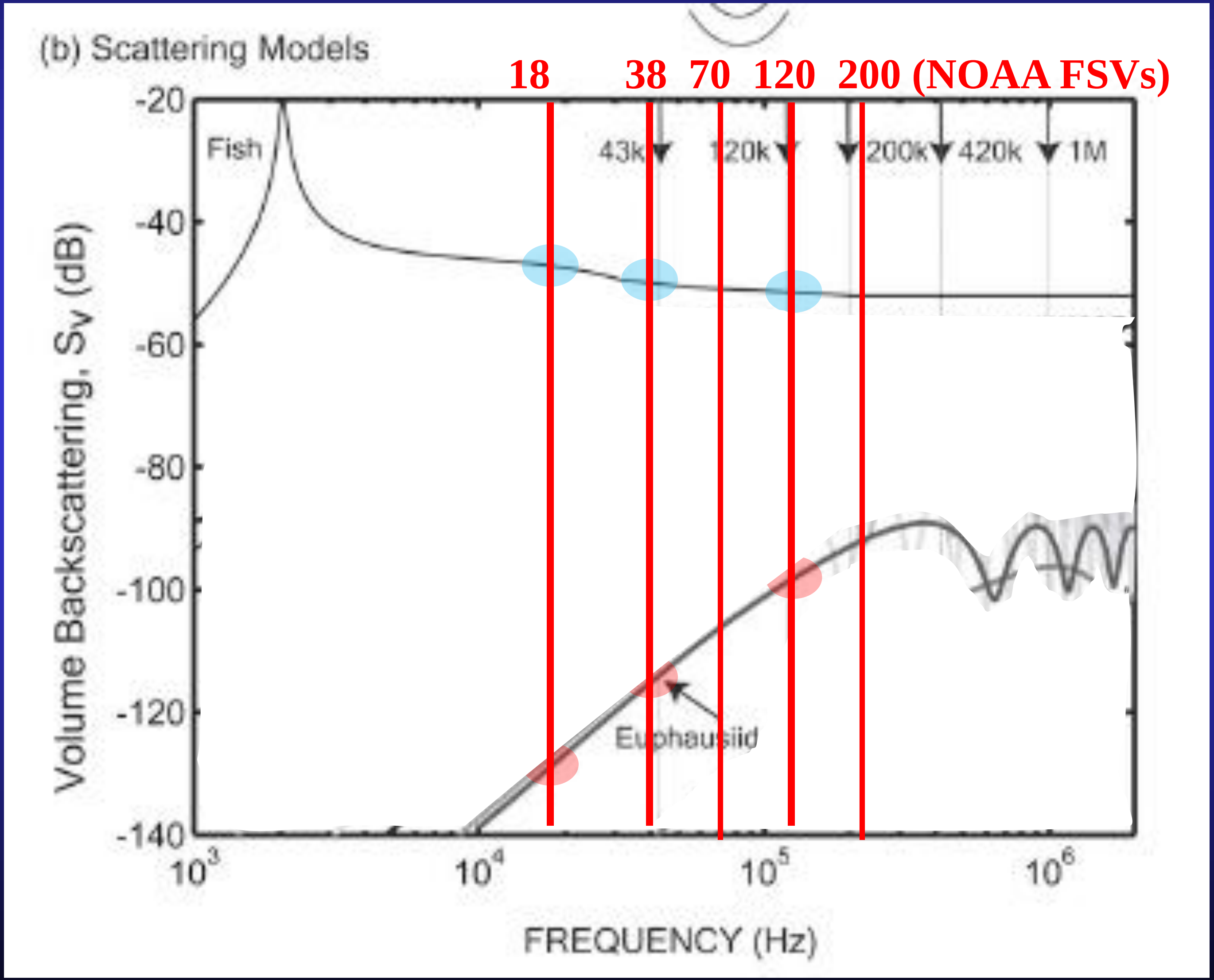
What makes an echo?

Sound bounces off an object that has material properties that are different than water. The greater the contrast – the bigger the echo.

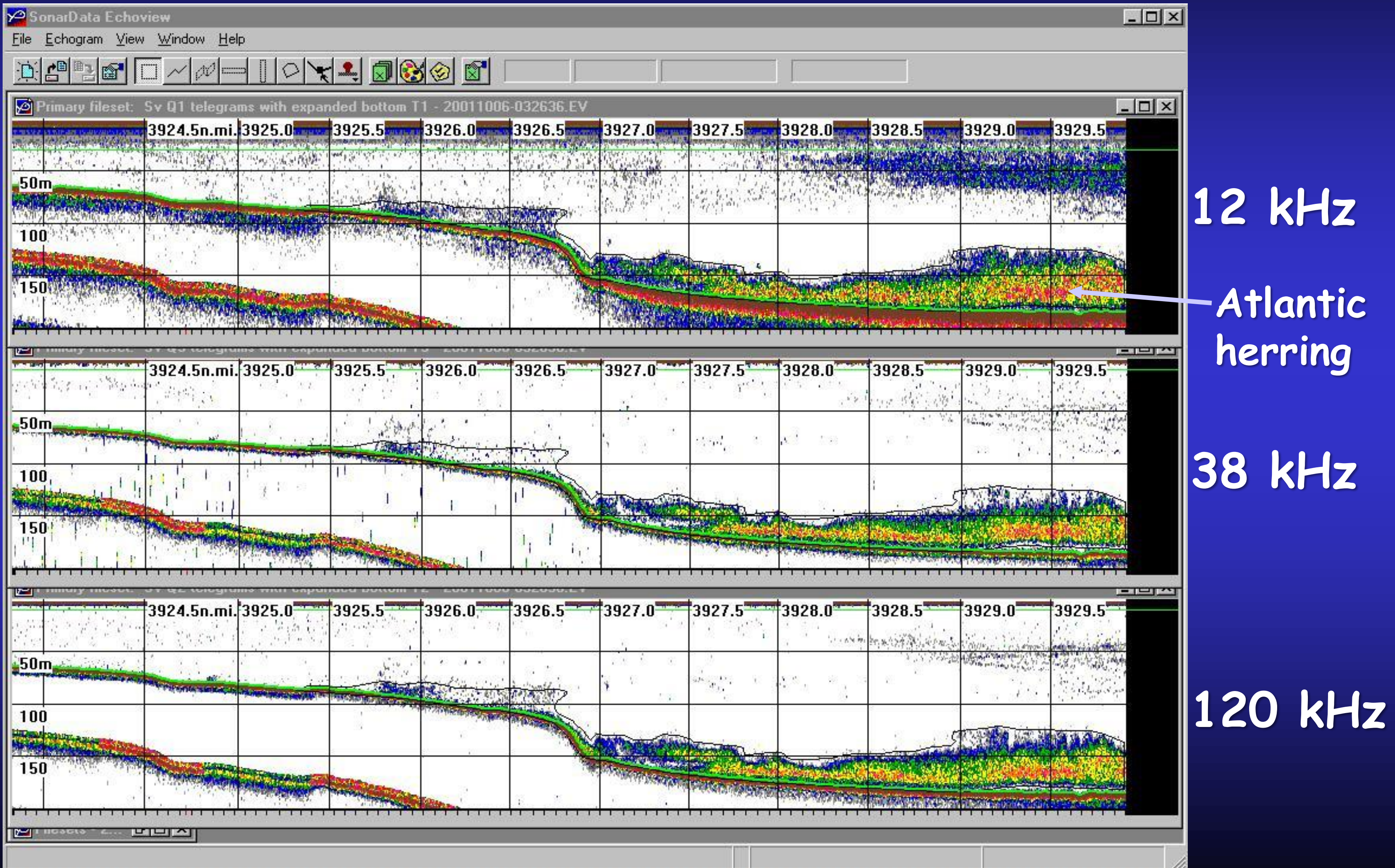
Muscle and flesh have a lot of water in them, so they are similar to water and make a smaller echo.

Air is very different than water, so makes a big echo.

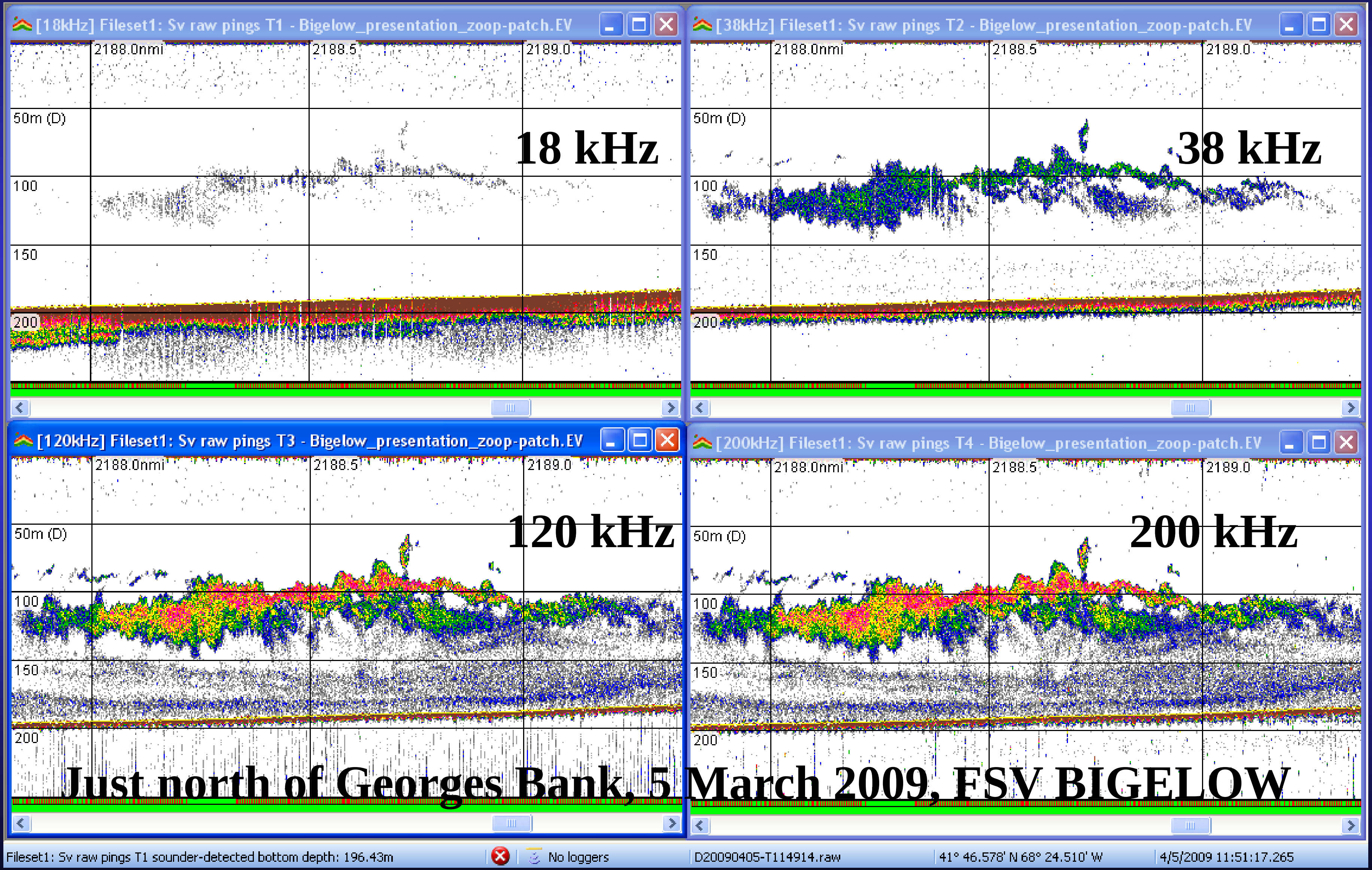
Theoretical acoustic models of fish with a gas-filled swimbladder and krill



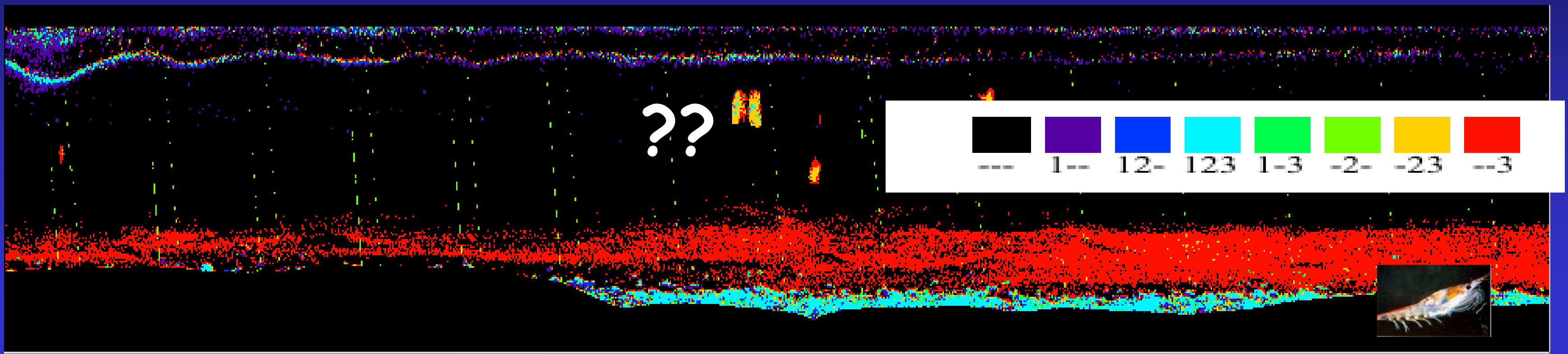
Atlantic herring aggregations on the northern edge of Georges Bank

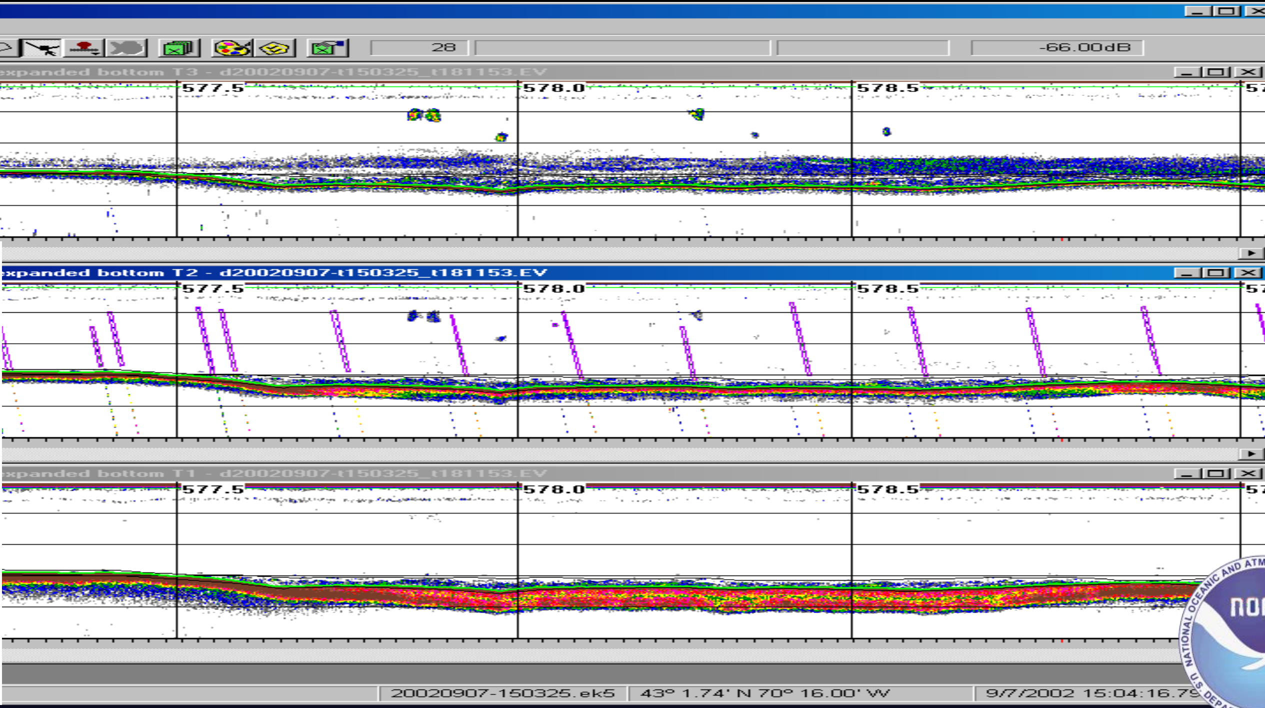


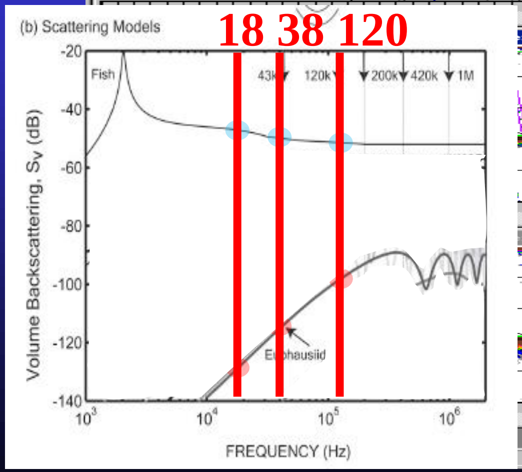
Big zooplankton patch!



Now that we have empirical and theoretical evidence of types of scatterers, we can develop automated and objective algorithms to process the data





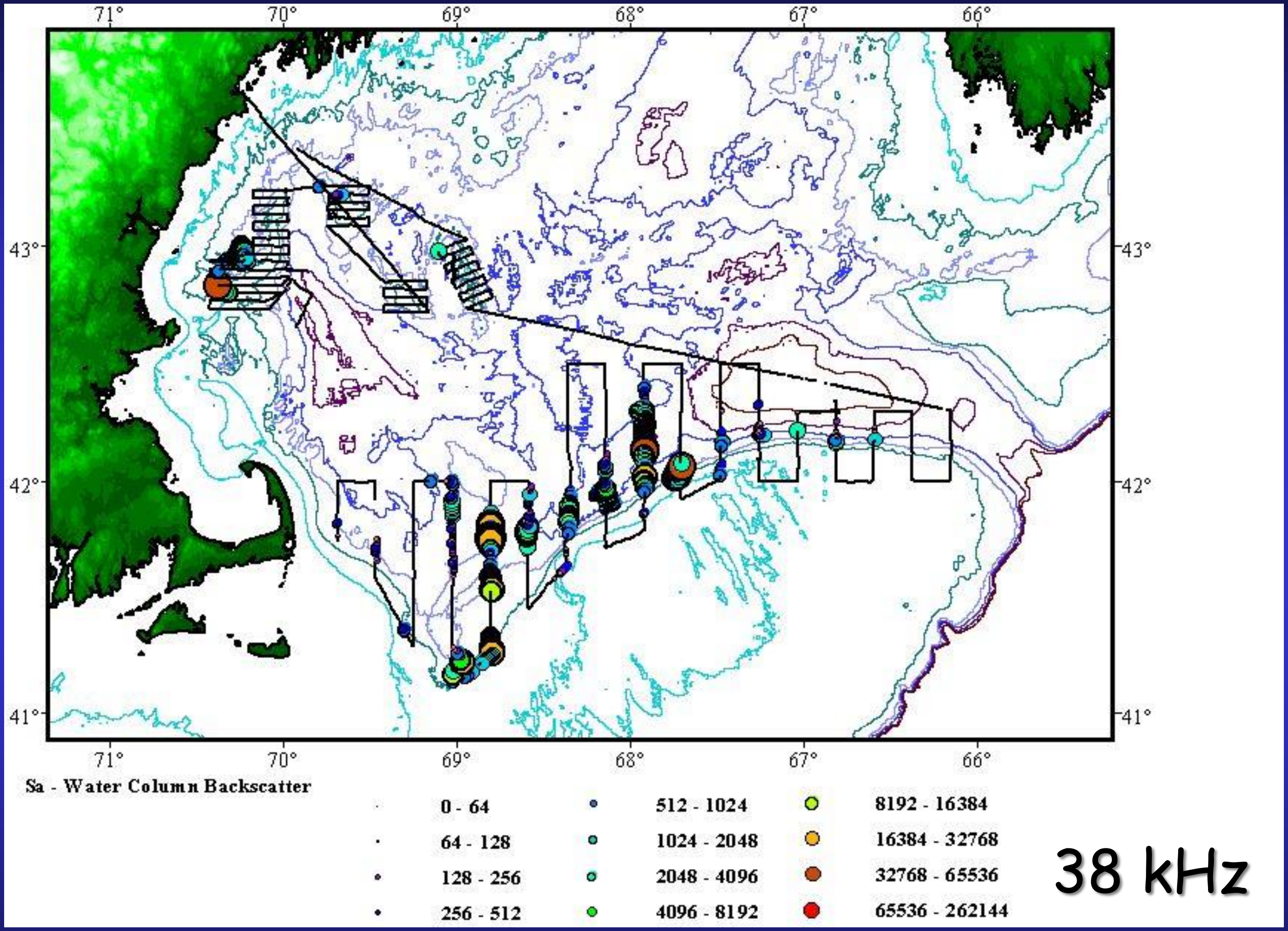


In New England, we have attempted a dedicated acoustic/midwater trawl for Atlantic herring, and we have collected acoustic data during the bottom trawl survey conducted in spring and fall.

Short story: Dedicated survey data were not included in the benchmark assessment in 2012. The confluence of that rejection and we went from 2 ships to 1 ship, effectively killed that survey.

However, as we speak, the acoustic data collected during the bottom trawl survey are being considered for this year's assessment.

Dedicated Atlantic herring acoustic survey – pre-spawning herring



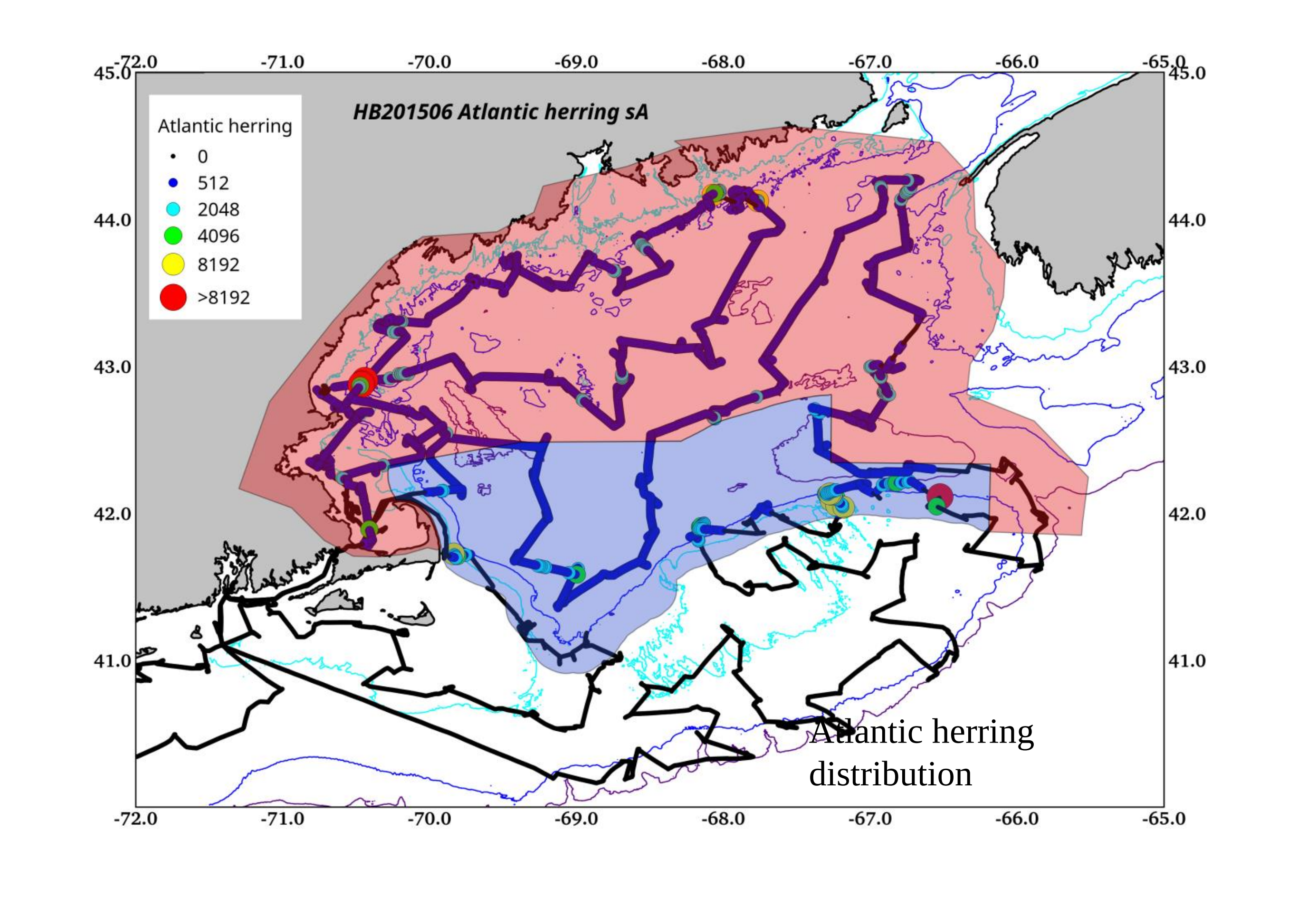
1998-2012

Relies on spatially and temporally consistent herring spawning

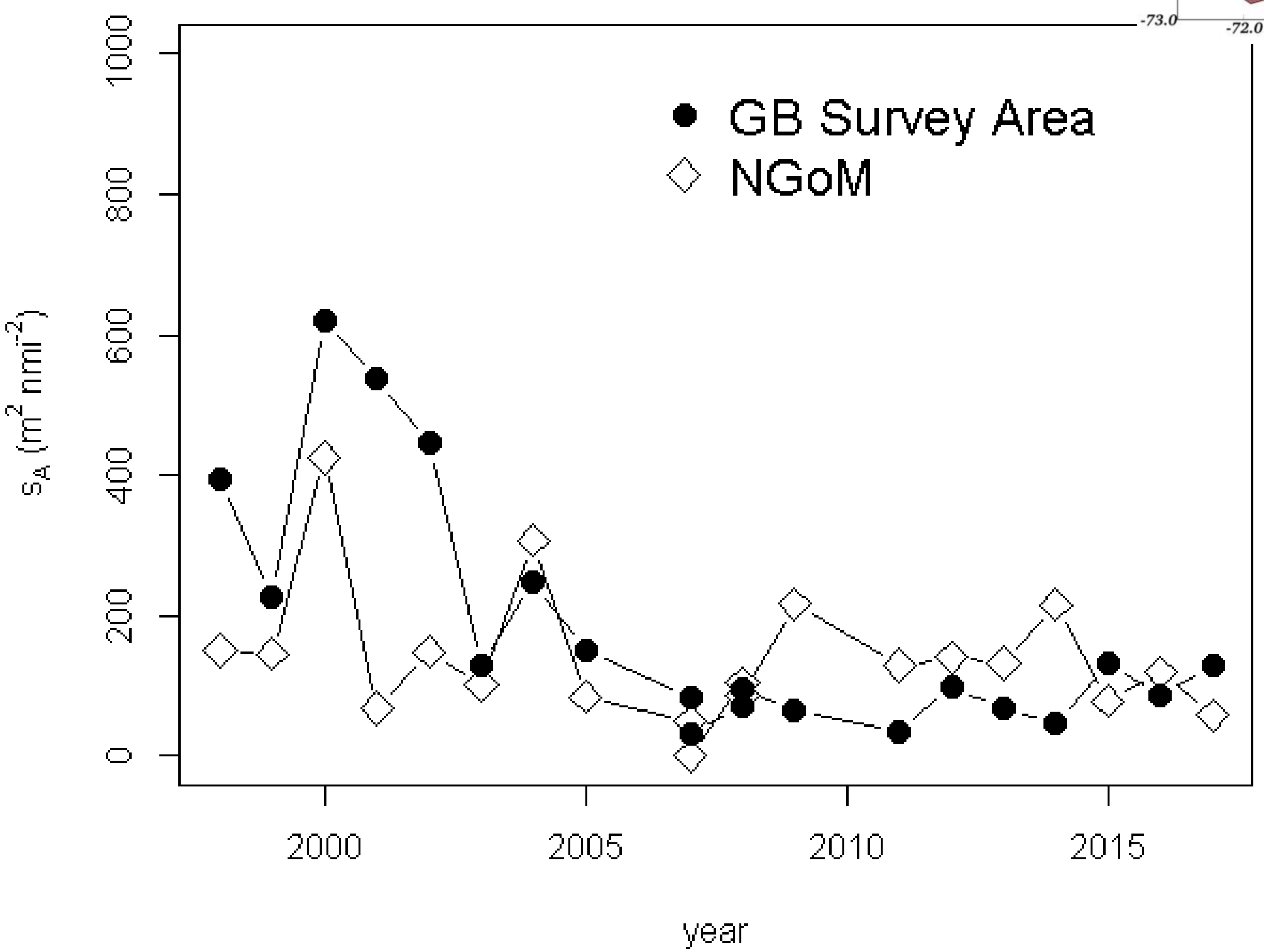
Atlantic herring distribution in 2000

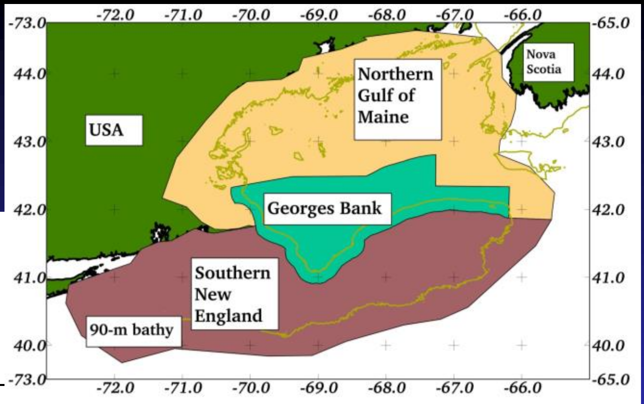
The bottom trawl survey begins encountering herring off Long Island and north and east. Created two areas, Georges Bank (GB) and northern Gulf of Maine (NGOM).

- The survey reaches the northern extent at approximately the same period – mid Oct. into Nov. – every year.
- Was designed to cover the entire Gulf of Maine using a random design.



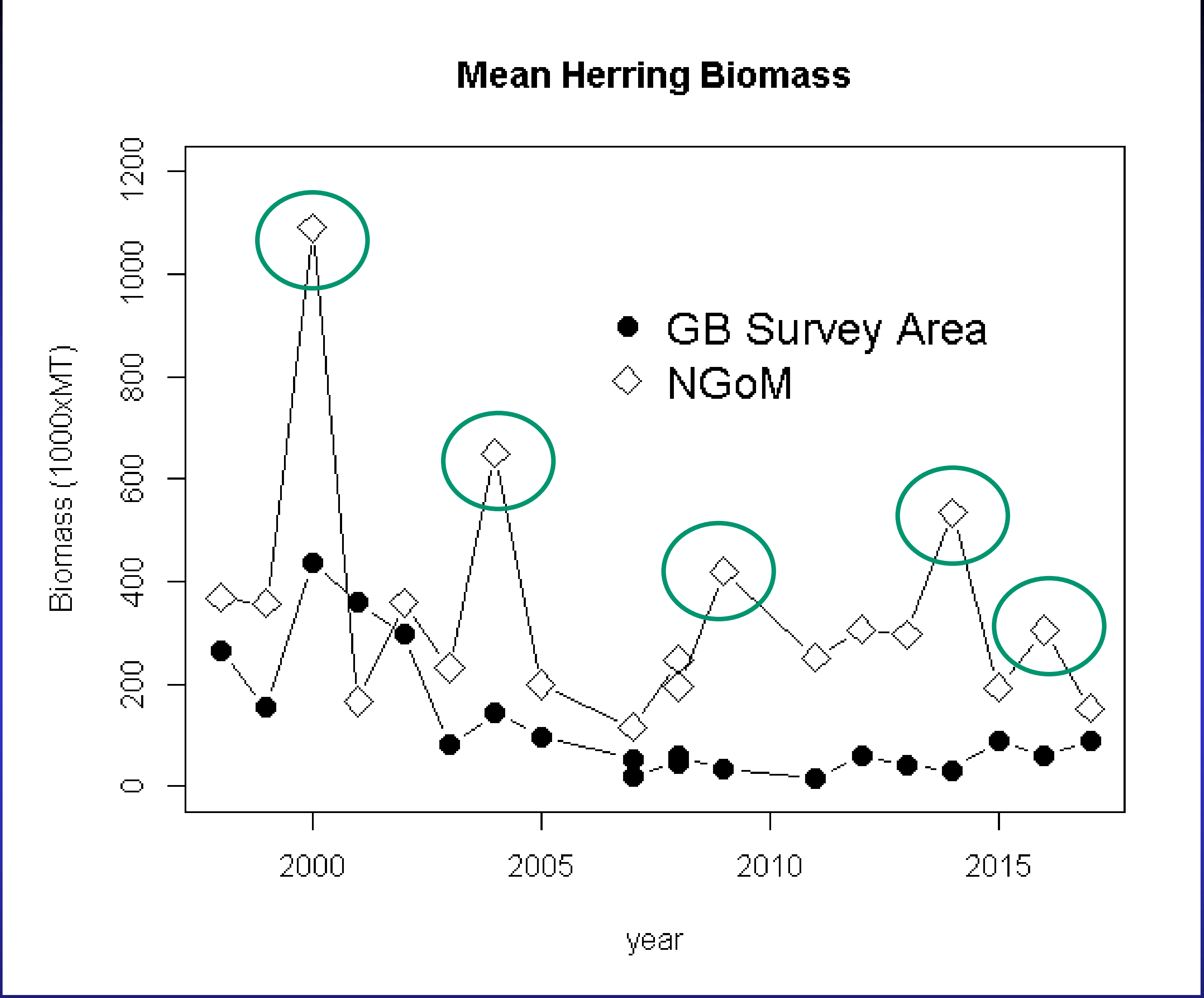
Mean Herring sA





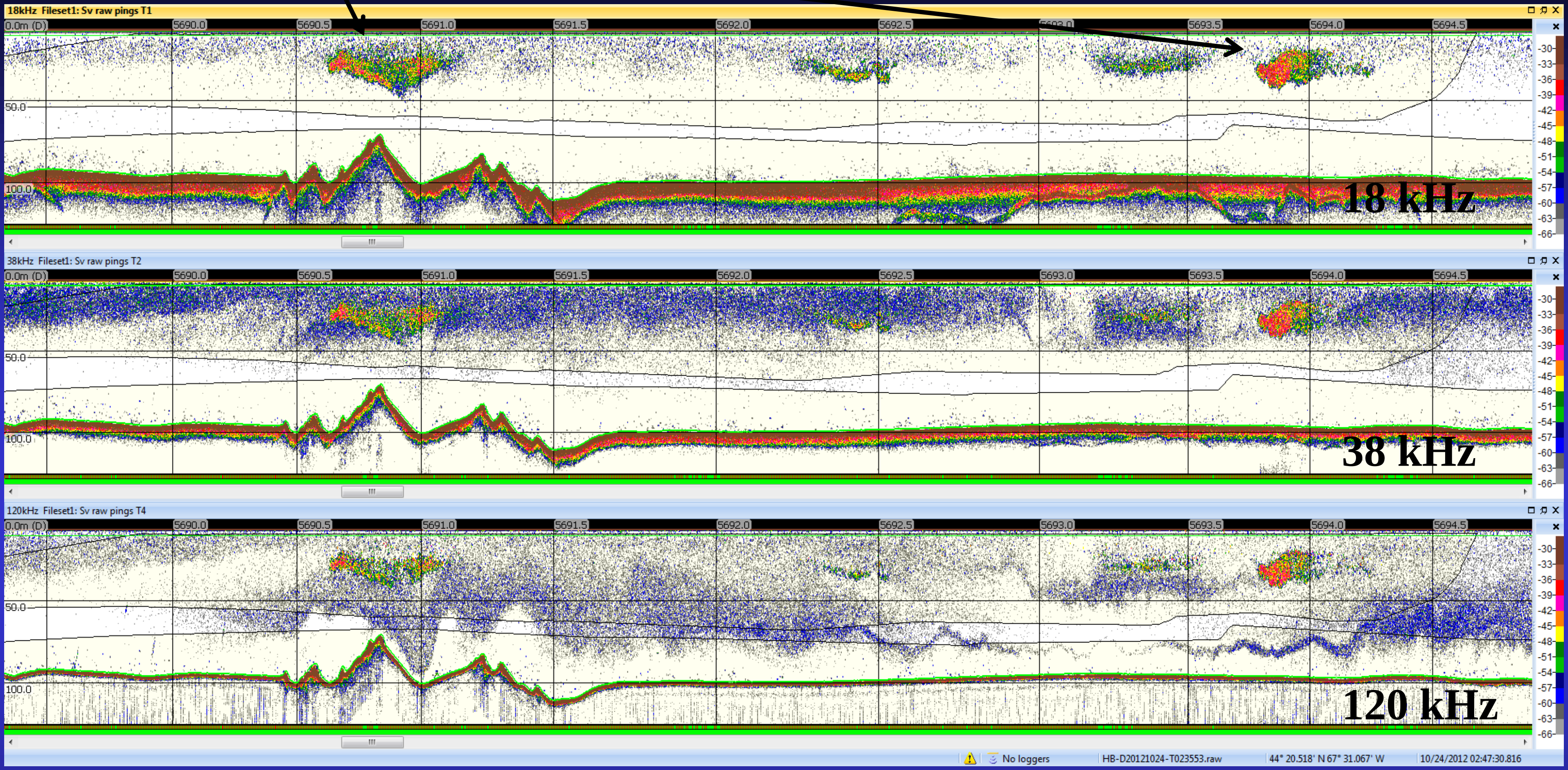
Scaling acoustic energy to abundance and biomass

- Need target strength (TS, dB re 1 m^2) to convert acoustic energy to abundance and/or biomass.
  - Use a TS-TL relationship from Ona (2003): $TS=20*\log_{10}(TL)-2.3*\log_{10}(1+z/10)-65.4$
  - "z" is depth. For the Georges Bank survey, we had the average depth of the herring aggregations by year. We don't have that yet for the BTS data.

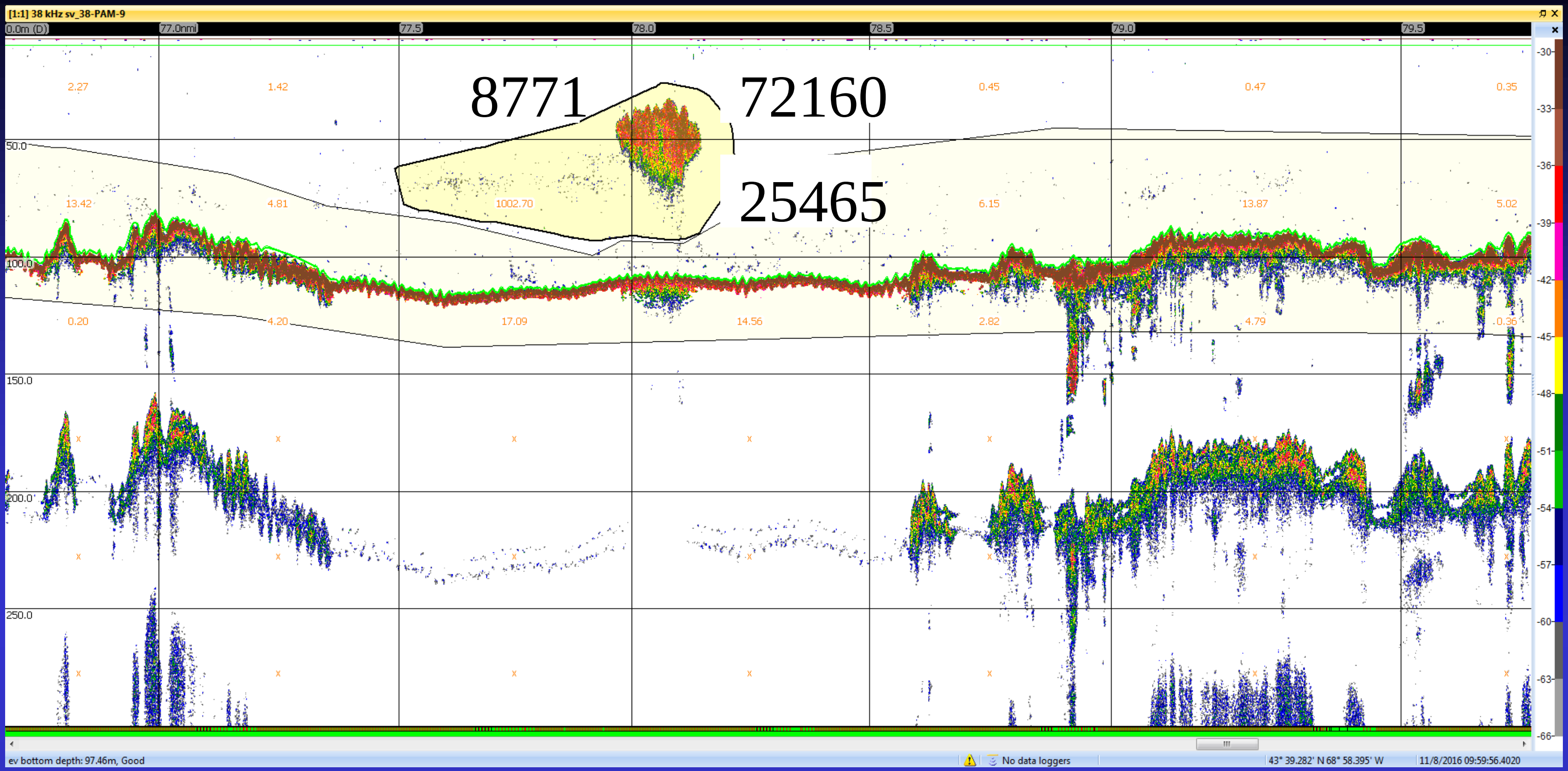


- Area(GB) = 9,279 nmi^2 (Georges Bank)
- Area(NGoM) = 33,717 nmi^2 (NGoM)

Atlantic herring (*Clupea harengus*) or other clupeid species??



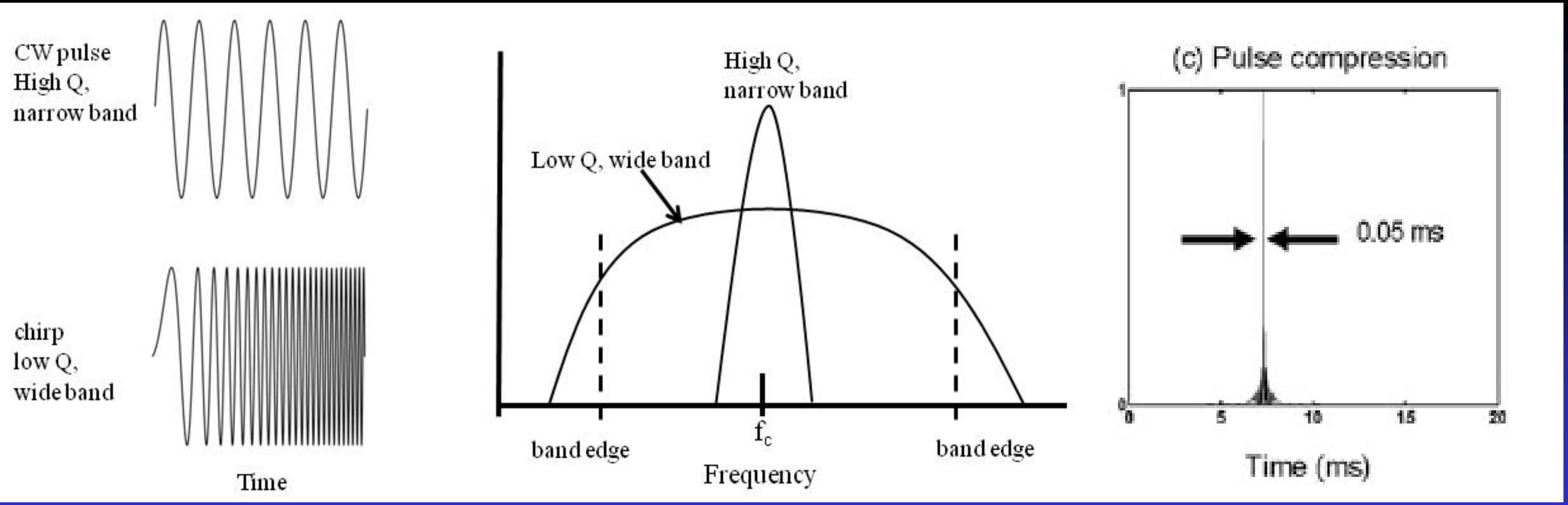
- Difficult to use samples from a bottom trawl to characterize fish in the water column.
- This increases uncertainty in verification.



- As an example, this school was encountered off Penobscot Bay in 2016. The total s_A is about 106,400 m^2 nmi^{-2} (or about 13,000 mt)
- When compared to cumulative s_A values from the entire survey (e.g., 472,873 for NGoM without this school), this school can contribute a substantial proportion (~18% in this case) of the biomass.
- River herring (alewife and blueback) are now quite abundant and can be a confounding species in inshore areas.

Up to now we've used narrow bandwidth echosounders. These systems have decades of experience, measurements, and algorithm development. Within the next few years, these will be replaced with broad bandwidth echosounders.

There is an international effort to transition from narrow bandwidth (aka narrowband) to broad bandwidth (aka broadband, "chirp").



Broad bandwidth (aka, braodband)

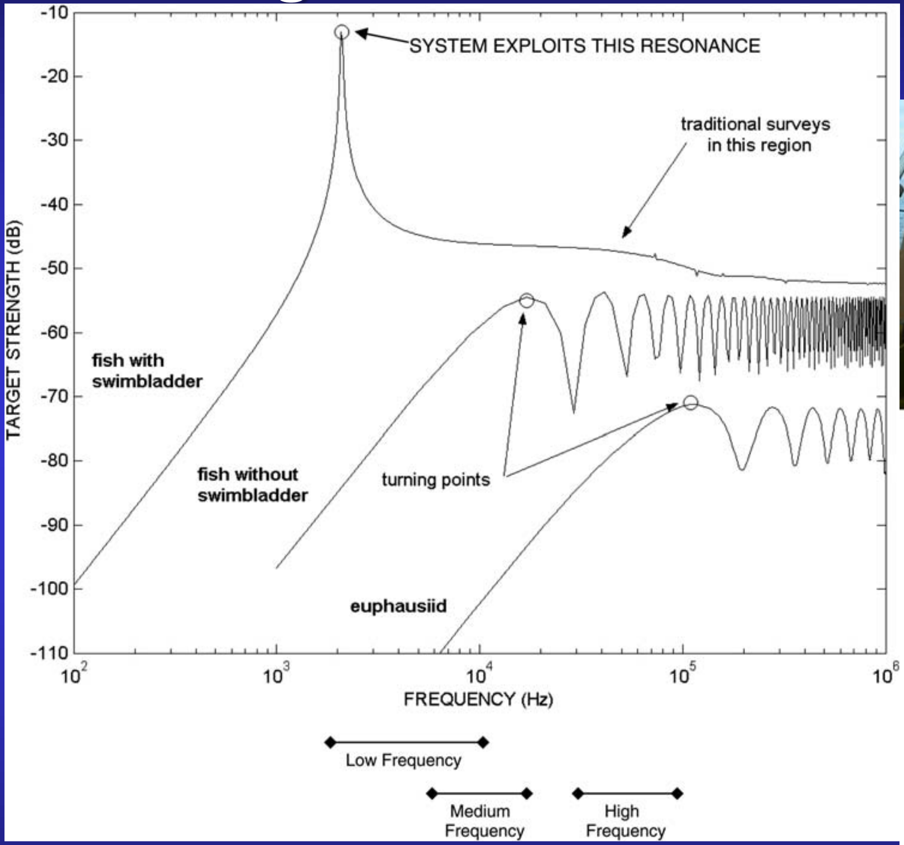
Benefits:

- Information over a continuous spectrum
- Very high resolution

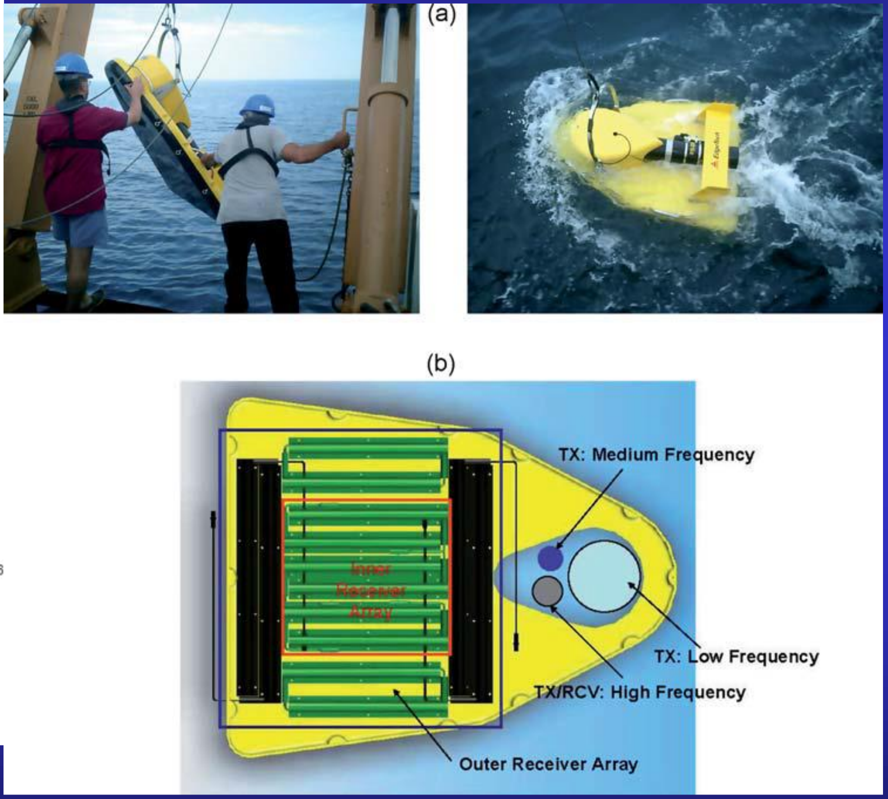
Limitations:

- Lower energy per frequency – less range
- Advanced Technology
- Need to be judicious in which frequencies to select

Resonance scattering region – gas bubbles (e.g., gas-filled swimbladders) resonate at frequencies that are dependent on the volume of gas.

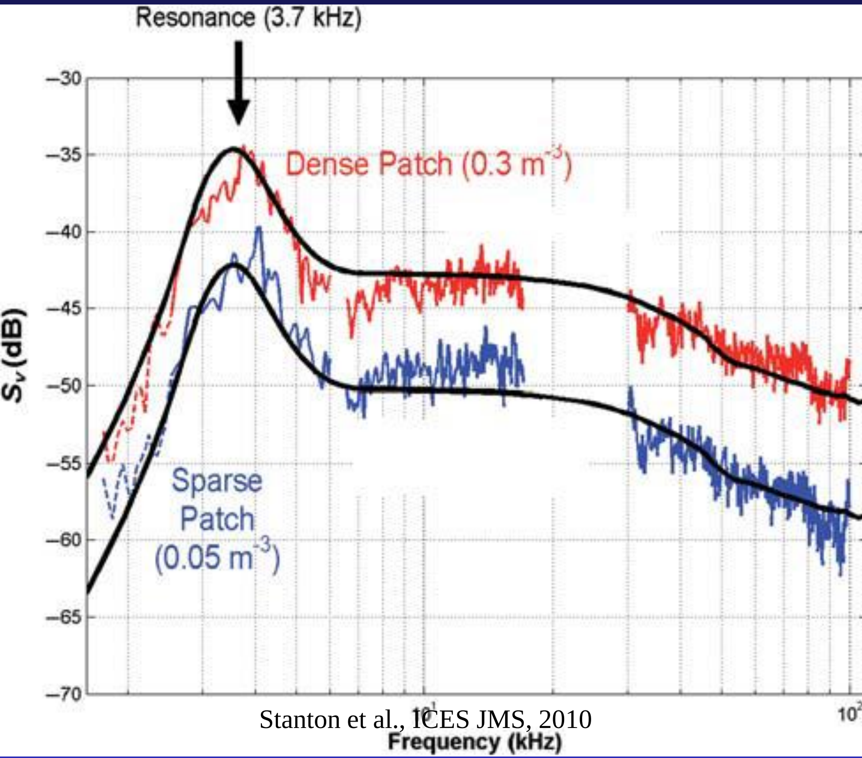


Stanton et al., ICES JMS, 2010



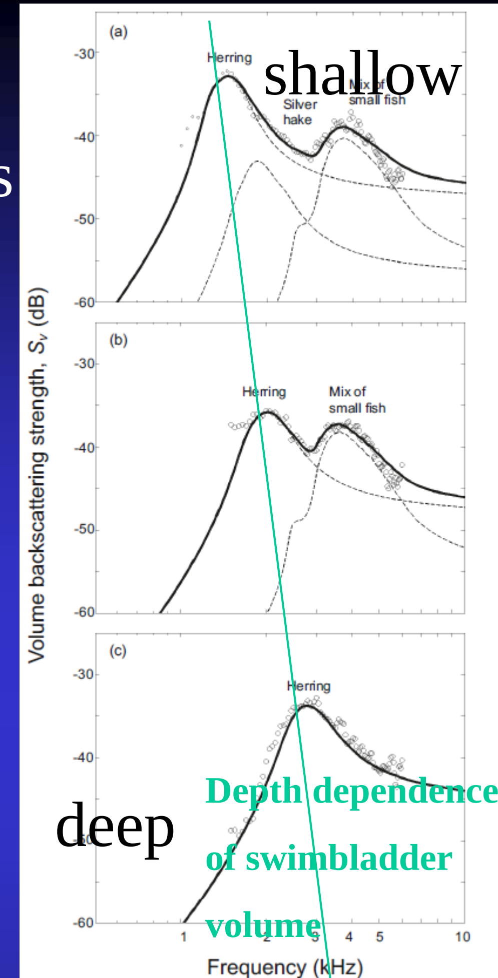
"low" frequency system by Edgetech: 1-6 kHz

"medium" frequency system by Edgetech: 4-24 kHz



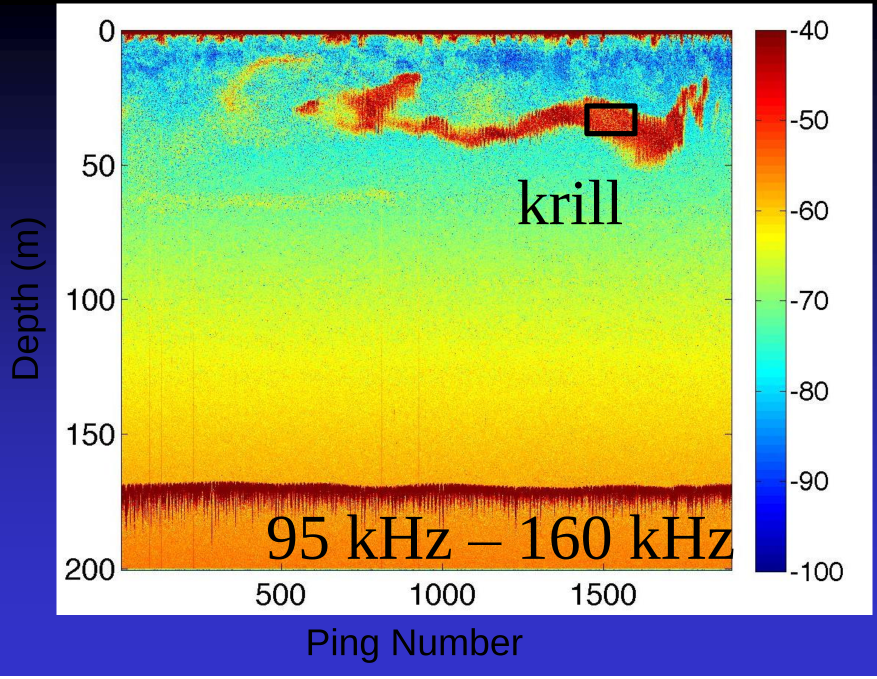
Stanton et al., ICES JMS, 2010

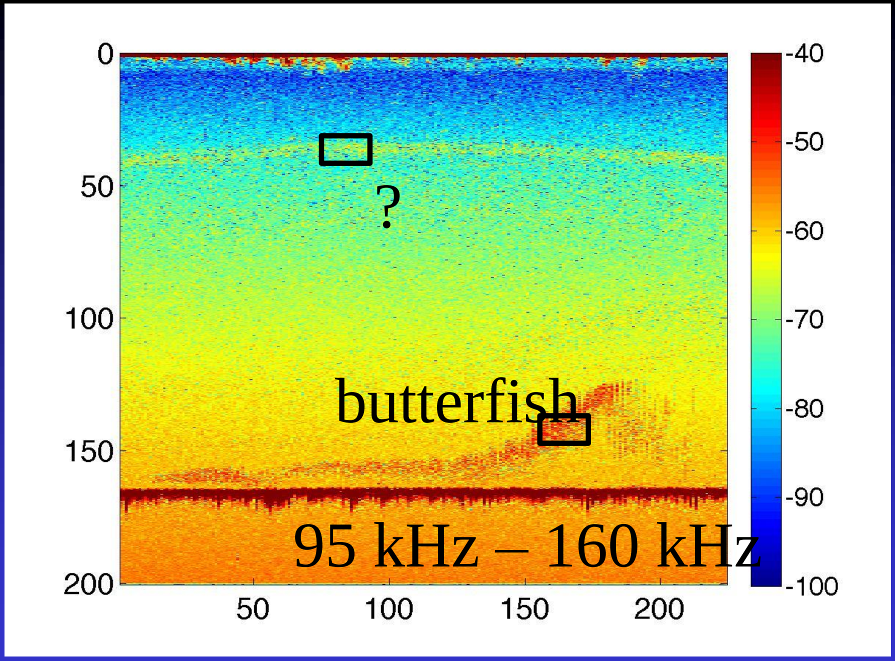
Mixed aggregations in 2008

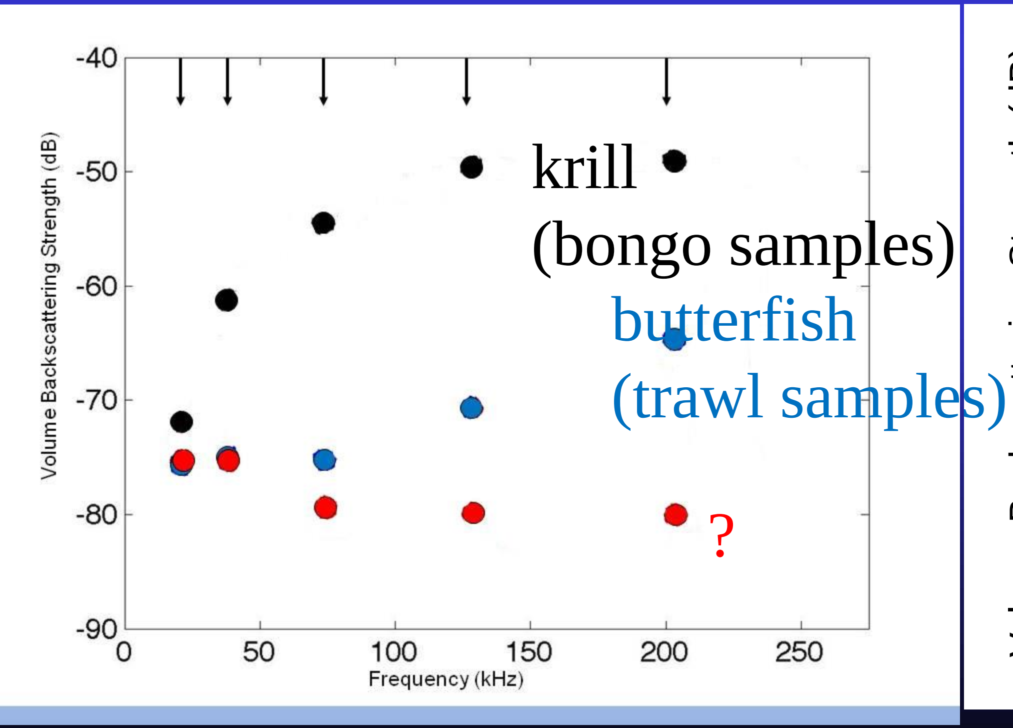


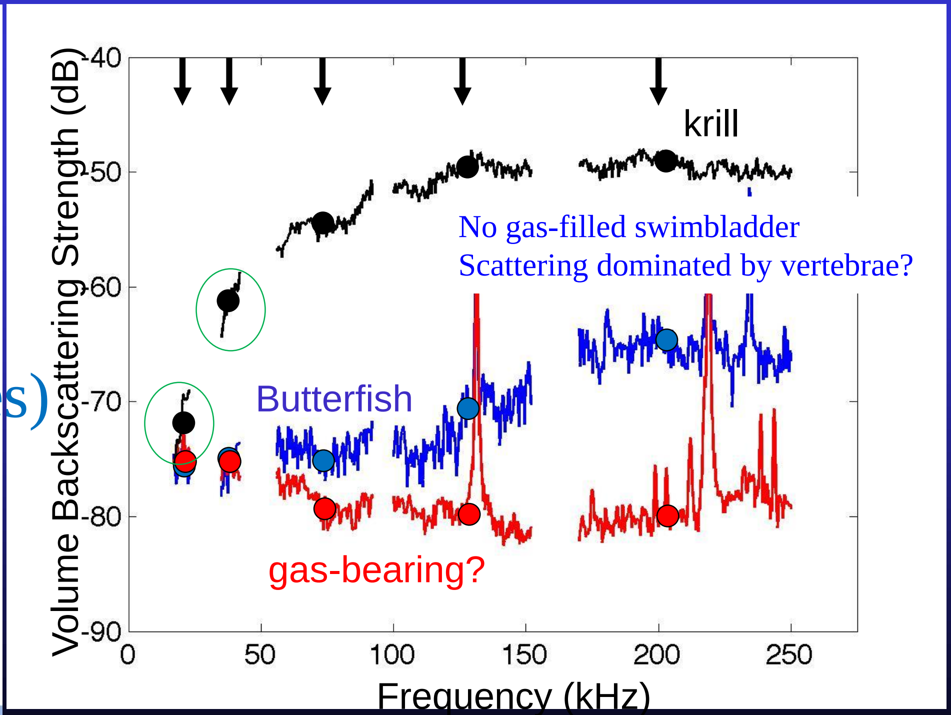
Stanton et al., CJFAS, 2012

By measuring the resonance frequency in different parts of an aggregation, we know the fish have the same swimbladder volume, and infer that the fish are the same size (left panels) or different sizes (right panels). This is important when translating S_v to density, abundance, and biomass.


krill
95 kHz – 160 kHz
Depth (m)
Ping Number
0
50
100
150
200
500
1000
1500
-40
-50
-60
-70
-80
-90
-100

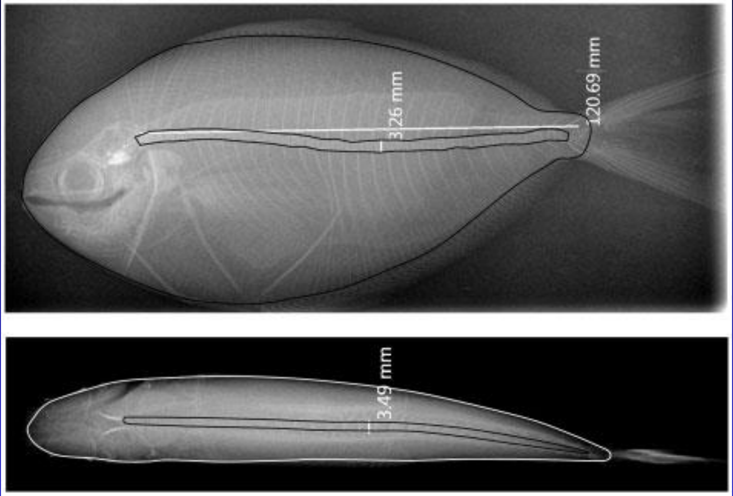

?
butterfish
95 kHz – 160 kHz
0
50
100
150
200
-40
-50
-60
-70
-80
-90
-100


krill
(bongo samples)
butterfish
(trawl samples)
?
Volume Backscattering Strength (dB)
Frequency (kHz)

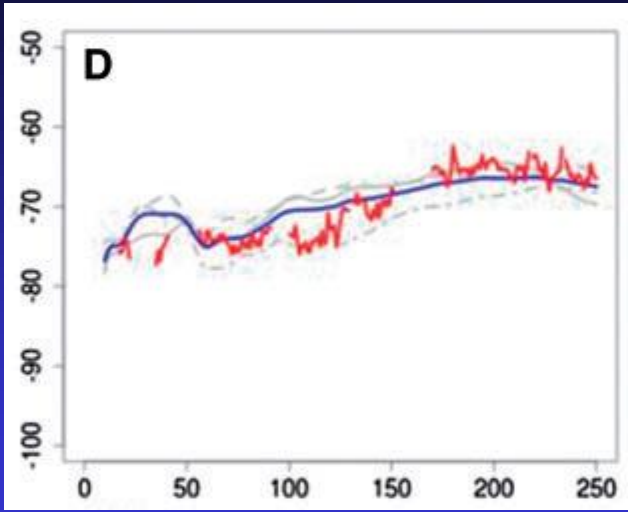

krill
No gas-filled swimbladder
Scattering dominated by vertebrae?
Butterfish
gas-bearing?
Volume Backscattering Strength (dB)
Frequency (kHz)

Theoretical scattering models can be used to improve interpretation

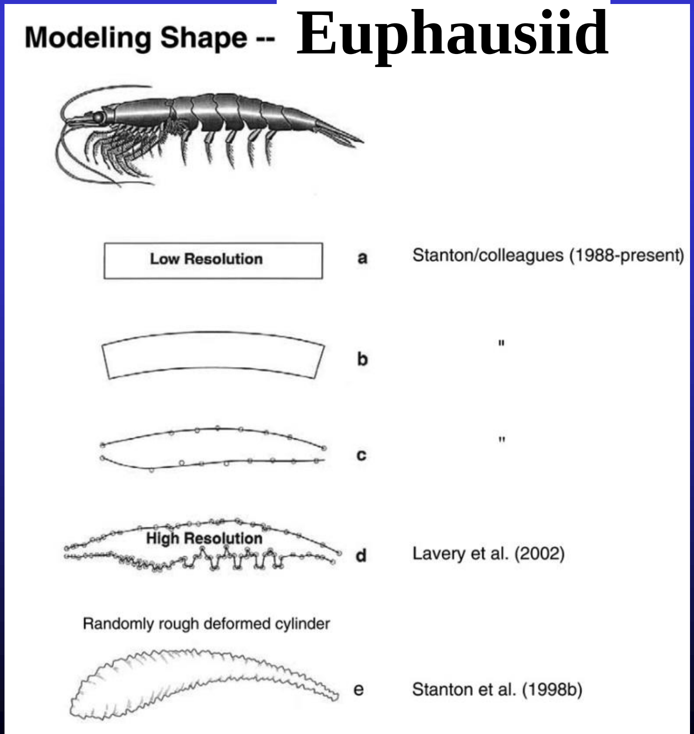
Butterfish



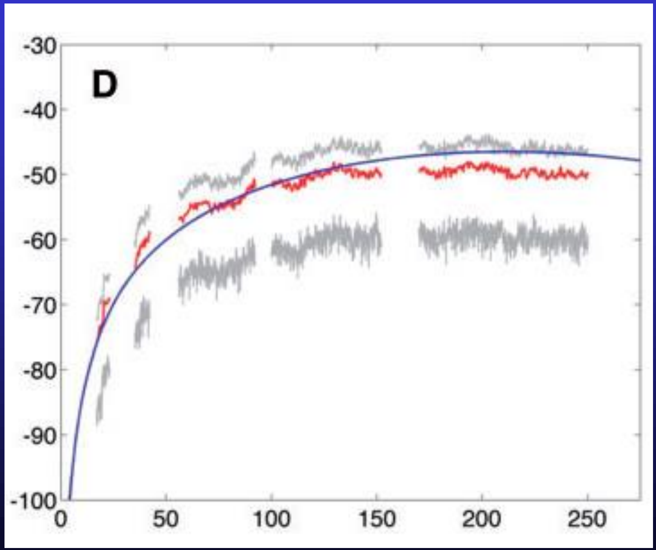
- X-rays provide anatomy and morphology
- Kirchhoff ray-mode (KRM) model provides backscatter



Euphausiid



- Distorted wave Born approximation (DWBA) model provides backscatter



Thank you!

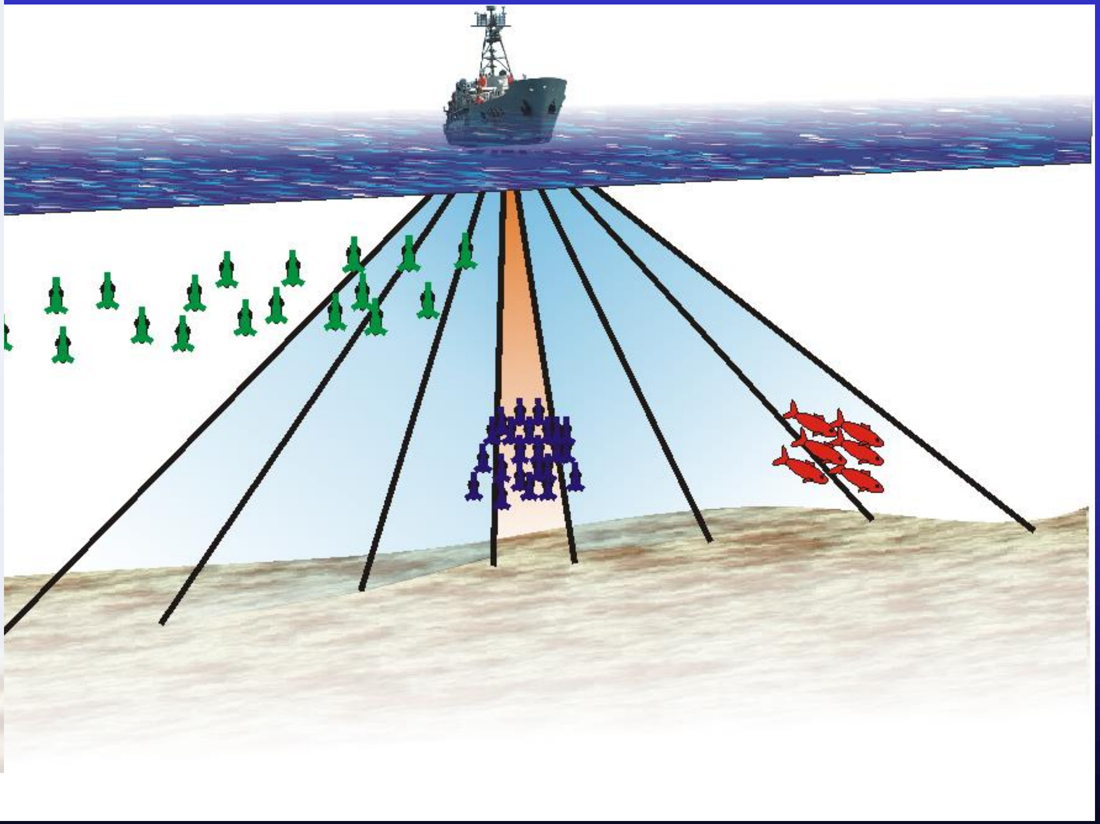
With special thanks to:

- **Andone Lavery,** Woods Hole Oceanographic Institution (WHOI), Woods Hole, MA, USA
- **Gareth Lawson,** WHOI, Woods Hole, MA, USA
- **Tim Stanton**, WHOI, Woods Hole, MA, USA
- **Christopher Bassett,** WHOI – now at NOAA Alaska Fisheries Science Center
- **Lars Andersen & Jeff Condiotty**, Kongsberg Underwater Technologies Inc. (aka Simrad), Horten, NO & Lynnwood, WA, USA
- **Chris Roebuck**, Captain of the F/V Karen Elizabeth, Pt. Judith, RI, USA
- **Tom Weber & Carlo Lanzoni**, UNH, Durham, NH, USA
- **Dezhang Chu**, NOAA, Northwest Fisheries Science Center, Seattle, WA, USA
- ICES WGFAST community

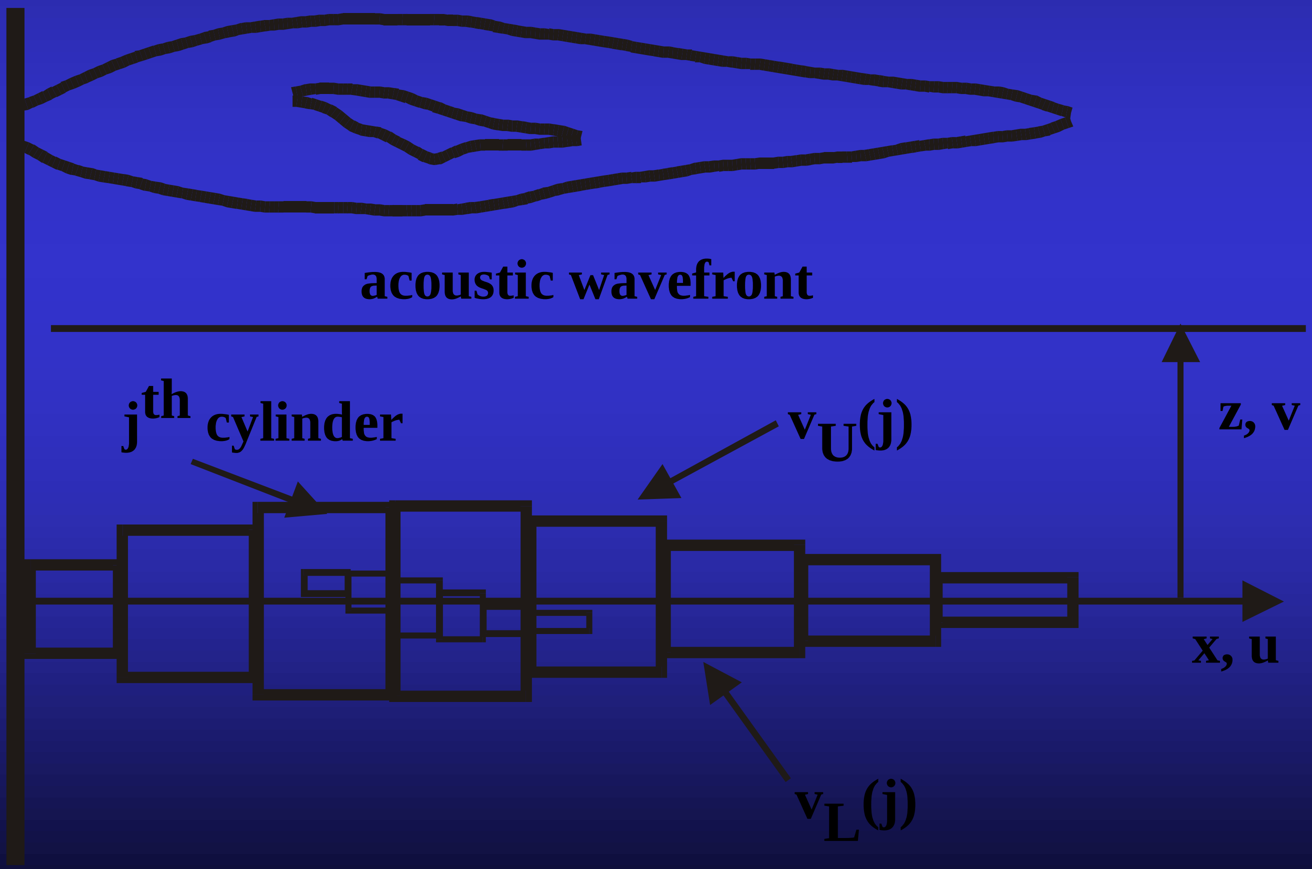
These examples have all been from traditional, single-beam (even though they are "split-beam") systems. Many fisheries vessels have multibeam systems, and there has been effort to quantify data from those systems.

NOAA Ship *Henry B. Bigelow* Simrad ME70 Multibeam Echo Sounder

- Most Technologically Advanced Mid-water Multibeam Sonar in the World
- Frequency Range from 70kHz to 120 kHz
- Configurable Beam Pattern from 3 to 45 Split- or Single-Beams
- Future capability for IHO Quality Bathymetry Capabilities
- Max Depth 300m (Approx).
- 140 degree Total Swath Width
- Steerable Fan, +/- 45 degrees Athwart Ship, 140 deg total swath width

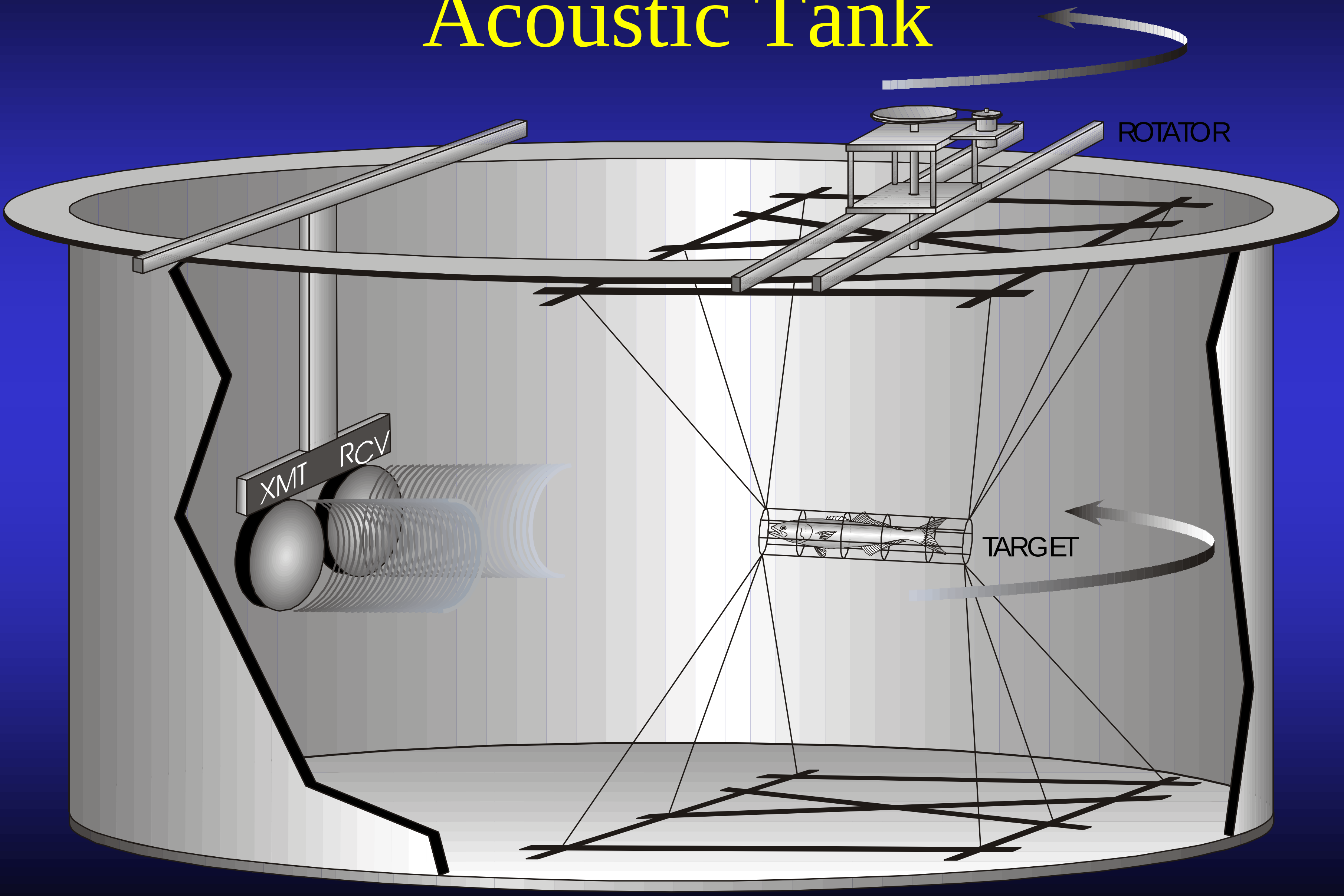


Fish outline from x-rays

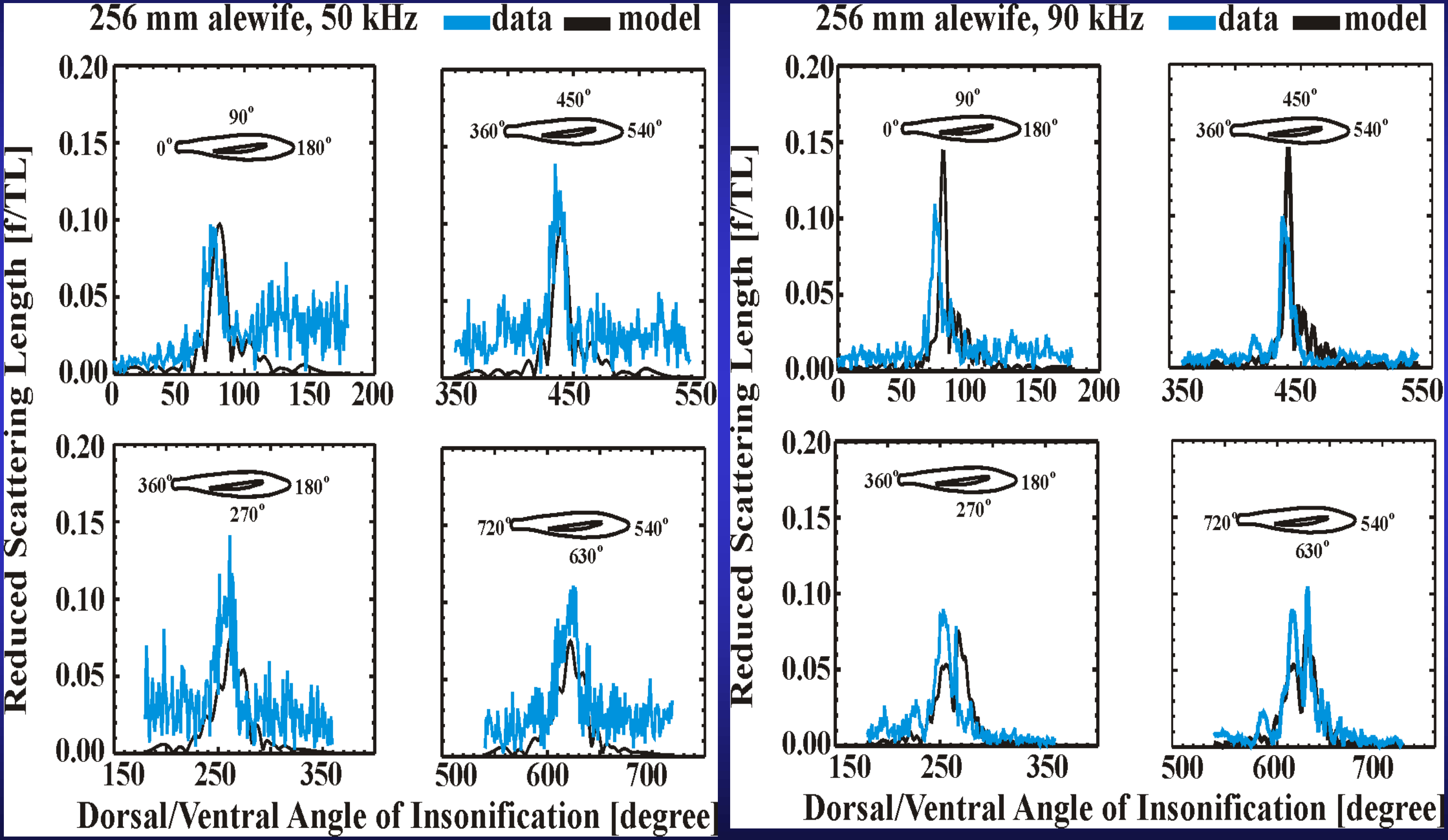


Equivalent Cylinders

Model Verification in an Acoustic Tank



Model – Measurement Comparisons



Looking forward to the mesopelagic zone.
Potentially a large source of protein.

Vertical migration of fish and plankton