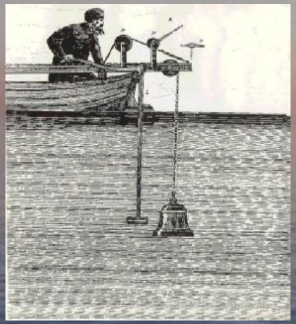
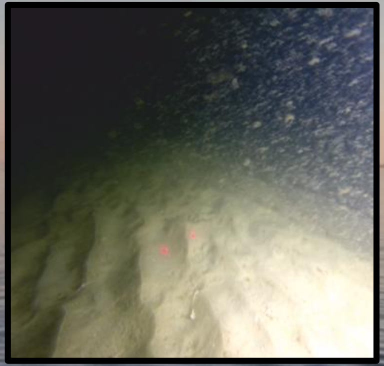
Unveiling complex seafloor environments: Expanding the potential of multibeam echo sounders (MBES)

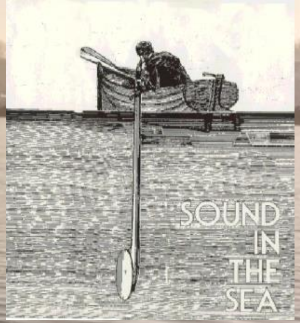


Substrate



Flora

Fauna



Jens Schneider von Deimling
Marine Geophysics and Hydroacoustics
Kiel University, Germany

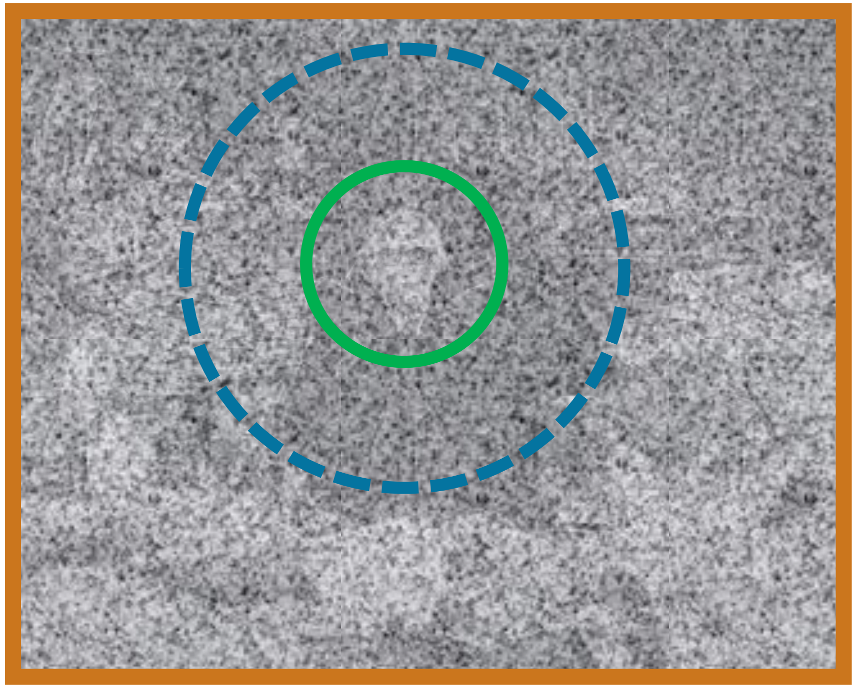
KIEL MARINE SCIENCE
CONNECTED RESEARCH

C A U
Kiel University
Christian-Albrechts-Universität zu Kiel

Peter Feldens
Leibniz Institute for Baltic Sea Research IOW
Warnemünde, Germany

Leibniz-Institut für Ostseeforschung Warnemünde
IOW

Benthic Habitat Mapping



Jean Piaget
Wikipedia.org

Scientist‘s Habitat?

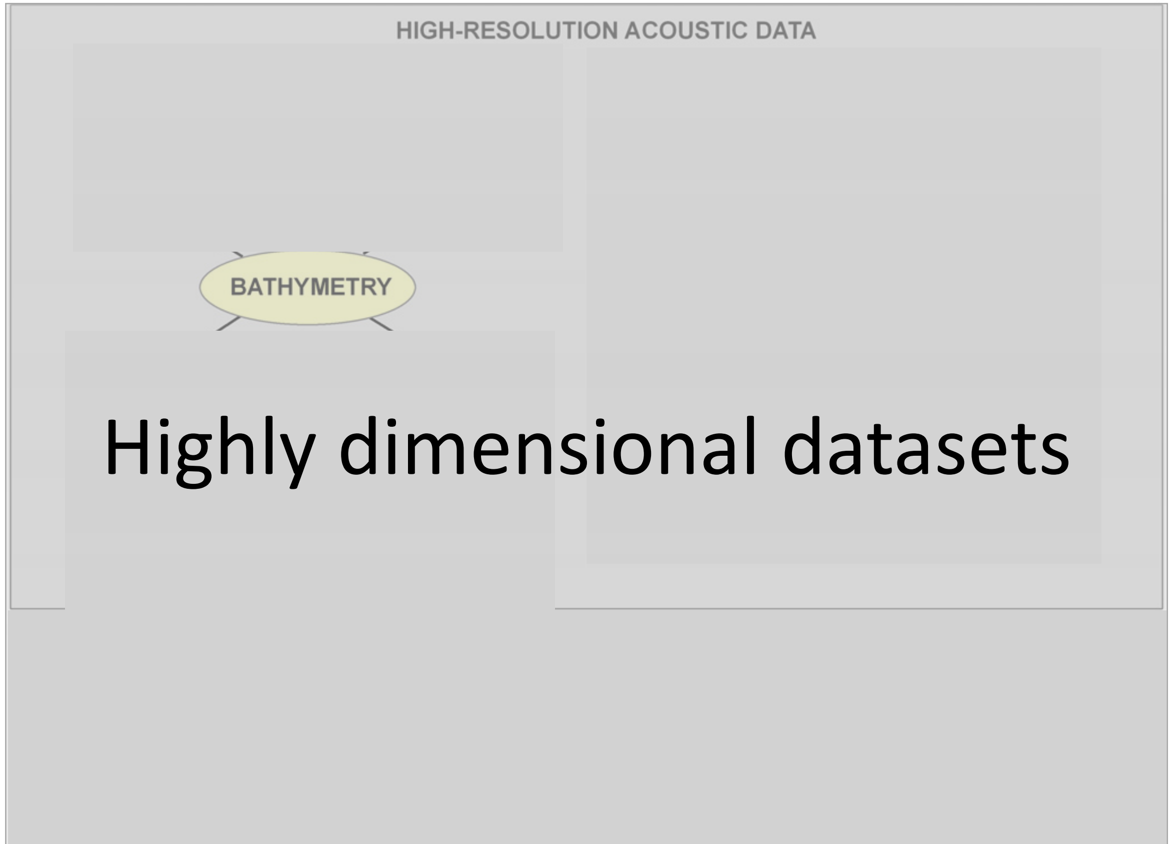
A specific Habitat has:

Environmental characteristics that support a species to live there (bio-geo-physico-chemical)

Some Habitat Mapping Goals:

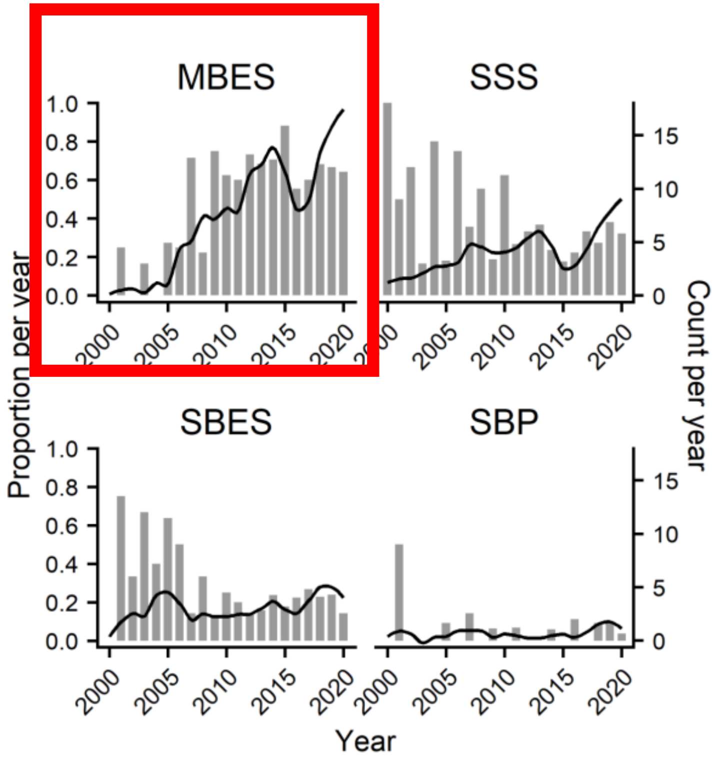
- Direct detection of living species
- Indirect environmental characterization
- Habitat Modeling

Benthic Habitat Mapping



Highly dimensional datasets

Brown et al. (2011)

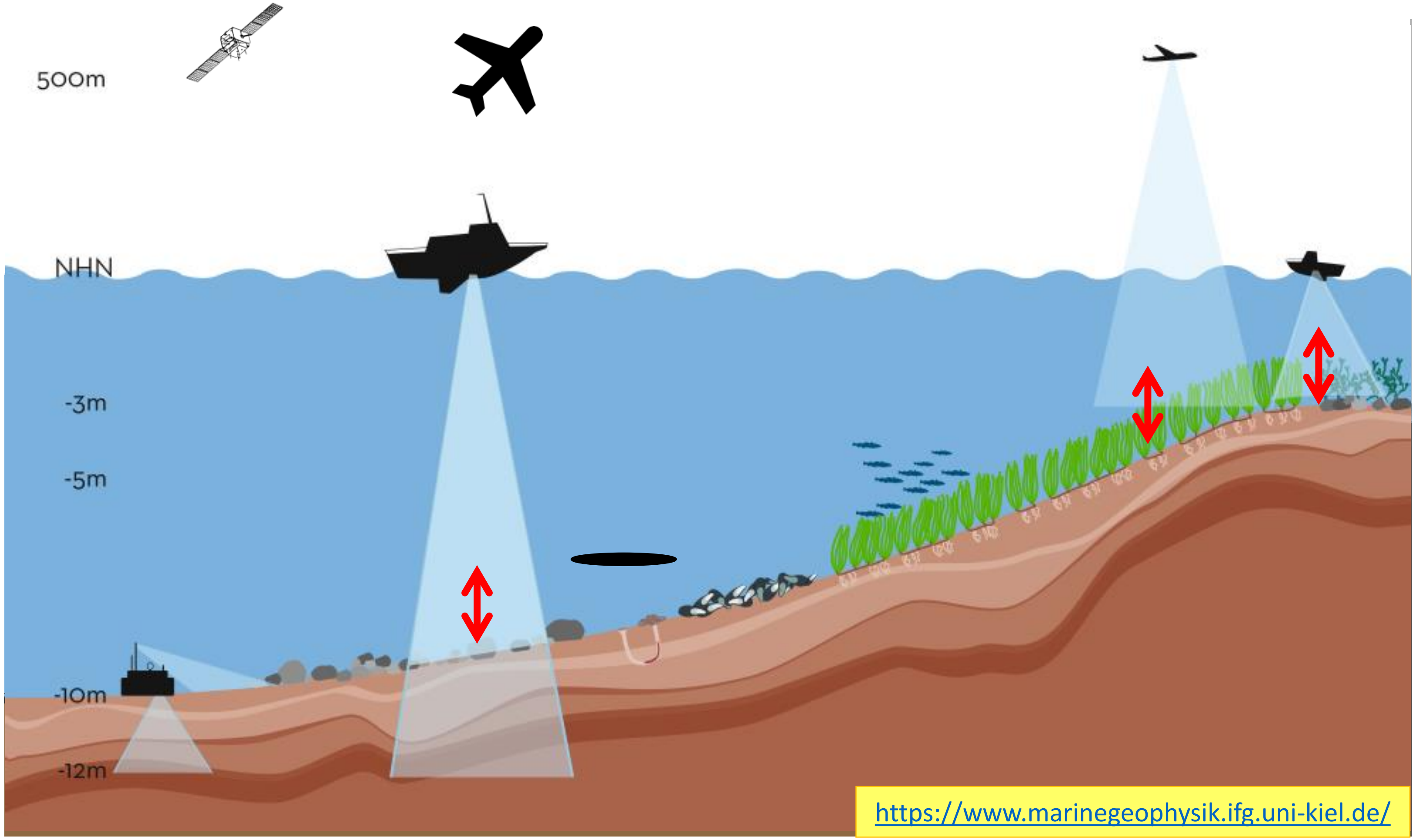


Misiuk and Brown (2023)

Habitat Mapping R&D

Since 2016

Opto-acoustic remote sensing, mapping, and monitoring



https://www.marinegeophysik.ifg.uni-kiel.de/

Projects:

ECO MAP

OCEANCITIZEN

sea4soCiety

marispace-x

Partners:

BSH – Bundesamt für Seeschifffahrt und Hydrographie

AHM – Airborne Hydro Mapping

EOMAP

Innomar

NORBIT – explore more –

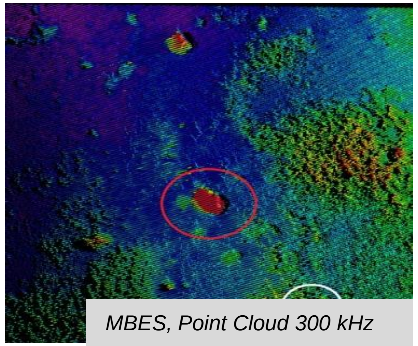
Experimental Hydroacoustics

Natural

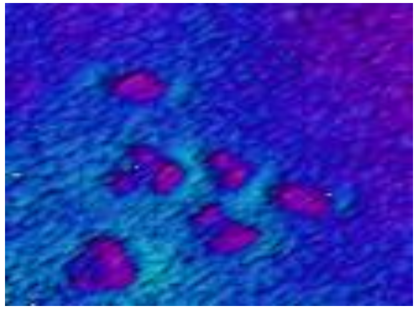
Rossbach & Herzing 1997

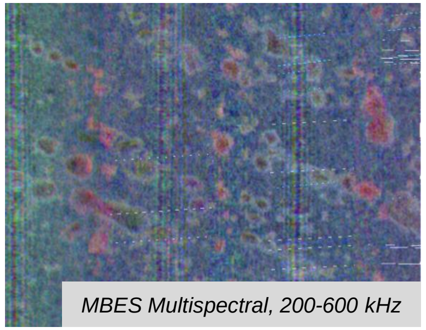
Heinrich et al 2016

Acoustic imaging



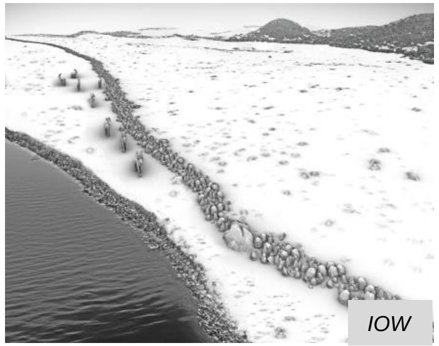
MBES, Point Cloud 300 kHz





MBES Multispectral, 200-600 kHz

Anthropogenic

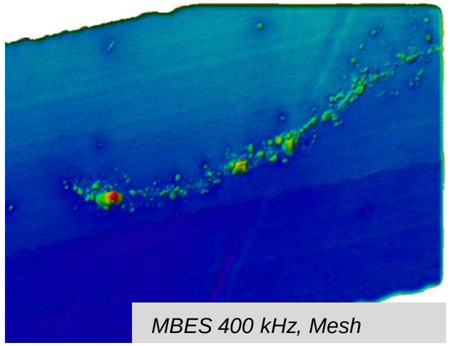


IOW

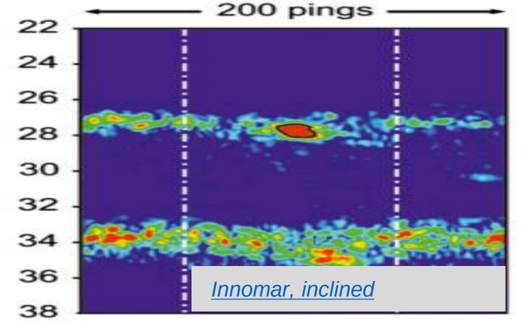
Wikipedia.org

MOBIL

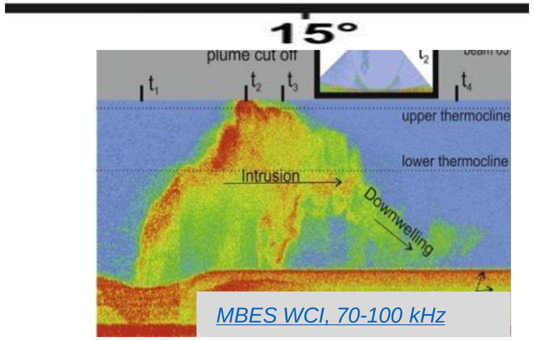
Acoustic imaging



MBES 400 kHz, Mesh



Innomar, inclined

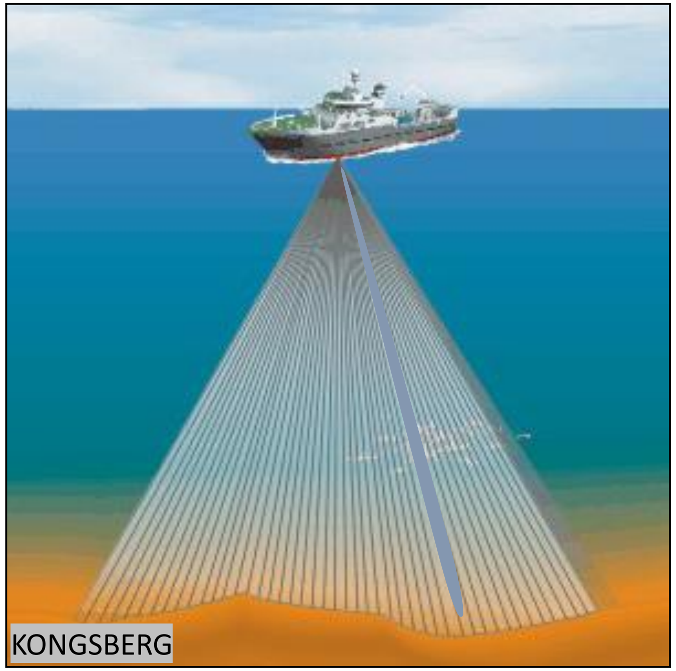


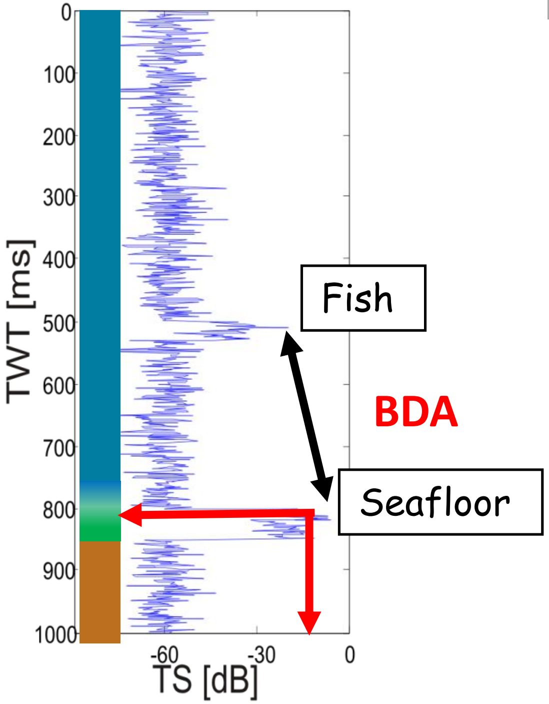
MBES WCI, 70-100 kHz

→ publications: https://www.marinegeophysik.ifg.uni-kiel.de/

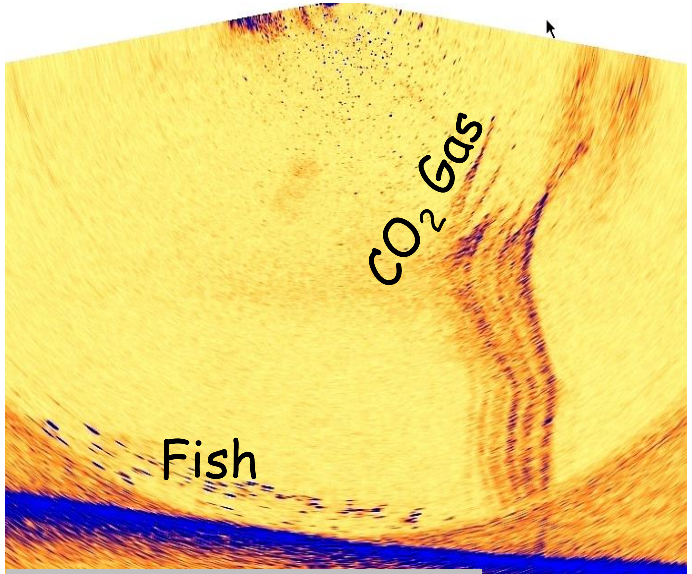
MBES expansions for detecting flora and fauna?

- Water Column Analyses
- Snippet Sidescan Backscatter
- Multidetect Soundings
- Point Cloud analytics
- Multispectral Backscatter





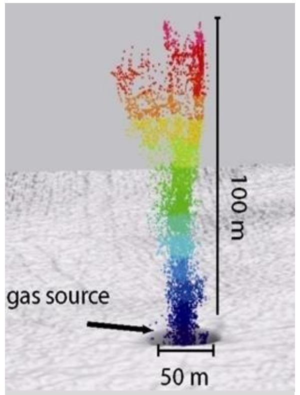
R2Sonic 2024, 400 kHz, Fan View



Schneider v . Deimling and Weinrebe (2014)

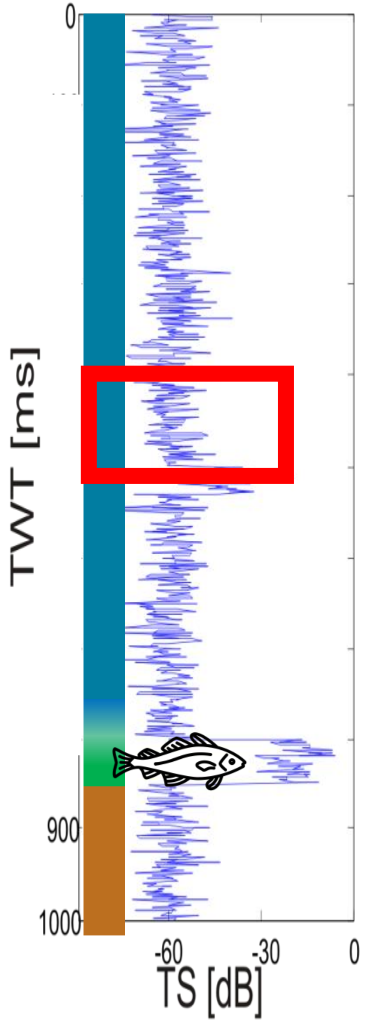
„Multidetect: compressed“ water column

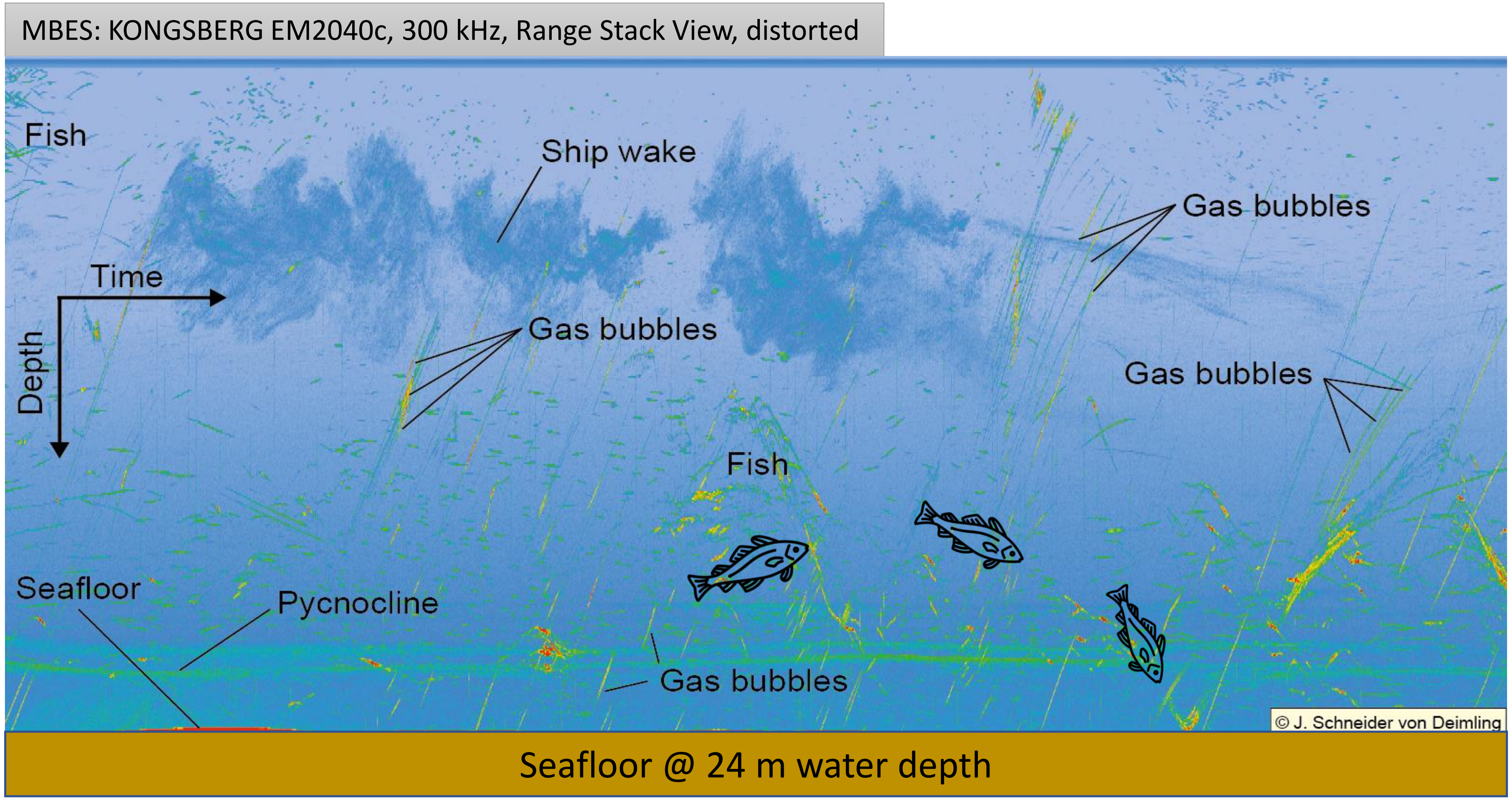
ELAC Seabeam, 180 kHz



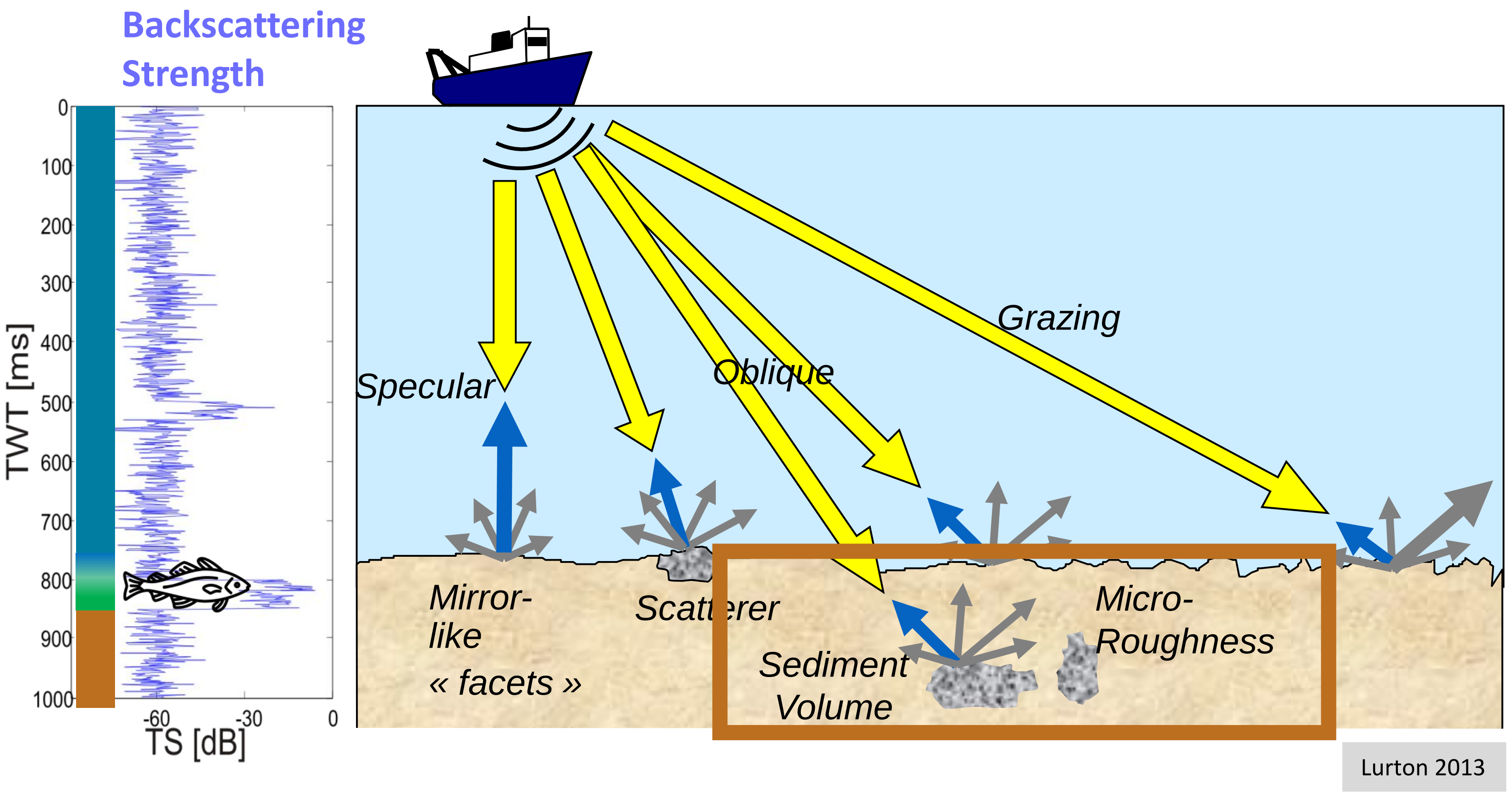
Schneider von Deimling et al. (2007)

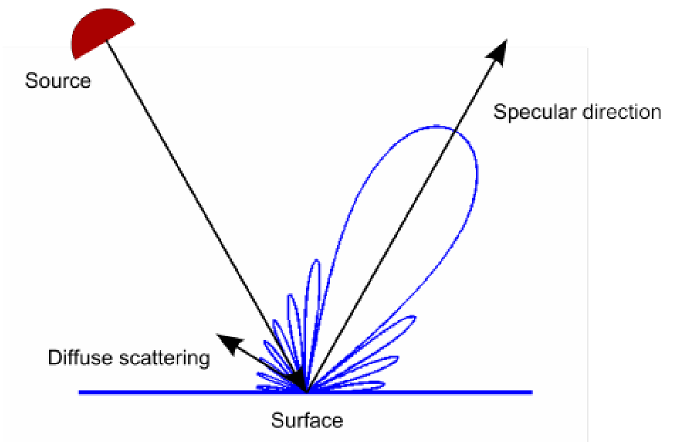
Backscattering Strength





Lohrberg et al. 2020





Wave Phenomena

- attenuation
- reflection
- refraction
- resonance
- volume scattering
- interface scattering
- ect. ect.

S/N: lost in **bottom reverberation**

Classic controls on seafloor backscattering

1. Surface roughness
2. Sensor-target geometry
3. Seafloor physical properties (also volume scattering)
4. Hardware, sonar settings

Roche 2013

Claim:

Underexplored biogenic controls

on seafloor backscattering

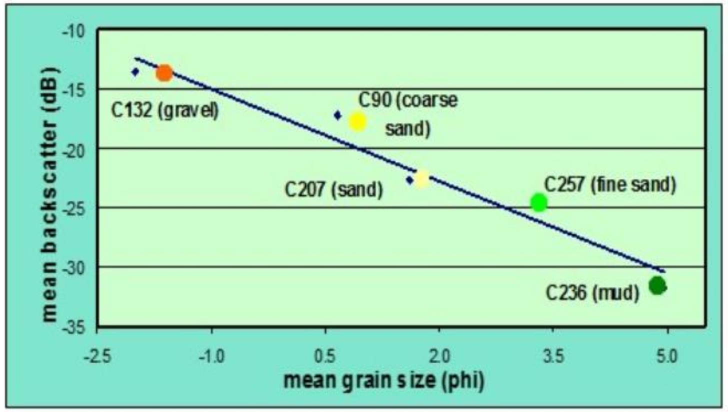


Figure 1-5 Relation Backscatter Strength (in dB) vs. sediment grain size (phi = -log2 (d), d=grain diameter in mm) on samples collected in Cook Strait, New Zealand (Lamarche et al., 2011). The plot makes clear the increase of BS with the grain size, caused by both the substrate hardness and its roughness, both correlated with grain size. Data recorded with the MBES Kongsberg EM 300 (30 kHz) on R/V Tangaroa.

BSWG Report 2015

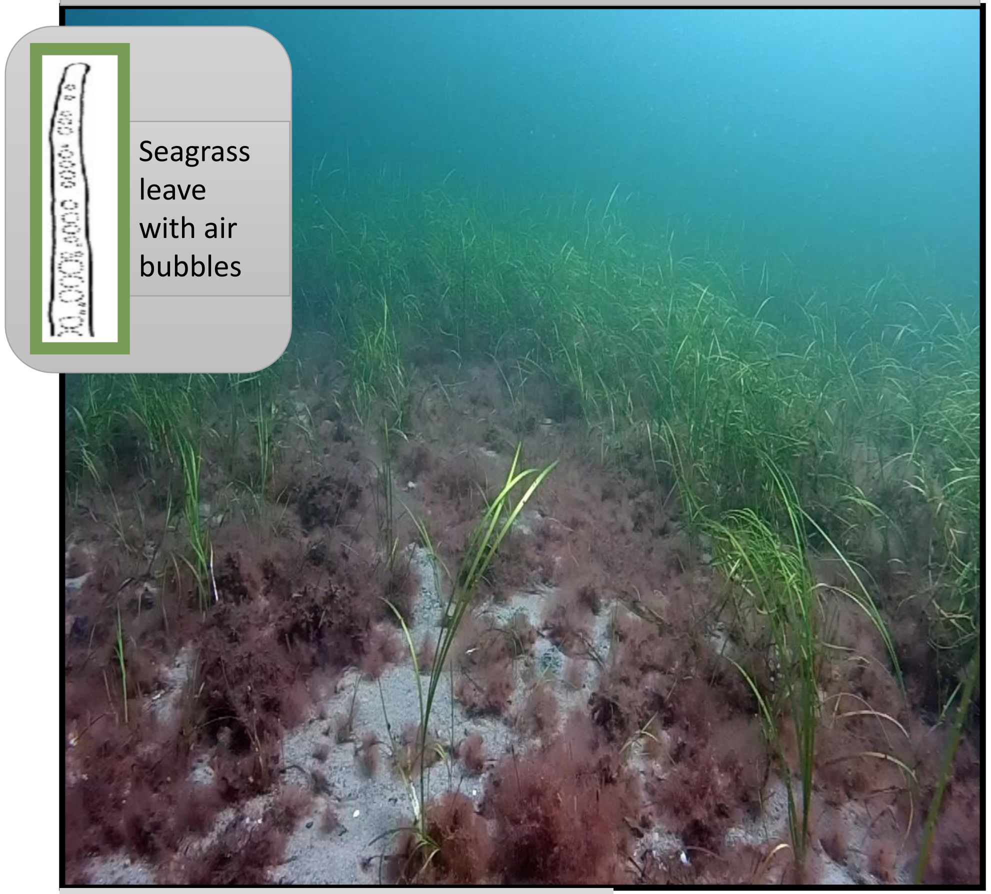
Global assessment of **forest** by sensing with RADAR

Seegrass is one of the most important habitats on Earth!

- nursery grounds for fish
- great carbon dioxide sinks
- sediment trapping
- increase water quality
- O_2 production

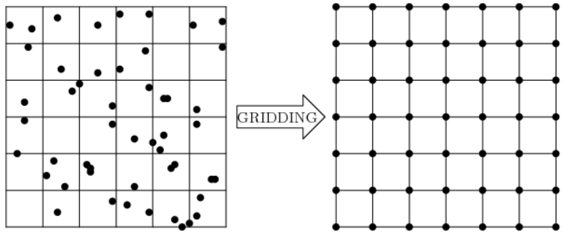
Martone et al. (2018)

NORBIT iWBMS 400 kHz - Point Cloud Analytics: Seagrass



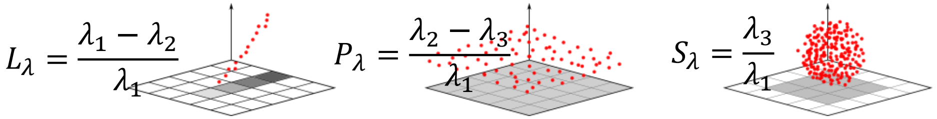
Held P and Schneider von Deimling J (2019)
https://doi.org/10.3390/geosciences9050235

Digital Terrain Model (DTM)



+ straight forward
- Information loss
- Falsification due to interpolation
- Only one surface

Point Cloud Analytics within 0.5m radius (PCL)

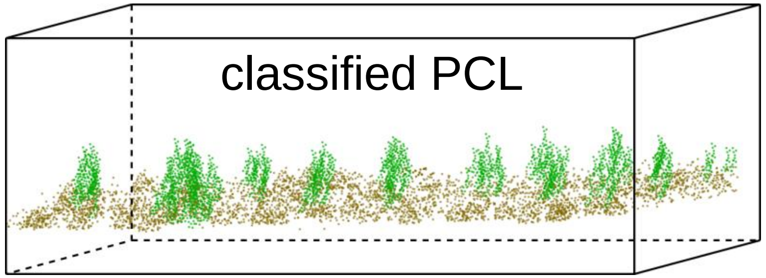


$L_\lambda = \frac{\lambda_1 - \lambda_2}{\lambda_1}$ Linearity

$P_\lambda = \frac{\lambda_2 - \lambda_3}{\lambda_1}$ Planarity

$S_\lambda = \frac{\lambda_3}{\lambda_1}$ Spherecity

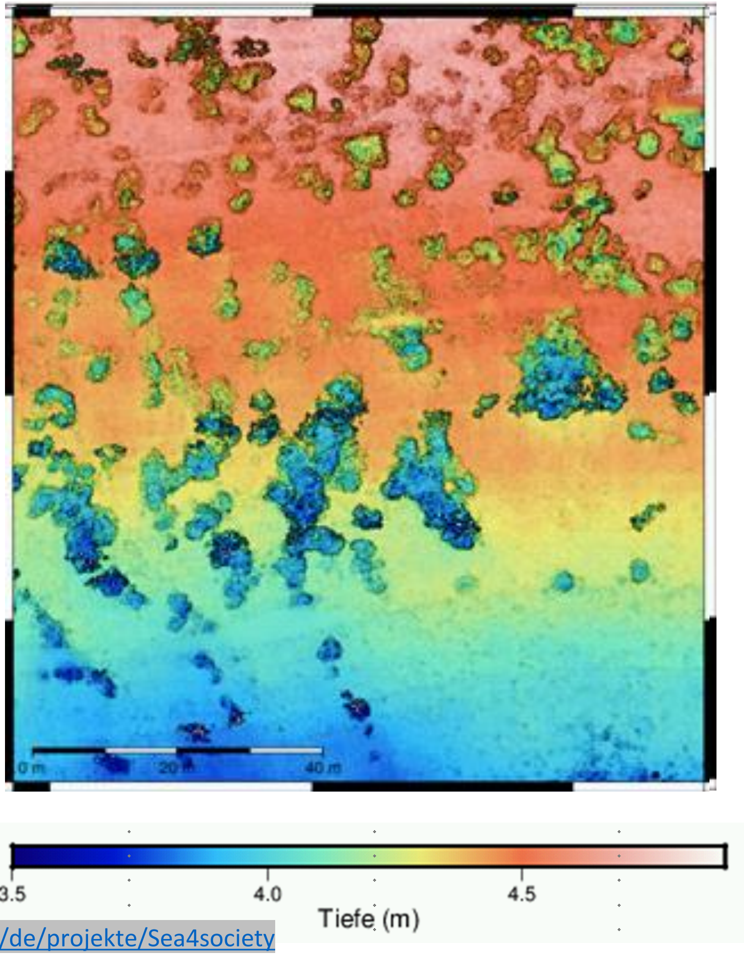
\+ Random forest classification



+ closer to physical reality
+ Allows for biomass estimates
- Computational expensive

MBES acoustics seagrass mapping – does it match optical data?

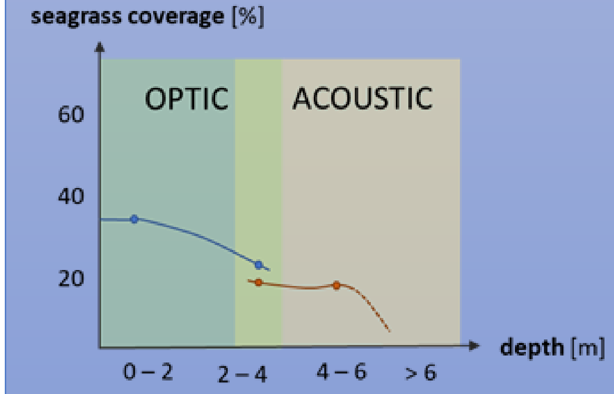
CAU Surveyboat
FB Zostera



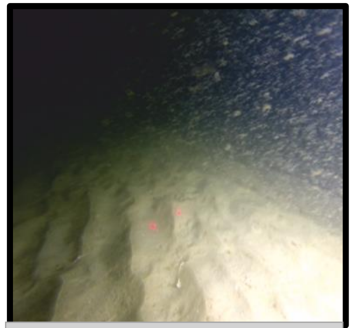
https://www.marinegeophysik.ifg.uni-kiel.de/de/projekte/Sea4society

Cross-validation and benefits of using acoustics

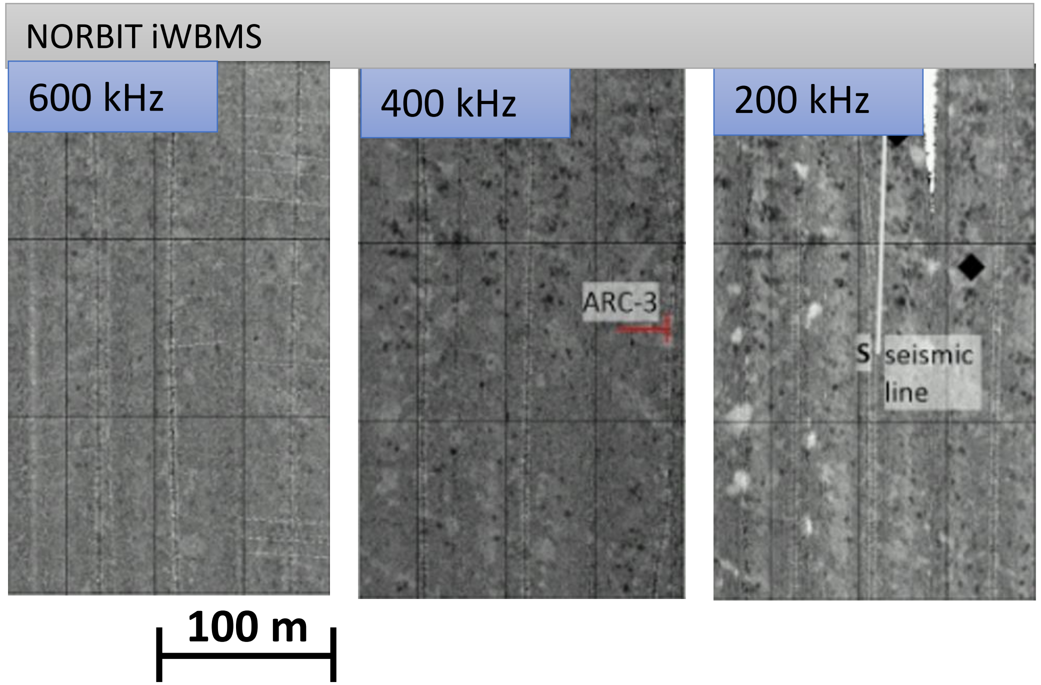
- Reliability Classification ~85%
- Without acoustics stock underestimated by 30%
- Acoustics deliver max. depth as ecosystem proxy

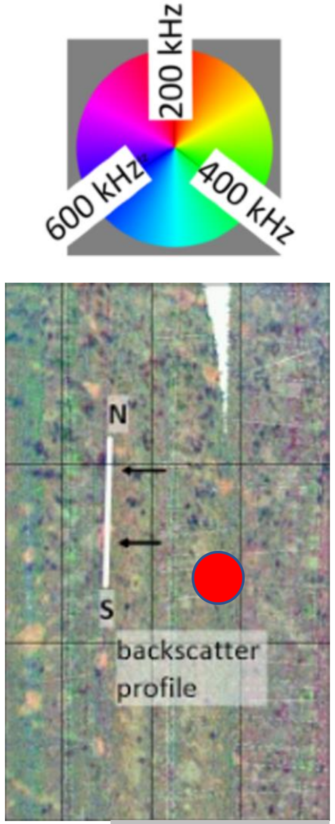


MBES – Multispectral Backscatter



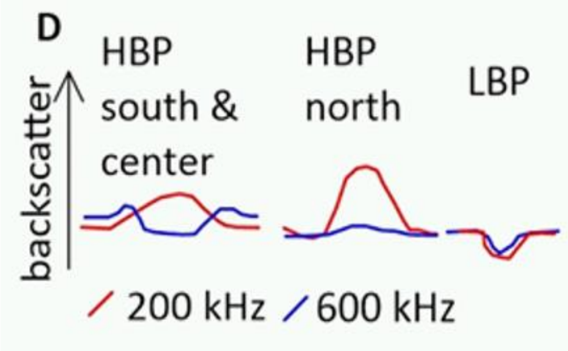
North Sea
- German Bight
- 15 m deep
- Fine sand
- Flat





Feldens et al. (2018)

Patches
- 10–70 m diameter
- -2 dB and +4 dB deviation from background



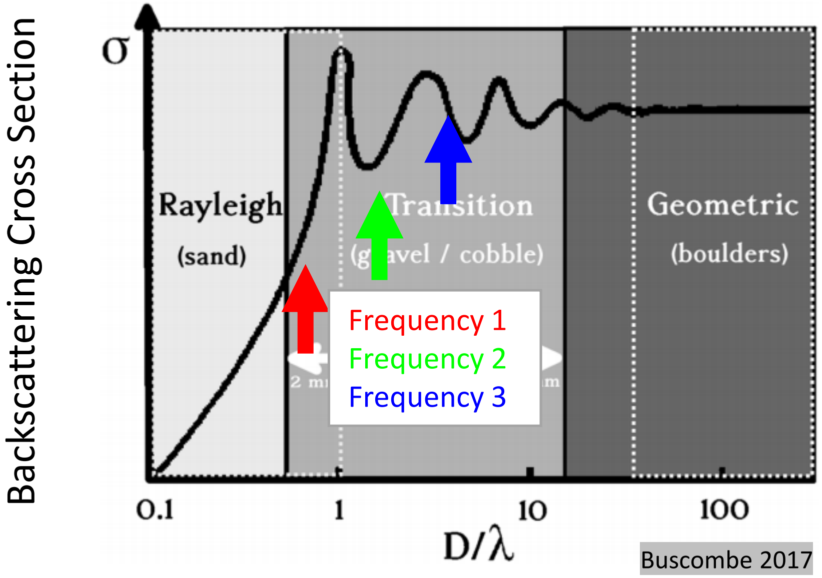
Microroughness
Bioturbation
Burrowers?
Biofilms?
Buried fish?

https://britishseafishing.co.uk/greater-and-lesser-sandeel/

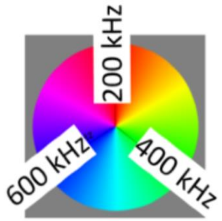
multispectral pattern?

MBES - Multispectral

nonlinear behaviour of scatteres



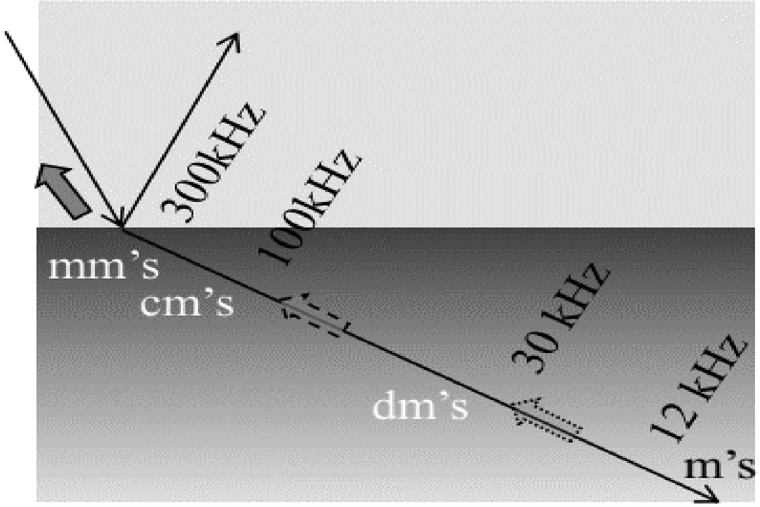
Buscombe 2017



$D = object\ diameter\ [mm]$

$\lambda_{400\ kHz\ @}$ 1500 m/s = 3.7 $[mm]$

Frequency dependent penetration

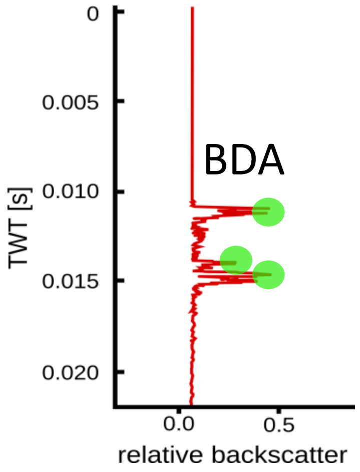


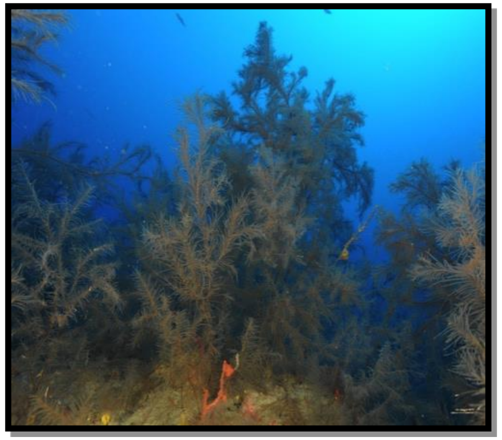
Hughes Clarke 2016

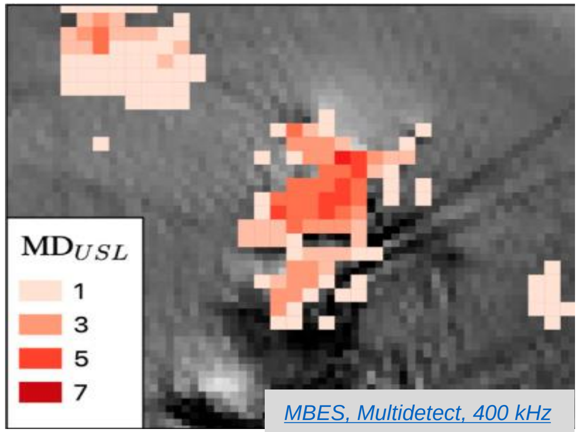
- Frequency dependent penetration
- Penetration with 400 kHz in sand ca. 8 cm, expect much more in silt and mud (decimeters)

MBES multidetect flora: more ongoing case studies

Black Corals
Canary Island
70 m water depth

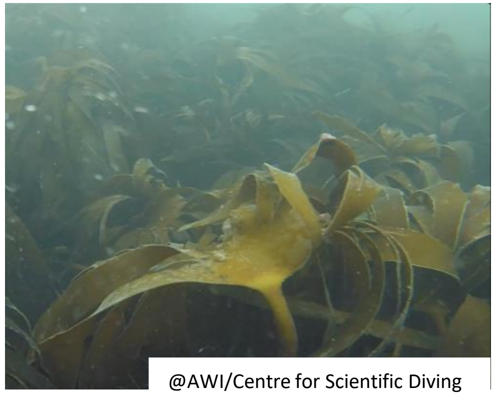


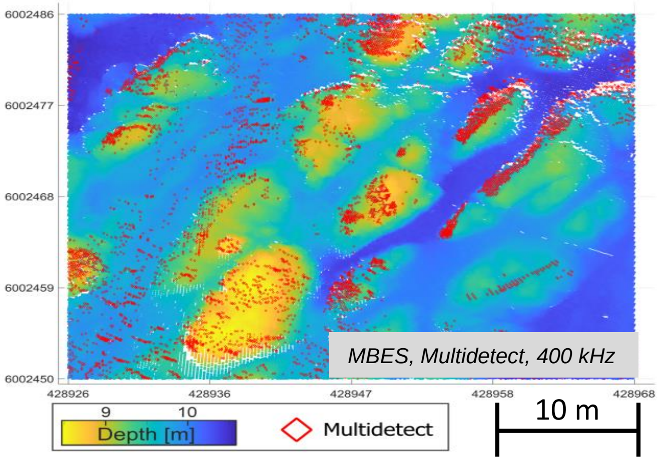




MBES expansion	Detection
Snippet Backscatter	Failed
Multispectral	Failed
Point Cloud Analyses	Failed
Multidetect	Partially successfull

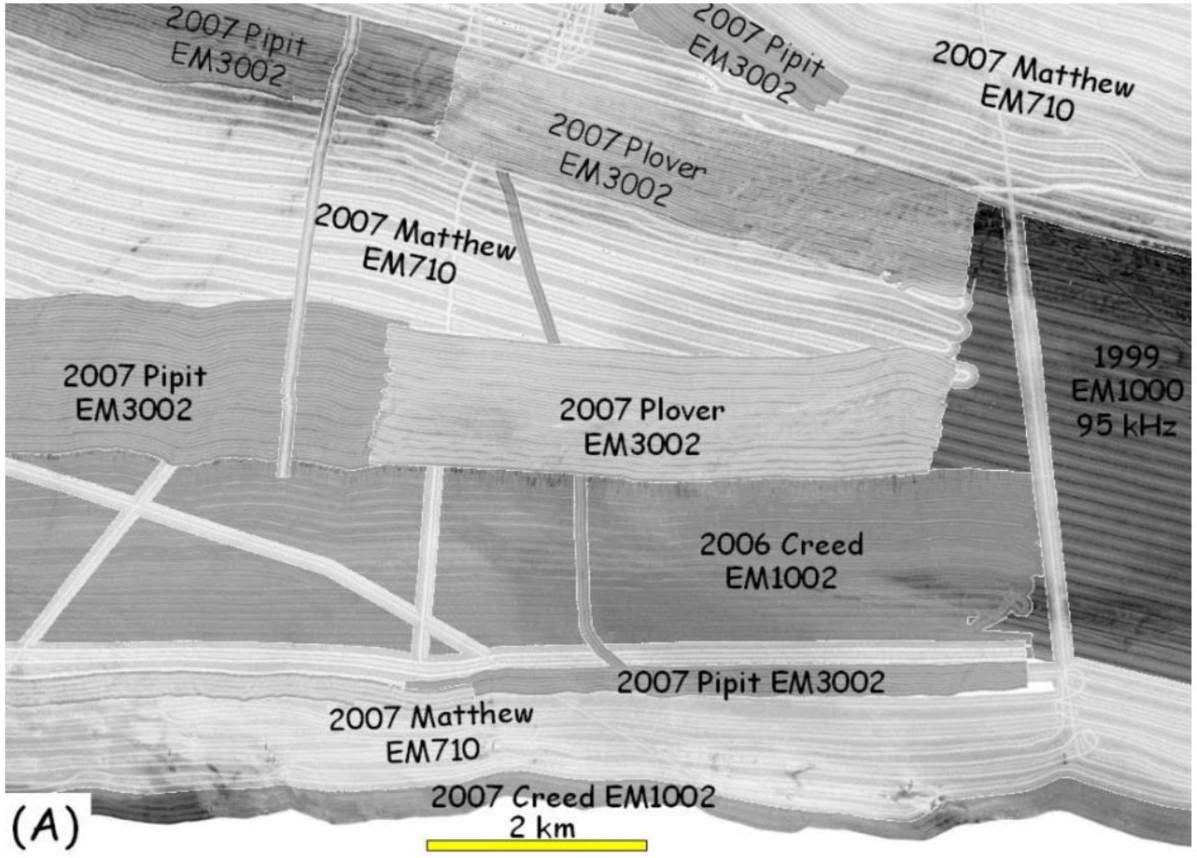
Kelp Forests
Heligoland,
Germany,
on complex
bathymetry


@AWI/Centre for Scientific Diving



MBES expansion	Detection
Snippet Backscatter	Not tested
Multispectral	Not tested
Point Cloud Analyses	Not tested
Multidetect	Poorly successfull

Harmonization of backscatter from different surveys remains a major problem



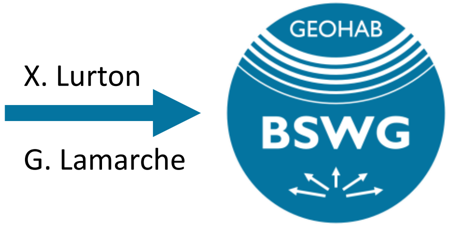
Hughes Clarke 2008, Bay of Fundy

Backscattering „instabilities“

ARC
AGC
Frequency Dependance
Calibration
Piezo Alteration
Anisotropy
Pulse Length
System Status/ Firmware
Temperatur Dependance

GEOHAB
Marine Geological and Biological Habitat Mapping

X. Lurton
G. Lamarche



- BS Multispectral
- BS Water column
- BS Acquisition
- BS Processing
- BS Calibration

https://geohab.org/backscatter-working-group/

First link being made with IOH-HSWG

Quality aspects of MBES measurements (10A)

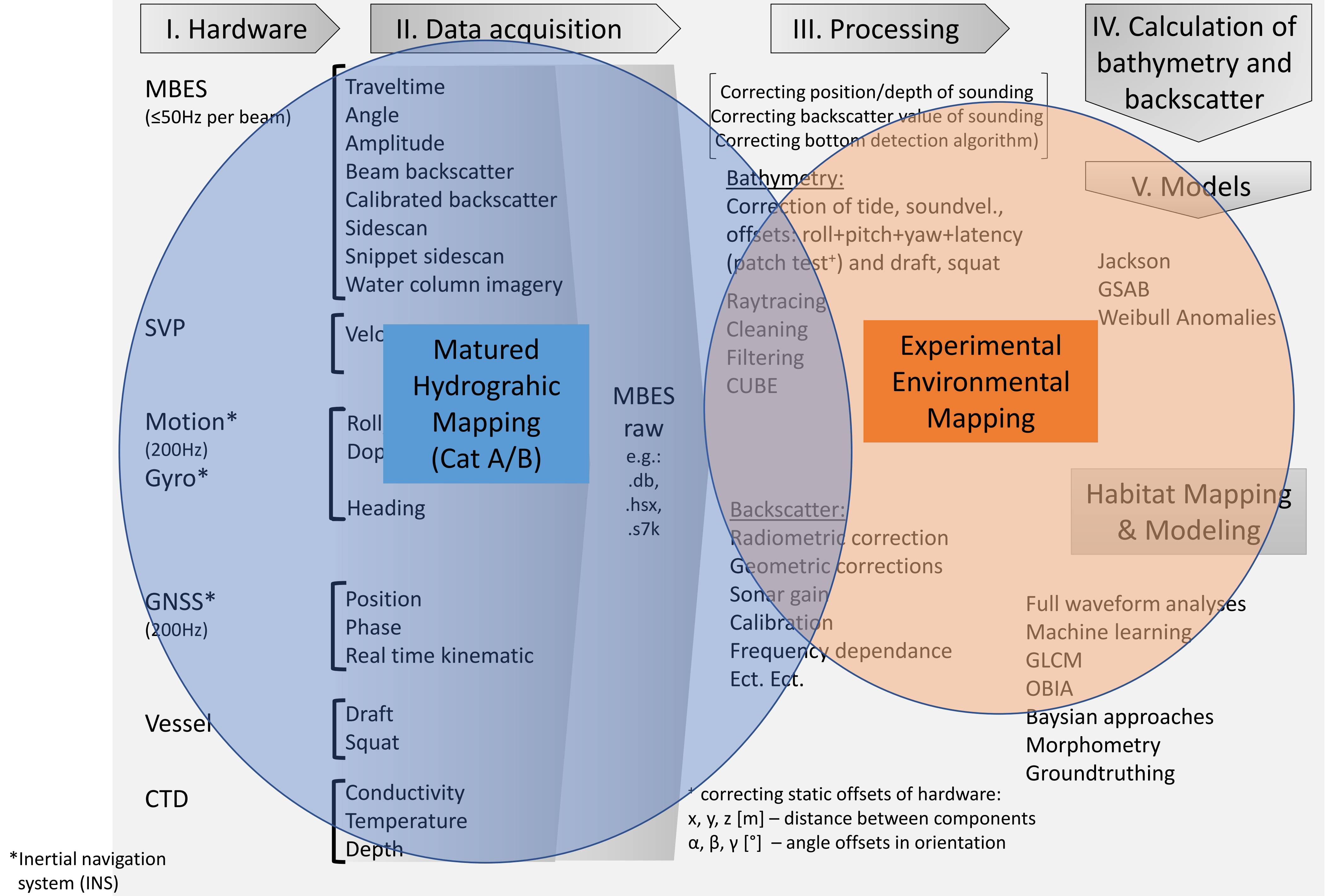
Coastal habitat mapping using modern MBES systems: **where are we?**

Some Tasks	Challenges	Solutions
Flora & Fauna Acoustics	Complex Seafloors	More case studies
Habitat Mapping & Modelling	High dimensionality	Machine Learning
Reliability Acoustics	Offsets backscatter	Manufacturer Standards Community Work

Emerging Market driven e.g. by MSFD

from infancy → to teenager → to mature

2005 2015 2025 2035



I. Hardware
II. Data acquisition
III. Processing
IV. Calculation of bathymetry and backscatter
MBES
(≤50Hz per beam)
Traveltime
Angle
Amplitude
Beam backscatter
Calibrated backscatter
Sidescan
Snippet sidescan
Water column imagery
SVP
Velo
Motion*
(200Hz)
Gyro*
Roll
Dop
Heading
GNSS*
(200Hz)
Position
Phase
Real time kinematic
Vessel
Draft
Squat
CTD
Conductivity
Temperature
Depth
*Inertial navigation system (INS)
Matured Hydrograhic Mapping (Cat A/B)
MBES raw
e.g.:
.db,
.hsx,
.s7k
Correcting position/depth of sounding
Correcting backscatter value of sounding
Correcting bottom detection algorithm)
Bathymetry:
Correction of tide, soundvel.,
offsets: roll+pitch+yaw+latency
(patch test+) and draft, squat
Raytracing
Cleaning
Filtering
CUBE
Backscatter:
Radiometric correction
Geometric corrections
Sonar gain
Calibration
Frequency dependance
Ect. Ect.
+ correcting static offsets of hardware:
x, y, z [m] – distance between components
α, β, γ [°] – angle offsets in orientation
Experimental Environmental Mapping
V. Models
Jackson
GSAB
Weibull Anomalies
Habitat Mapping & Modeling
Full waveform analyses
Machine learning
GLCM
OBIA
Baysian approaches
Morphometry
Groundtruthing

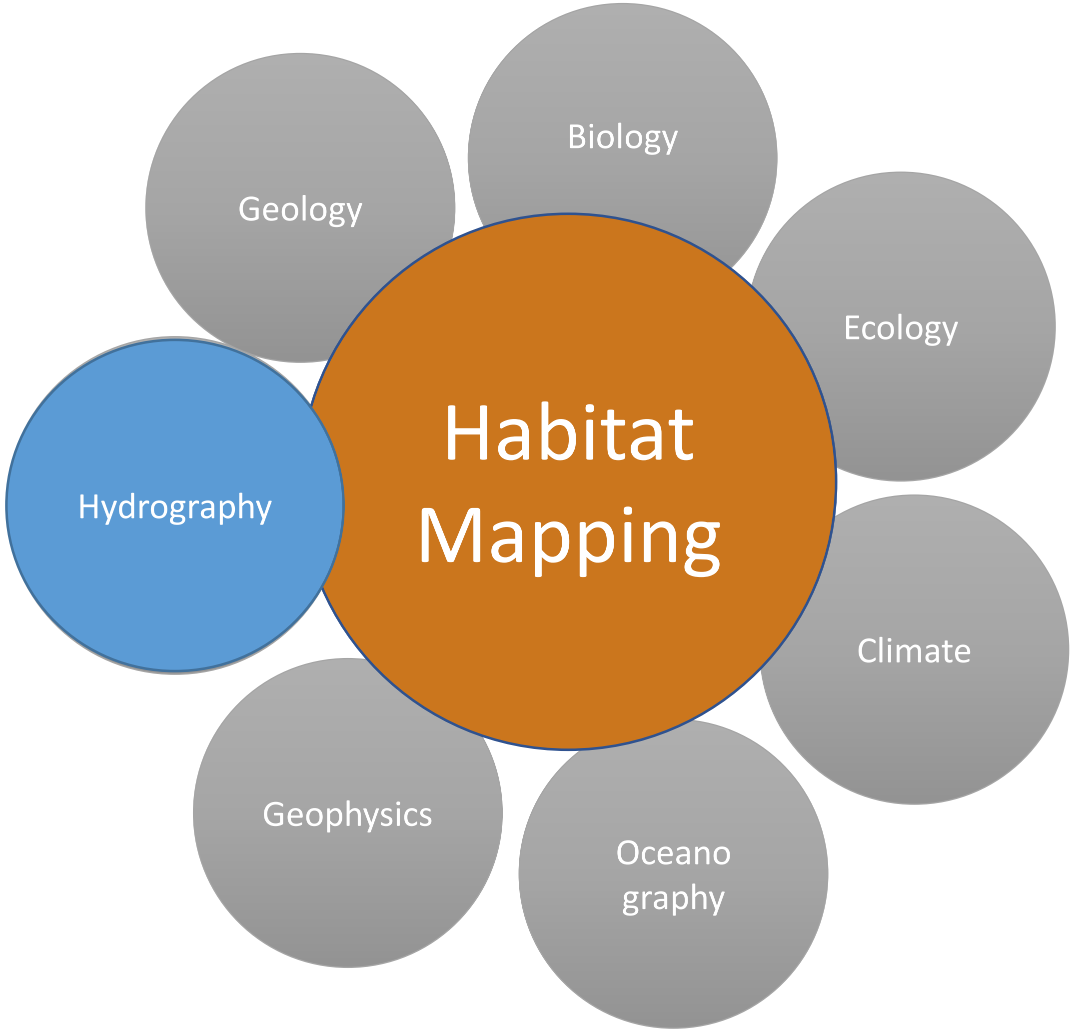
Disciplines:

Cross-disciplinary

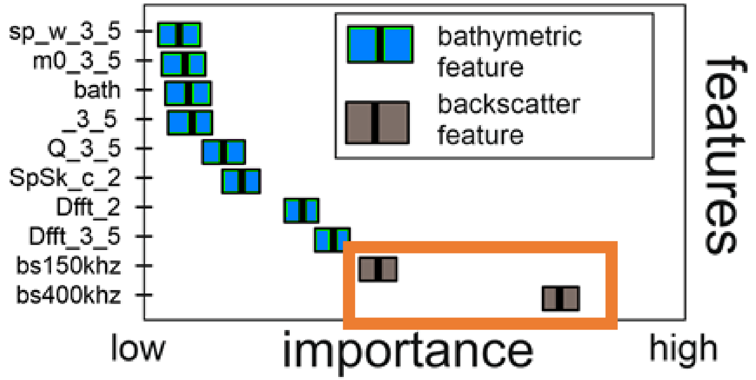
Acoustics

Optics

Engineering



Machine learning feature importance:
#1 Backscatter
#2 Backscatter
#3-10 Bathymetric



Adapted from Janowski et al. 2018

Comments and Conclusion

- MBES direct detection of flora and fauna often feasible – still experimental
- No consesus yet with multispectral, multidetect, water column, community effort needed
- Mutual benefits from close collaboration between the hydrographic and environmental world


Thanks for your attention!