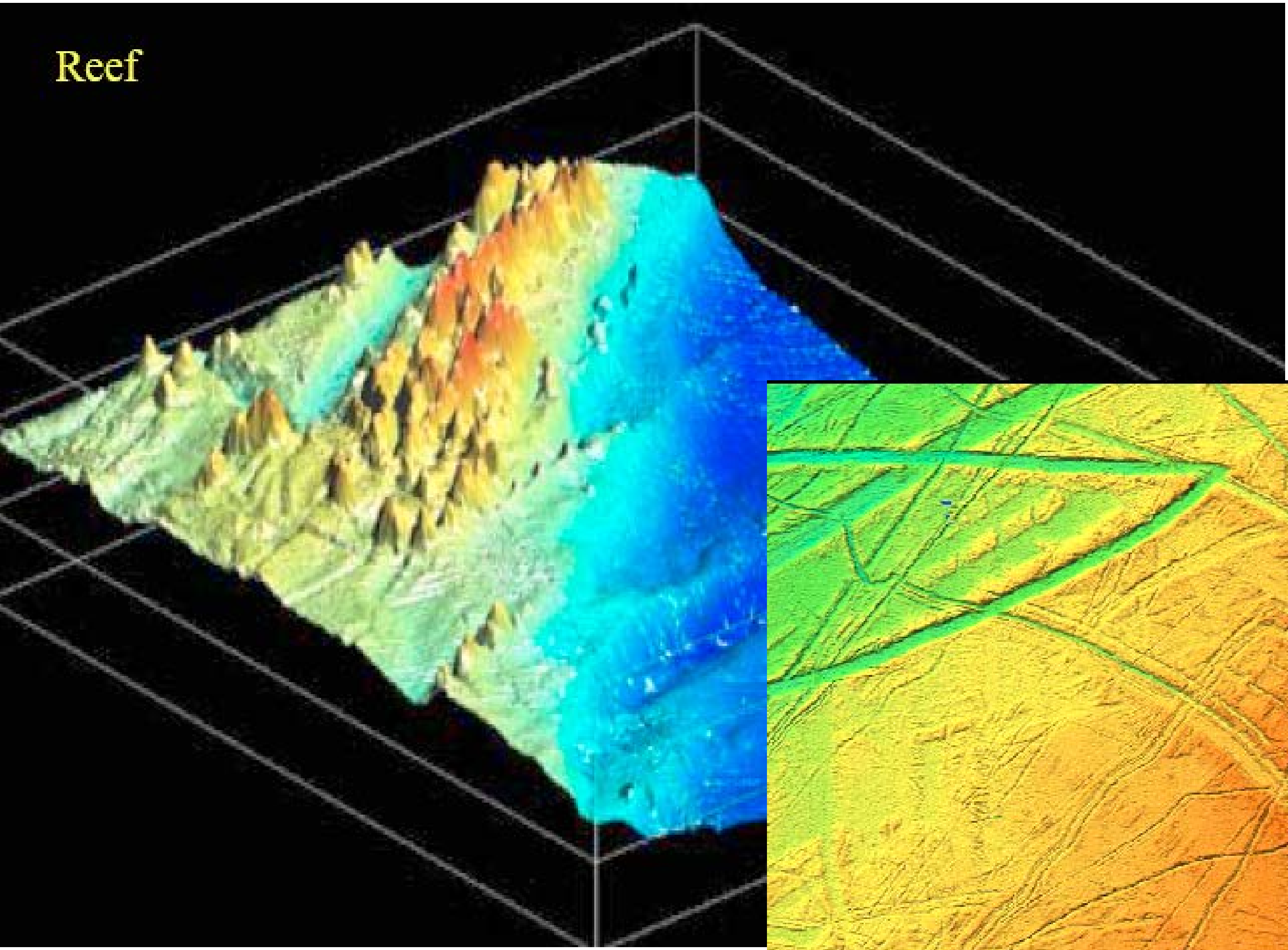
Acoustic Habitat Classification

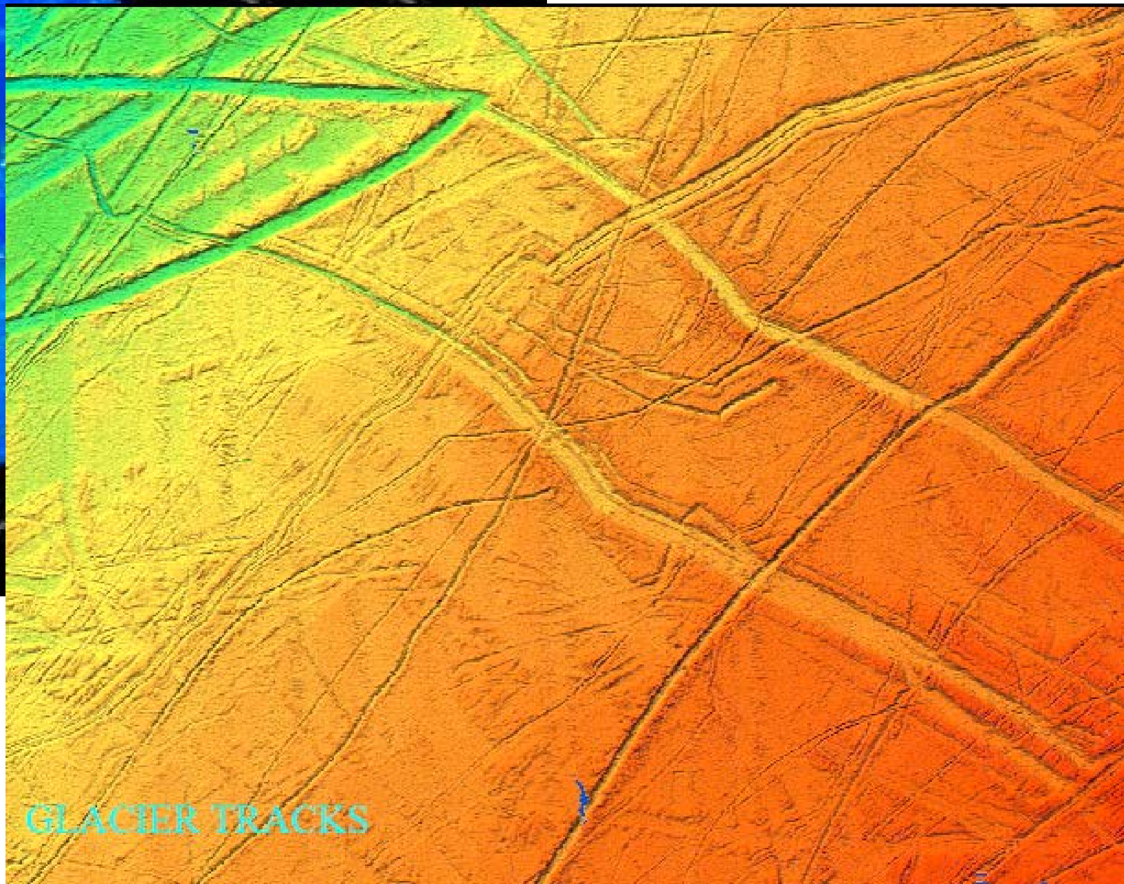
boat2.exe

animation courtesy of Bill Collins

John K. Horne

Seabed Mapping Examples





Acoustic Principles

- backscatter from bottom is used to determine depth and derive bathymetry
- metrics from the echo envelope or amplitude can be used to classify substrate types or ‘habitats’
- Categories: surficial seabed classification, sub-surface seabed classification, or sub-bottom profiling
- Habitat: 1 m below bottom to 1 m above bottom

Assumptions

- backscattered energy represents substrate type
- all substrate types have an equal probability of being detected
- classification categories are repeatable

Classification Objectives

- Categorize and map topography, geology, sediment, vegetation
- Assemble historical data
- Characterize species-specific habitat* models

Classification origins:

- correlate acoustic properties with surficial sediments (Nafe and Drake 1964, Morris et al. 1978)
- wider use with commercial system availability: singlebeam echosounder, sidescan sonar, multibeam sonar

*habitat: ecological or environmental area occupied by an organism, species, or population

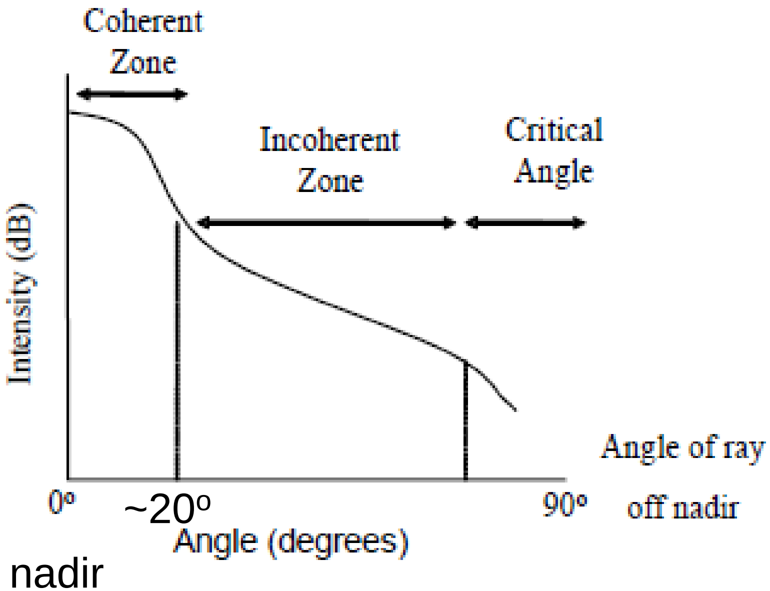
Classification Criteria

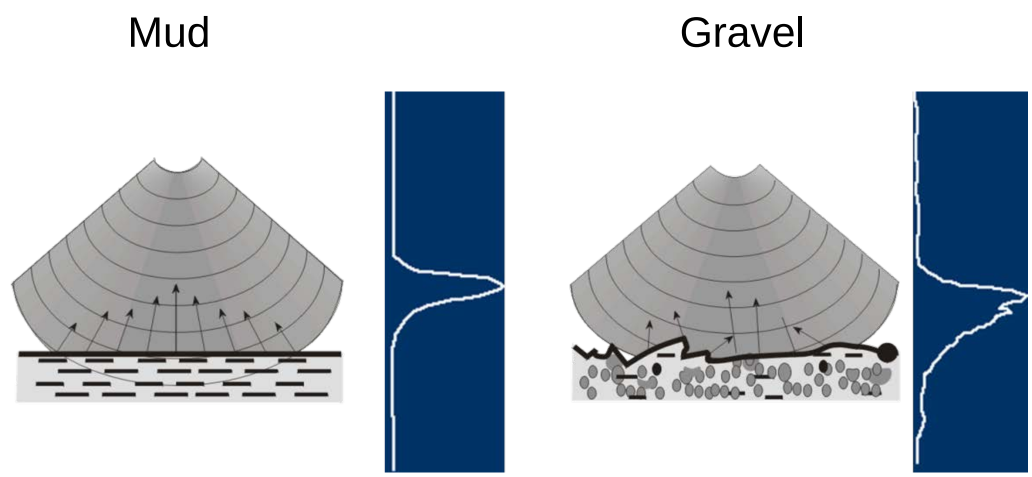
Surface properties: grain size, density/porosity

Roughness: regular or irregular (affecting echo coherence)

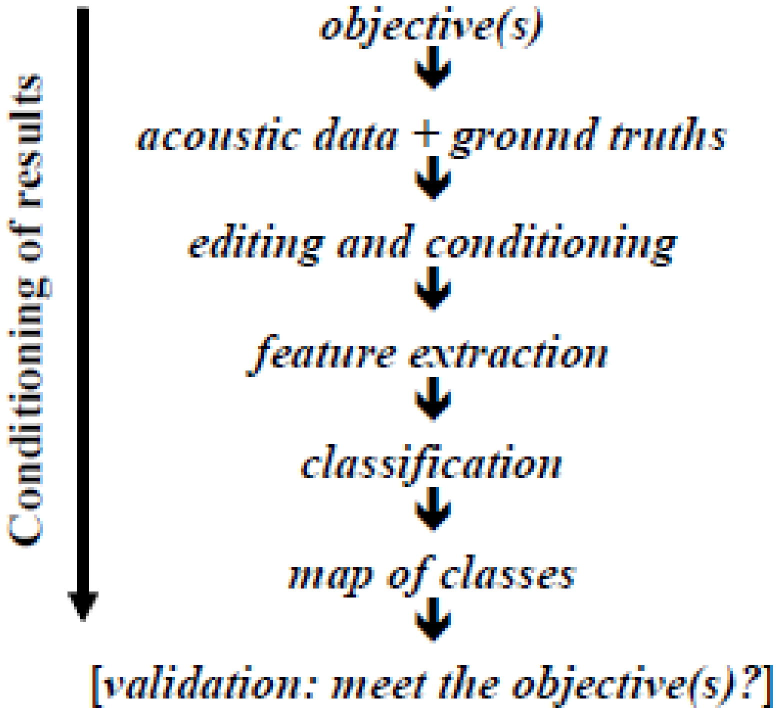
Biological properties: vegetation (not used in all)

Coherent: return energy equivalent to pulse duration (hardness of sediment)
Incoherent: any other energy after this time (roughness of geology)





Steps in Acoustic Seabed Classification



Type	Description	Note
Reconstructed seabed features	High-resolution bottom range and slope from time of flight	**MBES** all multibeam bathymetry maps
Signal or acoustic data features: (a) energy, (b) shape and incident angle response, (c) interrelation between successive echoes.	Bottom energy threshold and its continuity in a sliding window, range of energy threshold preceding the bottom pick, and its corresponding altitude	**SBES** Sabol *et al.*, 2002
	Square root of the ratio of the total significant energy of the second bottom echo to that of the first bottom echo, averaged over a number of pings	**SBES** Orlowski, 1984
	Sum of the energy from the tail of the first bottom echo (E1), used as an index representing the seabed roughness	**SBES** Chivers *et al.*, 1990; Heald and Pace, 1996; Siwabessy *et al.*, 2000
	Sum of the total energy of the second bottom echo (E2), used as an index representing the seabed hardness	*ibid.*
	Normalized cumulative function of the echo envelope	**SBES** Lurton and Pouliquen, 1994
	Probability density function of seabed backscattering amplitude	**PDSSS** Stewart *et al.*, 1994
	Cumulative normalized echo amplitude and ratios of samples of cumulative normalized amplitude, amplitude quantiles, amplitude histogram, power spectrum, and wavelet packet transform of the echo shape	**SBES** Preston *et al.*, 2004; Moszynski and Dung, 2000
	Profile of volume backscattering strength of the first bottom echo	**SBES** Sternlicht and de Moustier, 2003a, 2003b Hutin *et al.*, 2005
	Mean, standard deviation, and higher order moments, amplitude quantiles and histogram, power spectral ratio features, grey-level co-occurrence features, fractal dimension	**MBES, SSS** Preston *et al.*, 2004
	Residuals of the volume scattering strength (S_v) of the first bottom echo profile after regression on bottom depth	**SBES** Hutin *et al.*, 2005
	Bottom roughness power spectrum; slope of the averaged spectra in a given orientation	Briggs, 1989; Jackson and Briggs, 1992
	Bottom roughness expressed by the power spectrum of de-trended bathymetry, modelled by a power law, integrated over a band of roughness	**PDSSS** Stewart *et al.*, 1994
	As in the row above, but with bathymetry instead of de-trended bathymetry	**SBES** Sternlicht and de Moustier, 2003a, 2003b
	Similarity in proportion of the local variability of echoes described from principal components transform	**SBES** Kim *et al.*, 2002
	Seabed backscatter strength shape as function of the incident angle, described by a set of parameters	**MBES, SSS** Hughes-Clarke *et al.*, 1997
Ancillary	Water depth, slope, current strength, variance of temperature field over seasons	Kostylev *et al.*, 2001
	Aerial and multispectral camera images, satellite images	

cf. Table 5.3 ICES CRR 286

Modeling Seabed Habitats

Variables used in seabed models:

- Sediment physical properties ($n = 13$)
- Bulk and frame physical properties ($n = 25$)
- Properties of the interstitial fluid and porometry ($n = 8$)
- Properties of the overlying water column ($n = 7$)
- Surface morphology/topology ($n = 2$)
- Subsurface morphology/topology ($n = 4$)
- Discrete scatterers (surface and volume heterogeneity; $n = 5$)
- Biological organisms, communities, and processes ($n = 9$)

Scattering models used:

Empirical approaches: smooth impenetrable, random rough impenetrable, stochastically rough

Theoretical approaches: smooth penetrable, multilayered bottom, refractive bottom, rippled bottom

cf. Horton 1971

Data Classification

Supervised: reference samples to train system

Unsupervised: raw data statistically analyzed to define categories

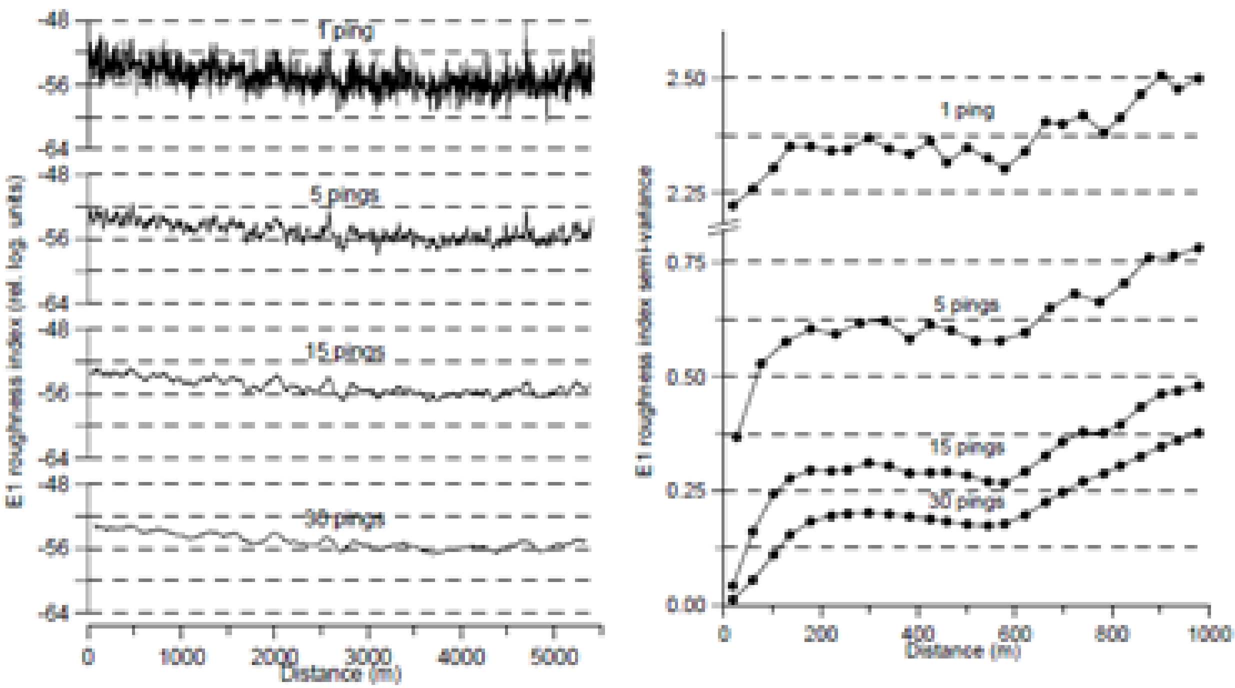
Methods:
empirical samples, ordination (PCA, FA, CCA), clustering (k-means), discriminant analysis, AI (neural networks, genetic algorithms), textural analysis (for optic data)

Scale-Dependent Pattern

observed patterns function of measurement resolution, including beamwidth and range of measurements

What constitutes a sample? independence

- Autocorrelation
- Geostatistics: semi-variogram
- Frequency domain: spectral analysis, wavelets



Arbitrary Scales

- perceived alignment with environmental features

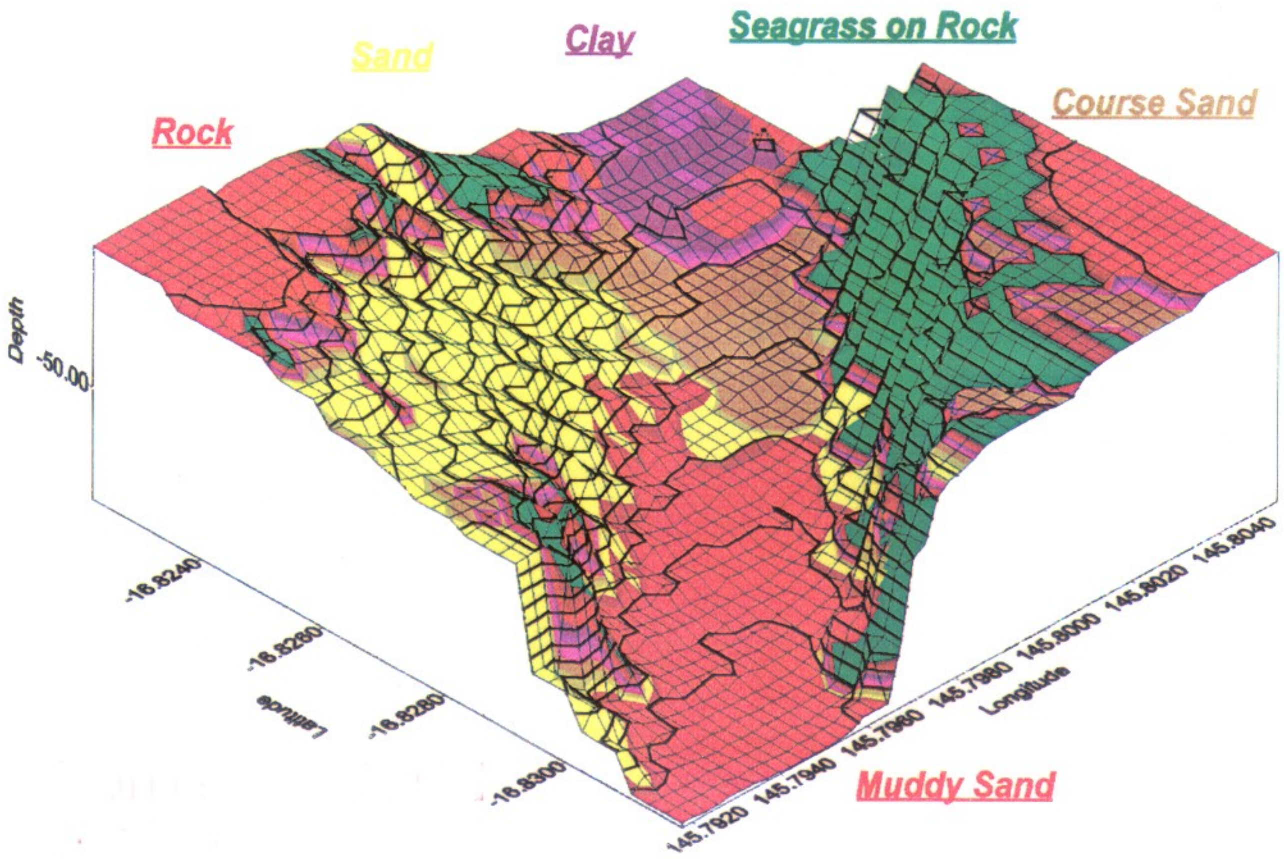
Type	Scales	Habitats (Greene *et al.*, 1999)	Survey scale (*depth-dependent)
Basin	>100 km	Megahabitats	Between surveys
Large	10–100 km	Megahabitats	Between strata and surveys/transects
Medium	1–10 km	Megahabitats	Between transects, between strata
Small	100 m to 1 km	Mesohabitats	Transects, between footprints*
Very small	10–100 m	Mesohabitats	Footprints*
Ultrasmall	1–10 m	Macrohabitats	Inside footprint* (fine-scale)

Greene et al. 1999

Seabed Classification Systems

ASC SYSTEM NAME	ACOUSTIC INSTRUMENTATION	CONTACT INFORMATION
QTC View/Impact QTC Sideview QTC Multiview	Single-beam echosounder Sidescan Multibeam	Quester Tangent Corporation Sidney, British Columbia, Canada www.questertangent.com
ECHOplus SWATHplus	Single-beam echosounders Bathymetric sidescan	SEA (Advanced Products) Ltd, UK www.sea.co.uk
RoxAnn GroundMaster RoxAnn Swath	Single-beam echosounder Multibeam	SonaVision Ltd, Aberdeen, UK www.sonavision.co.uk
BioSonics EcoSAV BioSonics VBT	Single-beam echosounder (BioSonics DT/DE series)	BioSonics Inc., Seattle, WA, USA www.biosonicsinc.com
DHI Genius ImageClassifier using NeuroSolutions SOM_MLP Seabed	Sidescan	Danish Hydraulic Institute www.dhi.dk www.Neurosolutions.com
Triton SeaClass SS-MosaicRT	Sidescan	Triton Imaging Inc. www.tritonelics.com
Kongsberg SIS/Triton Neptune C Software	Multibeam (EM series)	Kongsberg Maritime Simrad www.Kongsberg.com
L-3 ELAC Nautik Sediment Classification	Echosounder (Hydrostar), Multibeam (SeaBeam)	L-3 Communication ELAC, Germany www.l-3com.com
Kongsberg SEABEC Seabed Classifier	Single-beam echosounder sweep echosounder	Kongsberg Maritime, Horten, Norway www.km.kongsberg.com
Kongsberg SEABEC SEABEd Classification	Echosounder (EA400/600)	Kongsberg Maritime Simrad www.Kongsberg.com
SeaScan System	Single-beam echosounder	Seatronics Ltd, Aberdeen, UK www.seascan.net; www.seatronics-group.com
Echoview Fish Habitat	Single-beam echosounder	SonarData, Hobart, Australia, www.sonardata.com

RoxAnn



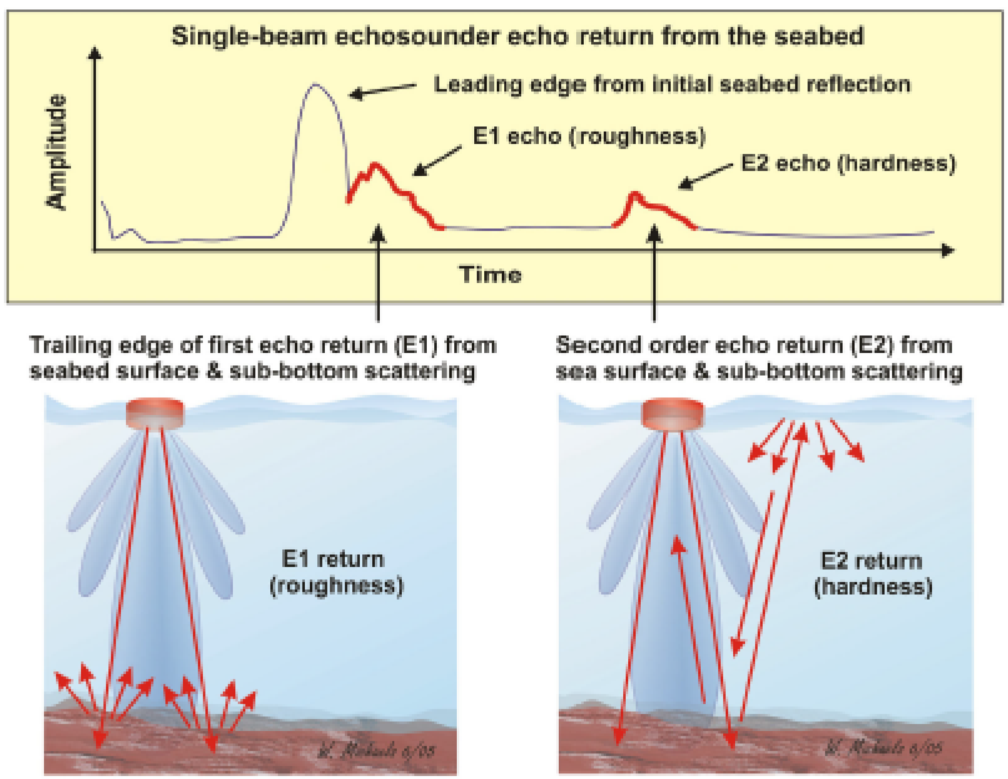
Seagrass on Rock
Clay
Sand
Rock
Course Sand
Depth
-50.00
-16.8240
-16.8260
-16.8280
-16.8300
Latitude
145.7920
145.7940
145.7960
145.7980
145.8000
145.8020
145.8040
Longitude
Muddy Sand

RoxAnn Algorithm

Two metrics with biological interpretation

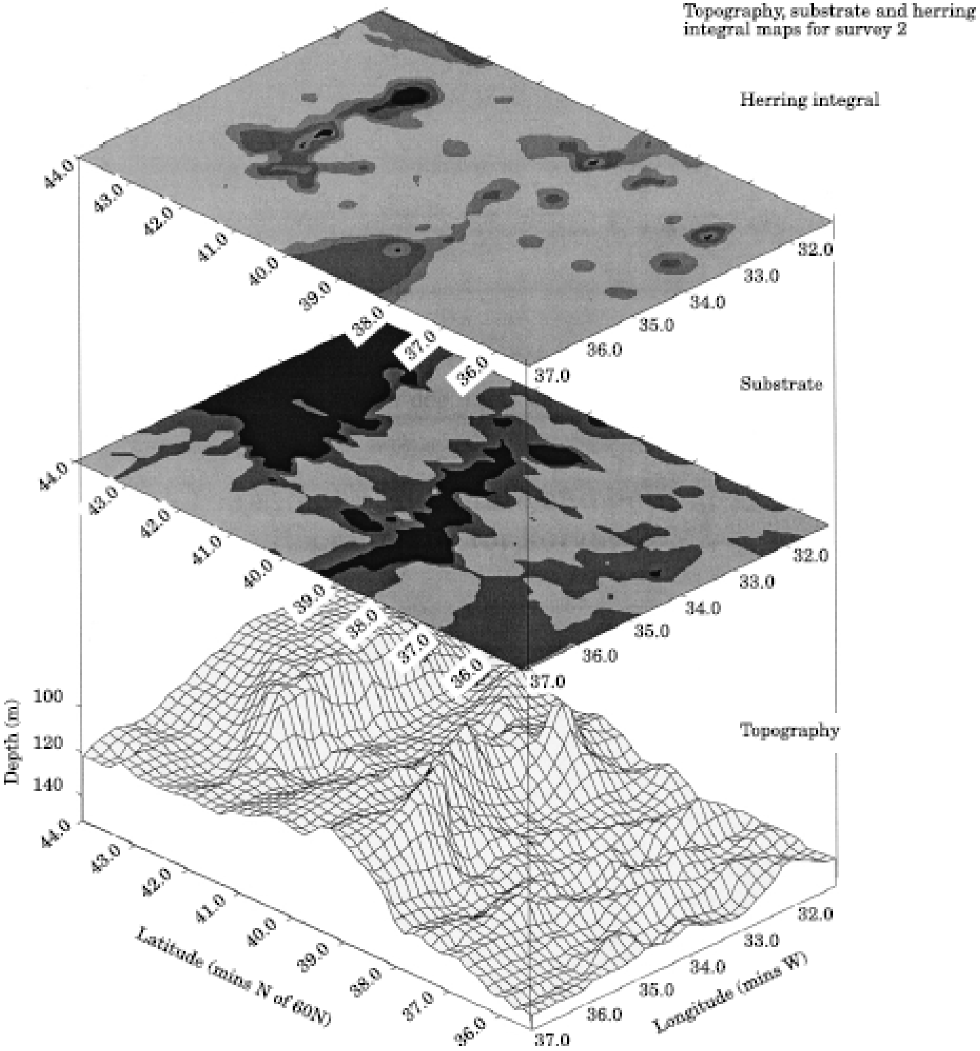
E1: roughness (incoherent)
    ratio of echo amplitudes

E2: hardness (coherent)
    acoustic impedance (units volts)



cf. Chivers 1990

RoxAnn + Acoustic Application



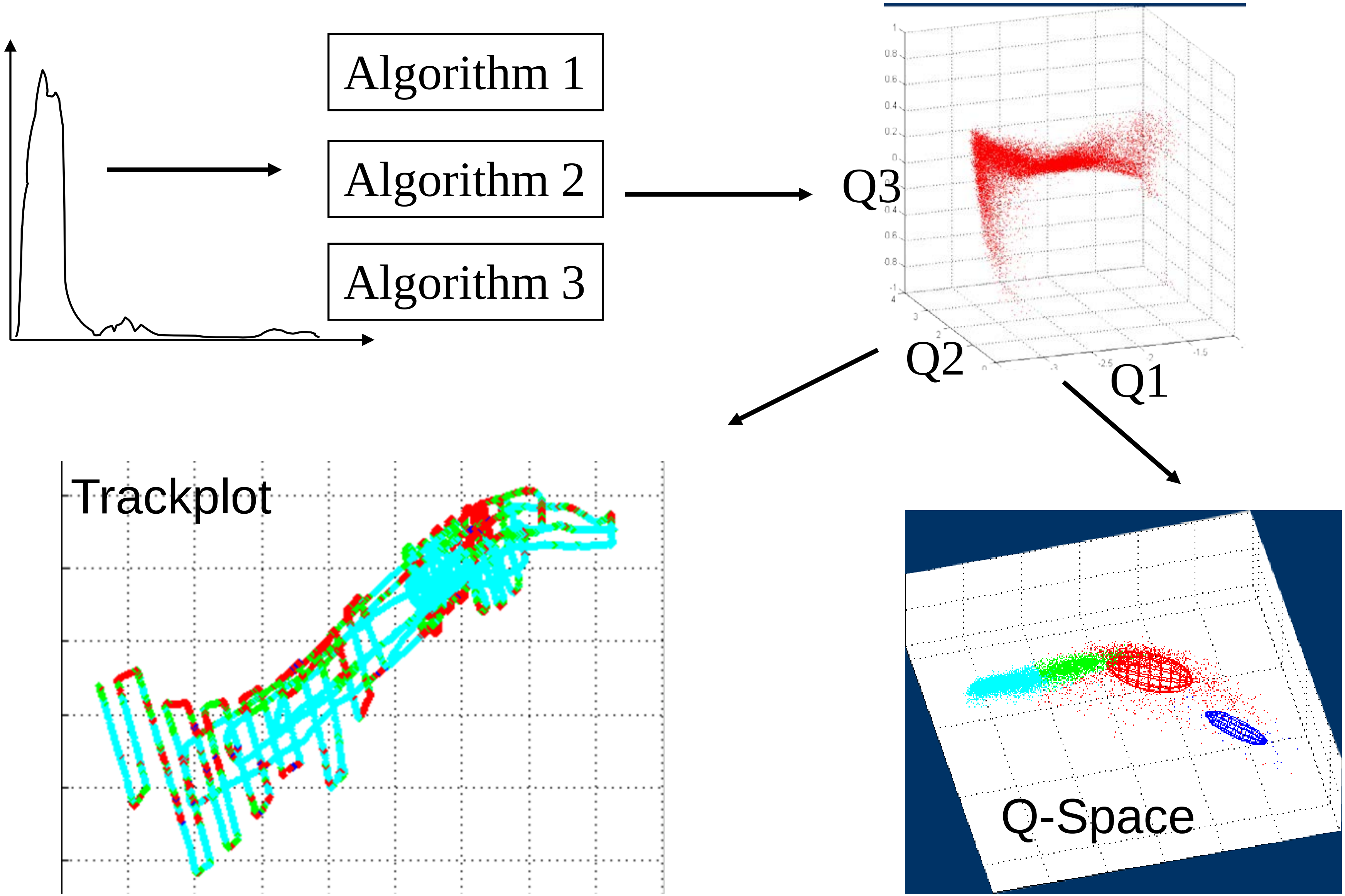
- port one quadrant from EK500 to RoxAnn software for classification
- looking for association between herring schools and substrate

Reid and Maravelias 2001

Questor Tangent Corporation: QTC

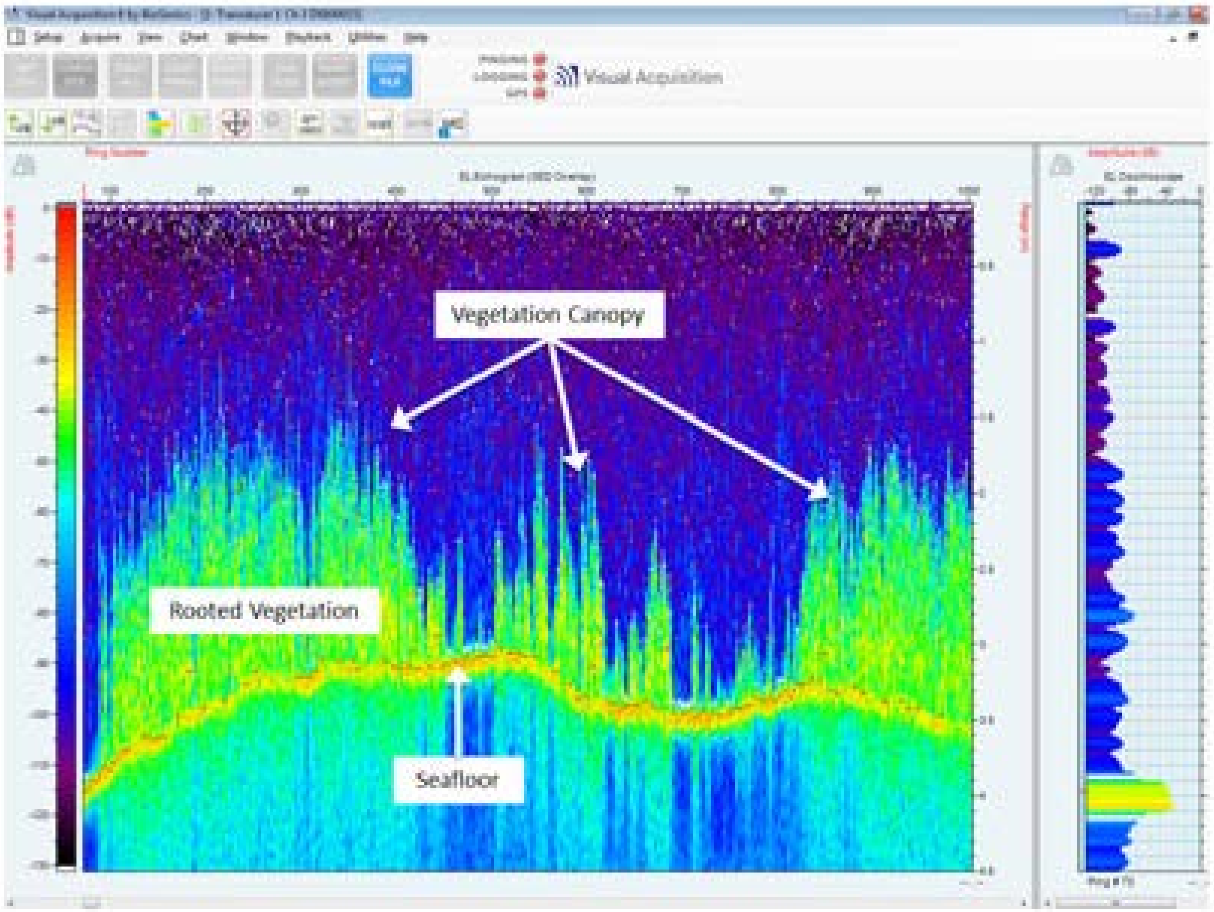
- Digitize signal
- Extract features: echo envelope metrics
- Reduce data: PCA of all measures (ordination)
- Identify clusters: group sample points
- Assign classes: label categories

Questor Tangent Corporation: QTC

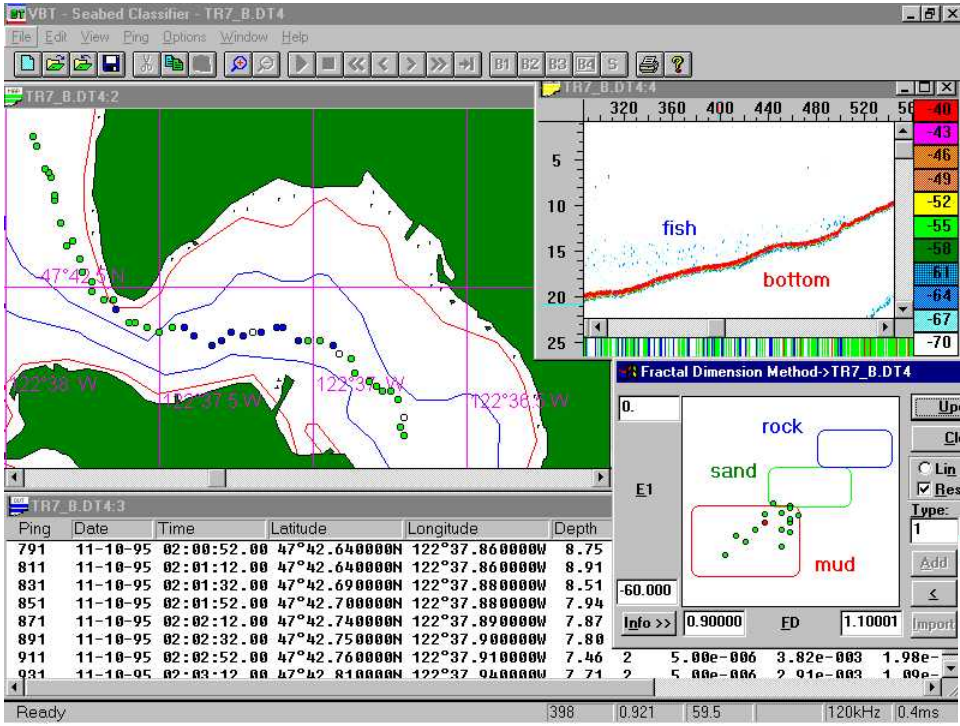


BioSonics: Visual Habitat, Visual Bottom Typer, Submersed Aquatic Vegetation

Submerged Aquatic Vegetation



Visual Bottom Typer

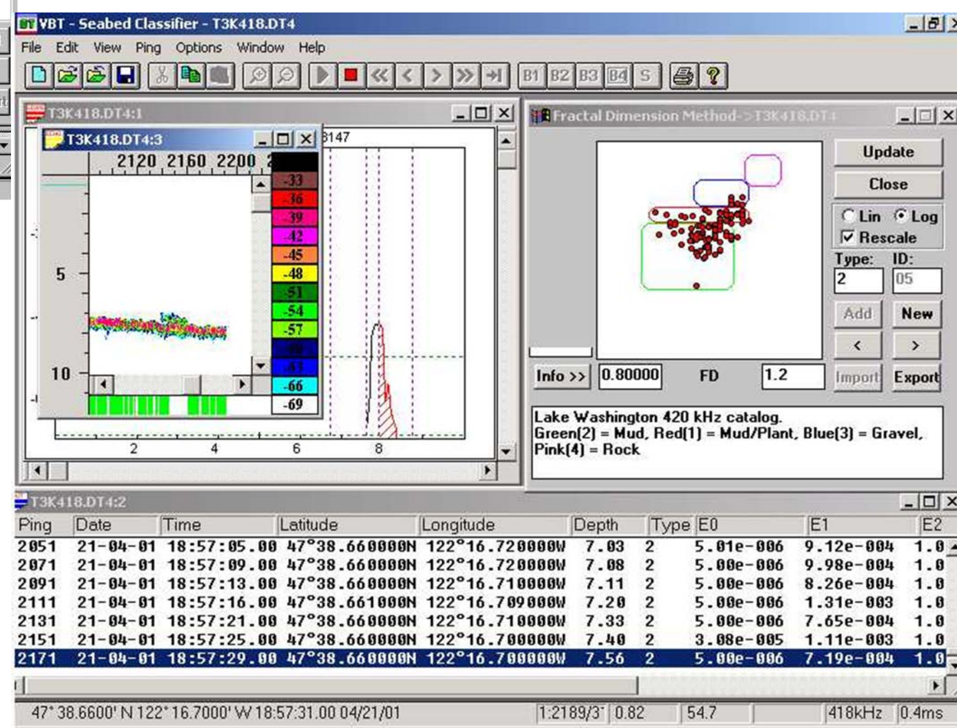


Bottom Classification Metrics

B2 - First/Second Bottom Ratio (~ E1)

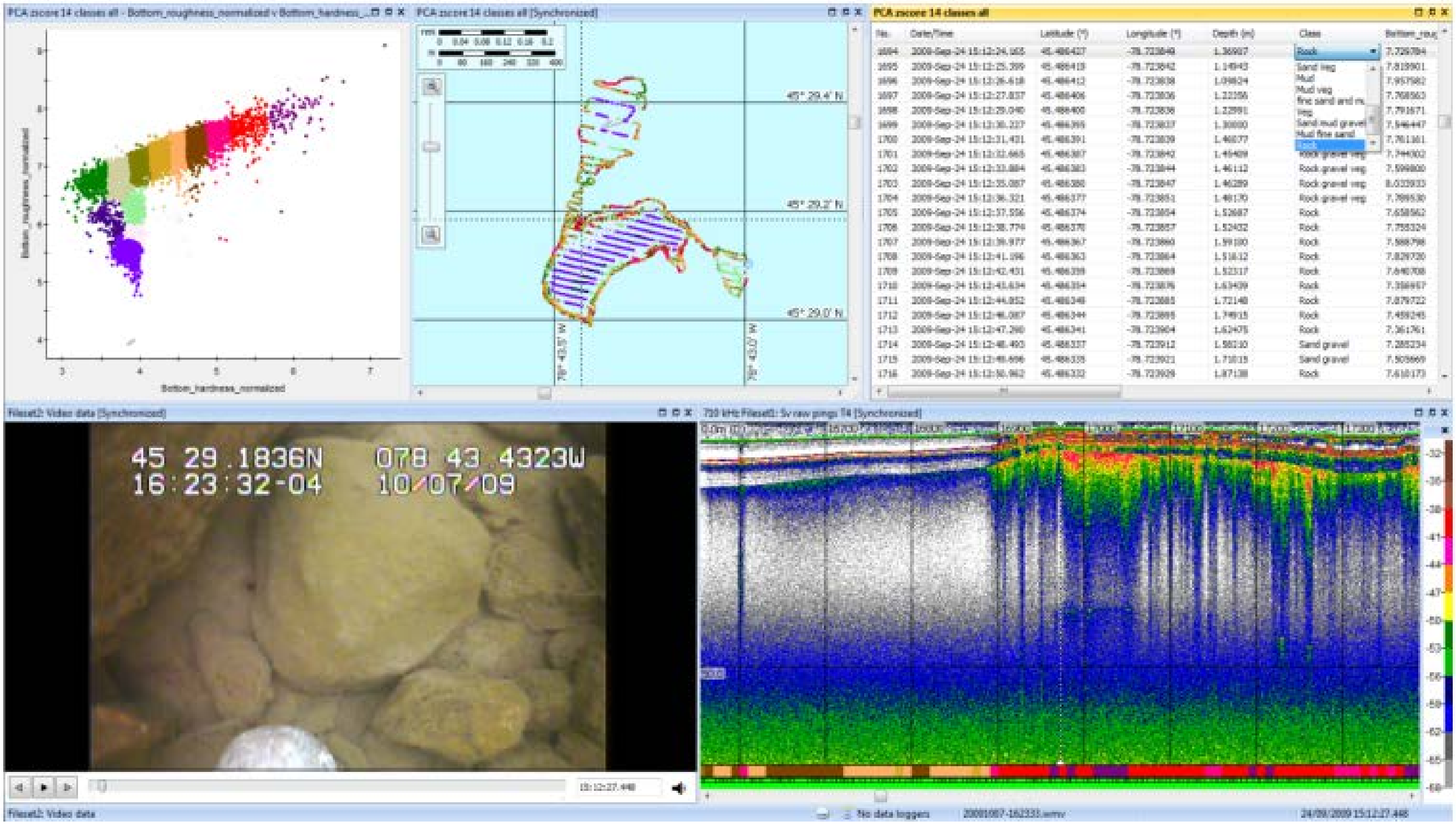
B3 - First Echo Division

B4 - Fractal Dimension



Echoview Habitat Classification

Supervised or unsupervised classification using ordination and clustering



Data/Category Verification

Characteristics: physics - geology, biology - epibenthos

Qualitative or semi-quantitative:

1. optics on platforms - drop platform, towed platforms, ROV, AUV, diver-deployed, sediment profile imagery (SPI)
2. Trawls and Dredges – beam trawls, rock dredge

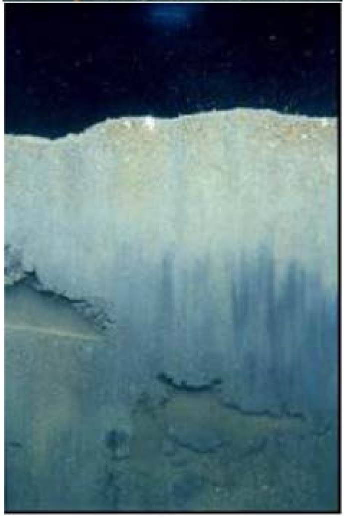
Quantitative:

1. grabs and cores – van Veen, boxcore
2. Trawls and Dredges – beam trawls, rock dredge

van Veen grab

boxcore

Sediment profile imagery system and image



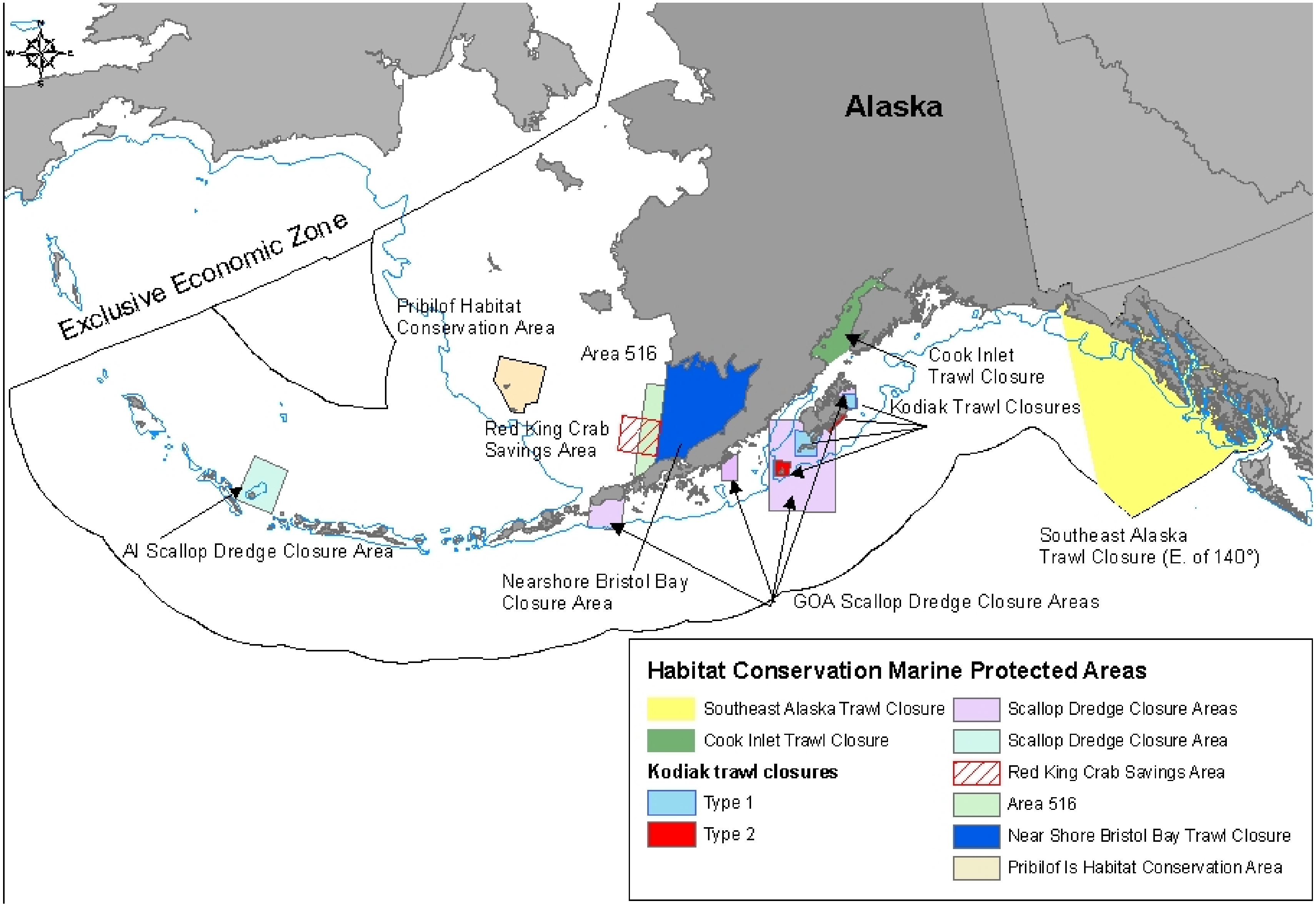
Essential Fish Habitat (EFH)

“those waters & substrate necessary to fish for spawning, feeding or growth to maturity”

‘necessary’ = habitat required to support a sustainable fishery and the managed species’ contribution to a healthy ecosystem

- MSFCMA mandates fish habitat studies
  - ✓ **characterize EFH**
  - – **adverse impacts (including fishing)**
- EFH adds a new management dimension
  - – **before: how many fish? harvest levels?**
  - – **after: numbers & locations of fish & harvest process?**
- EFH scope is enormous!
  - – **all managed species, all life history stages, prey**
  - – **descriptions must be in environmental terms**

Habitat Marine Protected Areas

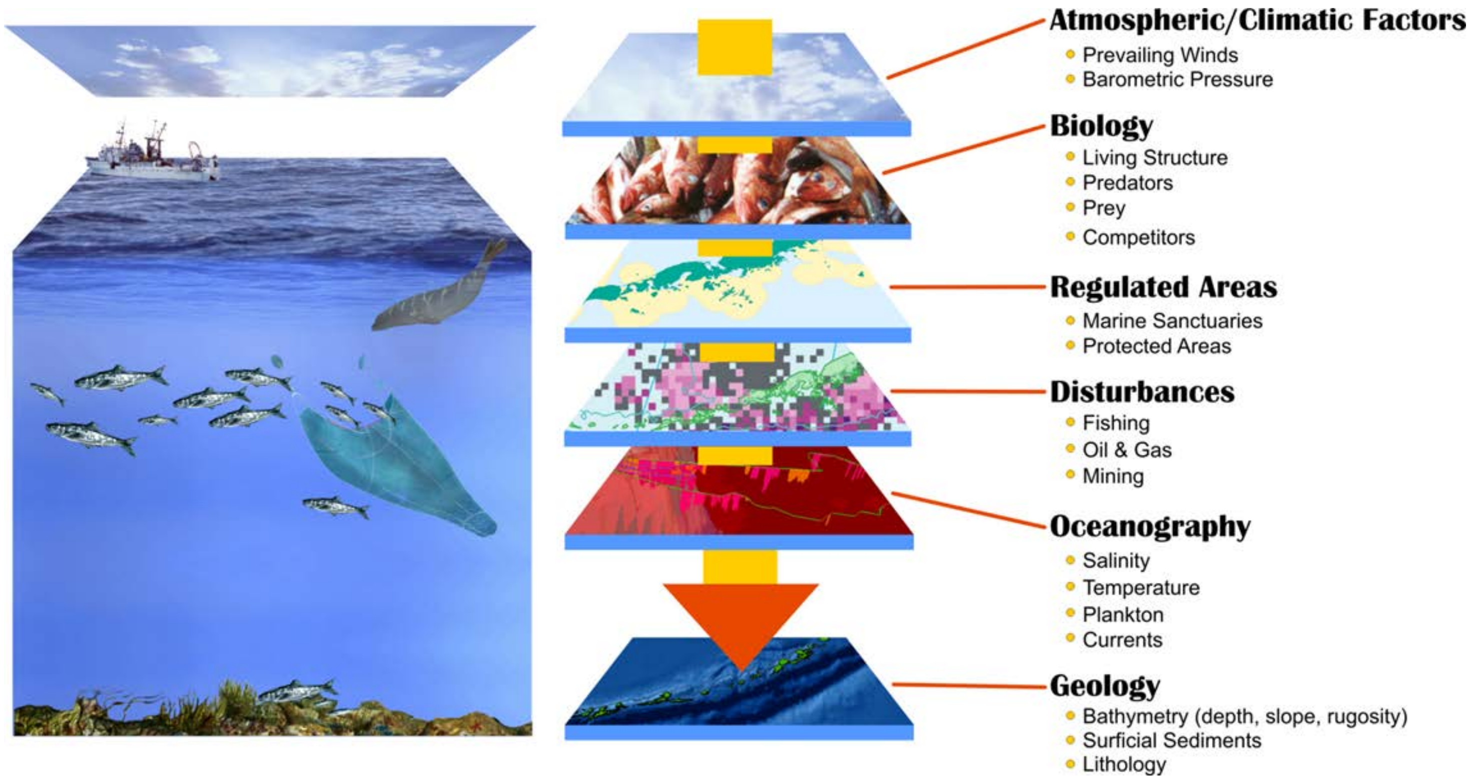


Management-Oriented Research

Scientific Objective: Explain the distribution & abundance of fish using **quantitative models**

Management Goal: Maintain healthy ecosystems and sustainable fisheries

1) Protect sensitive habitats from fishing
2) Plan for environmental change (LOSI, pH)



FISHPAC Cruise

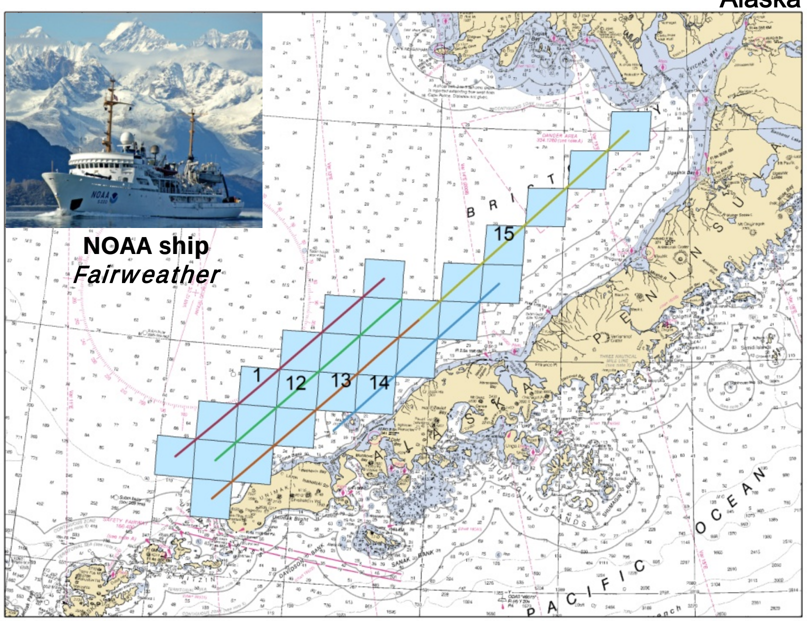
Eastern Bering Sea, 2012

Bob McConnaughey, AFSC

Cruise Plan

- Repeated surveys with 5 acoustic systems
- 2 (acoustic) + 1 (groundtruth) passes along 5 transects over 26 bottom-trawl-survey stations

Alaska



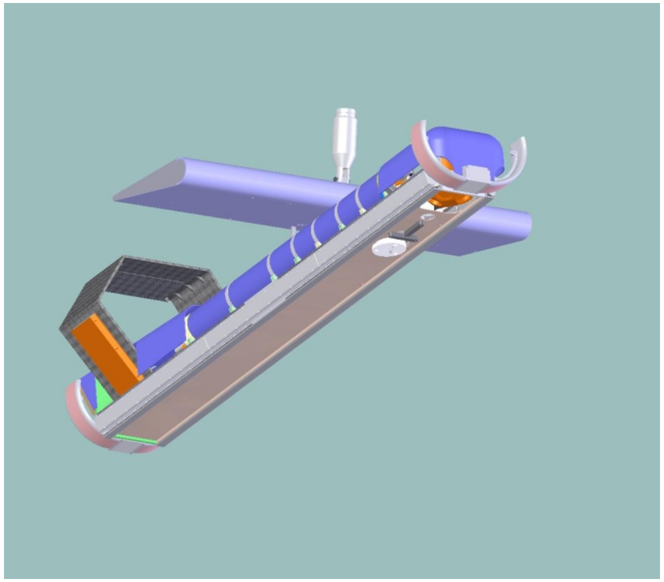
Results

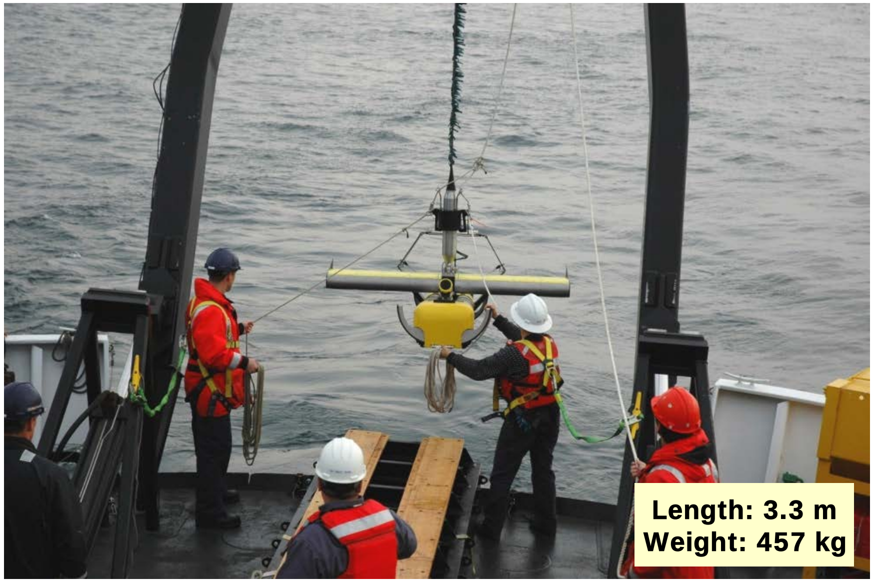
~3.7 TB of data simultaneously collected to support fish-habitat research & update nautical charts for an area with outdated or non-existent information.

Instrument	Total sampling units
Reson 8160 multibeam	1668 nm
Reson 7111 multibeam	1749 nm
Klein 5410 side scan	645 nm
Klein 7180 LRSSS	645 nm
SEABOSS grab (infauna)	25 stations sampled
SEABOSS grab (sediment)	25 stations sampled
SEABOSS still photos	13 stations
TACOS video	20 stations
FFCPT drops	28 stations (92 drops)

Long Range Fisheries Sonar

Klein 7180





Instruments

- Sidescan (180 kHz)
- Single beam (38 kHz)
- Nadir-filling sonars (180 kHz)
- Ancillary sensors

Features

- 1200 m max. swath
- Tow speed 7.5 kts (12 max)
- Resolution 12.5 cm (cross) x 50 cm (along-track)

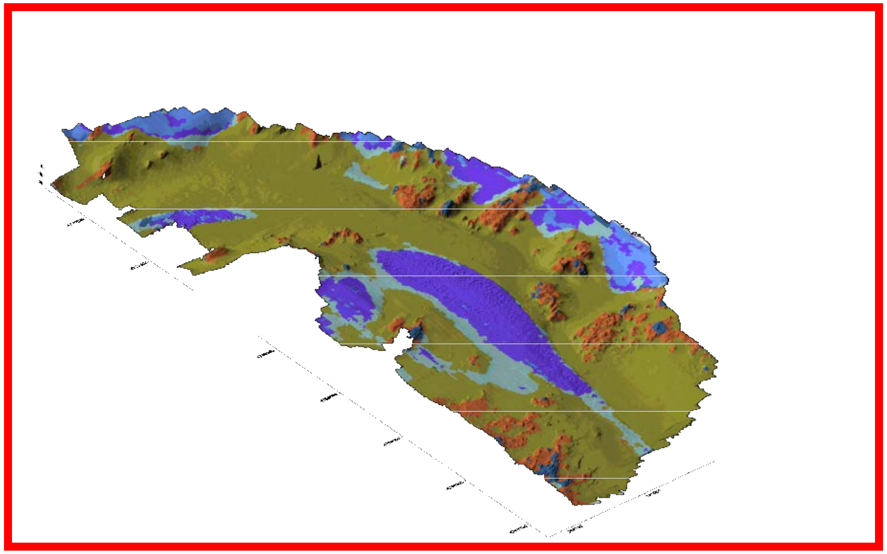
Nav Systems

- Octans III MRU
- Doppler Speed Log
- USBL responder
- Controllable depressor, tail

Produces quantitative backscatter (fully normalized) and co-registered bathymetry (interferometry)

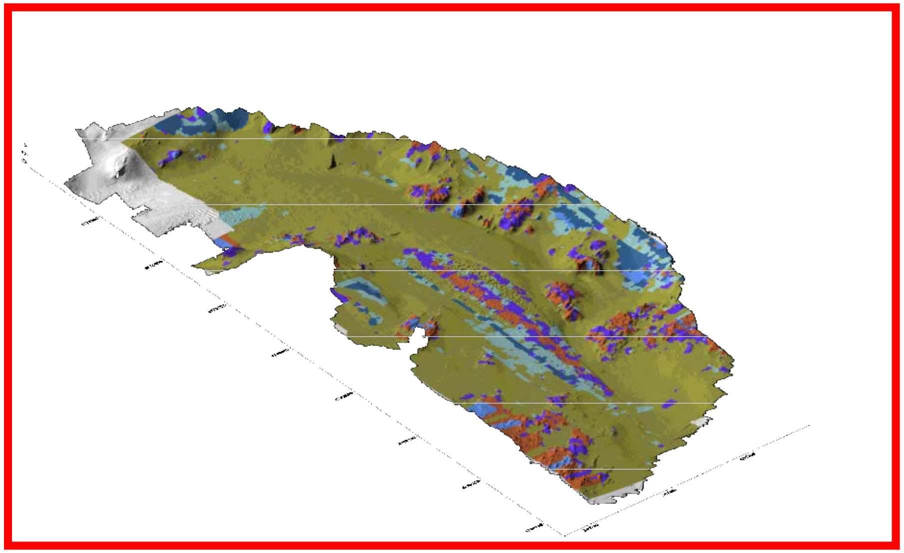
Seabed Classification Comparison

Reson 8101 multibeam



Classified with *QTC Multiview*

Klein 5500 side scan

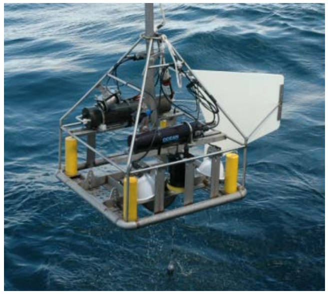


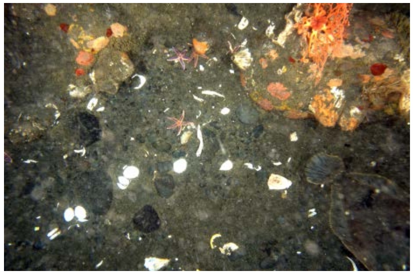
Classified with *QTC Sideview*

Groundtruth Systems

Complementary information to interpret acoustic data & biological responses

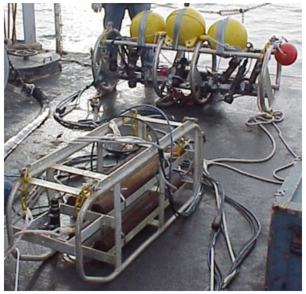
SEABOSS (still & video cameras, van Veen)





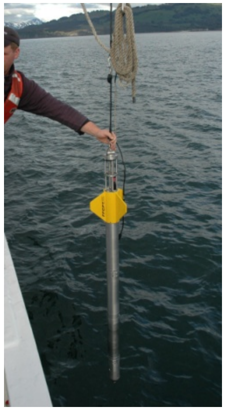
Sediments, infauna, still images, video

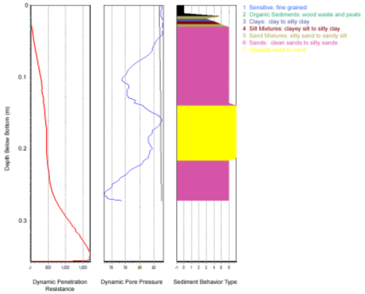
TACOS



Video mosaics

Free Fall Cone Penetrometer





Geotechnical data underway

Update EFH Models & Revise FMPs

1. **ID most cost-effective mapping tool**
   - **Process 2012 data**
   - **CPUE : backscatter analysis for each sonar (“benefits”)**
   - **Evaluate relative costs**
2. **Synoptic acoustic survey w/ best system**
   - **Status – cruise scheduled August 2016**
3. **Update models & FMPs - all EBS species**
4. **Develop next variable(s) or begin new area?**
   - **Satisfactory endpoint?**
   - **Consider “next-gen” variables (FFCPT, CDOM, chl-a, particulates)**
   - **Initiate Gulf of Alaska, Aleutian Islands**