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Turbidity Monitoring Using Echosounder Technology

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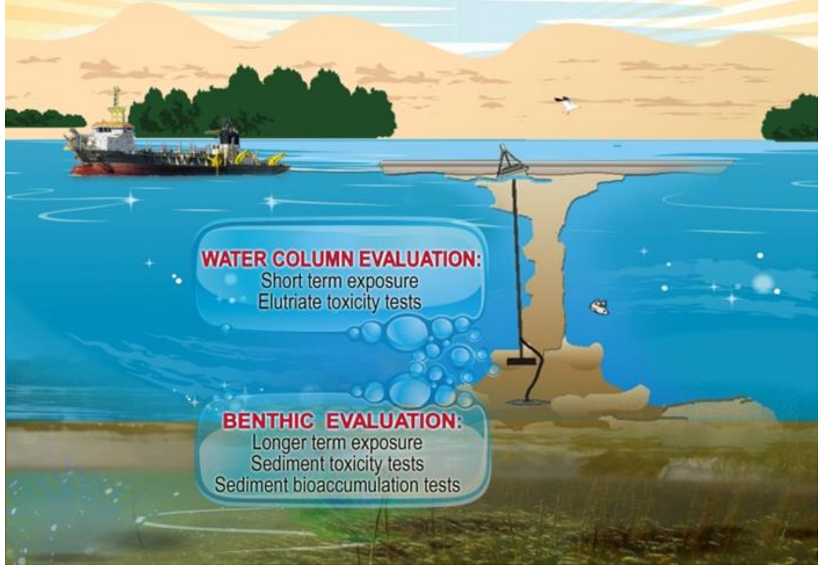
Dredging: Environmental Concerns

- ✓ Water Quality
  - Increased turbidity due to sediment resuspension
  - Contaminant mobilization and transport
- ✓ Air Quality
  - Sox (SO_2), Nox (NO_2), CO, Ozone (O3)
  - Carbon Emissions
- ✓ Ecological Health
  - Impacts to endangered species
  - Impacts to fish migration and spawning due to turbidity
  - Impacts to essential fish habitat
  - Loss of habitat or benthos by removal or smothering
  - Acute and chronic toxicity due to resuspension of contaminants
  - Underwater noise impacts on fish



- ✓ Human Health
  - Bioaccumulation
  - Social Impacts

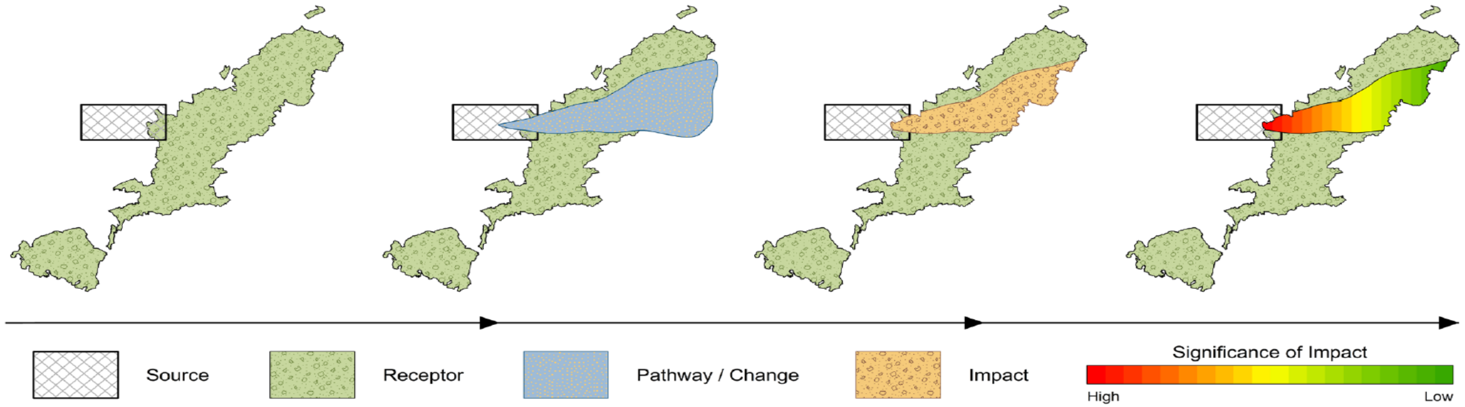
WEDA Western Dredging Association

Dredging – Water Quality

- ✓ Dredge actions result in sediment losses to the water column
- ✓ Sediment dislodged by dredging action, but not fully captured
- ✓ Currents induced by equipment movement can erode unstable sediment and redistribute them in the water column
- ✓ Barge, tug, and tender vessel movement impacts may exceed dredge impacts

Environmental Monitoring during Dredging

✓ Why do we monitor?
- Understand baseline conditions and document post project conditions
- Monitor potential impacts on receptors
- Demonstrate compliance with regulations and permit conditions
- Assess performance of BMPs



Source: CEDA 2015

https://dredging.org/media/ceda/org/documents/resources/cedaonline/2015-02-ceda_informationpaper-environmental_monitoring_procedures.pdf

Environmental Monitoring during Dredging

- ✓ Common challenges
  - Natural systems often produce high-turbidity environments making effects from dredging difficult to identify
  - Other sources of pollution (e.g., outfalls) can affect results of water and sediment quality monitoring or cause flora/fauna mortality
  - Inclement weather can cause changes to the system by increasing turbidity and erosion of work areas

Source: USGS (City of Tuscaloosa, Alabama)

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Example 1: Port of Tacoma

Stainer et al. 2019

- Port of Tacoma recently reconfigured Piers 3 and 4 to allow the berthing of two 18,000 TEU Ultra Large Container Vessels
- dredging of approximately 85,000 cubic yards or 65,000 cubic meters of contaminated material in a previous cleanup phase for a total of 550,000 cubic yards (420,500 cubic meters) of dredge material.

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Example 2: Port of Seattle and the U.S. EPA

Berlin et al. 2019

- controlling recontamination during dredging in an active waterway that may take up to 10 years to complete
- dredging of approximately 85,000 cubic yards or 65,000 cubic meters of contaminated material in a previous cleanup phase for a total of 550,000 cubic yards (420,500 cubic meters) of dredge material.
- Besides known levels of contaminants, the study notes that establishing preliminary remediation goals for natural background levels for PCBs, arsenic and dioxins/furans
- cleanup alternatives include removal of 810,000 to 1,080,000 cubic yards over 77 to 111 acres, with partial removal and capping over 7 to 13 acres

Mitigating Turbidity Impacts During Dredging

Image credit: https://www.iwr.usace.army.mil/About/Technical-Centers/NDC-Navigation-and-Civil-Works-Decision-Support/NDC-Dredges/

- Requires managing suspended solids released at site or entering sensitive areas
- Sonar using FM pulses has longer range than optic sensors
- Acquisition, analysis and verification of data is crucial
- Data must be manageable, easily understood, real-time
- Software functionality:
  - Turbidity measurements, bottom morphology
  - Layout plans, real estate boundaries, tolerance ranges
  - Slope angles, target and actual slopes
  - Remaining material thickness, estimation of dredged quantities for output assessment

Ocean Science Instruments

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Transducers

Transceivers

EK80 Series

- Broadband
- Split Beam
- Multiple Platform Systems:
  - Shipboard, Underwater Vehicle, Mooring and Portable Systems

EC150-3c

- PHASED ARRAY ADCP
- BROADBAND ECHO SOUNDER

ME70/MS70

- Calibratable Multibeam
- Individual Split Beams
- 10 to 120 kHz frequency range

ADCP vs. Split-beam Echosounder

Figure 2

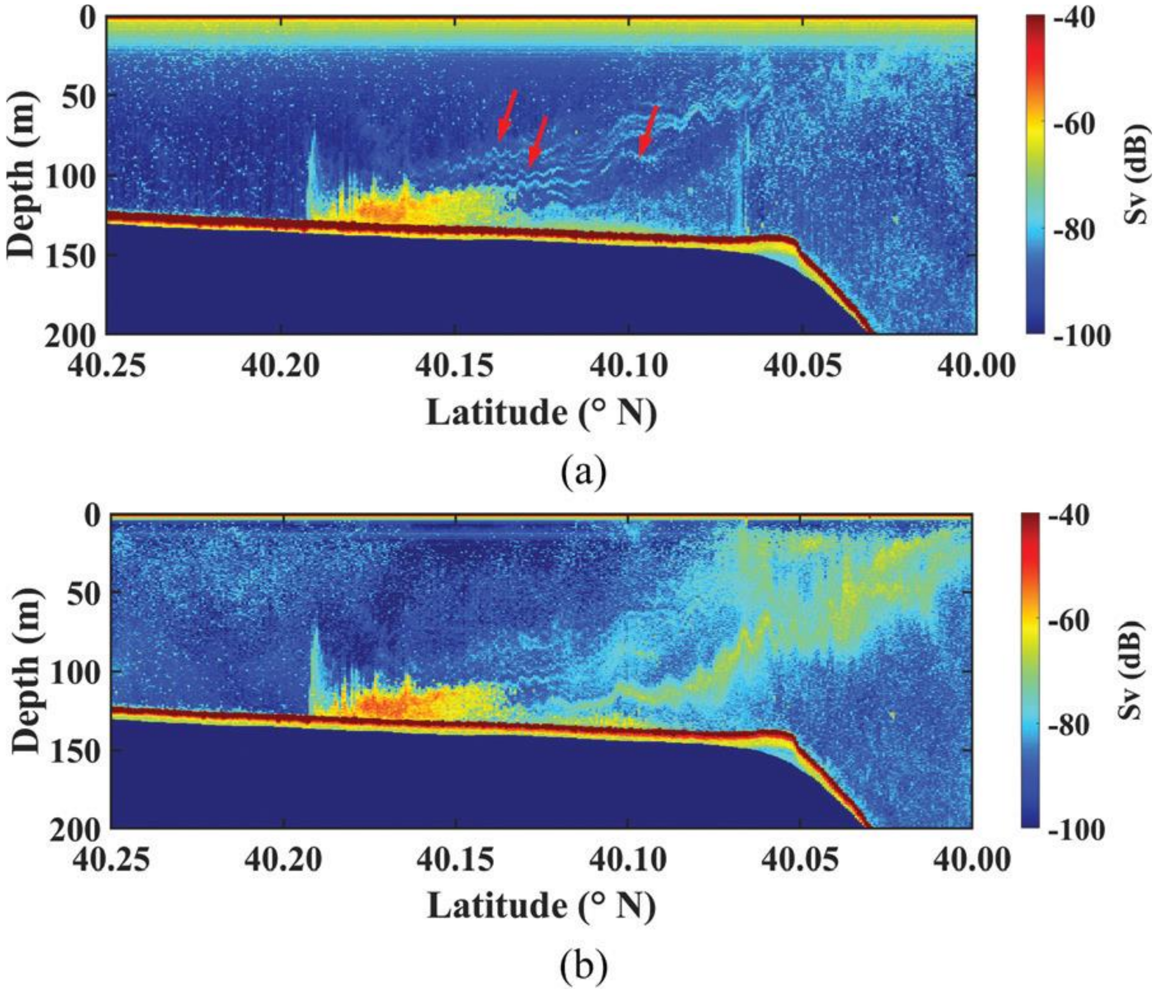
- ADCP measures doppler shift of small particles
  - You know ‘something is there’ – not how much

- Split-beam echosounder measures back-scatter
  - Allows user to quantify amount and density of solids
  - Allows user to quantify what the material is

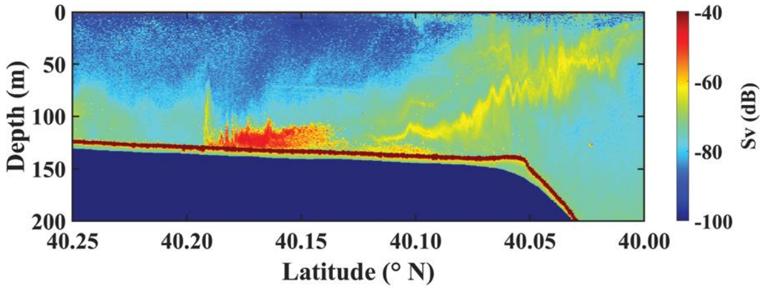
biomass characterization in oceans

Loranger et al. 2022

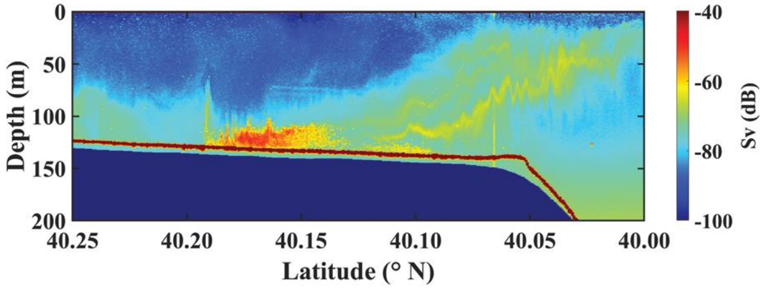
Figure 3. Split-beam echosounder data of marine biota through the water column. (a) is the echogram for an 18 kHz echo sounder and (b) is for a 38 kHz.



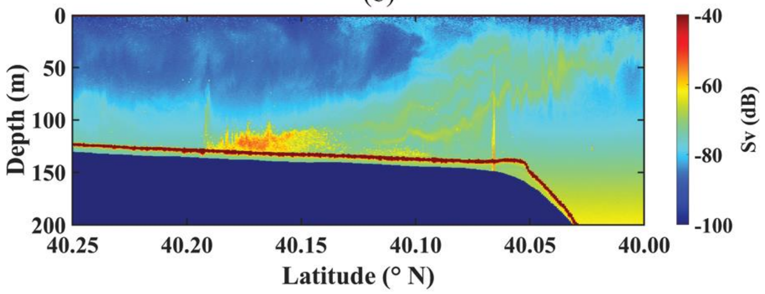
biomass characterization in oceans



(a)



(b)

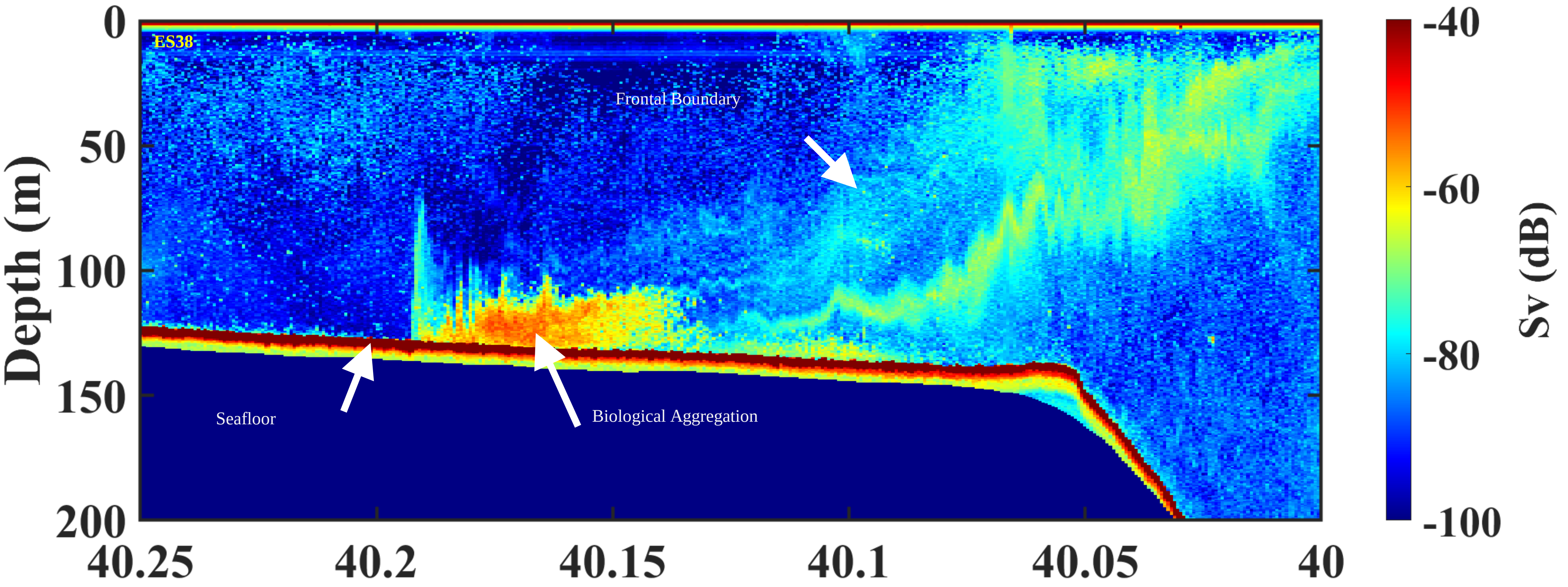


(c)

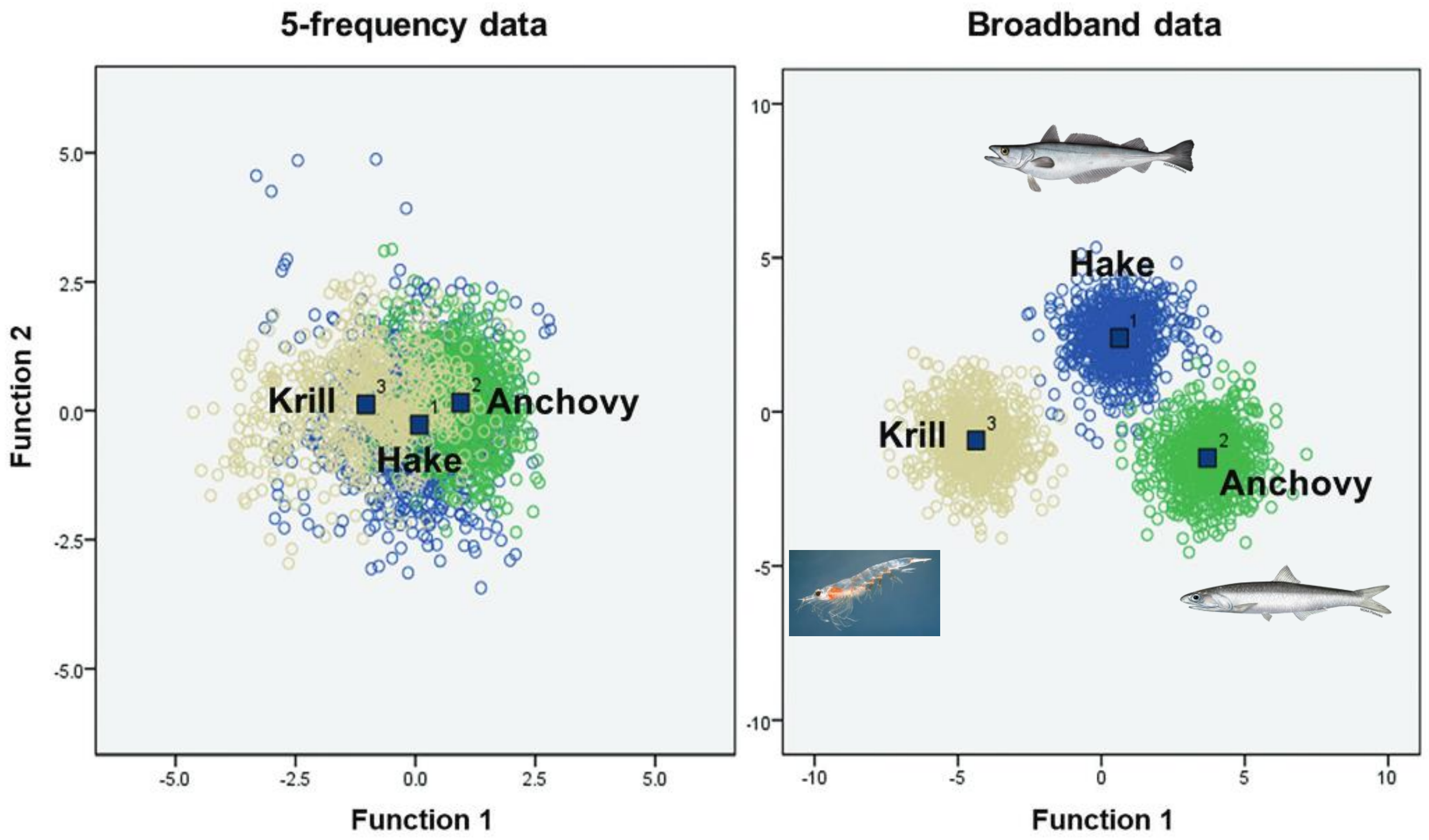
Echograms are shown for the broadband transducers with center frequencies 70 kHz (a), 120 kHz (b), and 200 kHz (c).

Species Identification and Biomass Measurement

Loranger et al 2022



Species Identification: Multispectral vs Broadband

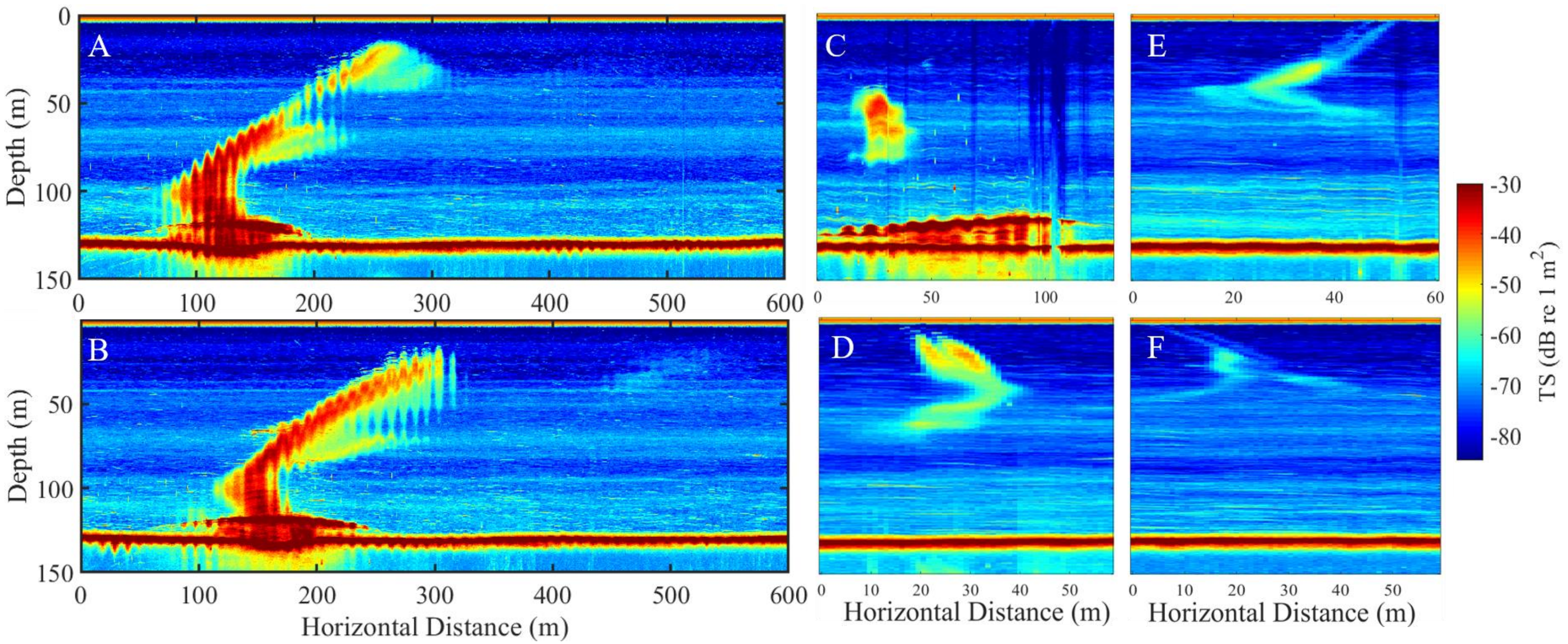


Benoit-Bird and Waluk 2020 Figure 6

Hydrocarbon Seep Studies

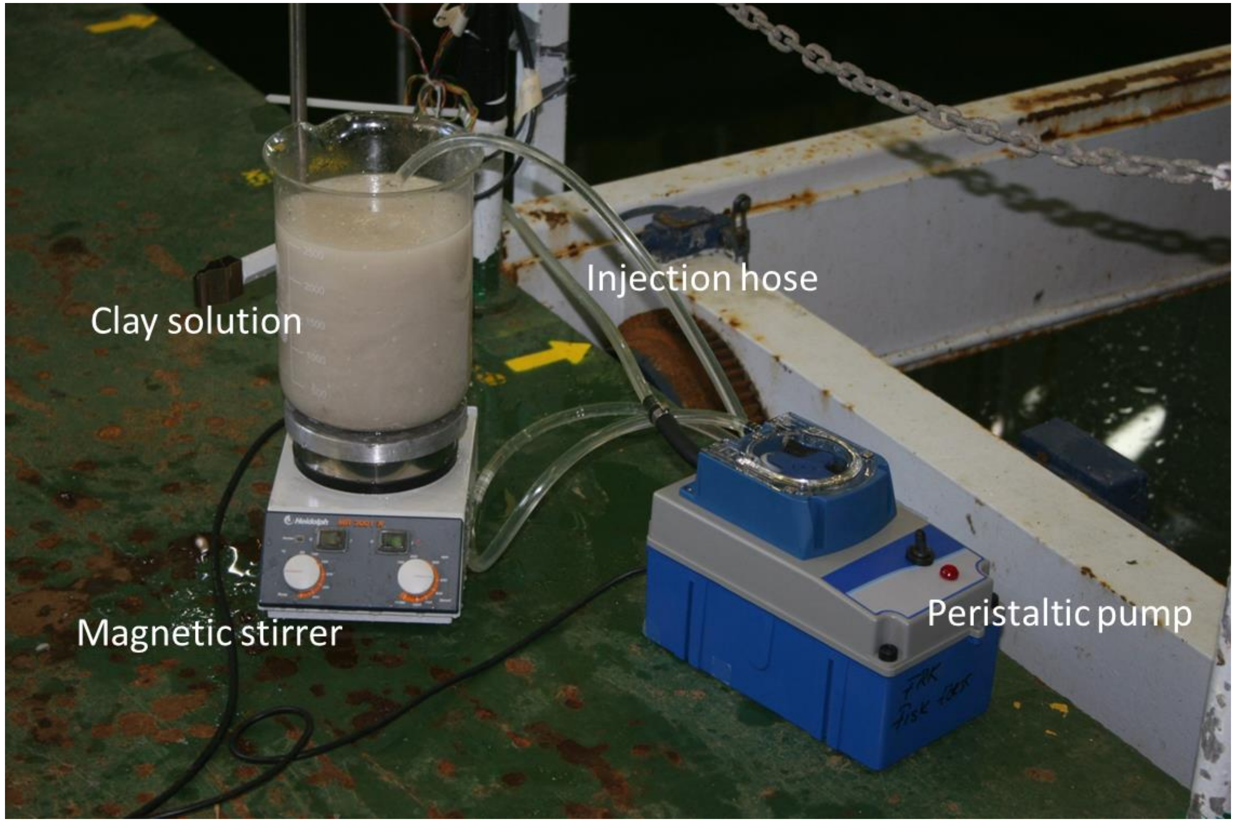
Figure 6

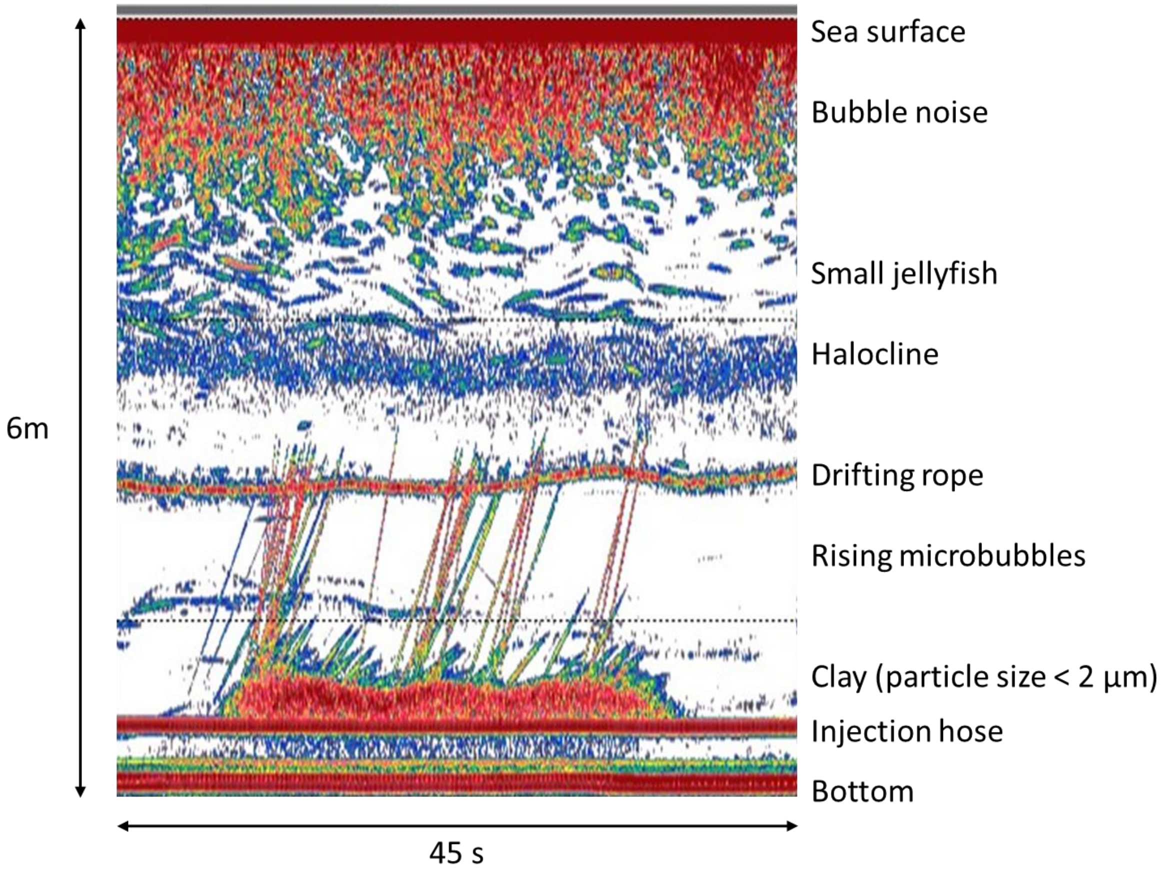
- Split-beam echosounders used in Gulf of Mexico to quantify hydrocarbon seeps
- Background measurements of natural seeps
- Quantification of new hydrocarbons above background due to spills
- Dredge turbidity monitoring has similar challenges



Preliminary Kongsberg Study (Frank Reier Knudsen)

Sediment detection experiments – injecting clay sediment bearing water samples and detecting their backscatter signals from chirped acoustic pulses





Observing sediment plumes in a controlled experiment with EK80 broadband echosounder during a preliminary experiment in the Delta Flume

(Deltares, Delft, NL)

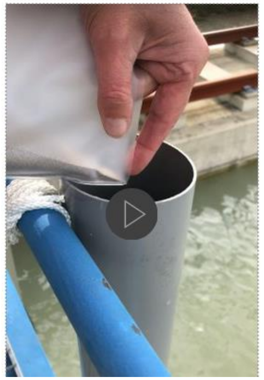
Preliminary data

Material

Kongsberg/Simrad EK80 FM mode :

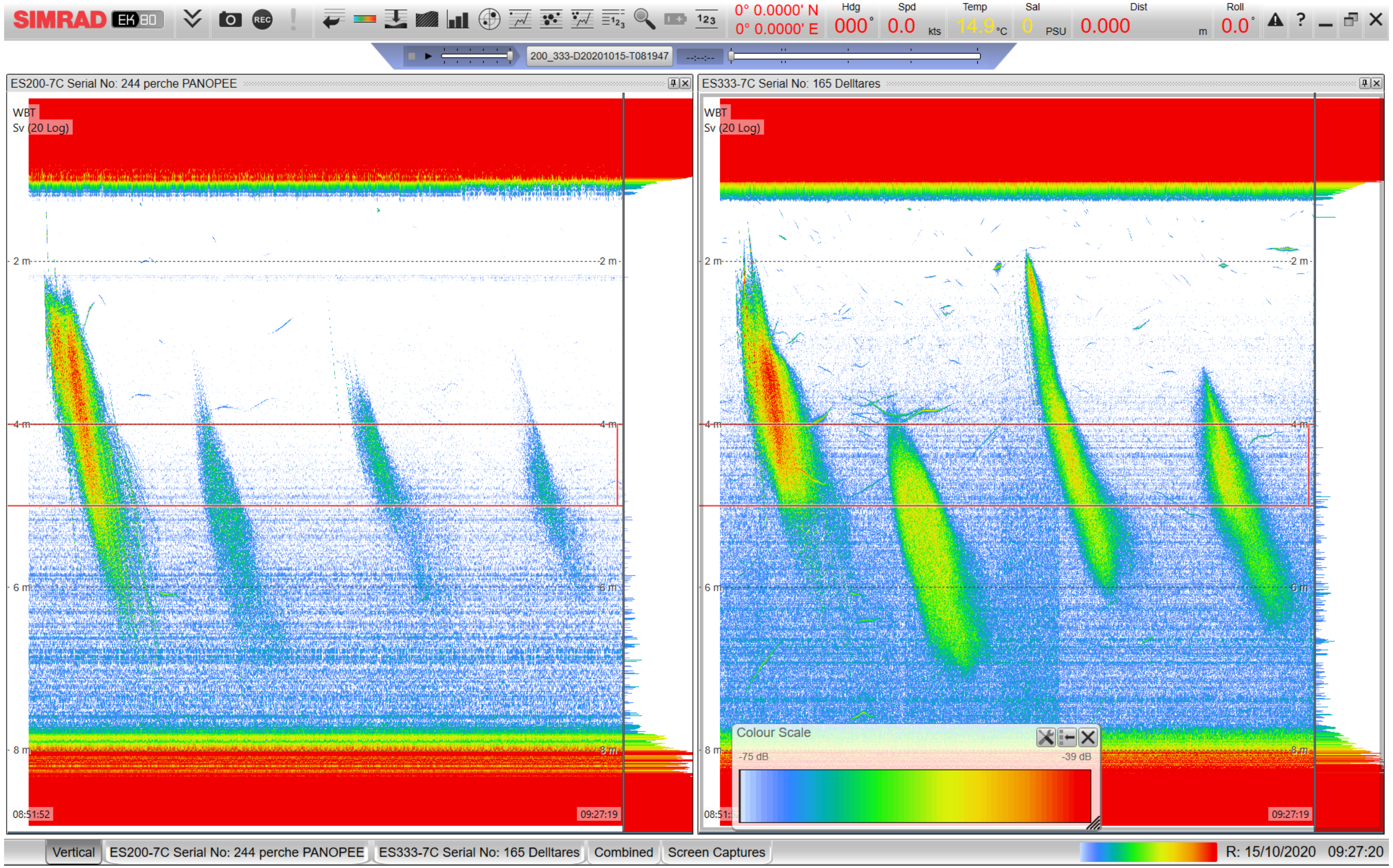
- 200kHz transducer [160-260] kHz
- 333kHz transducer [280-450] kHz
- 1ms pulse
- Calibrated with Tungsten Carbide sphere
- Steered 25°
- 8 m above floor
- 20g of sediment with four concentrations
  - >250 µm
  - [212:250] µm
  - [180:212] µm
  - [125:180] µm

EK80 antenna



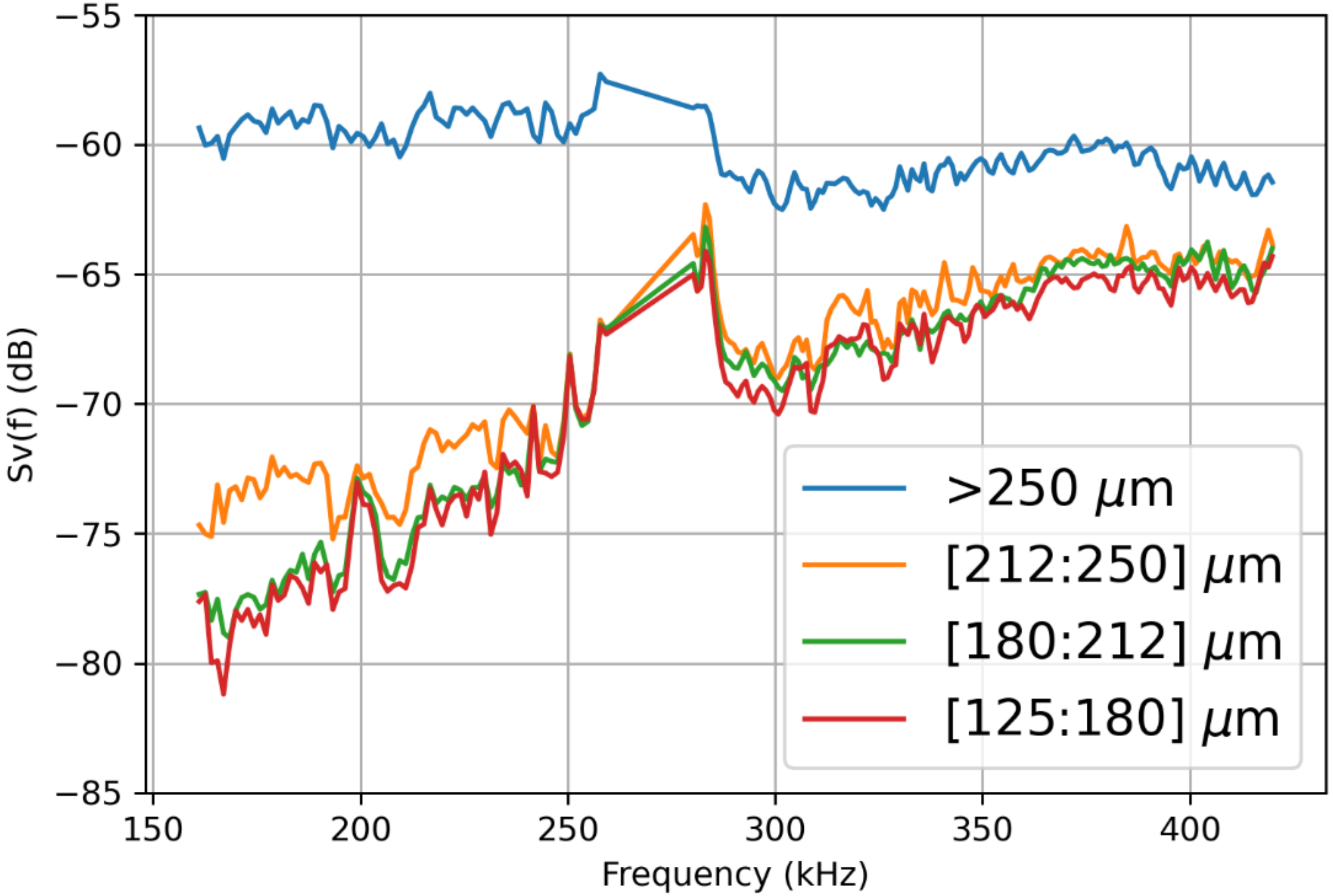
Preliminary data

Four sediment plumes of different grain size observed with an EK80



Preliminary data

Frequency response of sediment plumes extracted with Ifremer MOVIES3D software



Integrated volume backscatter in the layer from 4 to 5 m displayed on the echogram

Preliminary data

Recap – Boskalis study

Figure 10

Purpose:

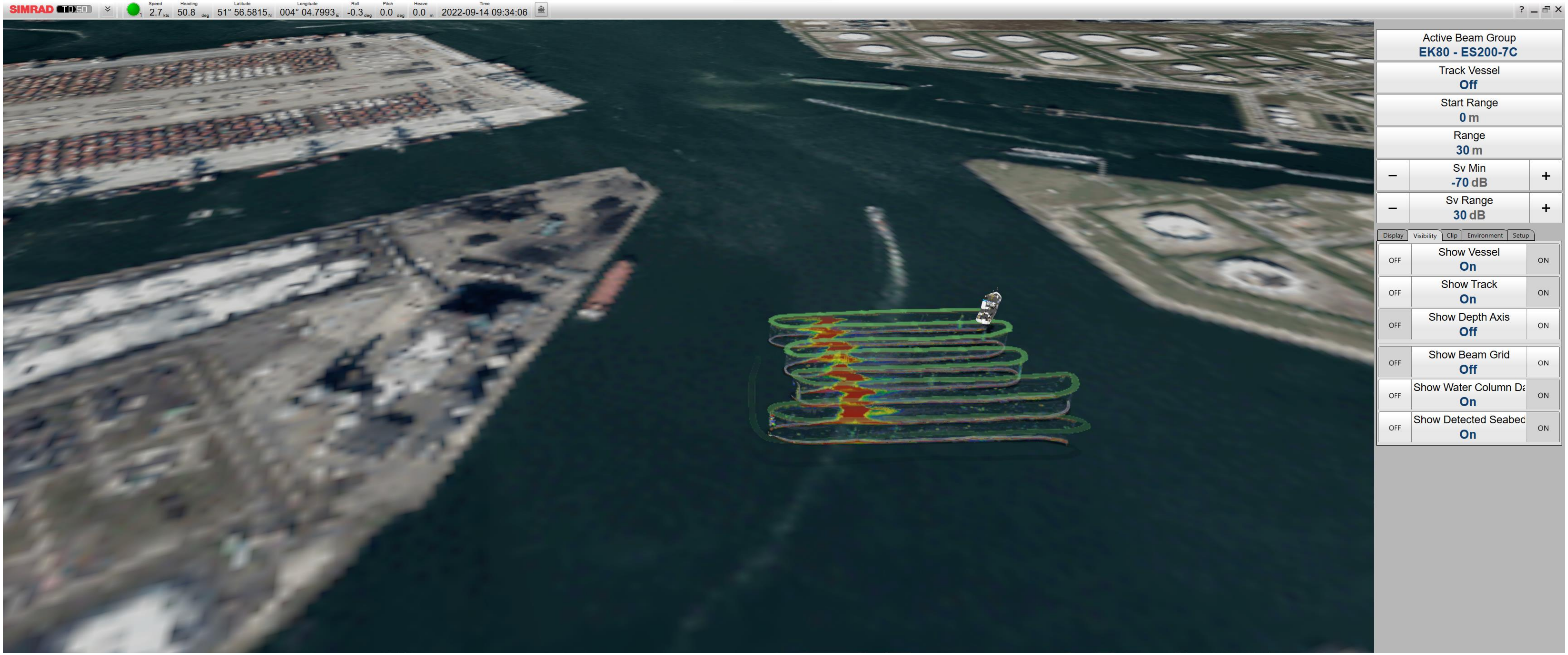
- Use EK80 to visualize what was going on in the water column and collect data for further analysis. We believe, based on other studies, that it's possible to make quantitative estimations of the sediments from the EK80 data.

Method:

- used a WBT Mini with an ES200-7C transducer over the side of a small vessel
- followed a water injection dredging operation in the port of Rotterdam.

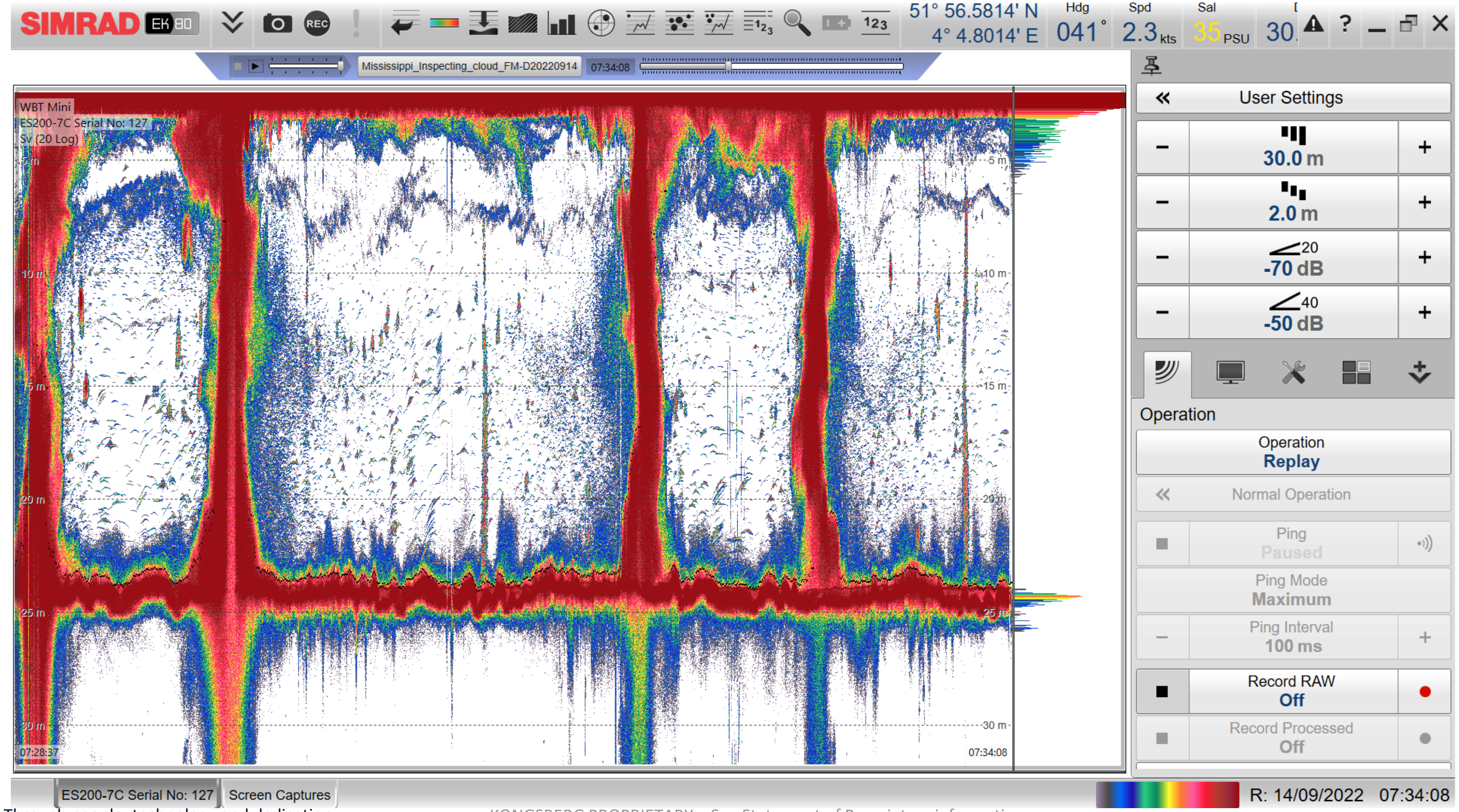
Recap – Boskalis study

Figure 11



Recap – Boskalis study

Figure 12



Conclusions and Next steps

- ADCPs alone can identify presence of particles in the water column. They typically cannot be used to easily quantify or characterize those particles.
- The EK80 split beam echosounders are successfully used to quantify and classify ocean biomass. They are also used to quantify and characterize hydrocarbon seeps in the Gulf of Mexico.
- Preliminary controlled environment studies in an outdoor tank by Deltares and Ifremer indicate the EK80 has potential to show sediment plume density, shape and rate of dispersion.
- Preliminary field work by Boskalis shows that the EK80 is able to track and quantify resuspended sediments in an open water column (a working port) even in presence of background sediments.
- This progress points to the potential for using split beam echosounders and ADCPs together to quantify the shape and density of resuspended solids during dredging operations and calculate where they will settle, based on current speed and direction provided by the current profiler.
- The EK80 can be installed on various types of platforms: from stationary deployments (moorings, buoys, landers) to mobile vehicles (USV, AUV, ROV, glider, Vessels), enabling flexible solutions within diverse environments

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Conclusions and Next steps

Further proof of concept work needs to be done to determine the following;

- Background turbidity
- Ability to track direction and dissipation / resettlement of plume
- Quantification of resuspended sediments caused by dredging operations;
- Ability to track the direction and dissipation / resettling of the plume; and
- How to present this data in an easy-to-interpret operator-friendly user interface in the dredge operator’s cab.