Examining the links between multifrequency backscatter, geomorphology and benthic habitat associations in marine protected areas.

Robert M Runya, Chris McGonigle and Rory Quinn

Ulster University School of Geography and Environmental Sciences

PhD Researcher

Email: runya-r@ulster.ac.uk

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Introduction

- Measured backscatter varies with operating frequency, angle of incidence and sediment characteristics (Brown *et al.,* 2019).
- The frequency response of backscatter varies greatly in soft sediments (Montereale-Gavazzi *et al.,* 2018).
- The linkage between acoustic signal and sediment properties is complex (Lamarche & Lurton, 2018).
- Current need and potential of multifrequency backscatter for improved seafloor characterisation and classification (Costa, 2019).

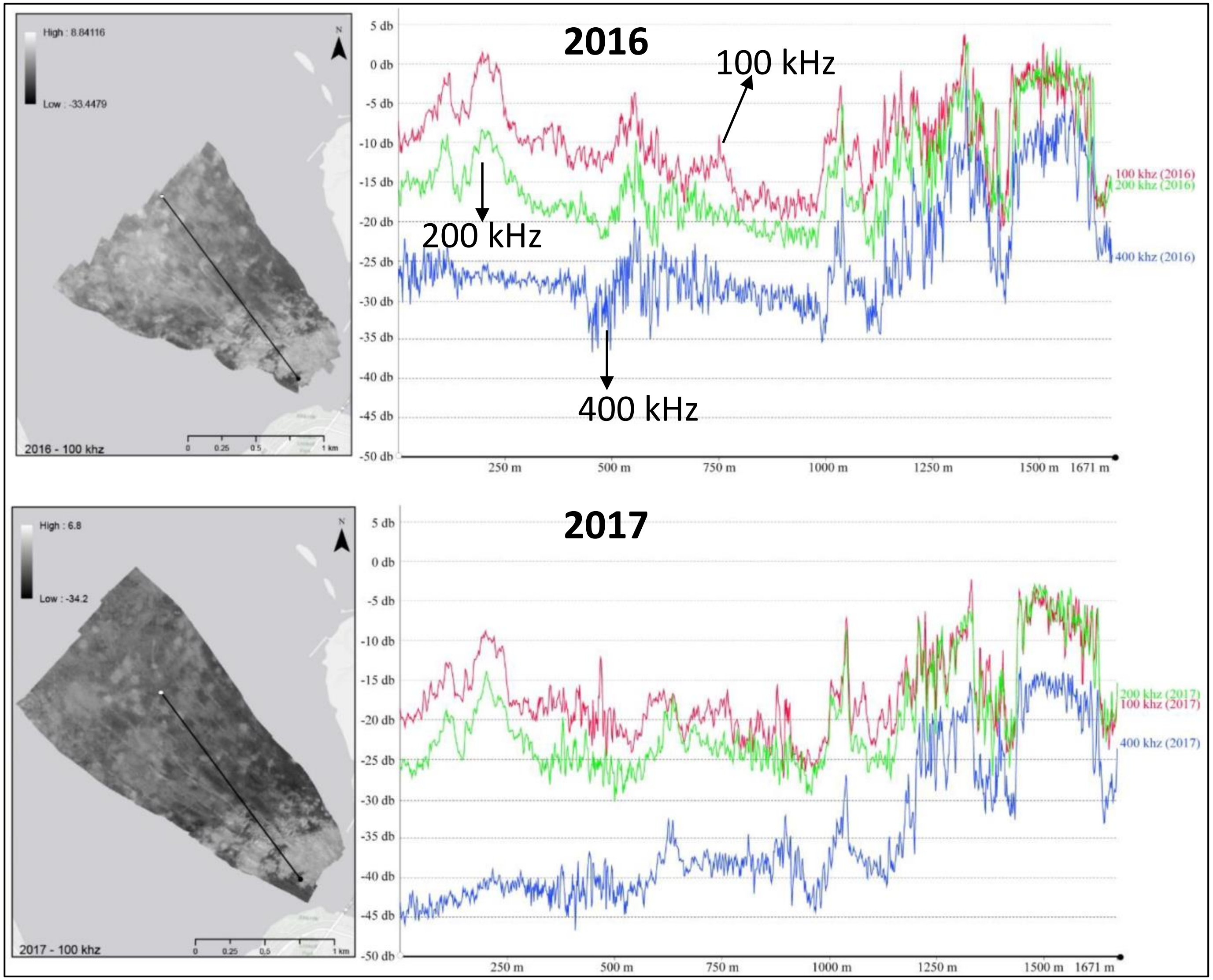
OVERVIEW

Motivation for the study

However the benefits of multifrequency has not been fully realized due to;

- ❑ Slow advancement in sonar technology (Feldens *et al.*, 2018).
- ❑ Backscatter measurements are not fully supervised and standardized (Lurton & Lamarche, 2015).
- ❑ Lack of calibration making it difficult to quantify seafloor properties from backscatter
- ❑ The use of multifrequency backscatter for seafloor discrimination is still a green area of research.

Multifrequency responses



Comparisons in backscatter intensities between multispectral mosaics (Brown *et al.,* 2019).

RESEARCH OBJECTIVES

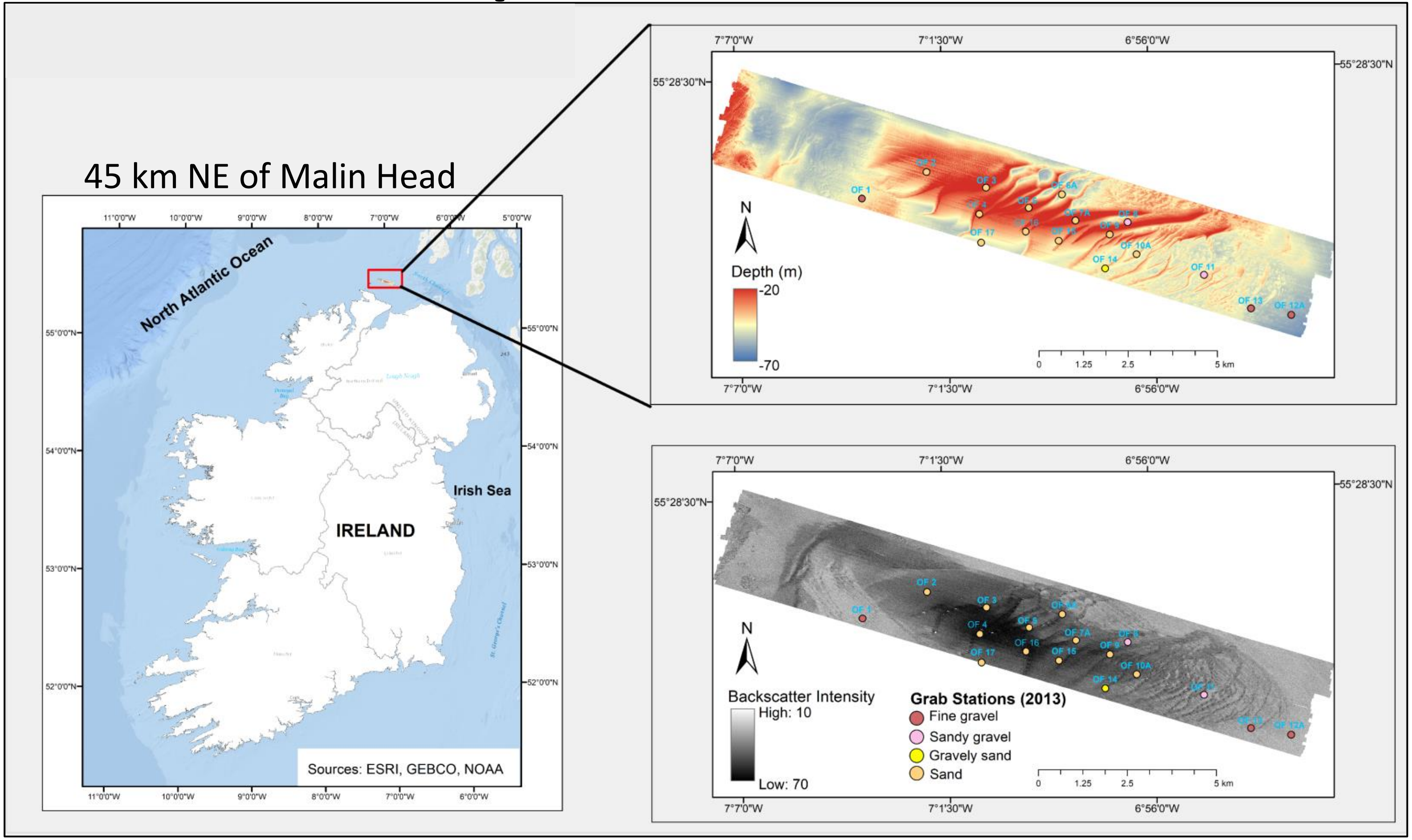
General objective: To critically examine the benefits of combining **multifrequency backscatter** responses optimized to discriminate seabed properties in areas with strong geomorphological gradients and associated ecological variability.

Specific objectives:

1. To examine multifrequency backscatter responses with geomorphological change at a temporal and spatial scale.
2. To examine the statistical relationship between multifrequency backscatter with sediment granulometry.

STUDY AREA

Hempton's Turbot Bank SAC



- Acoustic backscatter data collected in **2019;** EM302 (30 kHz), EM1002 (95 kHz), EM2040 (200 kHz) & **2013**; EM3002 (300 kHz) EM2040 (200 kHz).
- The area is designated by the **EC Habitats Directive** as a Special Area of Conservation as a sand feature.
- It harbours a high density of sand eels (*Ammodytes marinus),* a keystone species that is food to other species at higher trophic level.

METHODOLOGY

Grab sample deployment

CV130300 (2013) & CE19007 (2019)

METHODOLOGY

Workflow of Data Collection & Processing

Sediment grabs collected using Day grab

Data Acquisition

Backscatter using MBES; EM3002, EM2040, EM1002 and EM302

↓

Sediment grain size in GRADISTAT v.8.0

Data Processing

Beam pattern correction & AVG normalization in QPS FMGT v.7.8.9 (cell size: 0.5m *0.5m)

↓

Extraction of rasters around sediment grabs

ArcMap v.10.6.1

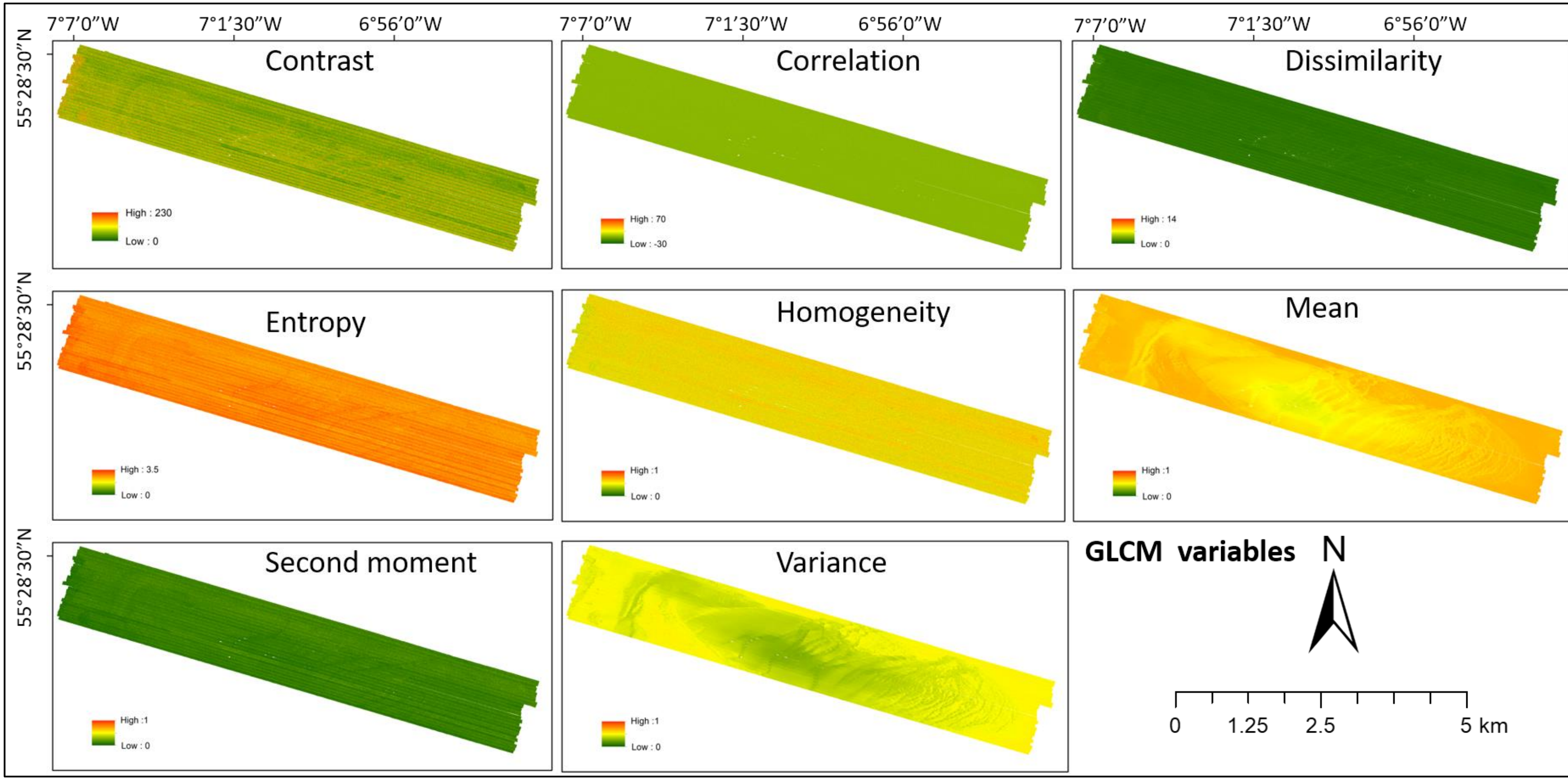
Data Analysis

GLCM feature extraction in R-package glcm v.1.6.5

↓ R v.3.6.0 & RStudio v.1.2.5033

Multifrequency Acoustic Responses of Sediments

METHODOLOGY Gray-Level Co-occurrence Matrix



The GLCM measures how frequent different combinations of neighbouring pixel values occur with an analysis window. The analysis here was carried out in a 5* 5 pixel window (Haralick et al., 1973).

METHODOLOGY GLCM equations

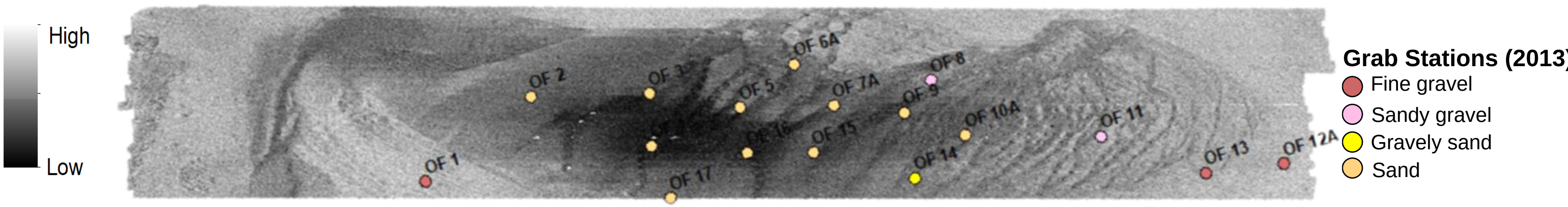
Contrast	$CO = \sum_{i,j=0}^{N-1} P_{i,j} (i-j)^2$
Correlation	$CC = \sum_{i,j=0}^{N-1} P_{i,j} \left[\frac{(i-ME)(j-ME)}{\sqrt{VA_i VA_j}} \right]$
Dissimilarity	$DI = \sum_{i,j=0}^{N-1} P_{i,j} \lvert i-j \rvert$
Entropy	$EN = \sum_{i,j=0}^{N-1} P_{i,j} (-\ln P_{i,j})$
Homogeneity	$HO = \sum_{i,j=0}^{N-1} \frac{P_{i,j}}{1+(i-j)^2}$
Mean	$ME = \sum_{i,j=0}^{N-1} P_{i,j}$
Second Moment	$SM = \sum_{i,j=0}^{N-1} P_{i,j}^2$
Variance	$VA = \sum_{i,j=0}^{N-1} P_{i,j} (i-ME)^2$

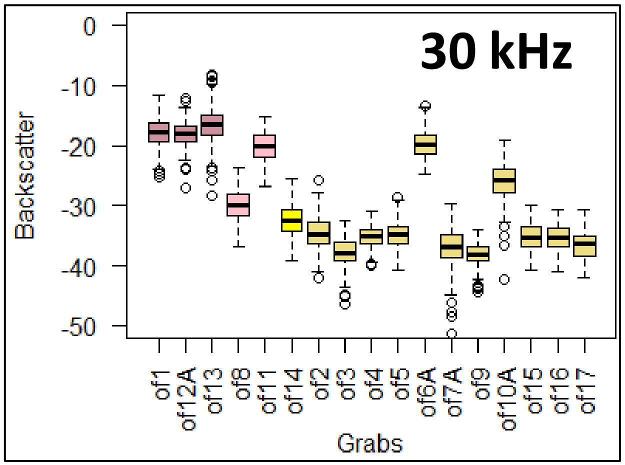
Note: $P_{i\,j} = V_{i,j}\ 1 \sum_{i,j=0}^{N-1} V_{i,j}$

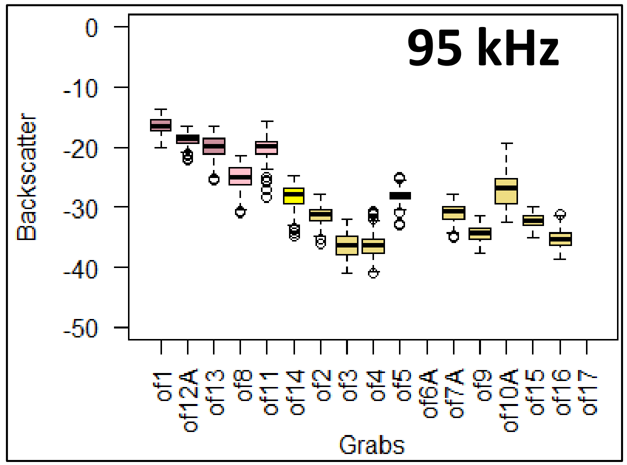
Where V_{ij} is the value in the cell I, j (row i and column j) of the moving window and N is the number of rows or columns.
Neighbouring pixels can be in four directions (0°, 45°, 90° and 135°). Source: Lu & Batistella (2005)

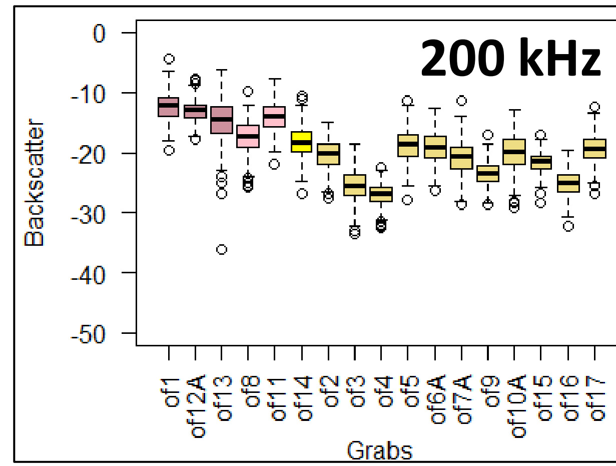
RESULTS

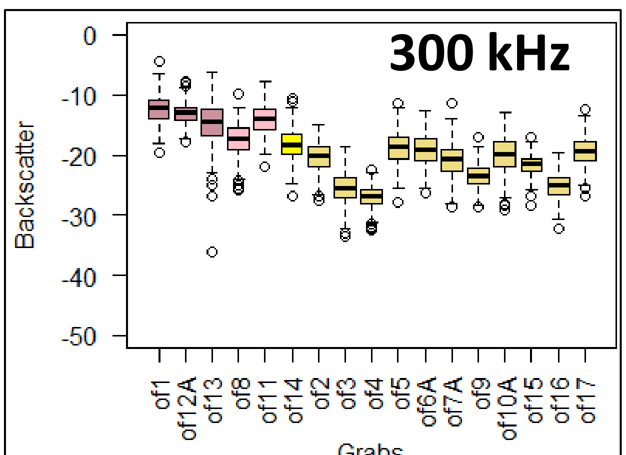
Multifrequency backscatter responses

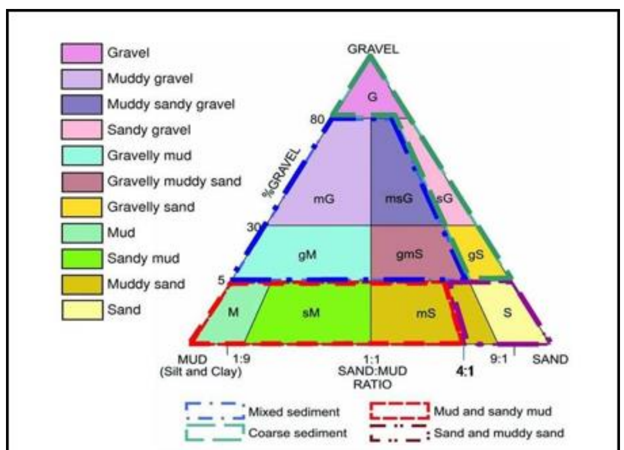










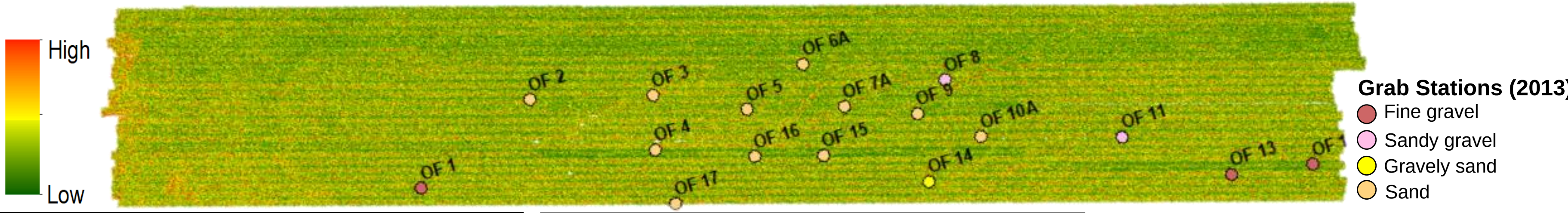


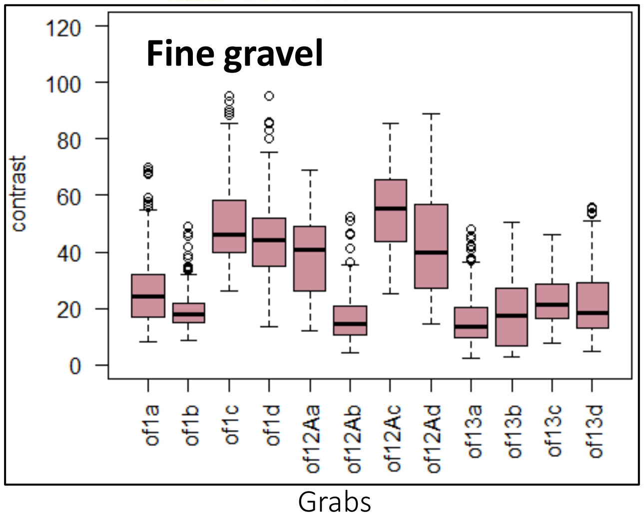
Folk-sediment-trigon

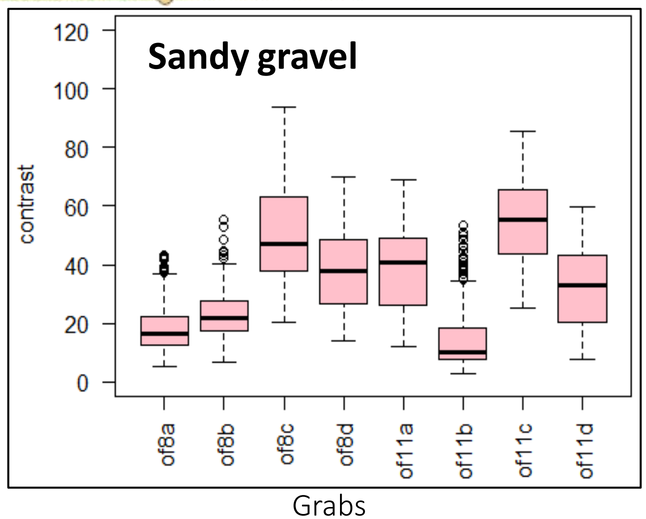
- Multifrequency variability in backscatter responses of four main sediment types: fine gravel, sandy gravel, gravely sand and sand as shown above.
- Also compares 2019 (30, 95, 200-kHz) and 2013 (300 kHz) dataset.

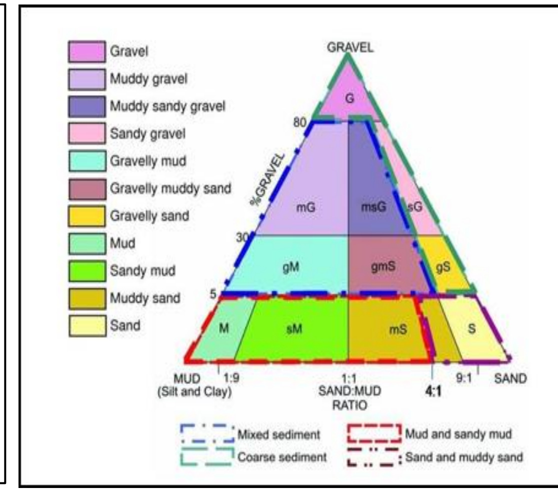
RESULTS

Multifrequency backscatter responses

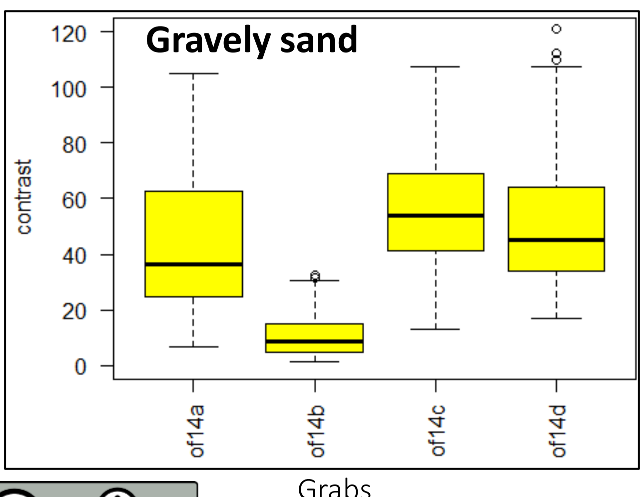


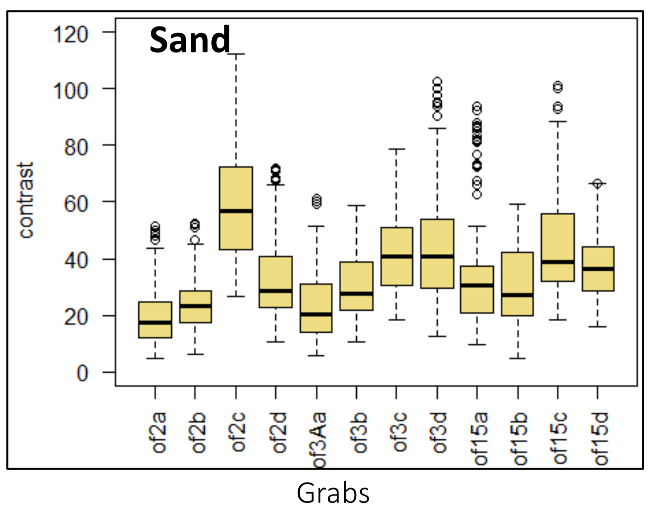






Folk-sediment-trigon



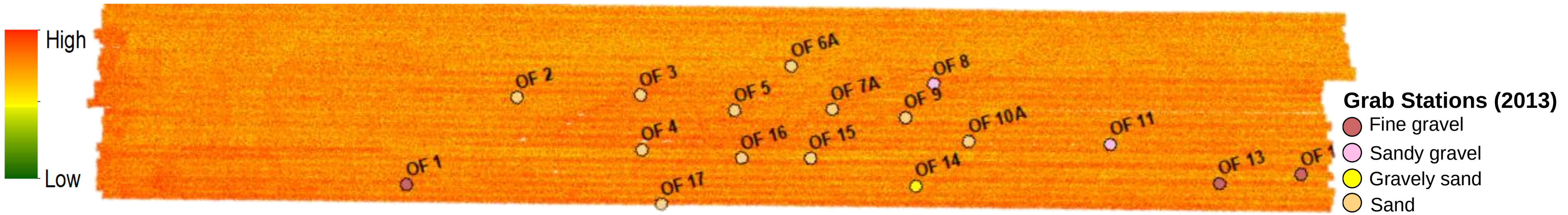


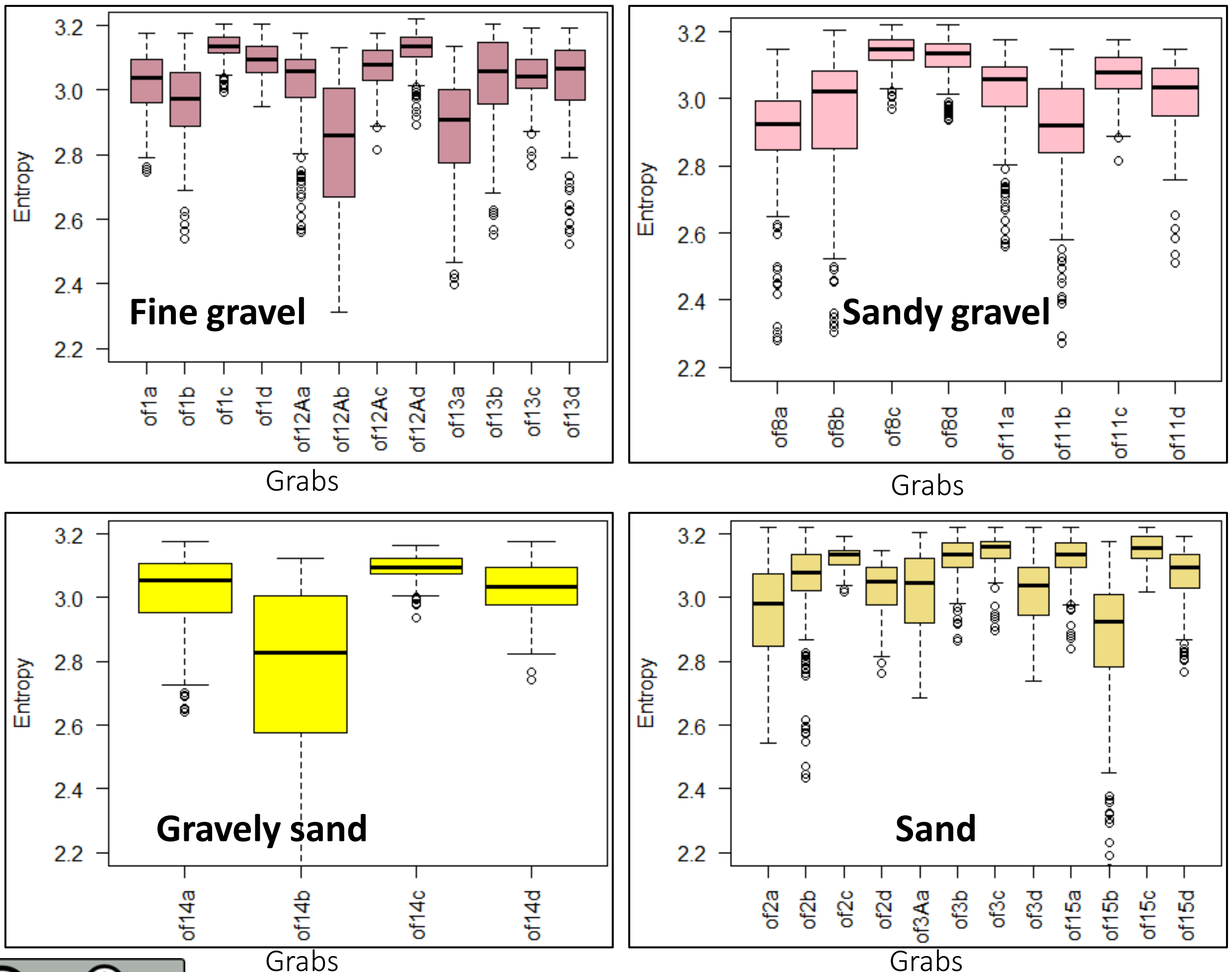
Contrast: represents local variations in in the GLCM.

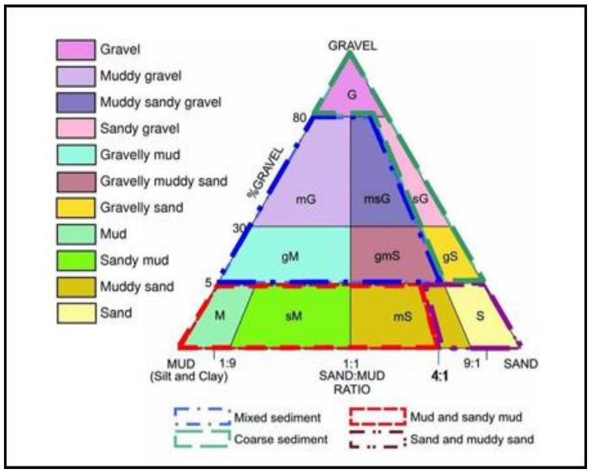
The 30, 95, 200, 300 (kHz) frequencies are represented by; **a, b, c, d** respectively.

RESULTS

Multifrequency backscatter responses







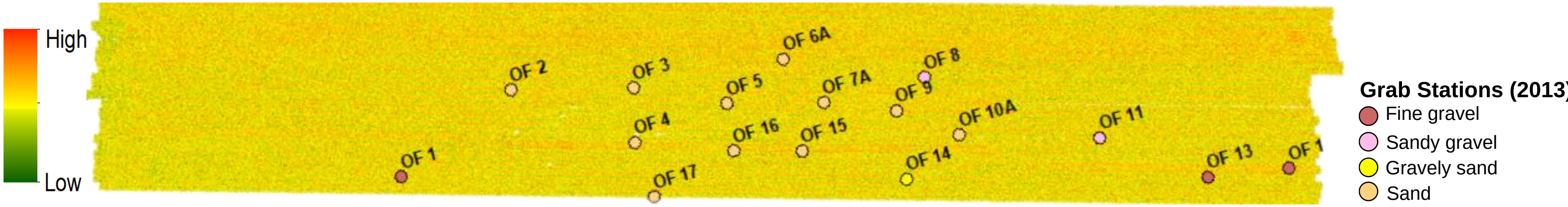
Folk-sediment-trigon

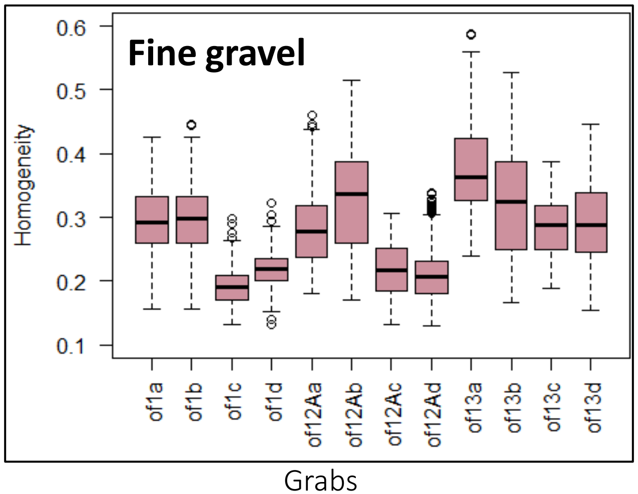
Entropy: measures the lack of spatial organization.

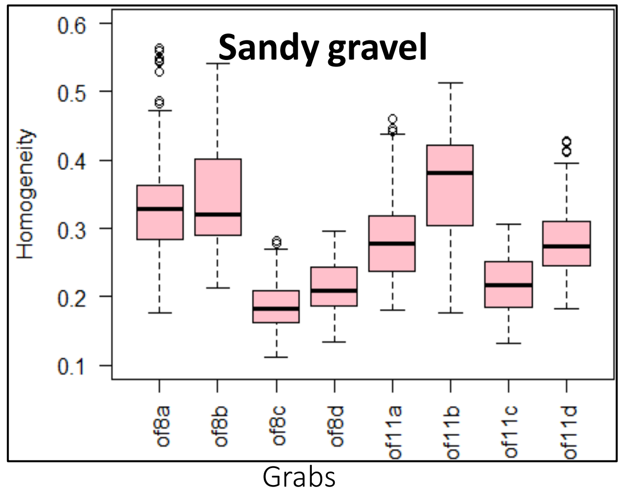
The 30, 95, 200, 300 (kHz) frequencies are represented by; **a, b, c, d** respectively.

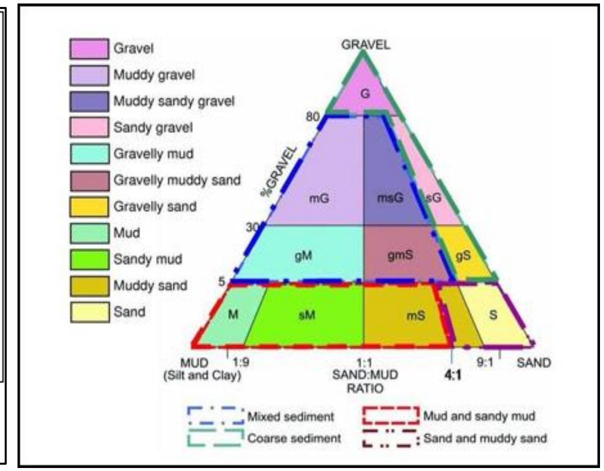
RESULTS

Multifrequency backscatter responses

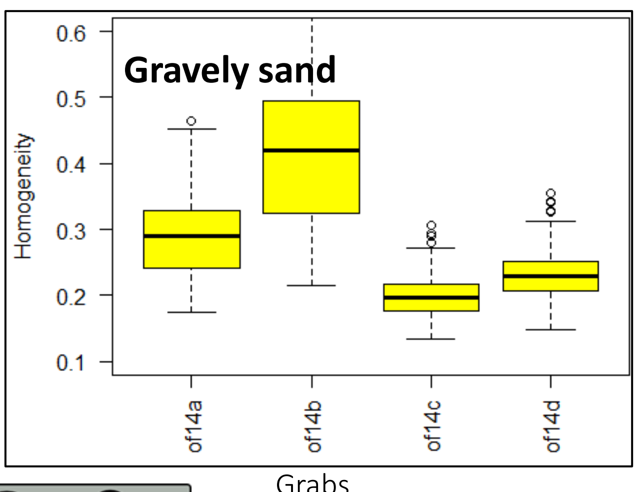


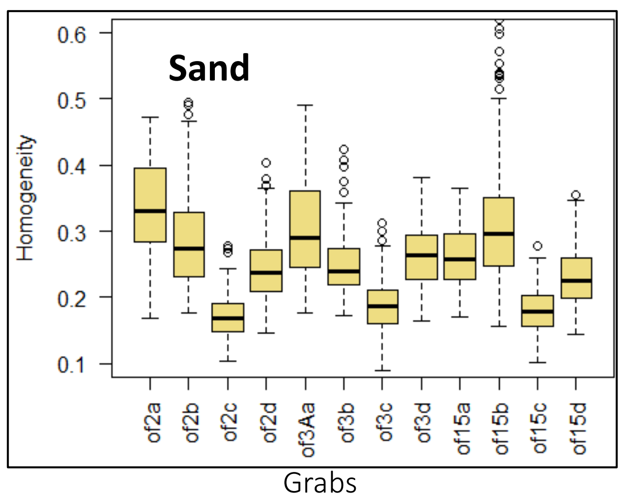






Folk-sediment-trigon

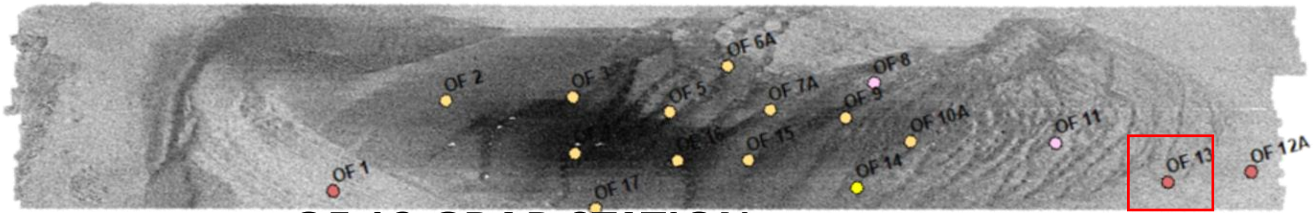




Homogeneity: measures the amount of similarities within a window.

The 30, 95, 200, 300 (kHz) frequencies are represented by; **a, b, c, d** respectively.

RESULTS Spatial variability for fine gravel

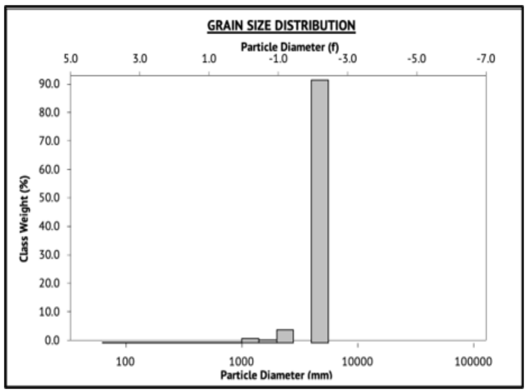


Grab Stations (2013)
- Fine gravel
- Sandy gravel
- Gravely sand
- Sand

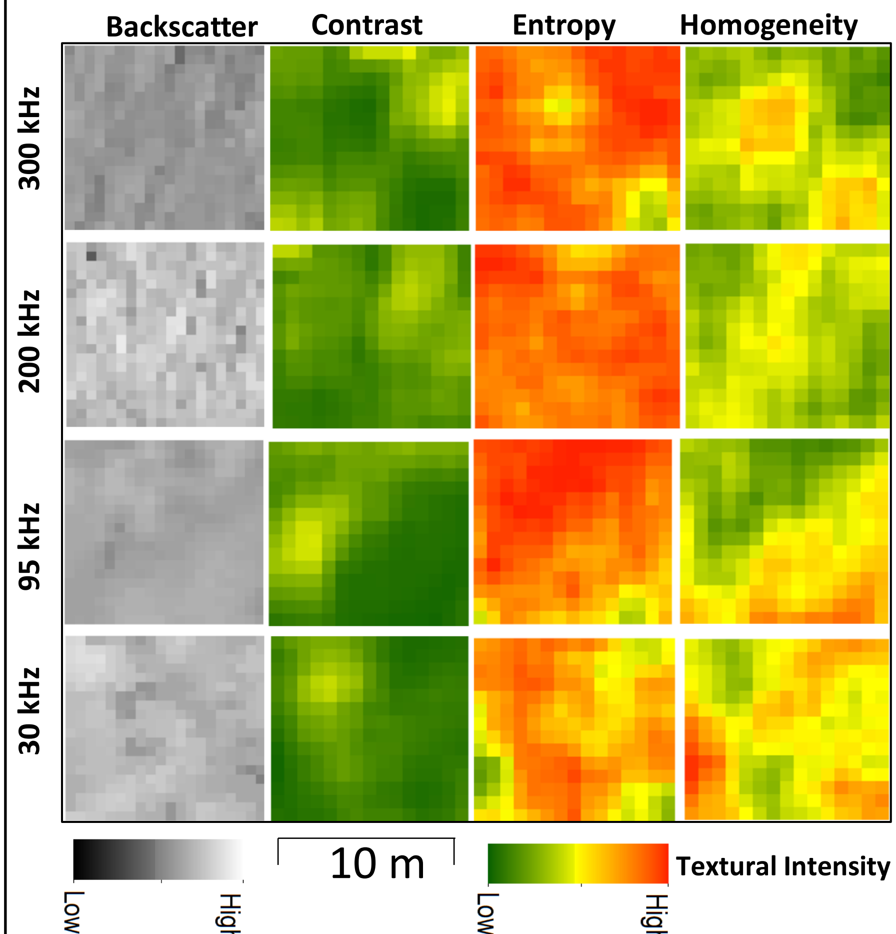
OF 13 GRAB STATION (Mean depth: 48.5m)

DEPENDENT/RESPONSE

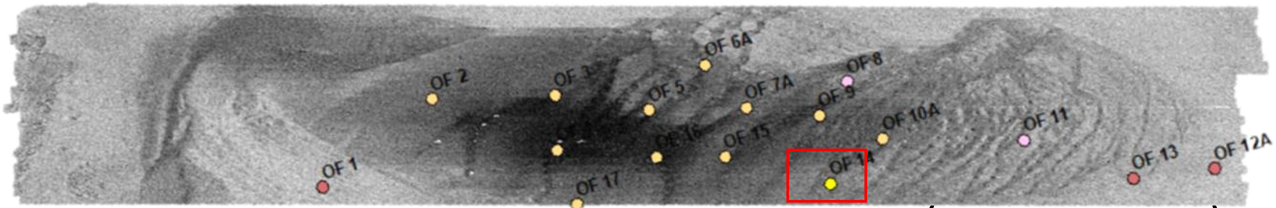
Grain Size Distribution



INDEPENDENT/EXPLANATORY



RESULTS Spatial variability for gravelly sand

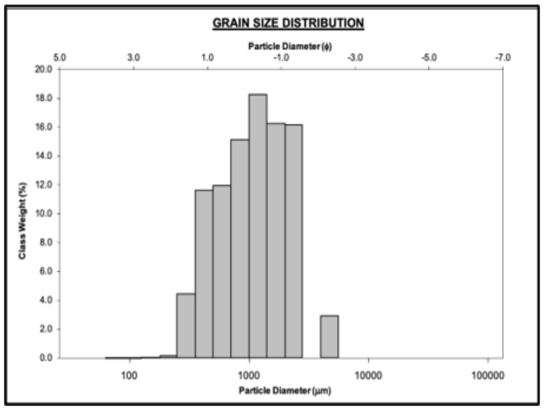


Grab Stations (2013)
- Fine gravel
- Sandy gravel
- Gravely sand
- Sand

OF 14 GRAB STATION (Mean depth: 44m)

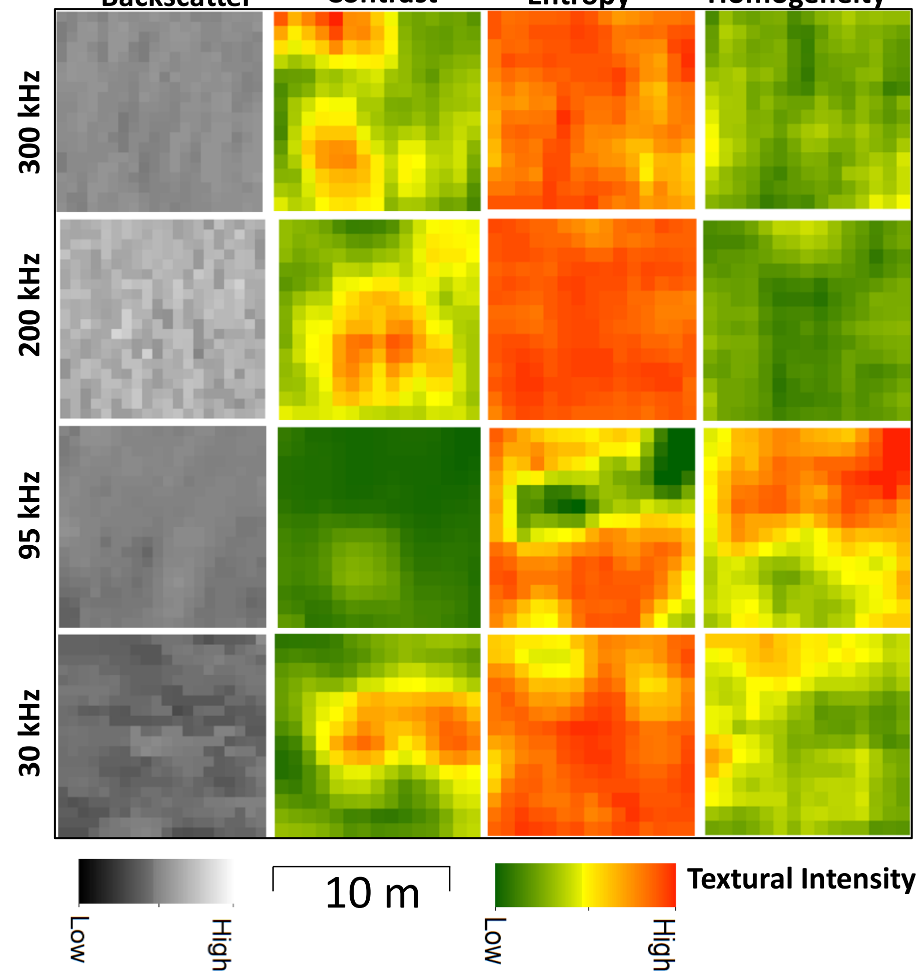
DEPENDENT/RESPONSE

Grain Size Distribution



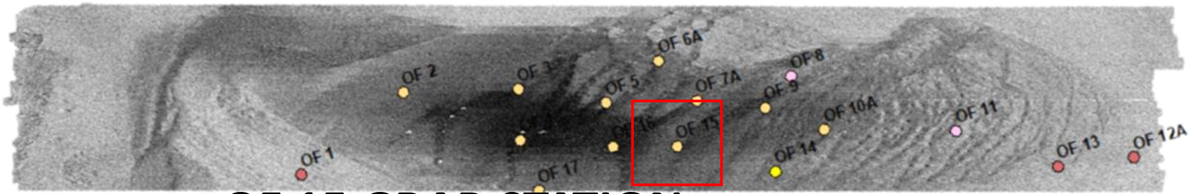
INDEPENDENT/EXPLANATORY

Backscatter | Contrast | Entropy | Homogeneity



RESULTS

Spatial variability for sand

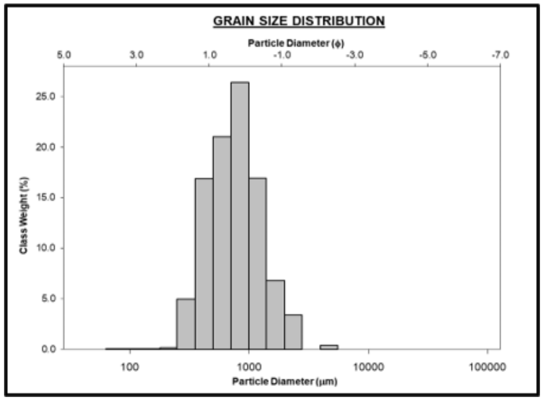


Grab Stations (2013)
- Fine gravel
- Sandy gravel
- Gravely sand
- Sand

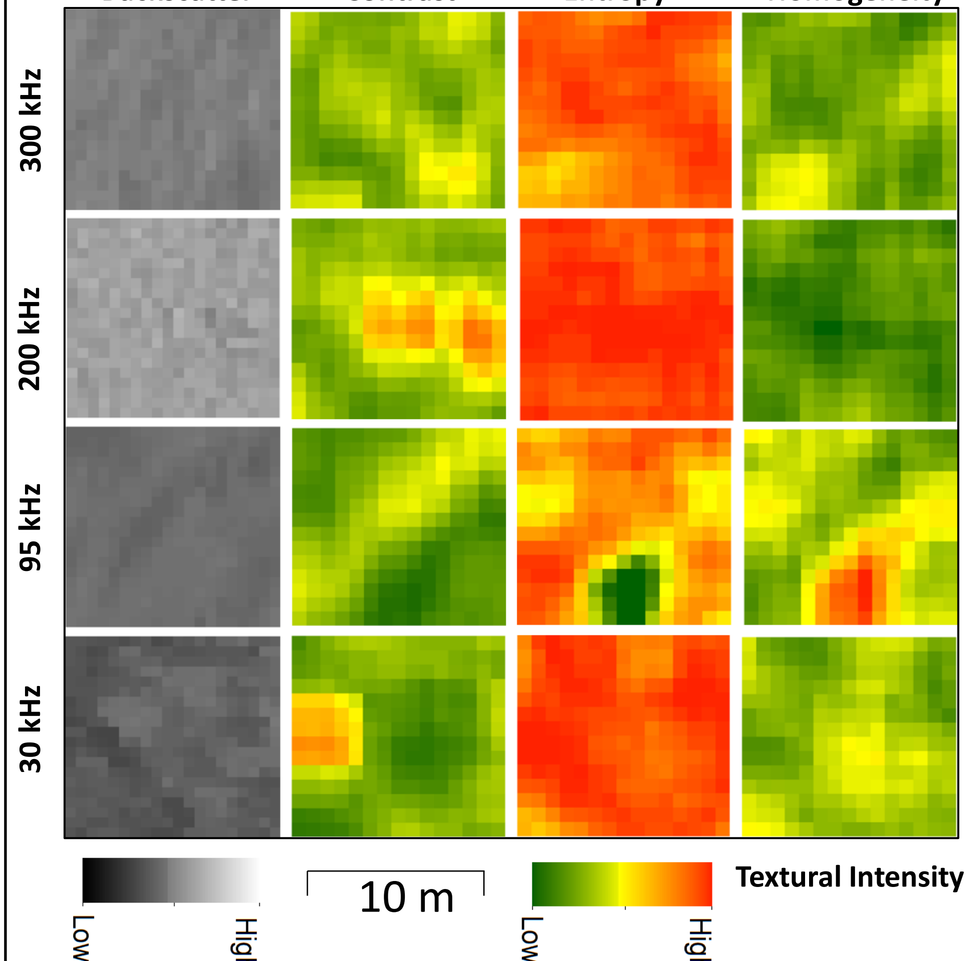
OF 15 GRAB STATION (Mean depth: 42.2m)

DEPENDENT/RESPONSE

Grain Size Distribution



INDEPENDENT/EXPLANATORY



RESULTS

Relationship between multifrequency backscatter & grain size

Table: Shows the relationship between mean grain size (response variable) and GLCM features contrast(2nd order statistics), and mean backscatter(1st order statistics).

Frequency/ GLCM features	SPEARMAN'S RANK CORRELATION COEFFICIENTS			
	30 kHz (2019	95 kHz (2019)	200 kHz (2019)	300 kHz (2013)
Contrast	0.13	-0.01	-0.32	0.06
Entropy	-0.2	-0.07	-0.52	0.31
Homogeneity	-0.02	-0.06	0.7	-0.07
Mean-Backscatter	0.85	0.44	0.86	0.34

Mean backscatter has a strong linear relationship with grain size for 30 & 95-kHz, homogeneity corelates positively with grain size at 200 kHz.

Solid colour: *strong correlation*

Light colour: *weak correlation*

SUMMARY & FUTURE WORK

Conclusions

- The preliminary results reveal the presence of a ***frequency response*** of different sediment types; high local variation.
- The multifrequency textural features provides evidence for ***fine scale spatial variability*** of geomorphological gradients that cannot be fully revealed by backscatter imagery alone.
- Mean backscatter from backscatter imagery is a stronger linear predictor of mean sediment grain size than 2^{nd} order GLCM statistics. Mean backscatter had a higher correlation coefficient with grain size; 0.85 and 0.86 for 30 kHz and 200 kHz respectively.
- Lack of a linear relationship between grain size and 2^{nd} order statistics except for *"homogeneity"* at 200 kHz with a correlation coefficient of 0.7.

SUMMARY & FUTURE WORK

Perspective and future work

- ❑ The relationship between backscatter, its derivates and sediment granulometry is complex.
- ❑ We are working to explore further the explanatory power of multifrequency for an improved seafloor discrimination and ecological characterization.
- ❑ This ongoing work will provide useful insights on optimizing acquisition and processing parameters to generate best practices and enhance our ability for monitoring Marine Protected Areas.

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THANK YOU!

Runya et al., 2020