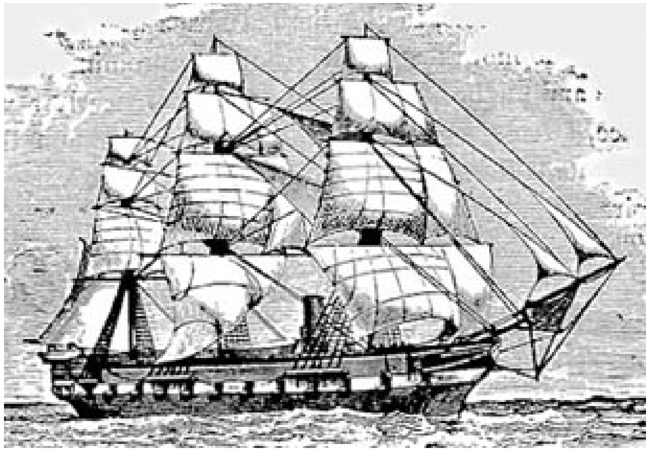
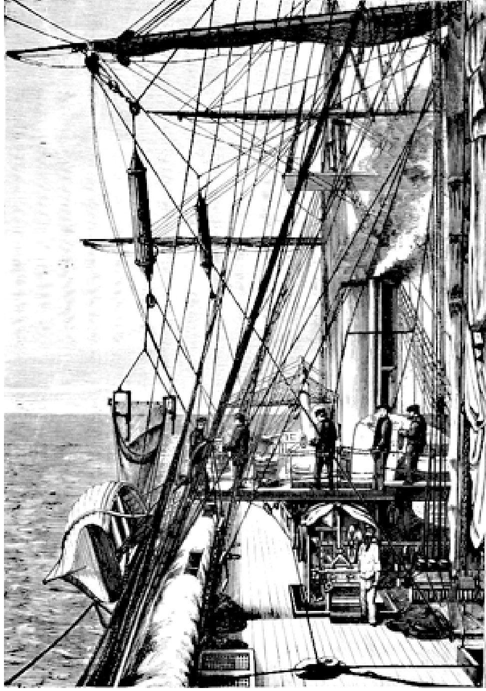
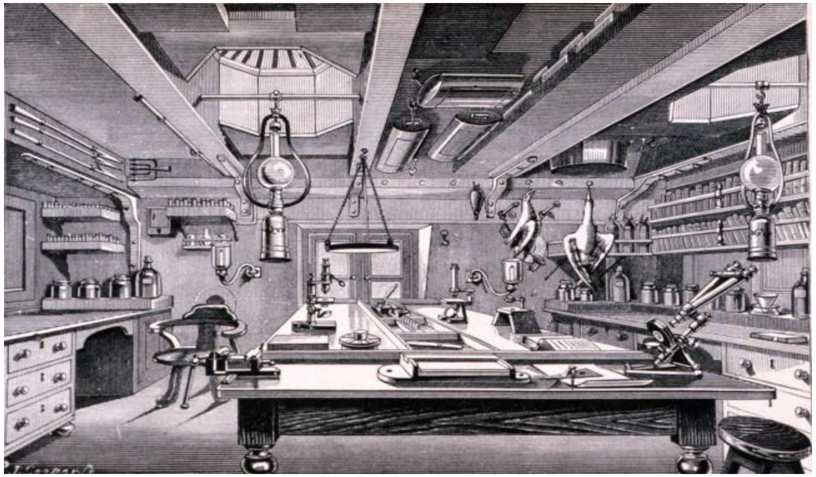
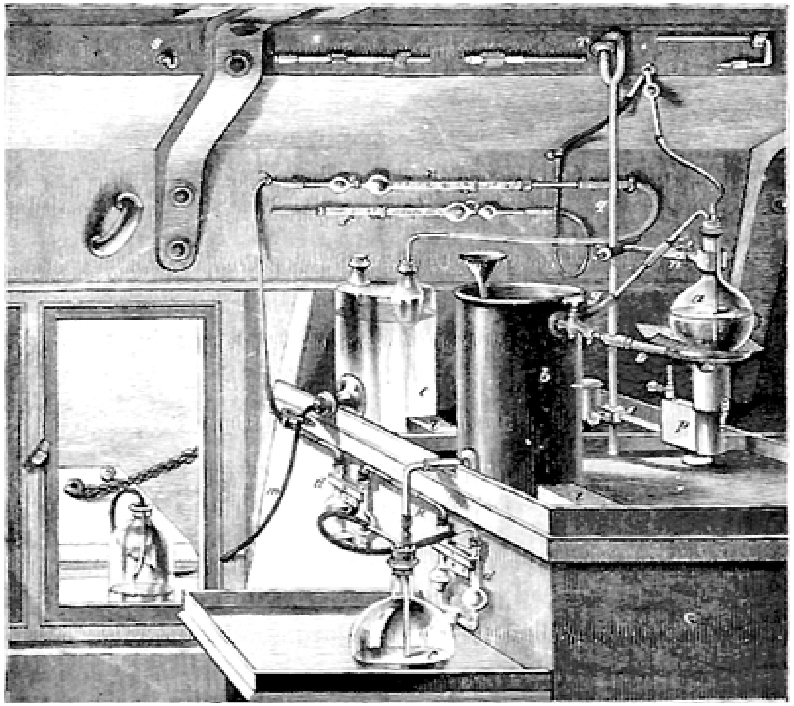
Sonar Technologies







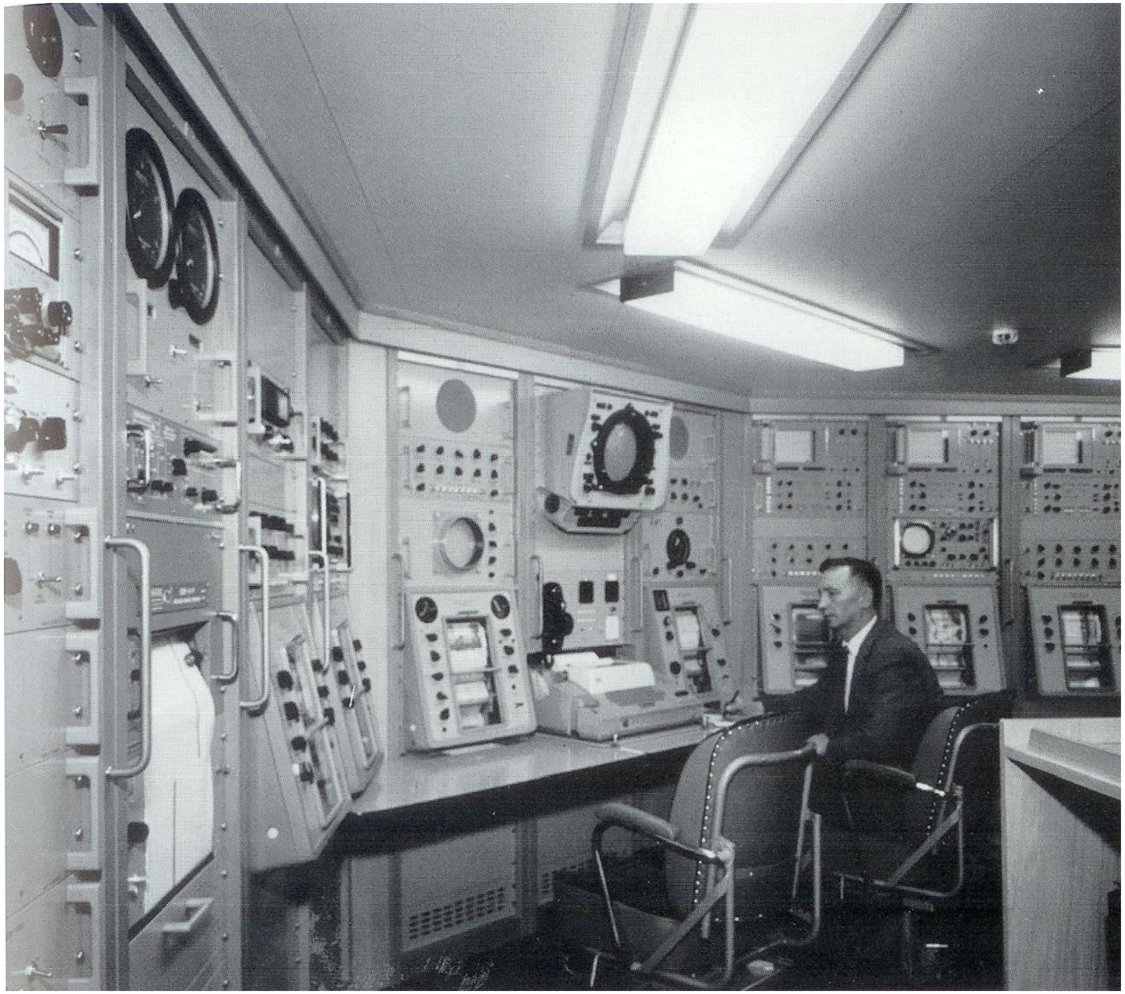


John K. Horne

Technology Evolution

WWII	detect fish in water	first applications	Sund, Tester, Balls
1946	broadband sonar	deep scattering layer	Duvall, Christensen
1946, 1960	sonar	school volume, shape	O.R. Smith, P.E. Smith
??	**T**ime **V**aried **G**ain	standard attenuation compensation	
1968	multi-frequency	species identification	McNaught
1970’s	TS-length relationships	convert relative to numeric densities	Love, Nakken, McCartney, Olsen, Stubbs
1977	inverse approach	size-based abundance estimates	Holliday
1979	species identification	demonstrated potential	Deuser et al. Giryn et al.
1983	standard calibration	enabled data comparison	Foote et al.
1974 - 1980	dual and splitbeam transducers	*in situ* echo amplitude measurement	Ehrenberg
1989	multibeam sonar	school shape, volume	Misund
2002-2015	autonomous echosounder	Increased applications	ASL, Kongsberg
2005	broadband, multibeam sonar	school shape, volume, abundance estimates, identity	Simrad
2007	autonomous platform	long temporal/large range data	Liquid Robotics
2010-2013	broadband echosounder	potential species discrimination	Edgetech, Kongsberg

Then…



G.O. Sars
1969

And Now

G.O. Sars III 2004

Trend: Increased Information

Obtained using:

1. Increased Frequency Range
   - narrowband discrete frequencies
   - broadband
2. Increased Swath
   - multibeam
   - other sonars
3. Increased Resolution
   - acoustic imaging
4. Integration with Other Technologies
   - sensors
   - platforms

1. Increase Frequency Range

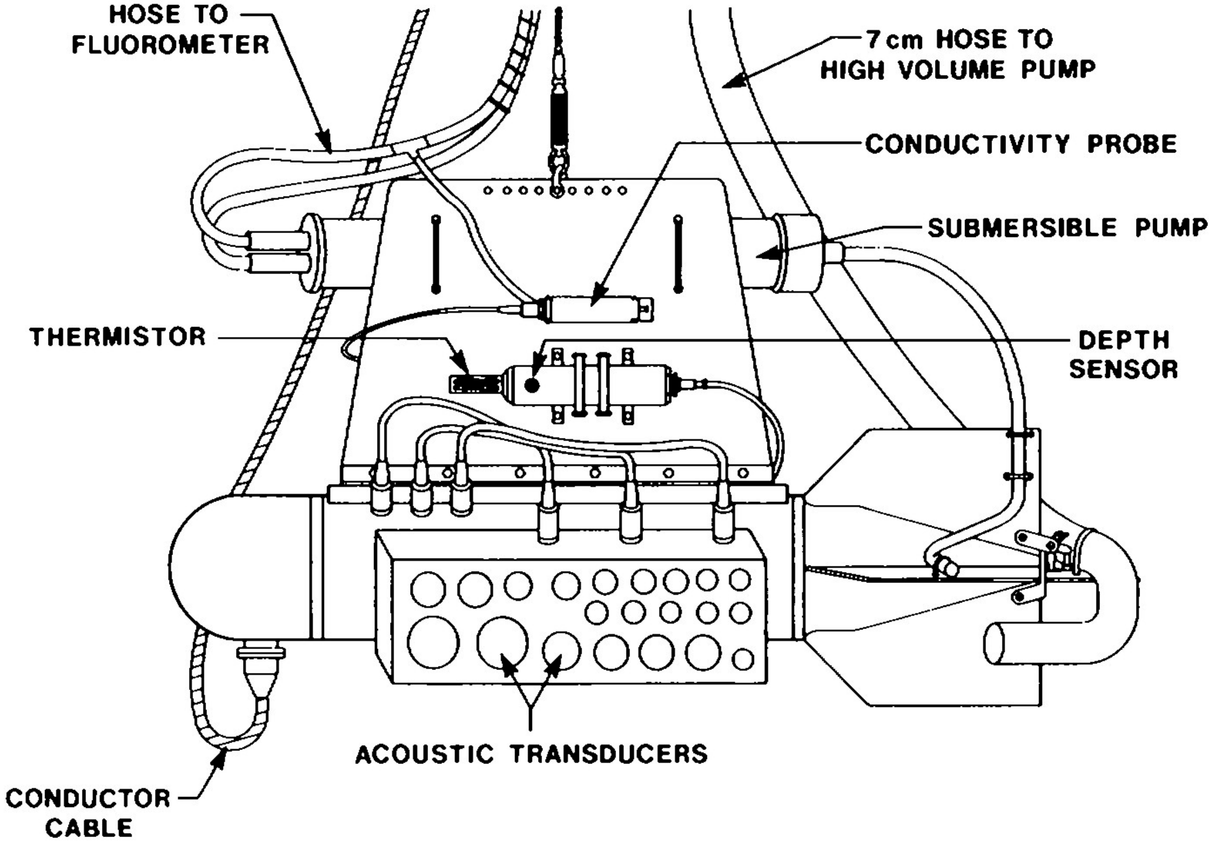
- **Multifrequency** echosounders: multiple, discrete frequency (i.e. narrowband) transducers
- **Broadband** echosounders: single or limited number of wideband transducers

Frequency-dependent backscatter (aka Frequency Response)

Multiple frequencies enables inverse approach (but best over Resonance peaks)

Multifrequency: Zooplankton Acoustics

Example: Multiple Acoustic Profiling System (MAPS)



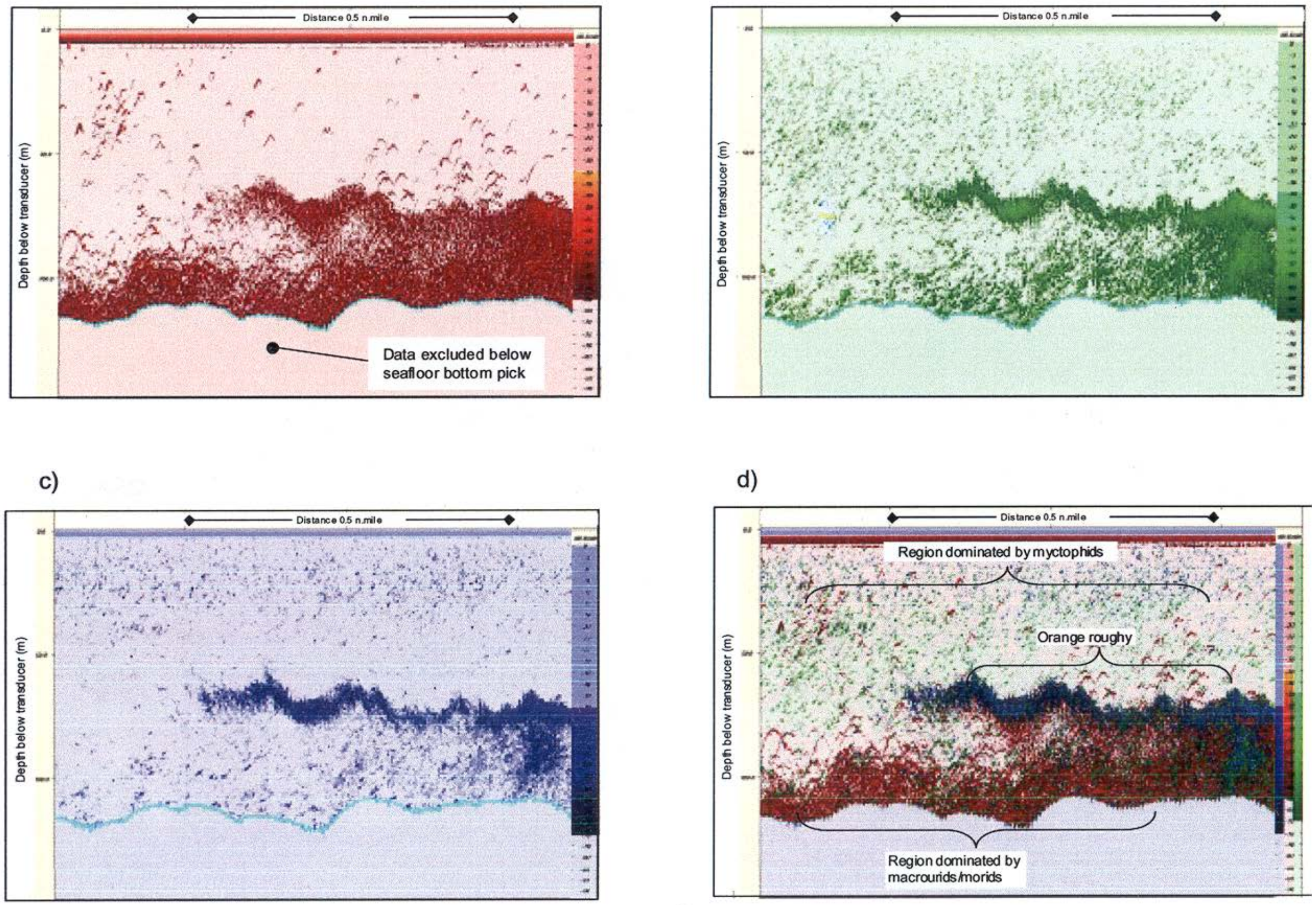
- 21 transducers
- frequency range 0.1 to 10 MHz
- Echo volume 0.01 m^3 at 1-2 m
- temperature, depth, salinity, fluorometry, and pump samples

Pieper *et al*. 1990

Multifrequency Fish Measures

12 kHz

38 kHz

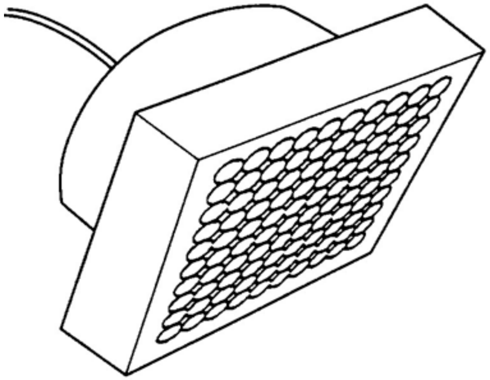


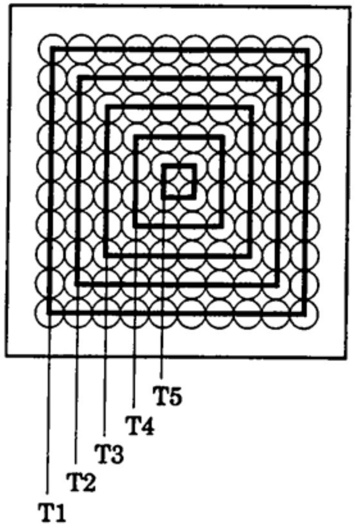
120 kHz

Mixed

Kloser *et al*. 2003

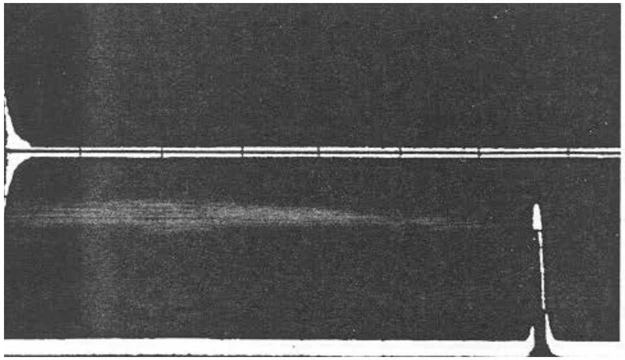
Broadband Sonars



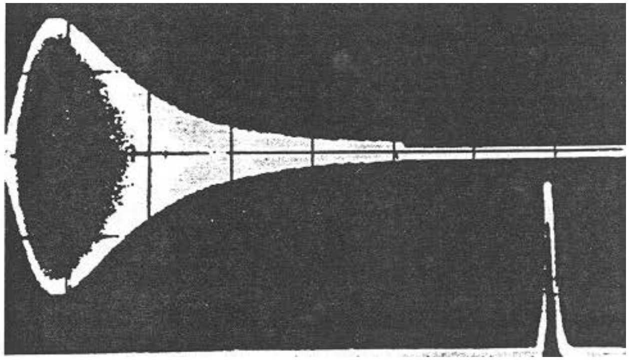


- 2 octaves 20 to 80 kHz
- combine rings to generate pulse
- low 20 – 40 kHz
- medium 40 – 60 kHz
- high 60 – 80 kHz

low, τ = 1ms



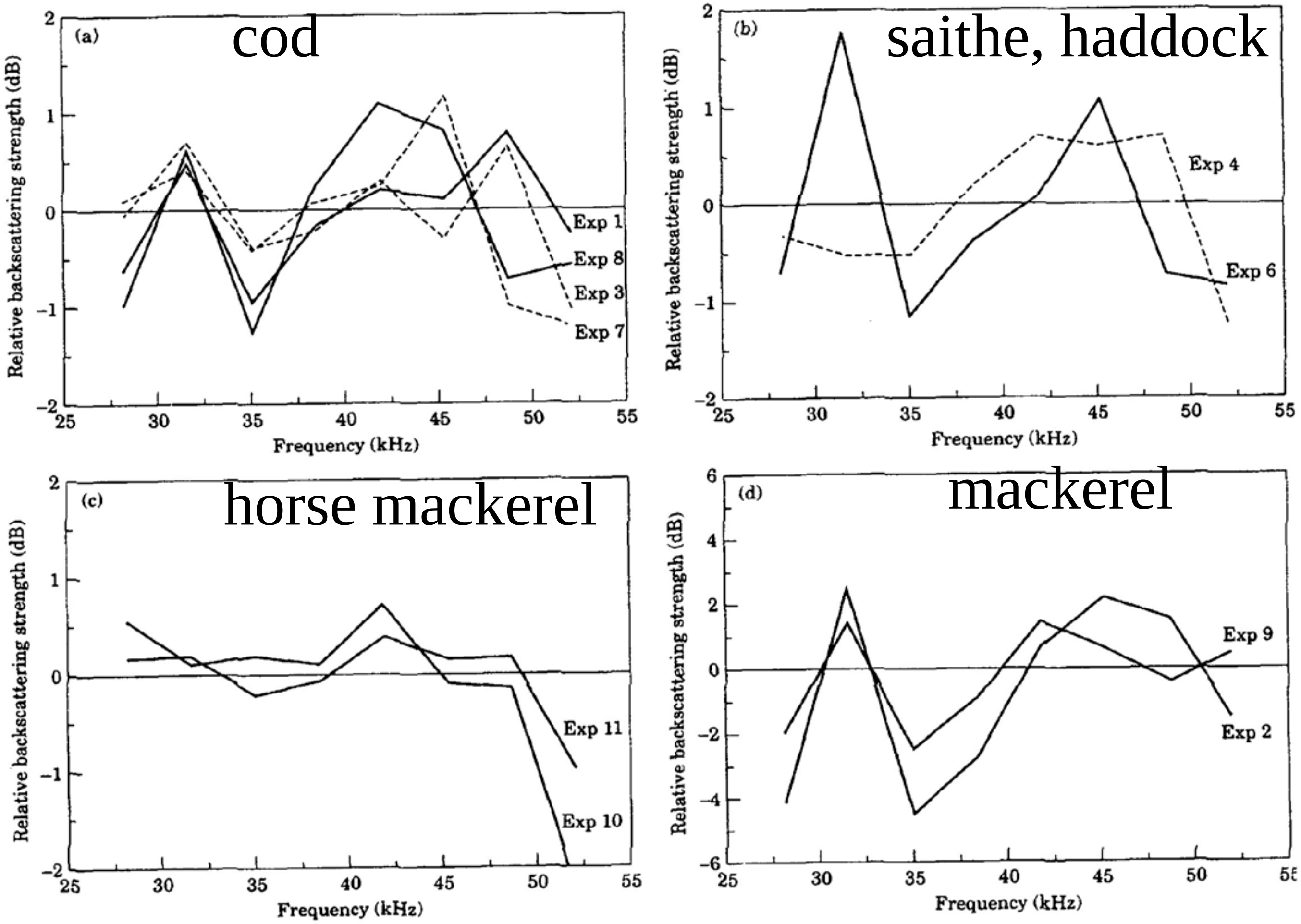
high, τ = 10 ms



Zakharia *et al*. 1996

Broadband Sonars

Use frequency spectra as characteristic signature



Simmonds *et al*. 1996

Increased Frequency Range Applications

- target discrimination
- target classification
- species identification

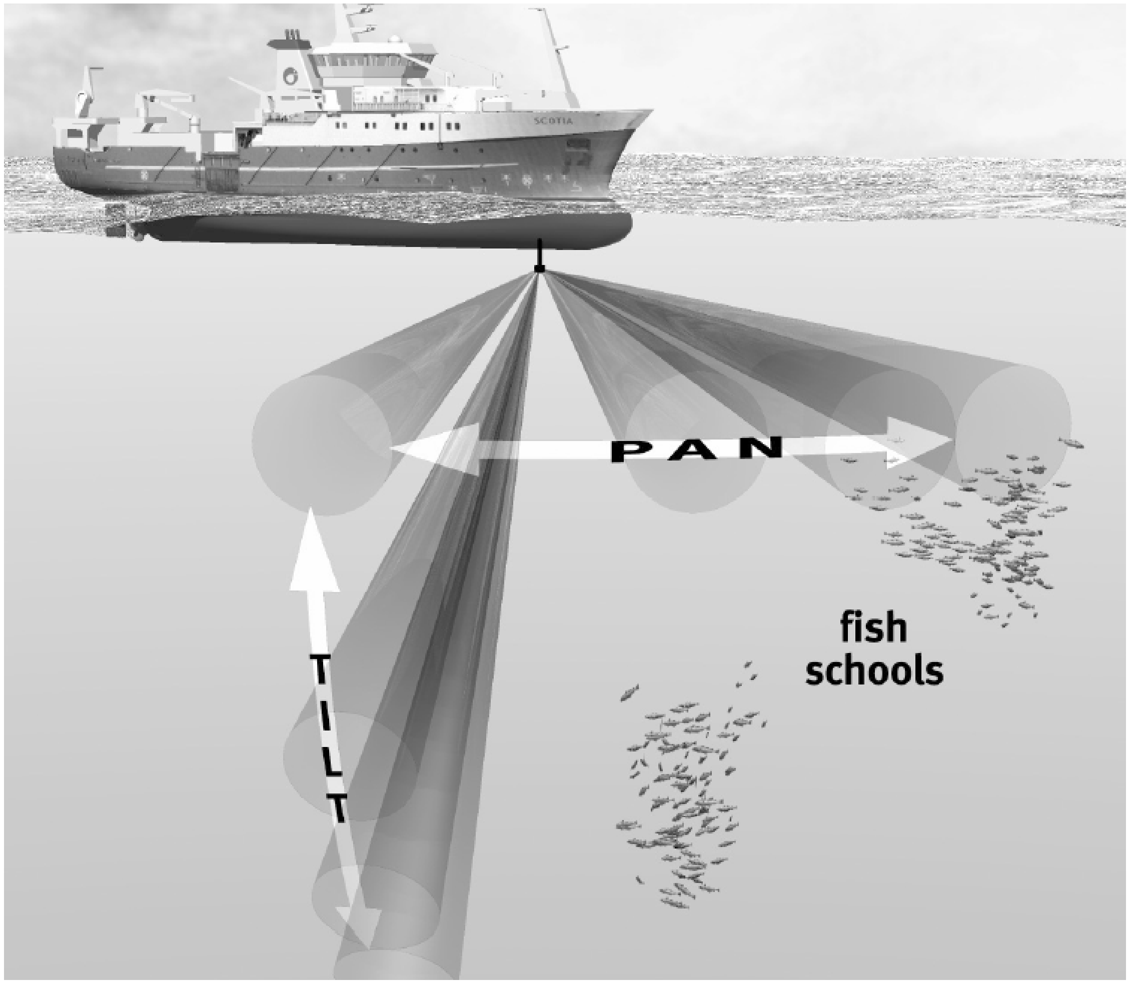
Data Attributes: frequency-dependent backscatter, multiple frequencies enables inverse approach, frequency domain analyses

2. Increase Swath

Multibeam echosounder/sonar: single frequency, multiple narrow transceivers in single transducer

SONAR systems: initially qualitative, visual tools transferred from military and commercial fishing, currently developed to extract water column and/or bathymetric data for scientific use

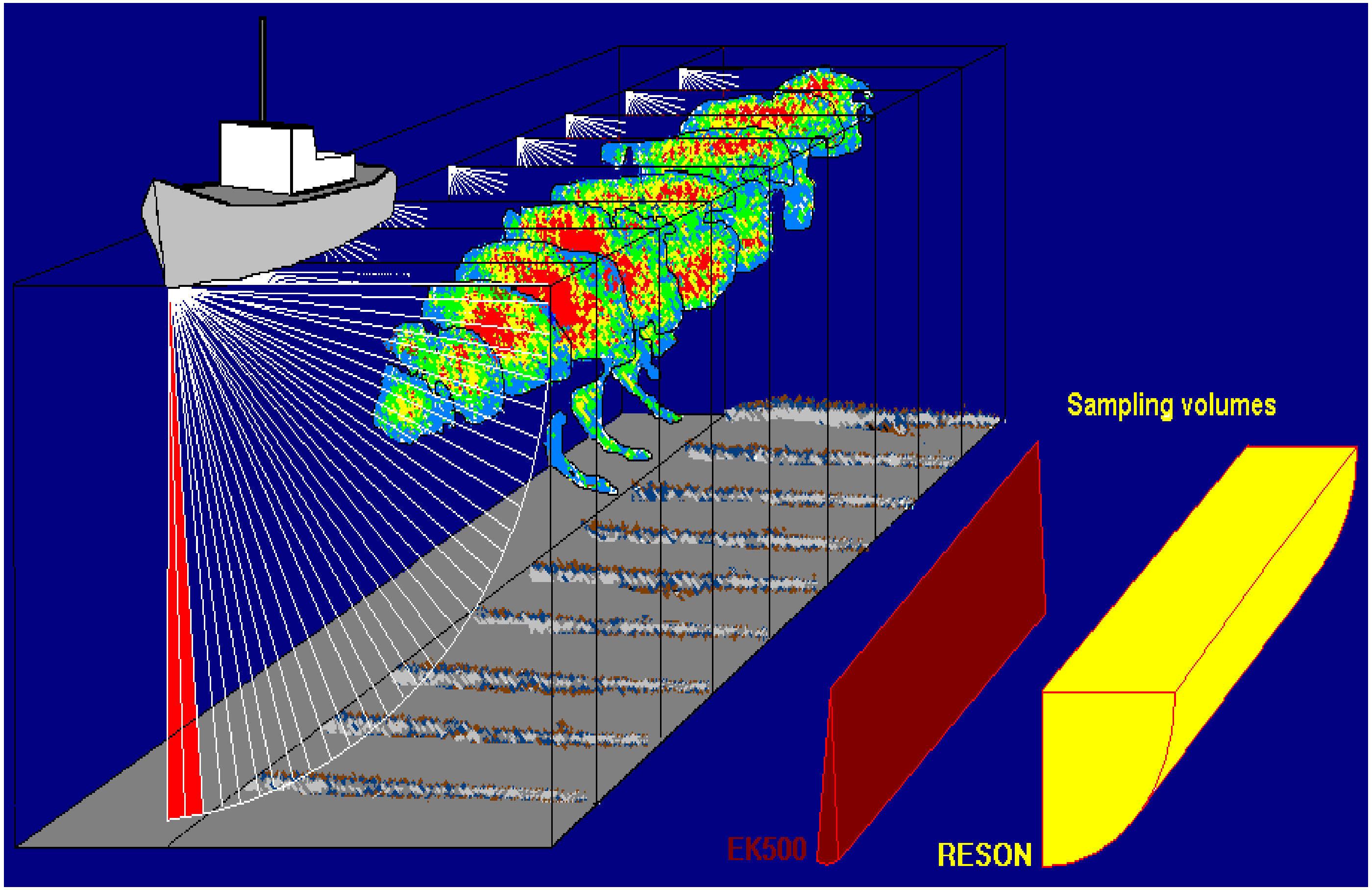
Sonar



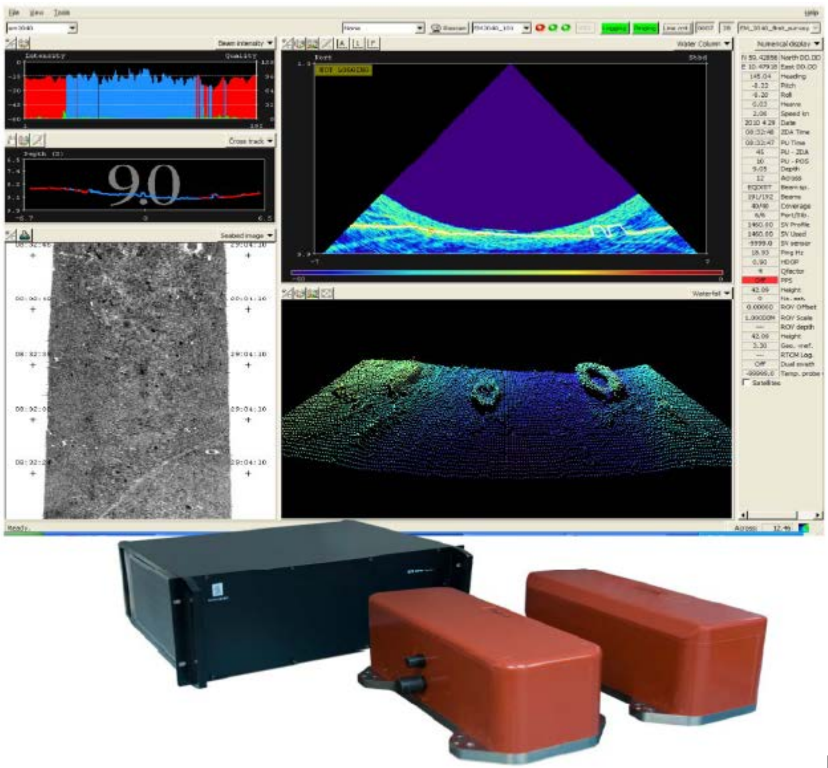
Sound ***N***avigation ***A***nd ***R***anging

- fixed swath
- sector-scanning
- omni-directional

Volume Ensonified and Swath Comparison



Multibeam Sonar Equipment



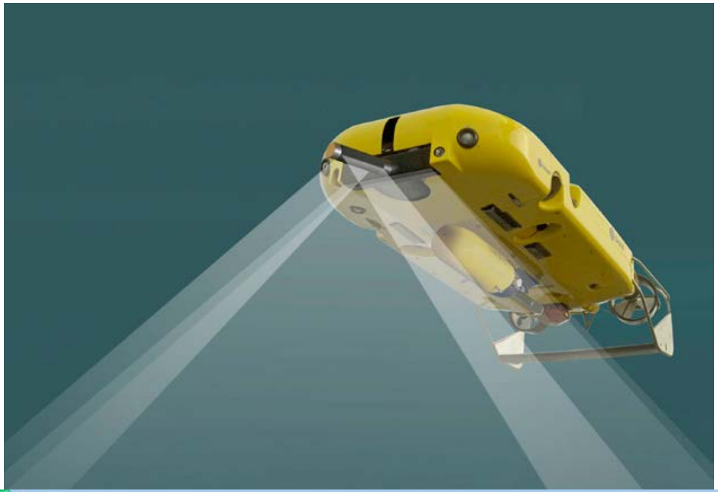
Konsberg EM 2040

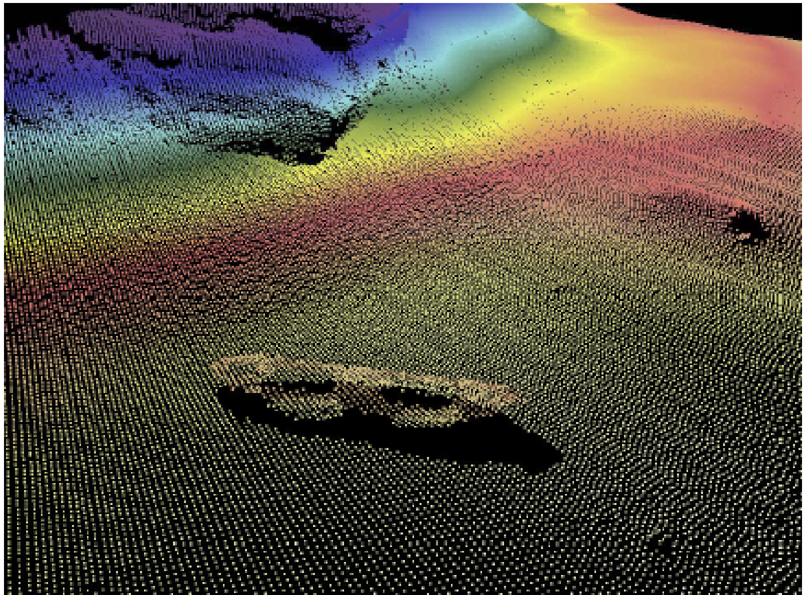
- 120^{o} – 180^{o} swath
- 0.5^{o} or 1^{o} x 1^{o} beamwidth
- 200, 300, 400 kHz chirp

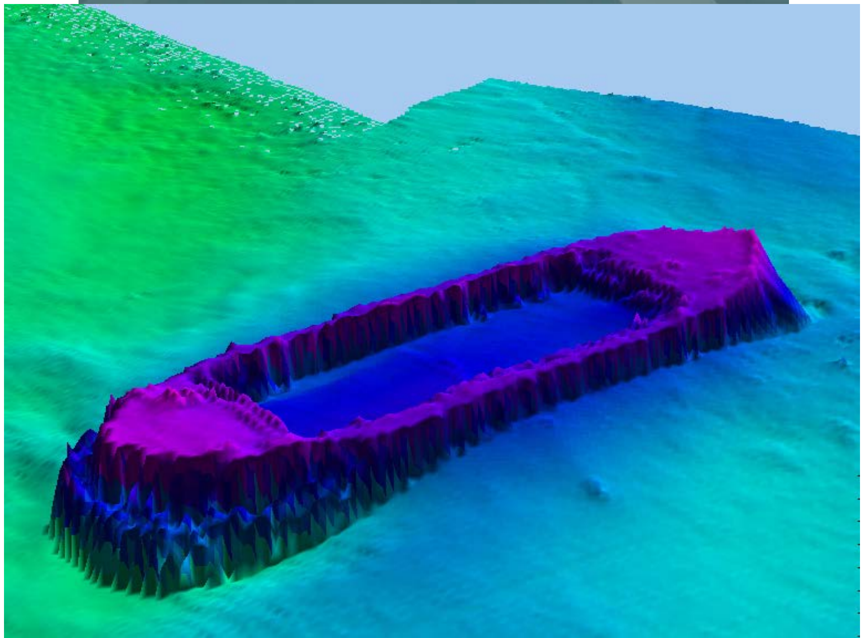
Reson Seabat 7125 (AUV)

- 128^{o} swath
- 1.1^{o} x 2.2^{o}
- 200 or 400 kHz

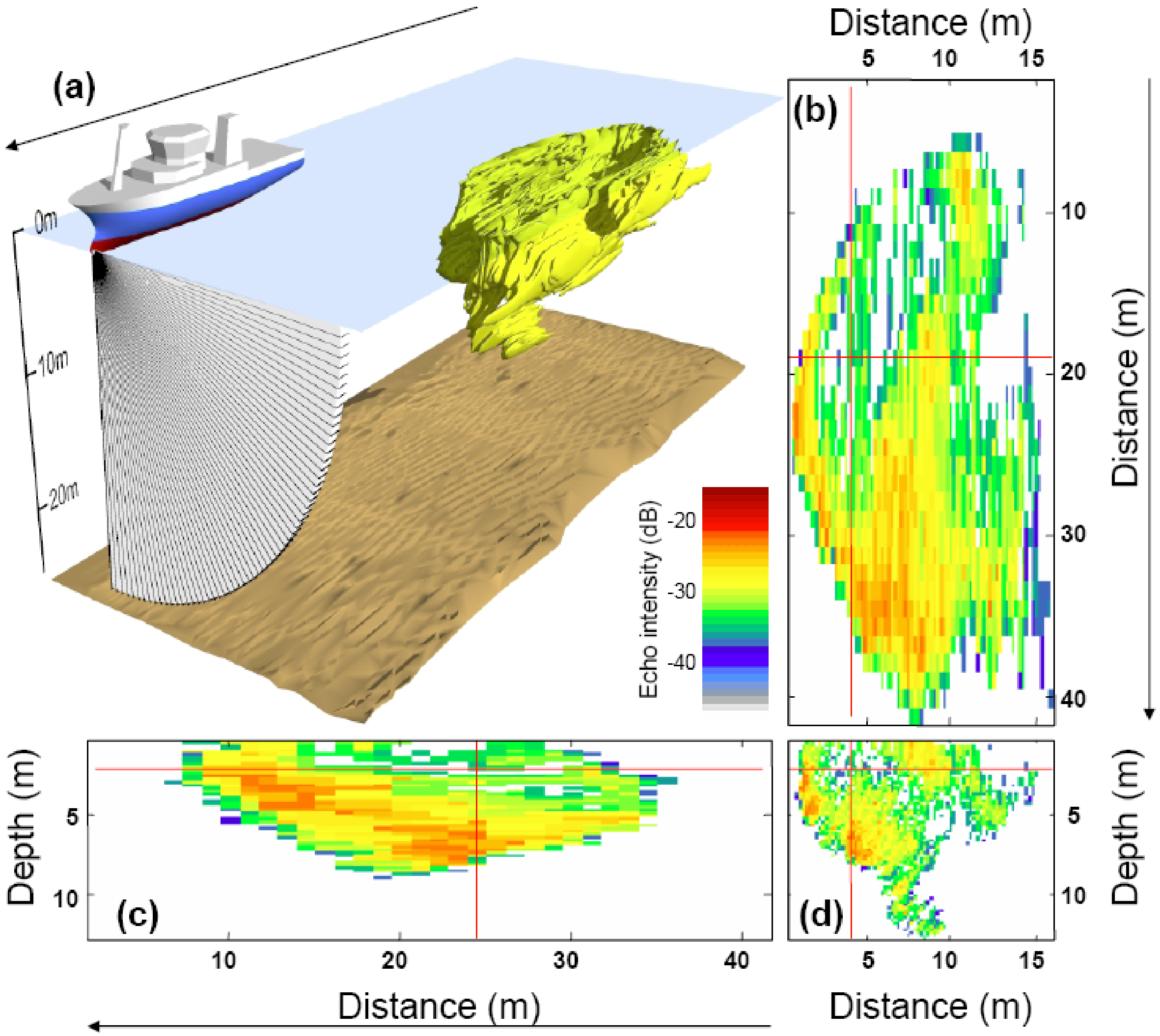
Bathymetric Applications







Water Column Application

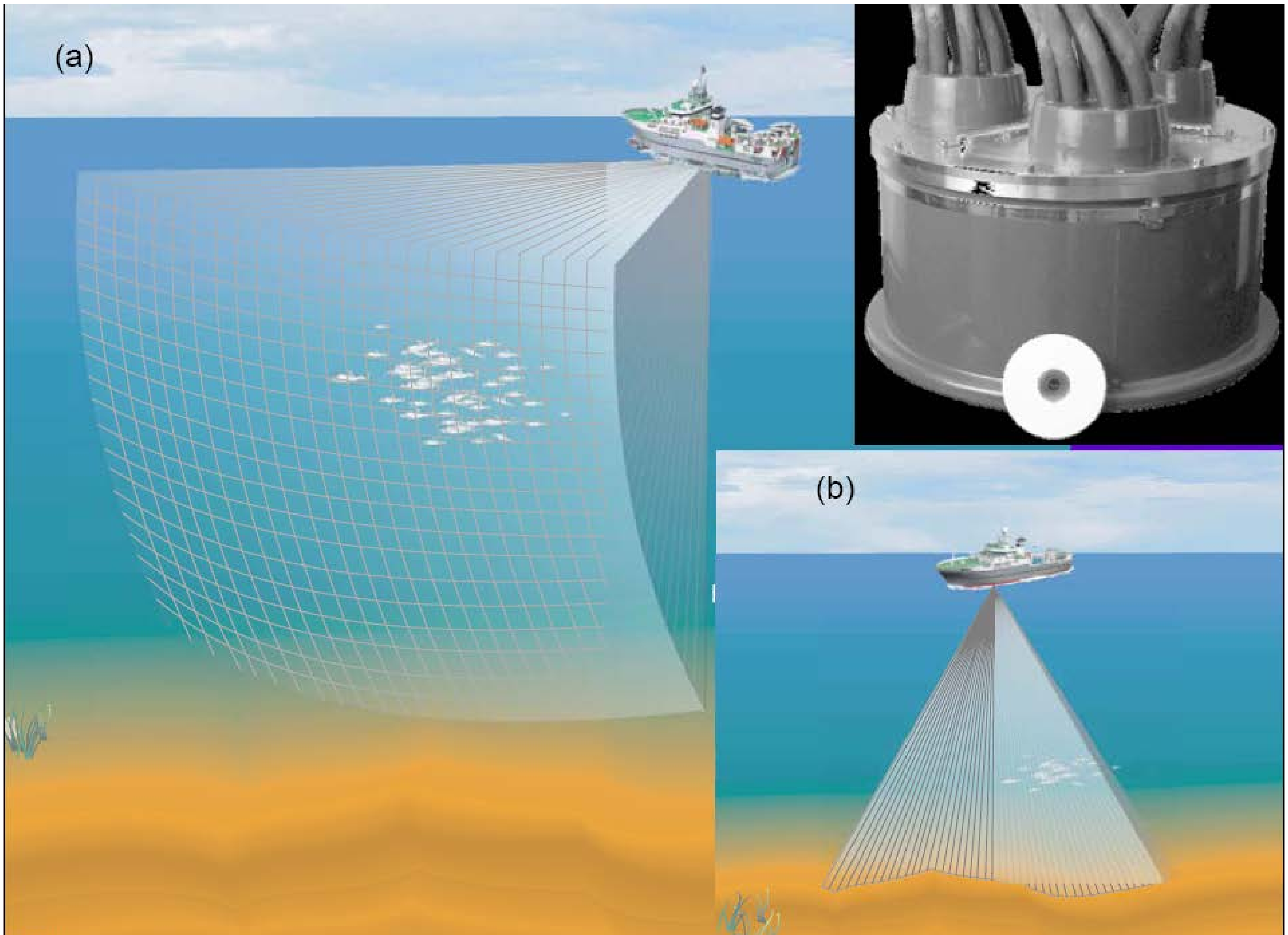


- sardine school (*Sardinella aurita*)

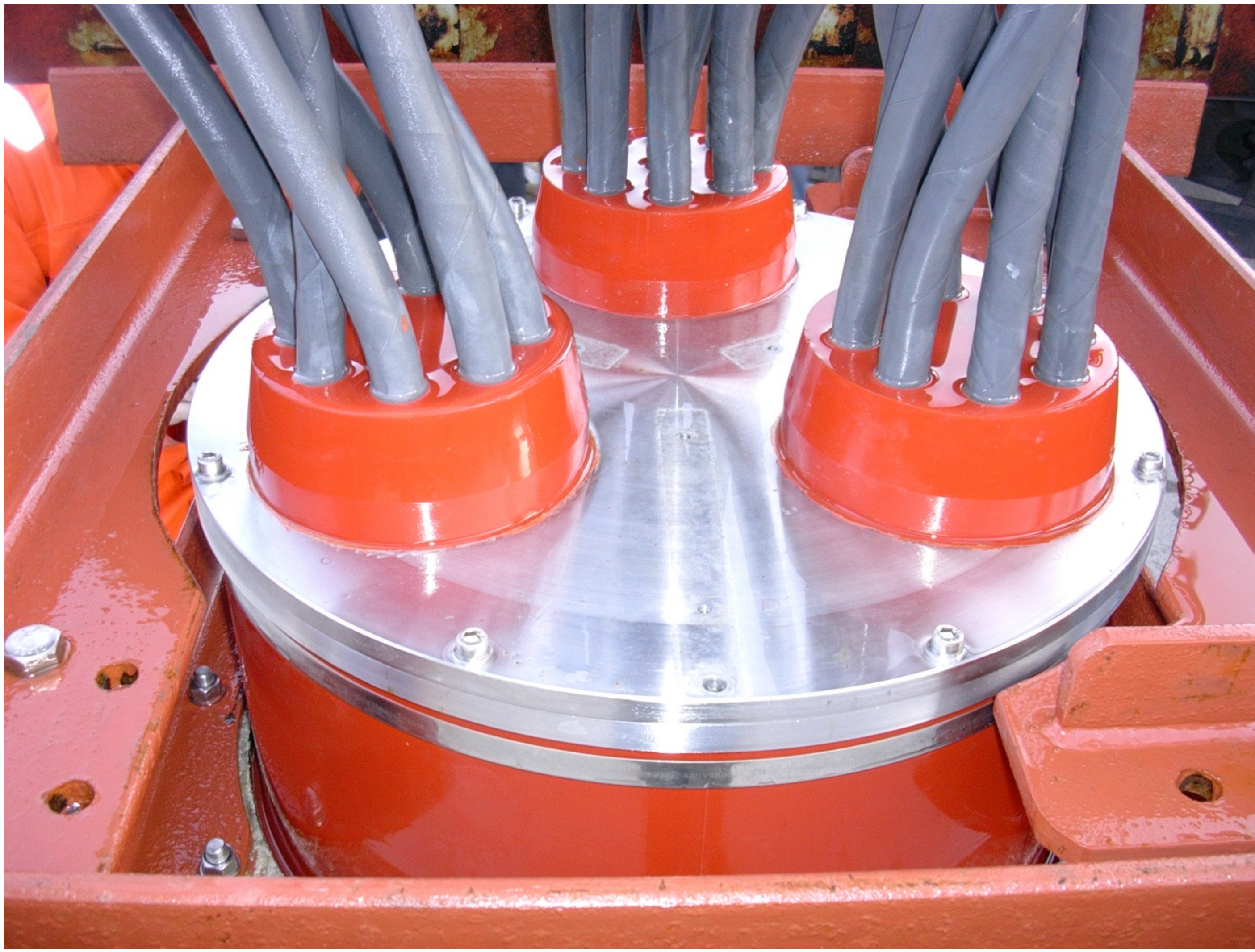
- vol. 2260 m^3, surface area 5796 m^2, length 41.6 m, width 16.7 m, height 14.9 m

P. Fernandes

Quantitative Water Column: ME/MS 70



ME 70 Transducer



- 25 cables
- 32 conductors/cable
- 800 channels
- 70 kHz – 120 kHz
- User configurable

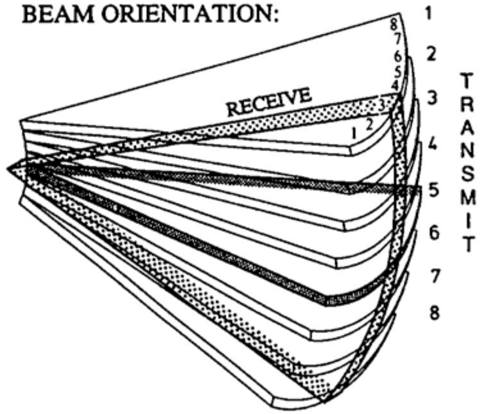
Increased Swath Applications

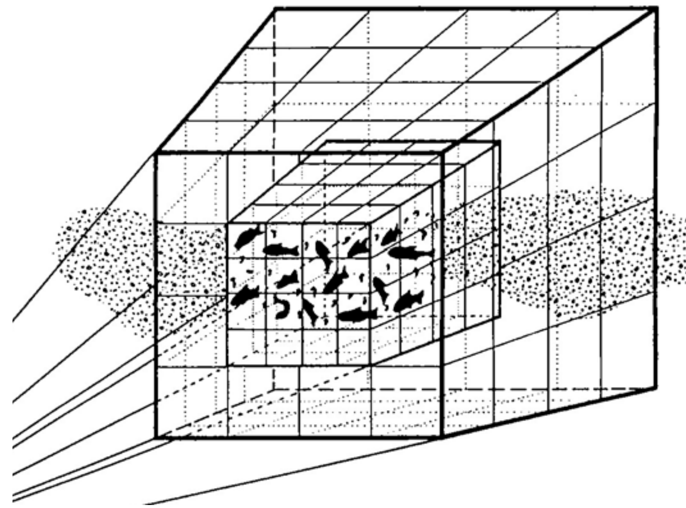
- target volume description (e.g. schools)
- target classification, discrimination
- target behavior (e.g. hydro dam passage)
- target abundance

Data Attributes: angle-dependent backscatter, volume insonification

3. Increased Resolution

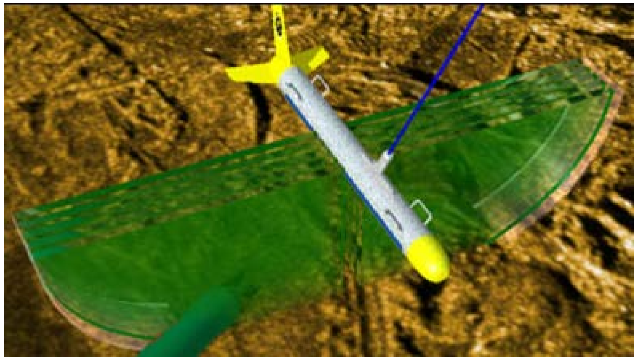
Fish TV (~1997)





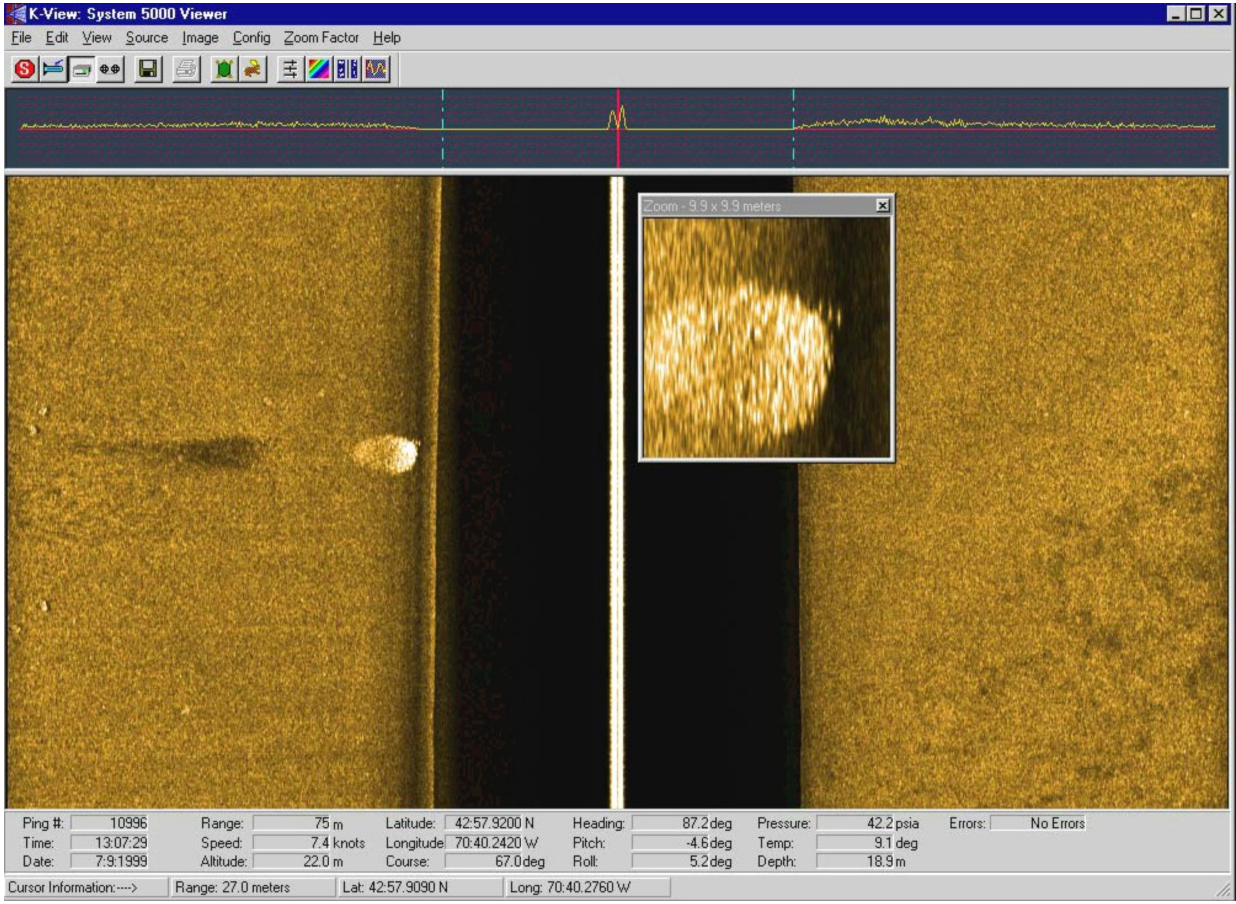
J. Jaffe

Multibeam Side-Scan Sonar



- 300 m swath at 150 m depth
- 455 kHz

Mackerel school



Blueview Sonar

www.blueview.com

2-D Imaging Sonar

P900- 45 to 130 sonar heads

- 45 to 130^{o} view (1 x 20^{o} beam width)
- 256 to 768 beams, spaced 0.18^{o}
- frequency 900 kHz
- size 11.3 x 5 inches

3-D Mechanical Scanning Sonar

BV-5000

- LIDAR (laser) system
- 360^{o} pan x 180^{o} tilt
- point cloud

MB1350-45, 2250-45

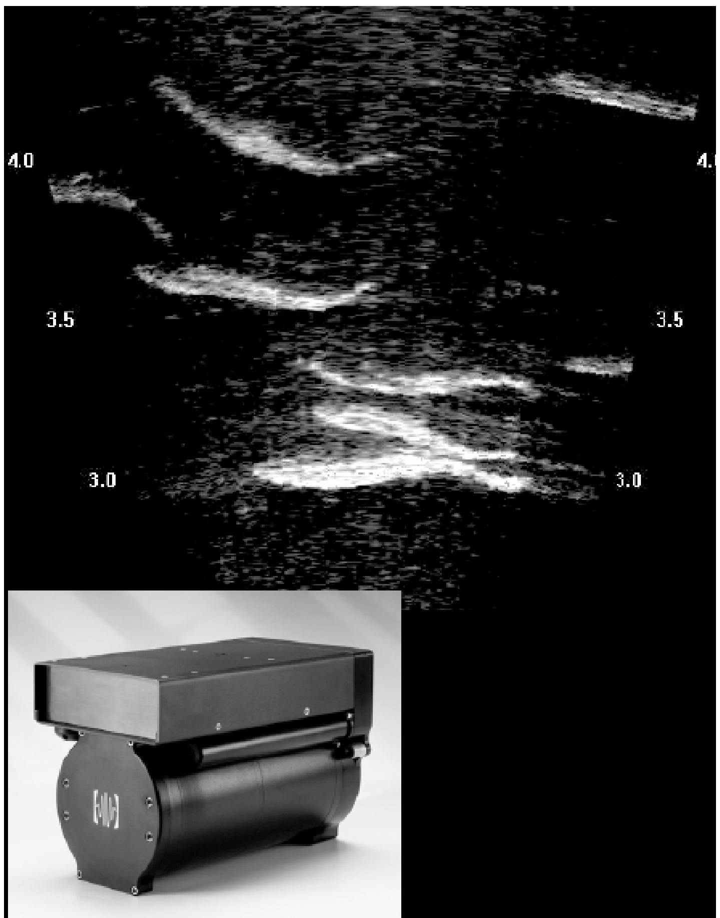
-1.35 to 2.25 MHz sonar

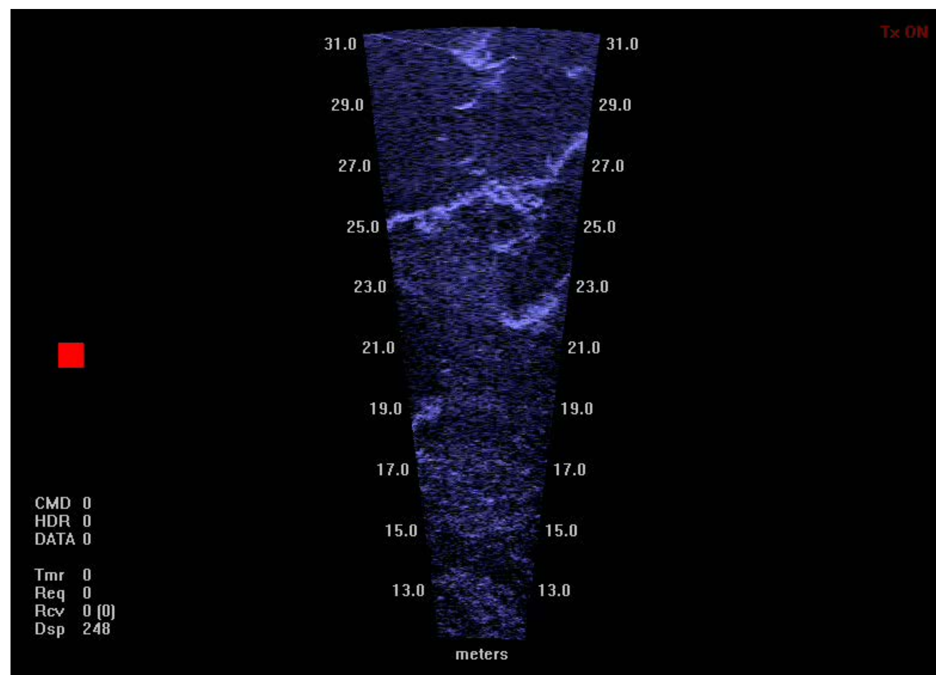
- 45^{o} x 1^{o} field of view
- 256 beams, 0.18^{o} spacing

Dual Frequency Identification Sonar: DIDSON

multibeam acoustic imaging sonar

- 900 kHz - 1.8 MHz
- 96 beams
- 0.3º horizontal x 11º vertical





Multibeam Imaging Sonar Applications

- near optical verification of targets (species identification)

- potential tracking of targets (harbor security)

- autonomous underwater inspection (inhospitable locations)

Data Attributes: high frequency, high resolution, low volume or range, approaching optical image

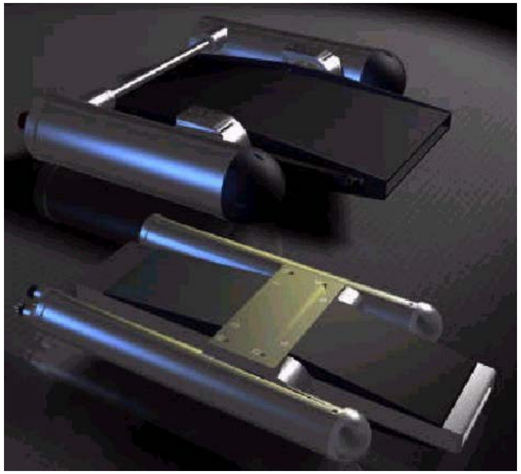
4. Integration with Other Sensors

- specialized acoustic or other samplers
- not typically used in large scale abundance surveys
- data streams integrated with acoustic sensor data

Optical Instruments

Video Plankton Recorder (VPR)

Optical Plankton Counter (OPC)

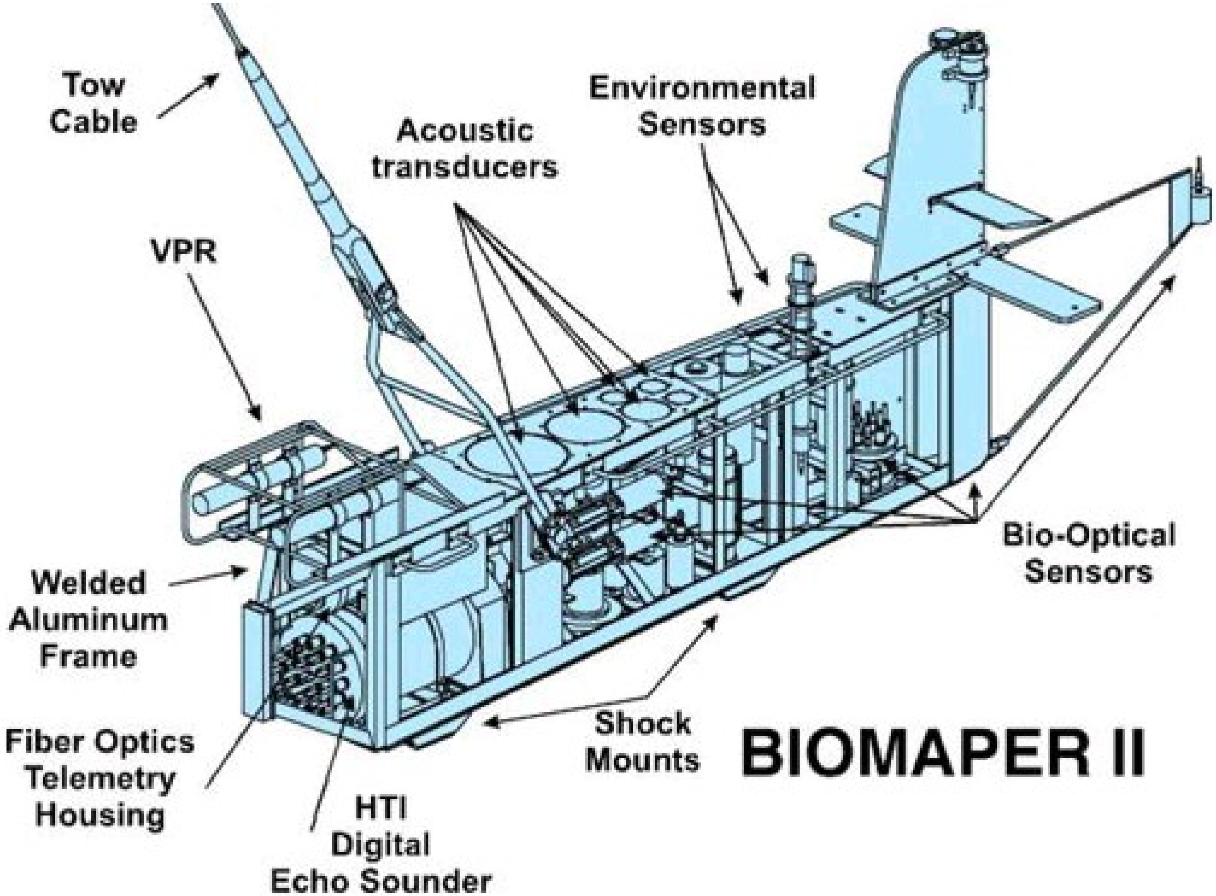


***Li**ght **D**etection **A**nd **R**anging (LIDAR)*

Integrated Alternate Platforms

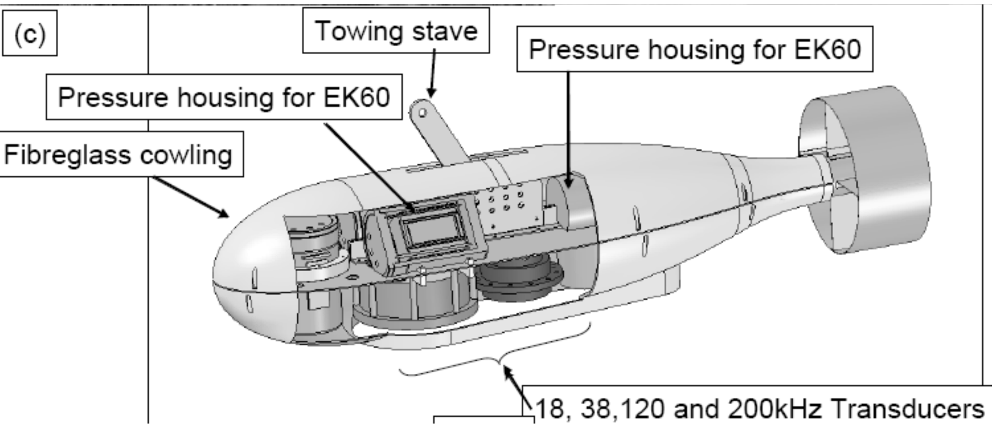
- increase the number and type of sampling tools
- increase the resolution and range of sampling
- increase the number of trophic levels sampled
- reduce radiated platform noise

Early Application: BioMapper II

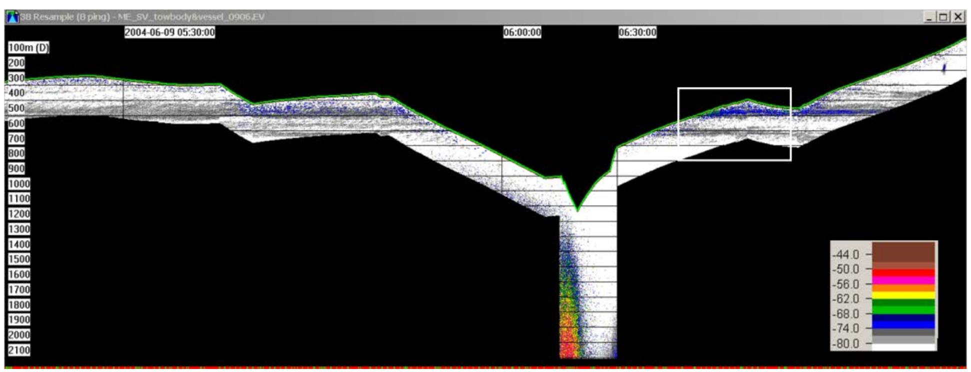


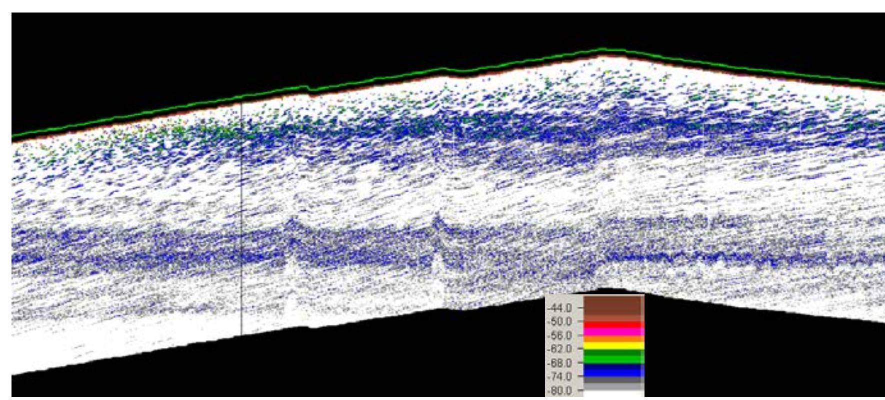
P. Wiebe

Deepwater Towbody

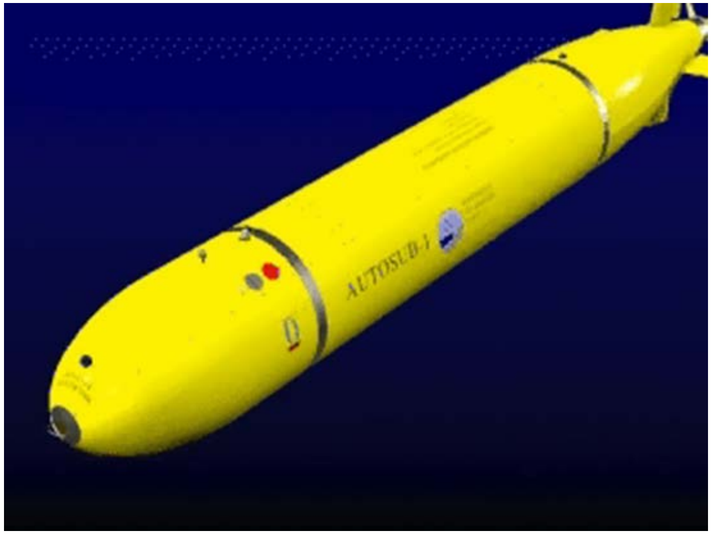


H.P. Knudson



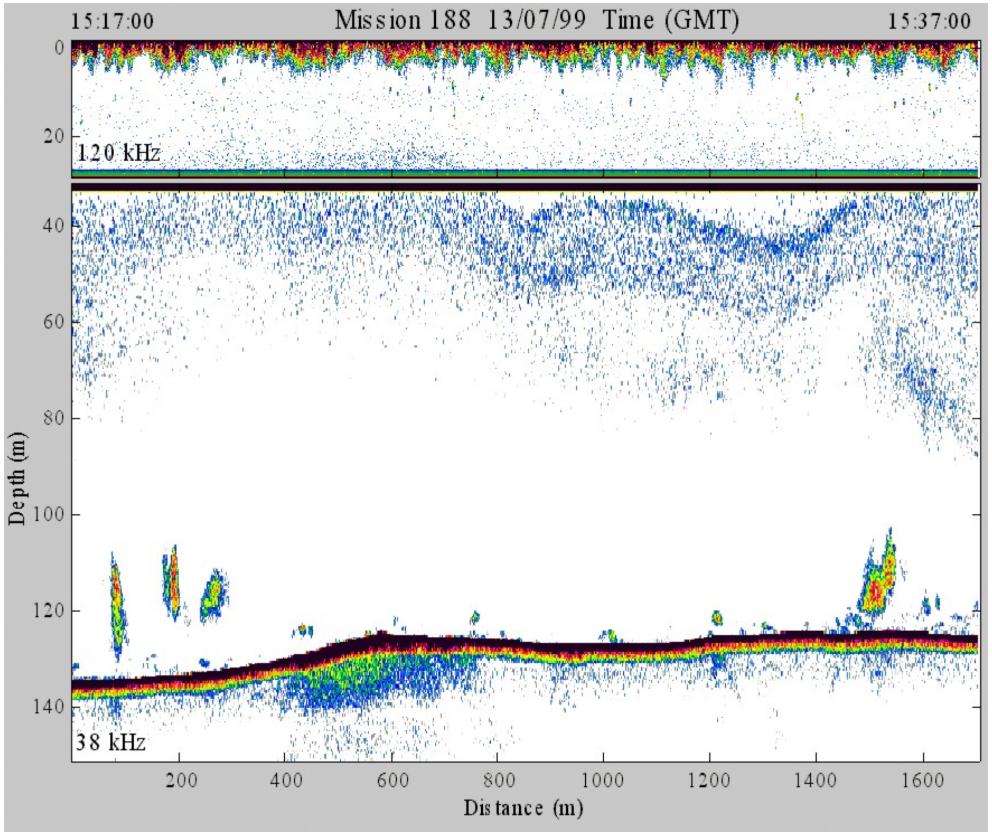


Early Application: AutoSub



120 kHz

38 kHz

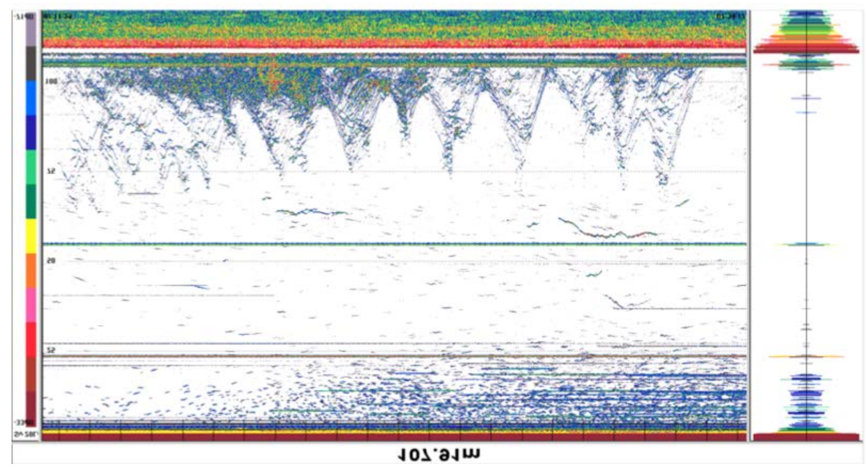


Autonomous Underwater Vehicle (AUV)

- acoustically quiet
- un-manned, docking station
- additional sampling packages
- slow speeds but near interfaces (surface, bottom, ice)

Acoustic Buoy

- free floating or moored at depth
- echosounder, compass, inclinometer, depth sensor
- additional scientific payload

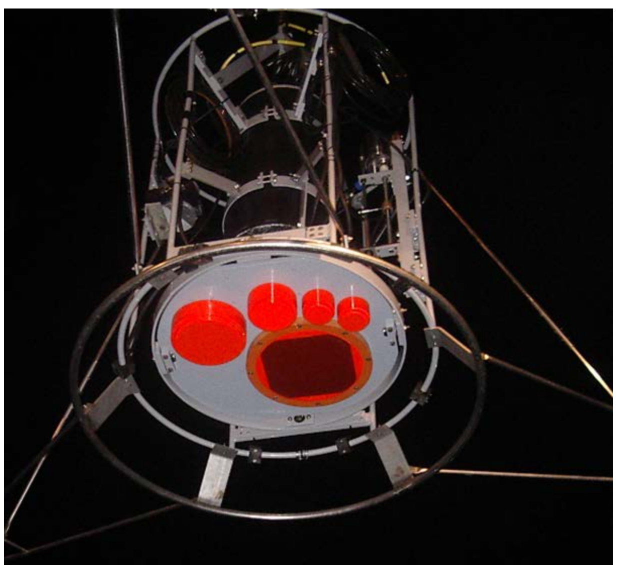


Age-0 cod and haddock near surface

www.metas.no

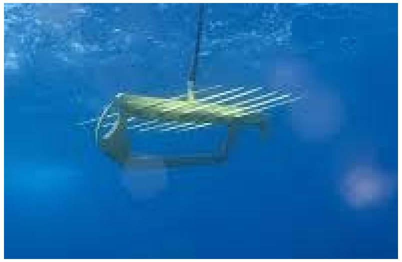
Acoustic Probe

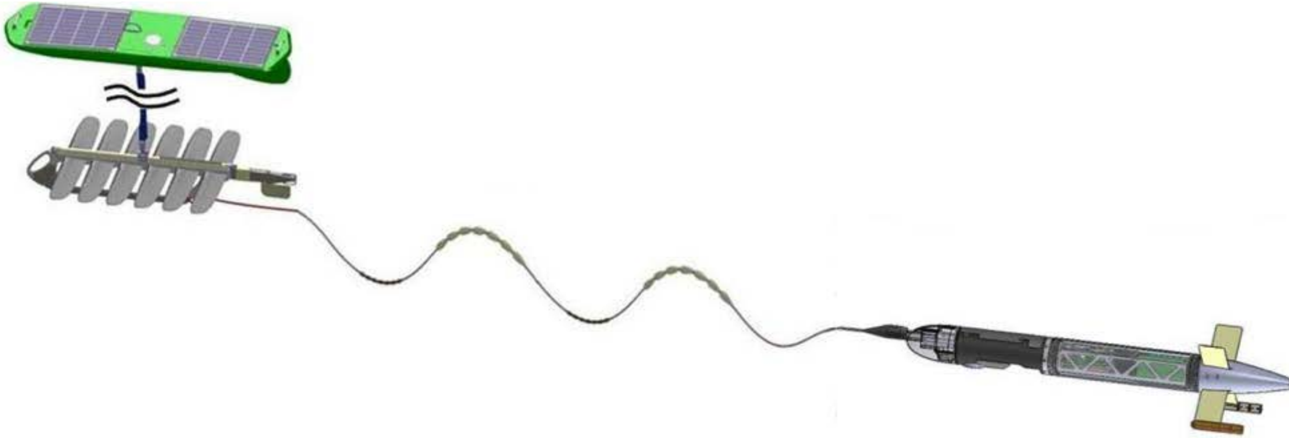
- autonomous echosounders
- 38, 70, 120, 200, 333 kHz
- motorized transducer platform
- calibrations, short range TS

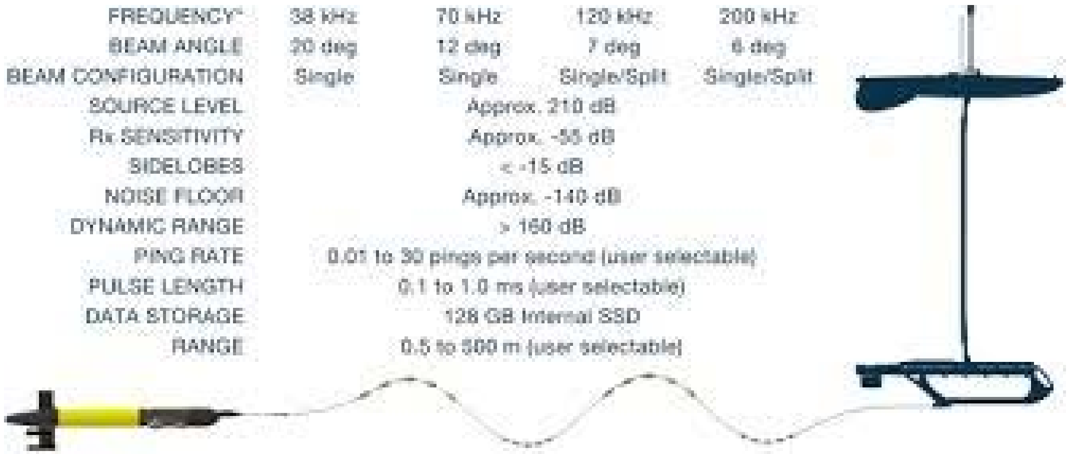


IMR

Wave Glider + echosounder







FREQUENCY*	38 kHz	70 kHz	120 kHz	200 kHz
BEAM ANGLE	20 deg	12 deg	7 deg	6 deg
BEAM CONFIGURATION	Single	Single	Single/Split	Single/Split
SOURCE LEVEL	Approx. 210 dB			
Rx SENSITIVITY	Approx. -55 dB			
SIDELOBES	< -15 dB			
NOISE FLOOR	Approx. -140 dB			
DYNAMIC RANGE	> 160 dB			
PING RATE	0.01 to 30 pings per second (user selectable)			
PULSE LENGTH	0.1 to 1.0 ms (user selectable)			
DATA STORAGE	128 GB Internal SSD			
RANGE	0.5 to 500 m (user selectable)			

*Towbody can be equipped with two transducers in any configuration

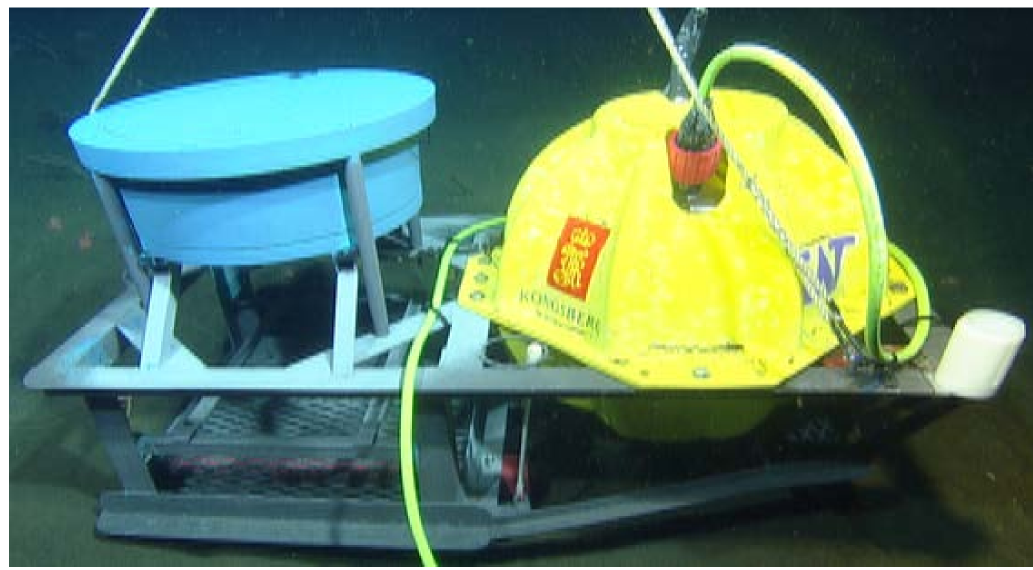
liquidr.com

Temporal Platforms

Acoustic Lander, IMR

battery powered, autonomous

DEIMOS, UW



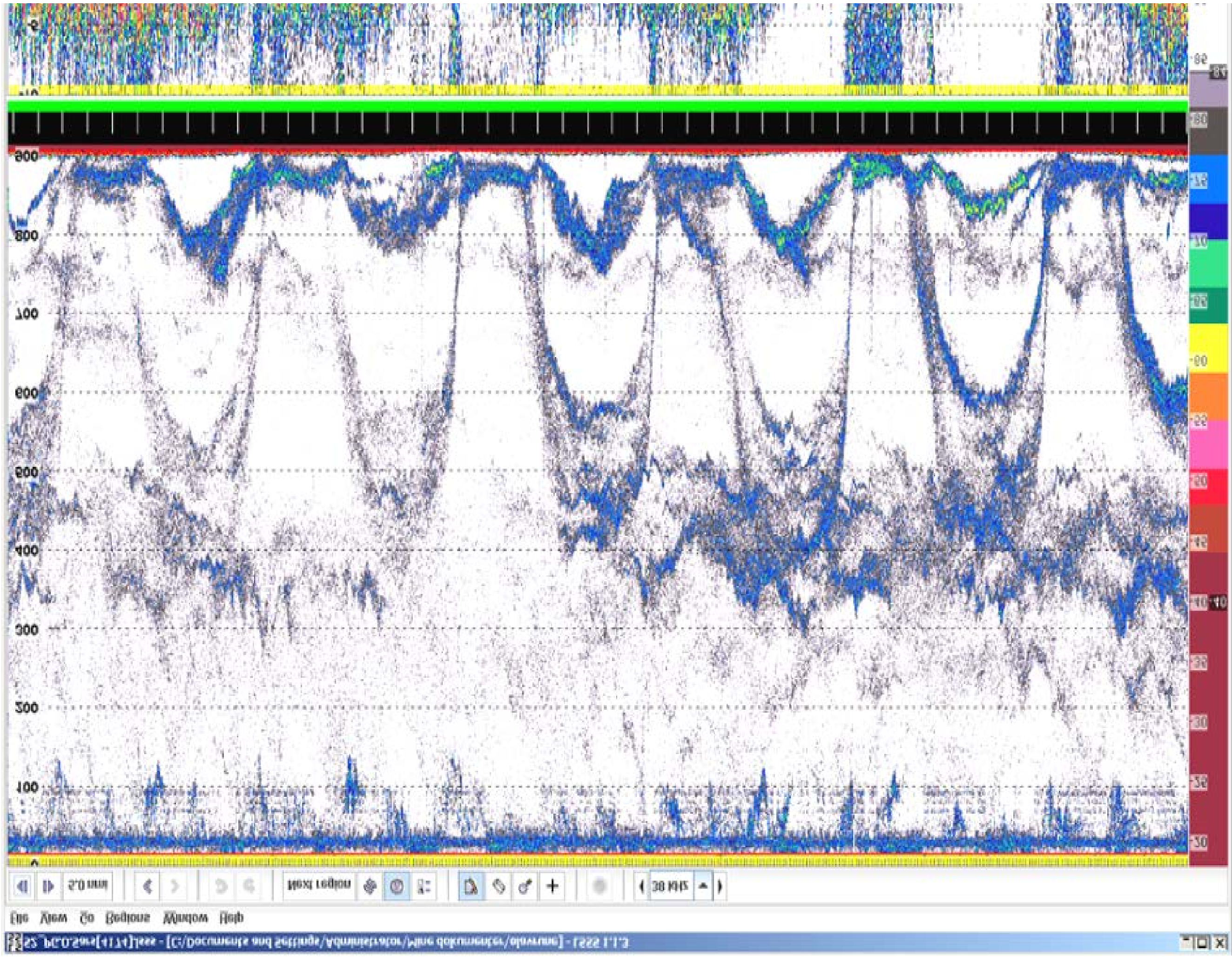
land powered, cabled observatory

Acoustic Lander Echogram

10 m

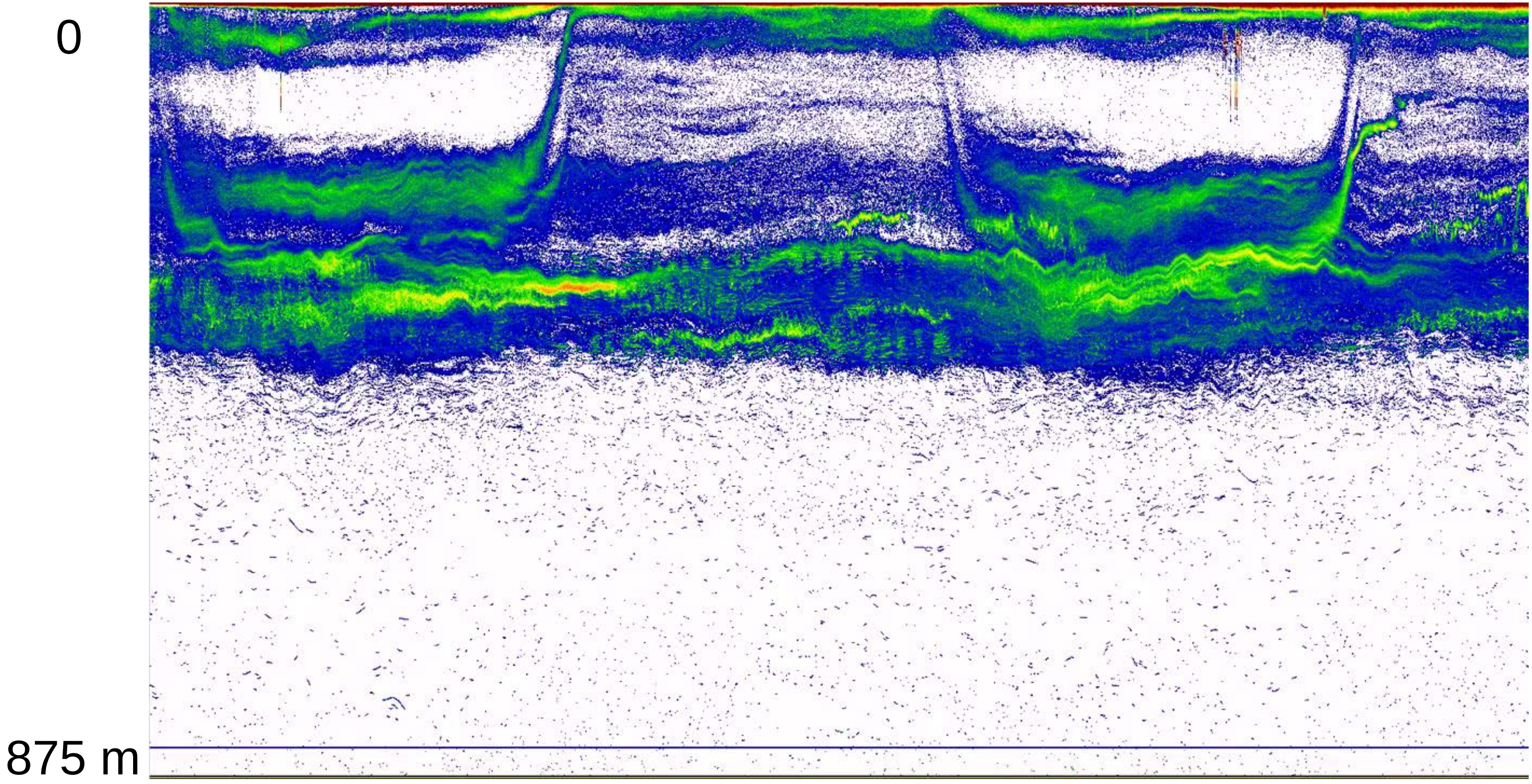
900 m

6.5 days



OR Godoe

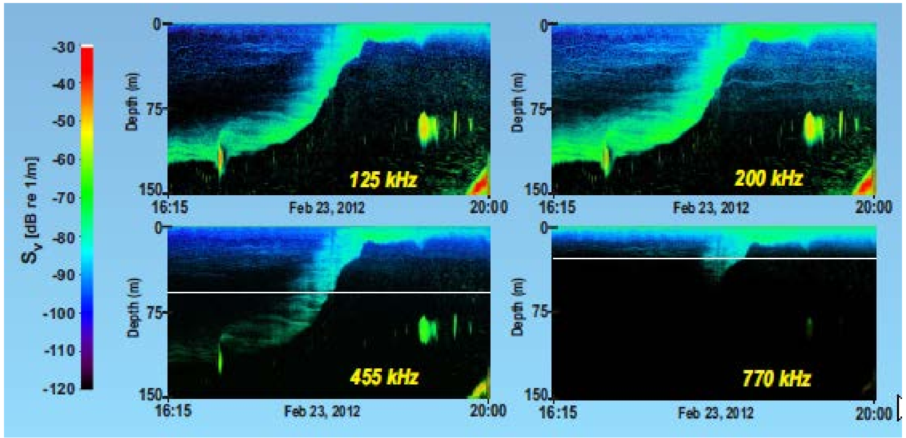
DEIMOS Data

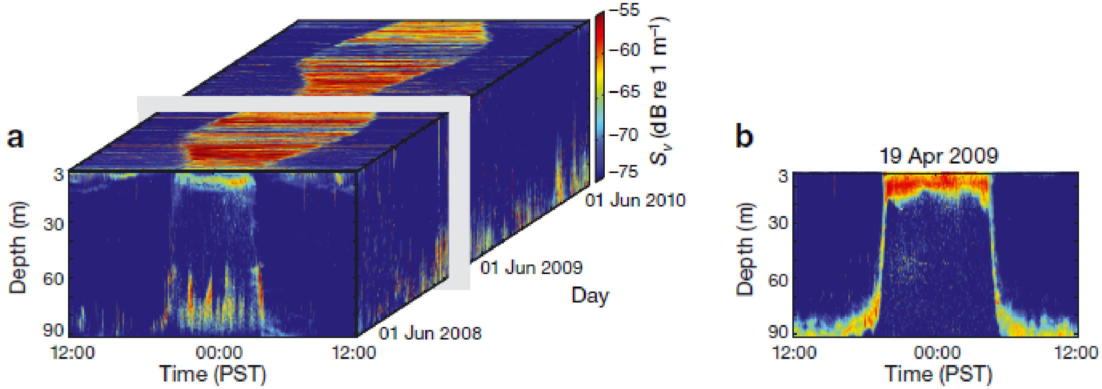


Autonomous Acoustic Recorders

ASL

Single and multifrequency configurations



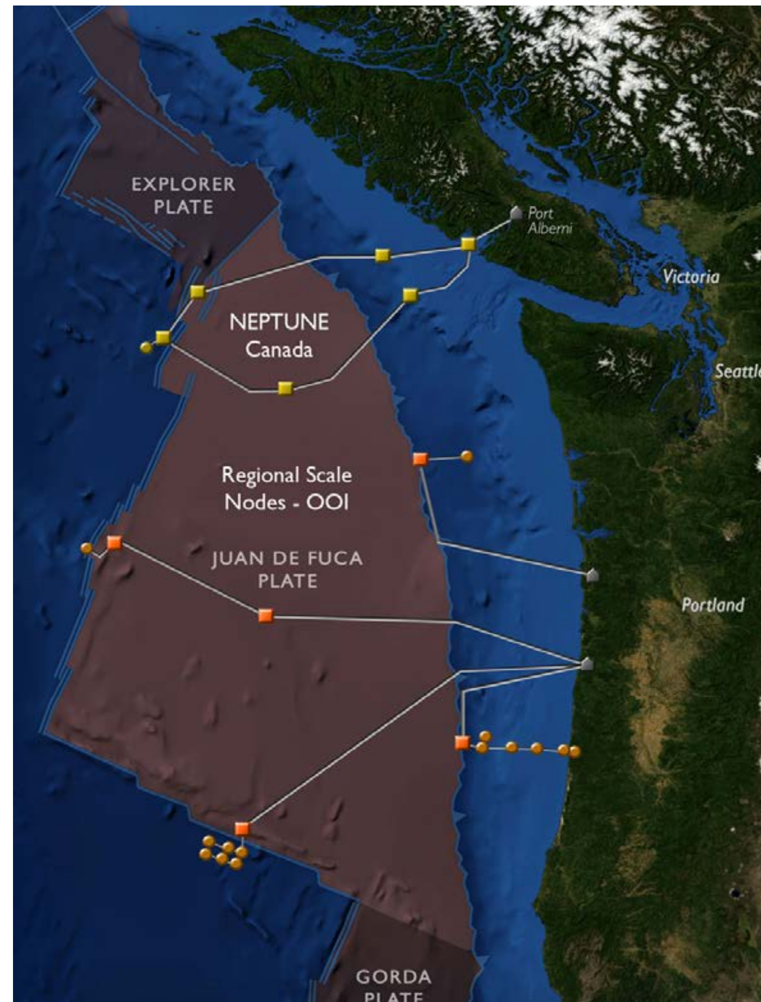


Sato et al. 2012

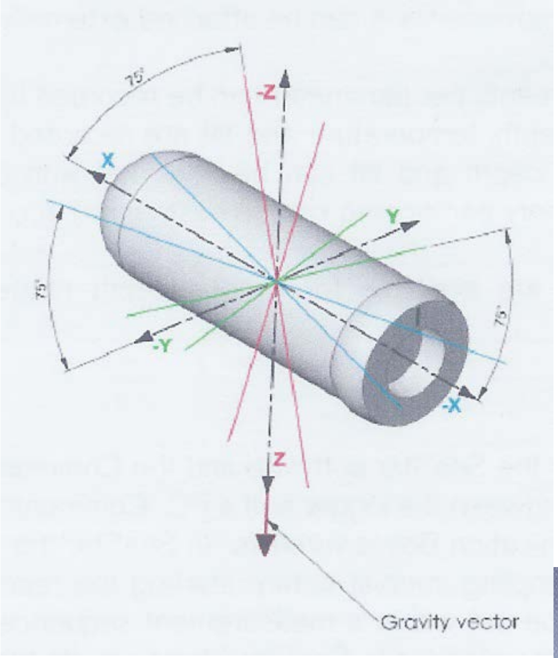
OOI: cabled & uncabled Ocean Observatory

Regional cabled

Stable Platform?

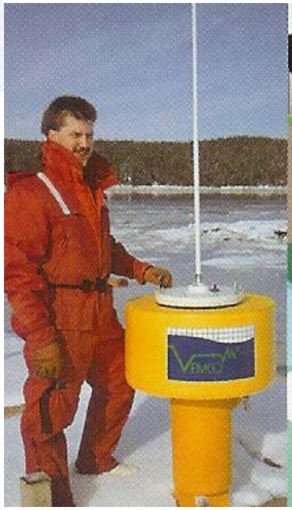


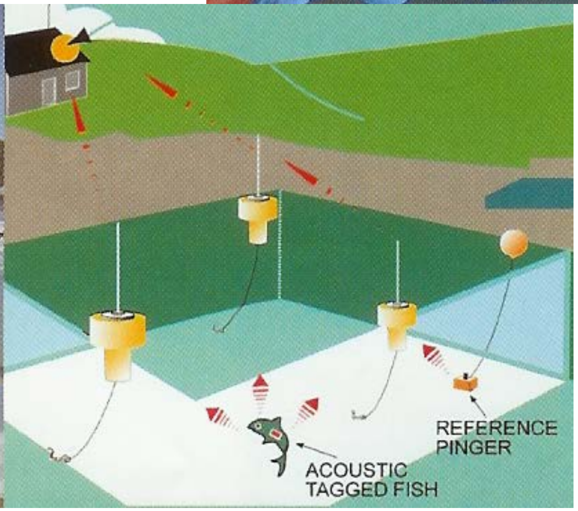
Active Acoustic Tags



Orientation tag

Tagged fish



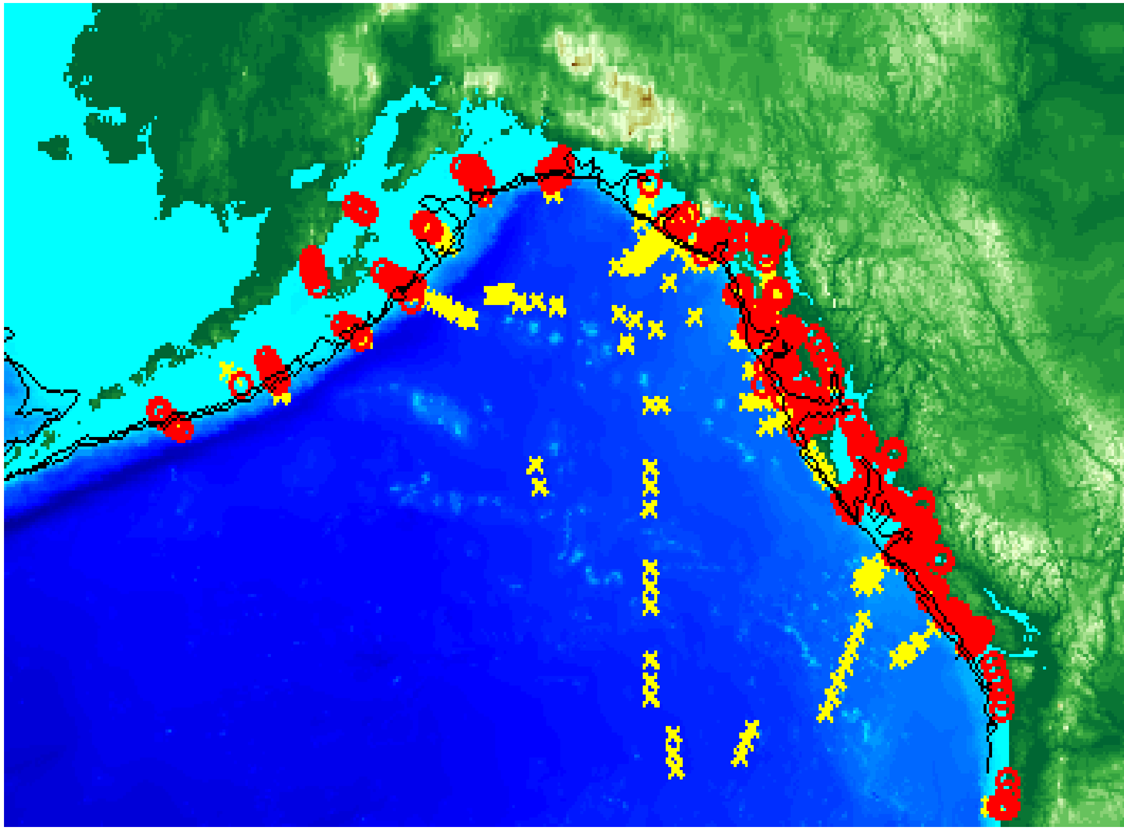


Hydrophone array

POST: Pacific Ocean Shelf Tracking

Juvenile salmon remain on-shelf for many months

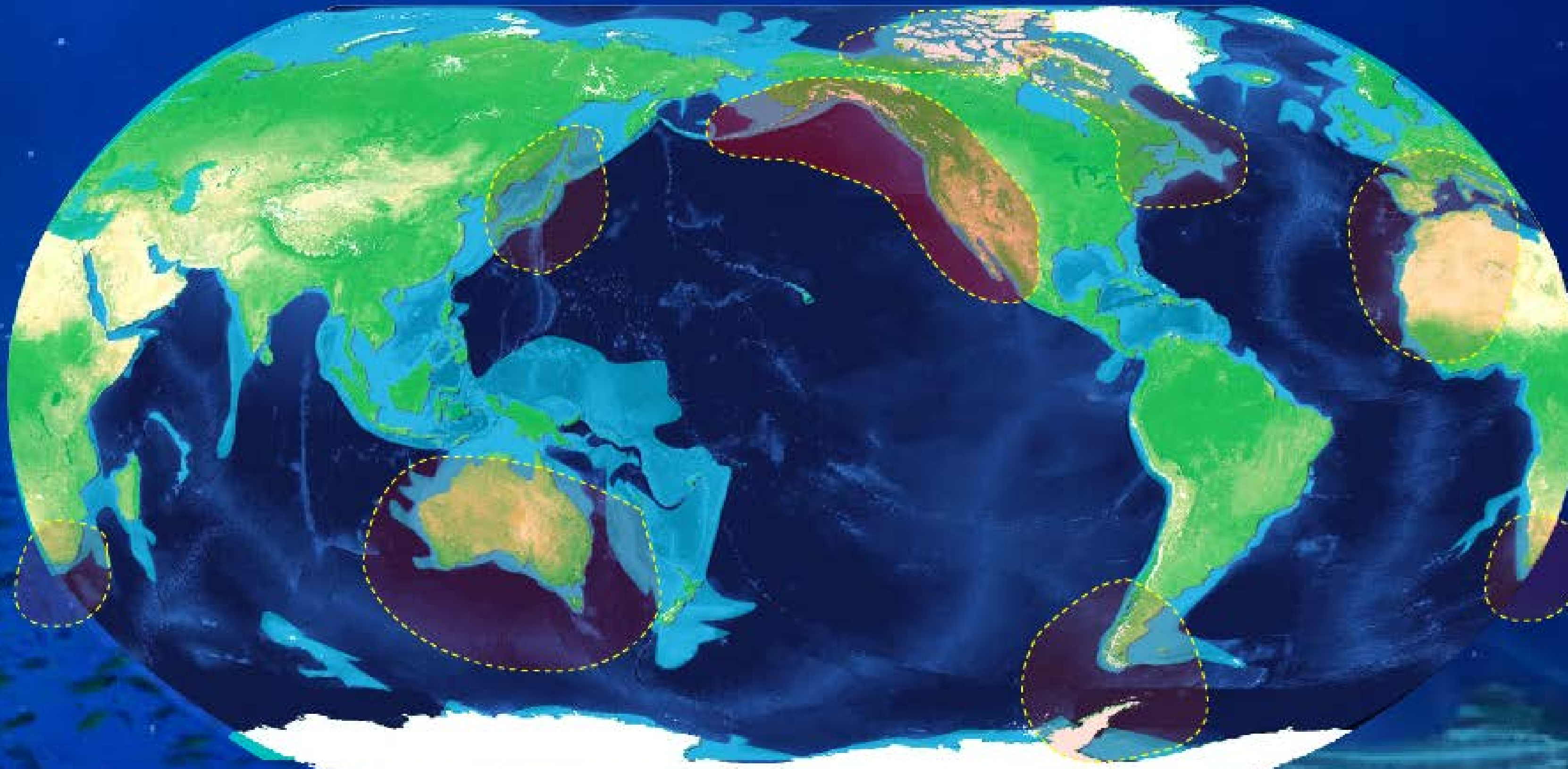
- Red circles: where salmon are caught
- Yellow crosses: zero catches



D. Welch

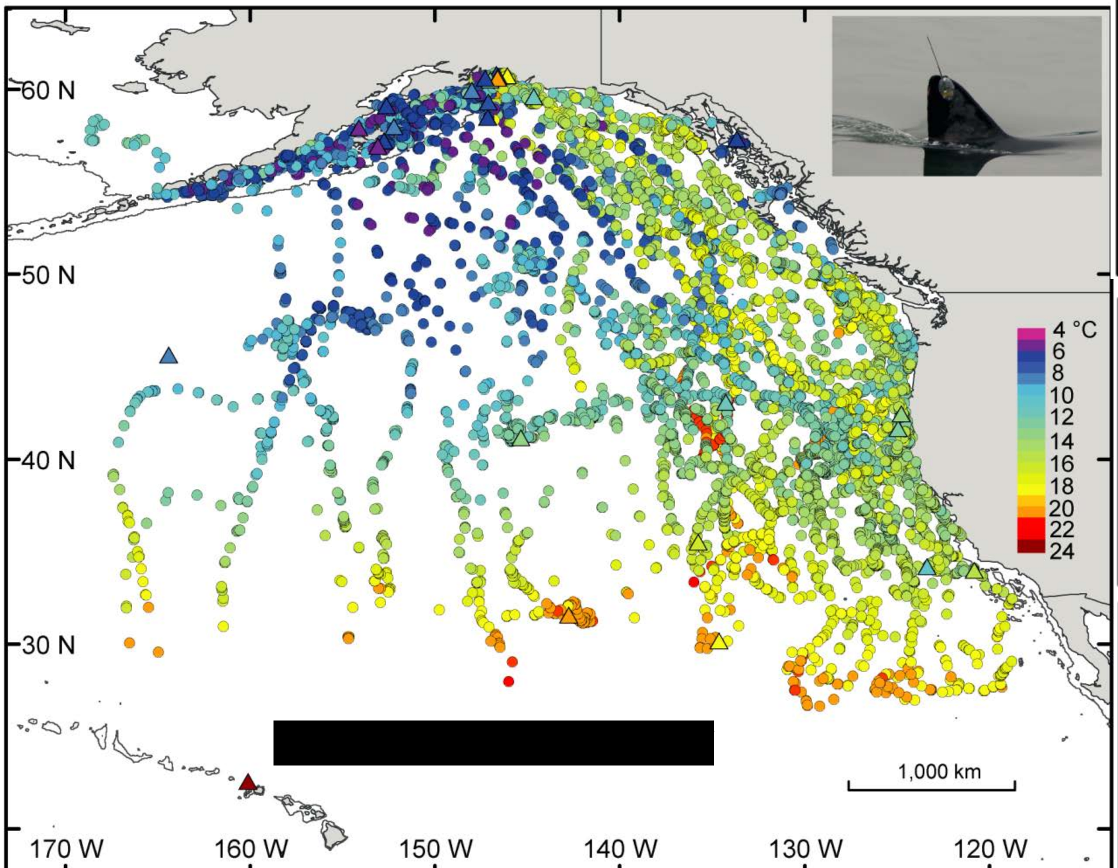
OCEAN TRACKING NETWORK

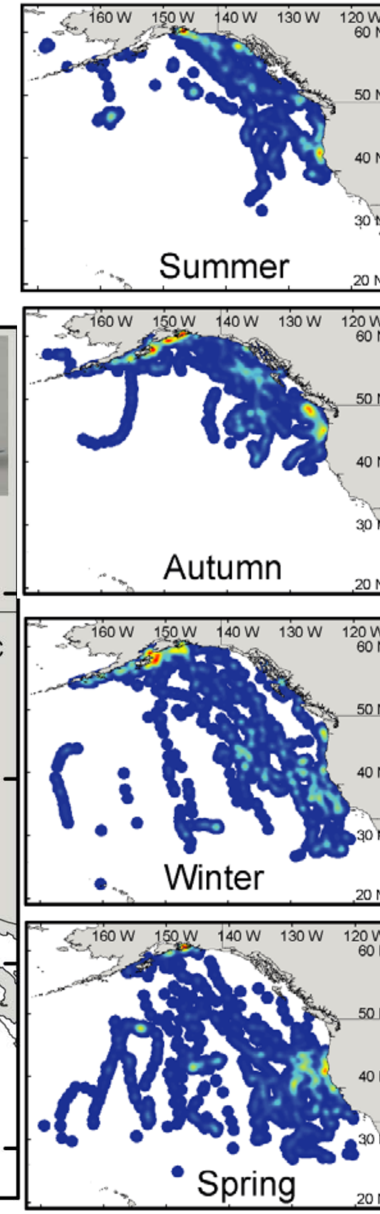
LISTENING CURTAINS



TOPP: Tagging of Pacific Pelagics

Salmon Sharks as temperature probes

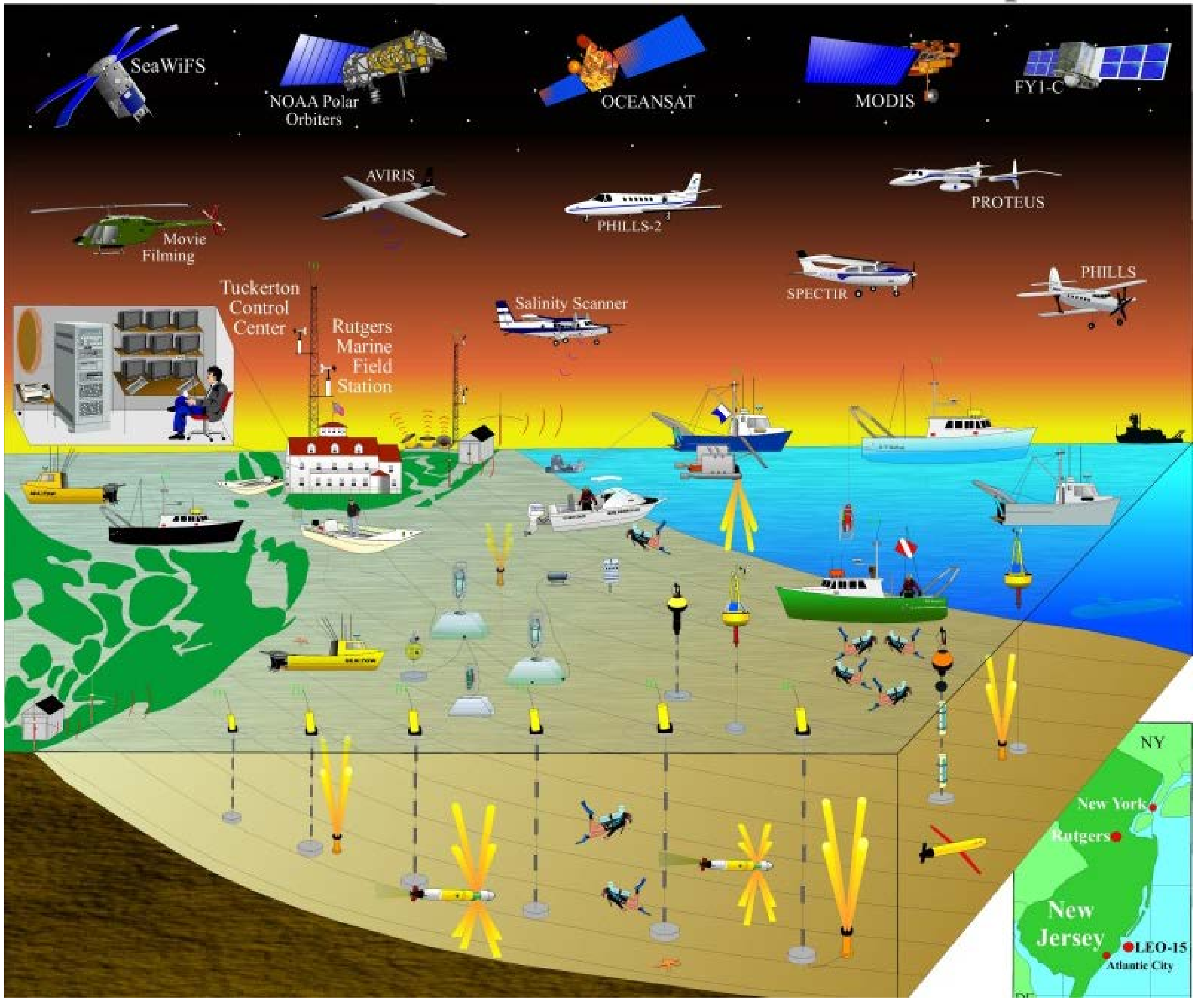




B. Block

Integrated Ocean Sensing

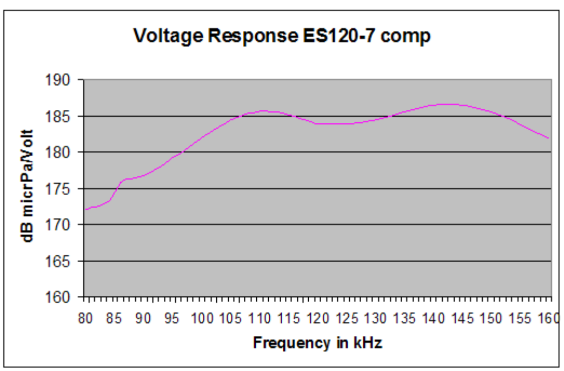
LEO 15: Long-term Ecosystem Observatory (2000-2001)

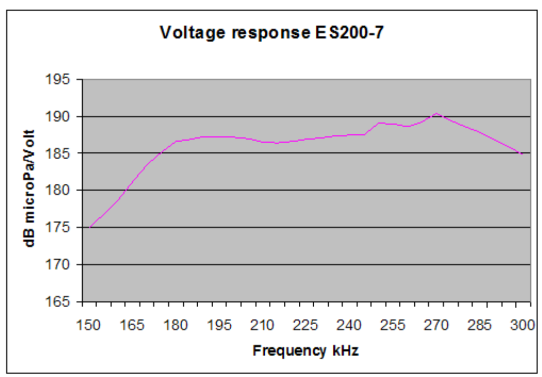


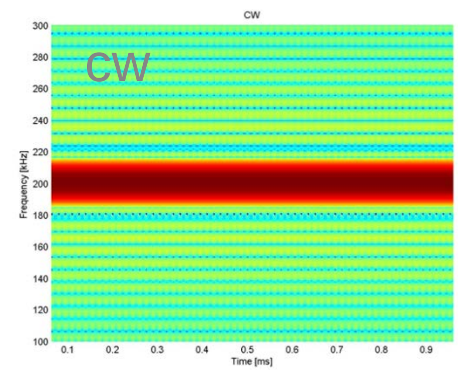
Technology Convergence?

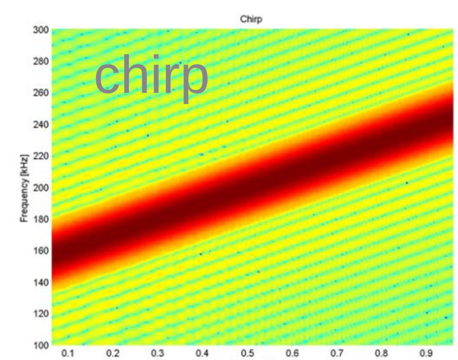
EK 80: narrowband and wideband echosounder

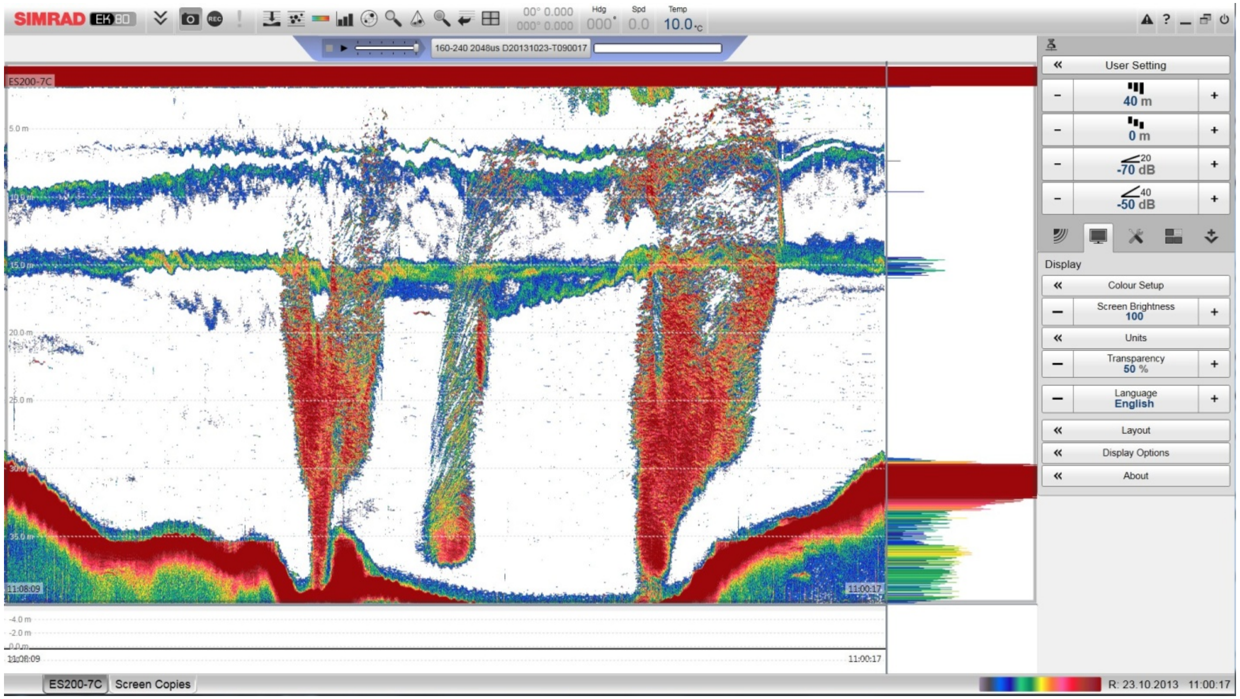
- Split beam or wideband (4 channels)
- High resolution



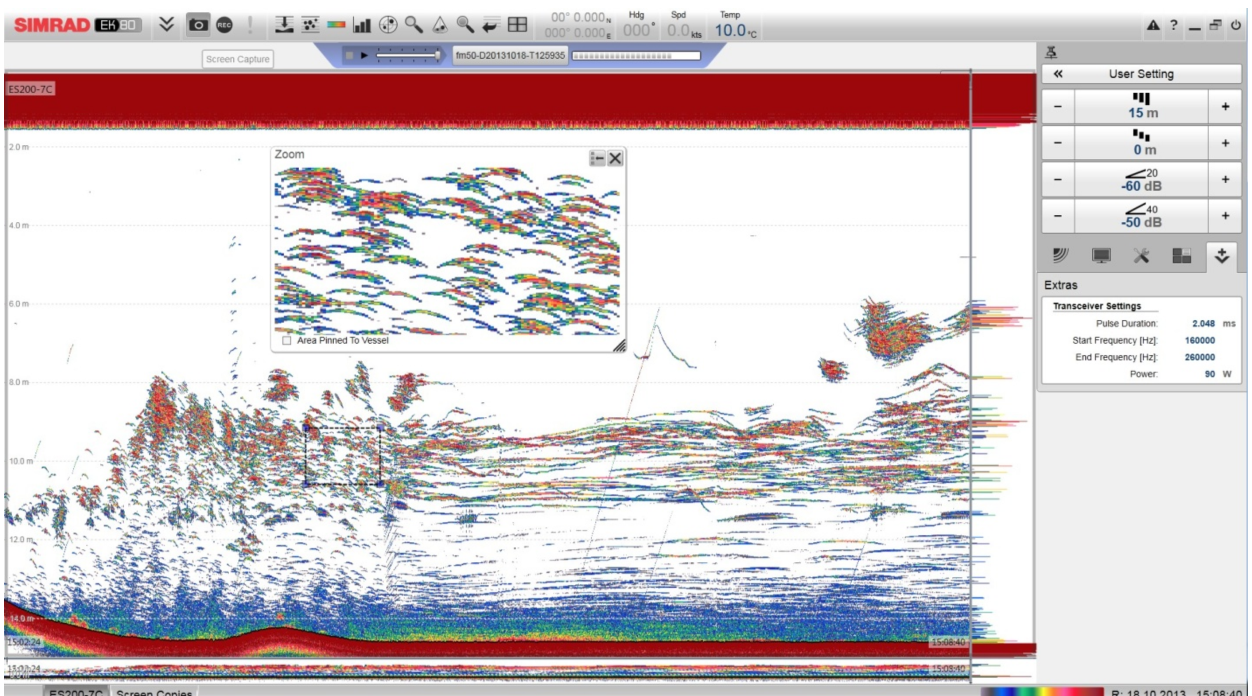








- marine
- chirp 160-240 kHz
- plankton layers
- herring schools



- freshwater
- chirp 160-260 kHz
- larval fish bottom
- schooling fish, methane

Sampling Gear Strengths/Weaknesses

	Nets	Pumps	Acoustics	Optics
Physical Sample	🙂	🙂	🙁	🙁
High Tow Velocity	🙁	🙁	🙂	🙂
Rapid Processing	😐	😐	🙂	😐
Rare Taxa	🙂	🙁	😐	🙁
Fragile Taxa	🙁	🙁	😐	🙂
Fine Vertical Resolution	😐	🙂	🙂	🙂
Fine Horizontal Resolution	🙁	😐	🙂	🙂
High Taxonomic Resolution	🙂	🙂	🙁	😐
Relative Cost	**MEDIUM**	**LOW**	**MEDIUM**	**HIGH**
Low Avoidance	😐	🙁	🙂	😐

courtesy M. Benfield