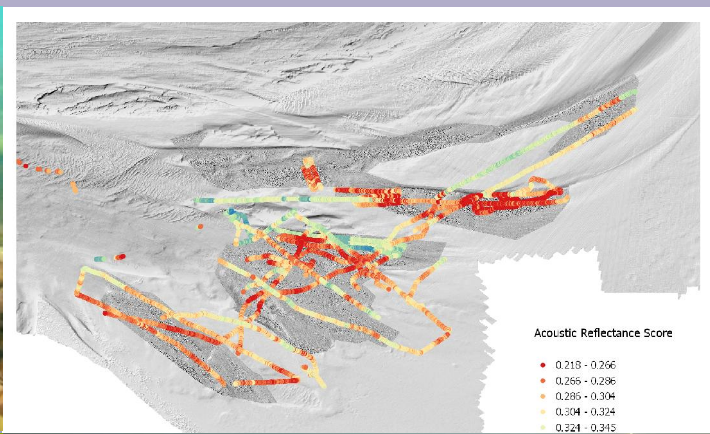
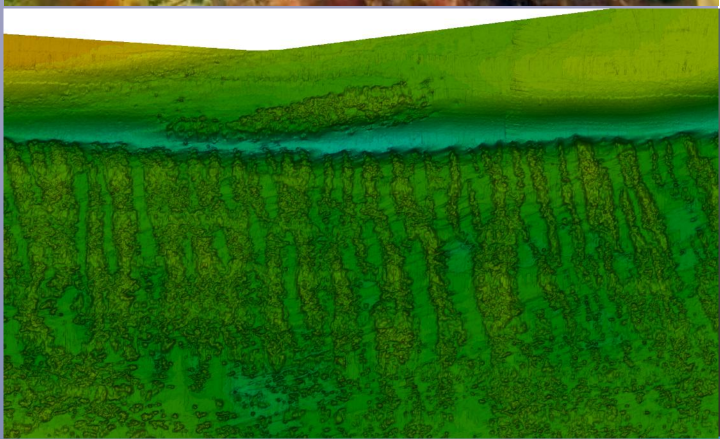
Western Port Bryozoan Reefs Research Project

Report 4: Reef Extent Monitoring – A Citizen Science Approach





Report to La Trobe University and AGL

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Western Port Bryozoan Reefs Project

Part c: Citizen Science Monitoring

Report to AGL and La Trobe University

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1. Introduction

1.1. Background

The Western Port bryozoan reefs were described in 2016 and are the subject of a collaborative research project that began in 2019. Mapping of the reefs by multibeam echosounding is described in partner Report 2 (Fathom Pacific 2020a) and aspects of the biology of the reefs are described in partner Report 3 (Fathom Pacific 2020b). This unique biotope is of national and global significance and is exposed to both natural and anthropogenic pressures that warrant monitoring.

Biotope extent is recognised as a key monitoring indicator, the premise being that for a biogenic reef structure, maintenance of habitat extent and juxtaposition among other habitats contributes in some part to a maintenance of ecological values and services. Multibeam echosounding provided high resolution mapping of the reefs, but the method may be costly for continued monitoring. The location of the bryozoan reefs in areas of interest to recreational fishers affords the opportunity to implement a citizen science based acoustic monitoring program. In the state of Victoria, citizen science monitoring programs have become an important dimension to marine environmental monitoring in the absence of dedicated scientific monitoring. Examples in the marine environment include The Great Victorian Fish Count, ReefLife Survey, Seagrass Watch, the Two Bays Whale Project and sector volunteer organisations such as OzFish.

Globally, the value of citizen science monitoring is recognised, and it is imperative that such monitoring is carefully gauged to the correct level of expertise and data utility. The most successful citizen science programs are those which generate robust data, avoid subjectivity, involve a simple metric that is directly relatable to the condition or status of the environment and are directly interpretable to managers with respect to triggering action.

1.2. Objectives

For this project, a low-cost, simple method of monitoring the extent and condition of bryozoan reefs was sought. An approach that engaged recreational fishers was considered advantageous given the importance of the area to fishers and the expectation that future management responses may involve some form of protection of the reef and educating fishers as to responsible anchoring practices. Engaging recreational fishers in collection of scientific data that will secure fish stocks is a model that has been used in other projects (e.g. installation of artificial reefs) and was considered useful for the bryozoan reefs.

Modern recreational echosounders and chart plotters (known as “fish finders”) are recognised in the fishing community as an essential fishing tool. Recreational echosounders have become progressively sophisticated high resolution and relatively inexpensive as technology has improved. Today, mid- to high-budget recreational echosounders have the capacity to record georeferenced acoustic data. These acoustic data are usually interpreted for the purposes of detecting fish targets in the water column and depth/structure of the seabed. However, embedded in the acoustic data is information about the relative “hardness” of the seabed. Because acoustic energy reaching the seafloor is differentially absorbed and reflected depending on the type of substrate, the characteristics of the return echo can be used as a proxy for seabed type.

This project sought to identify and trial an end-to-end method for monitoring the bryozoan reef biotope, and other seabed habitats, using recreational "fish finders". The technique provides lower resolution data than that achievable by dedicated high-resolution multibeam echosounding, but was found to generate useful information that can be used to monitor changes in reef extent and provide an early warning system that could be used to trigger more detailed and focussed investigation.

2. Methods

2.1. Location

The bryozoan reefs study area is located between Corinella, Newhaven and Rhyll, Victoria, Australia (Figure 1). The bryozoan reefs are categorised into three cells, the Northern, Middle and Southern cells (see Fathom Pacific 2020a). The Northern Cell possess linear and patch reefs while the Middle and Southern cells possess only the patch reefs (Fathom Pacific 2020a). Between February 2018 to January 2020 multiple surveys, dedicated and opportunistic (random) transects were completed to collect data.

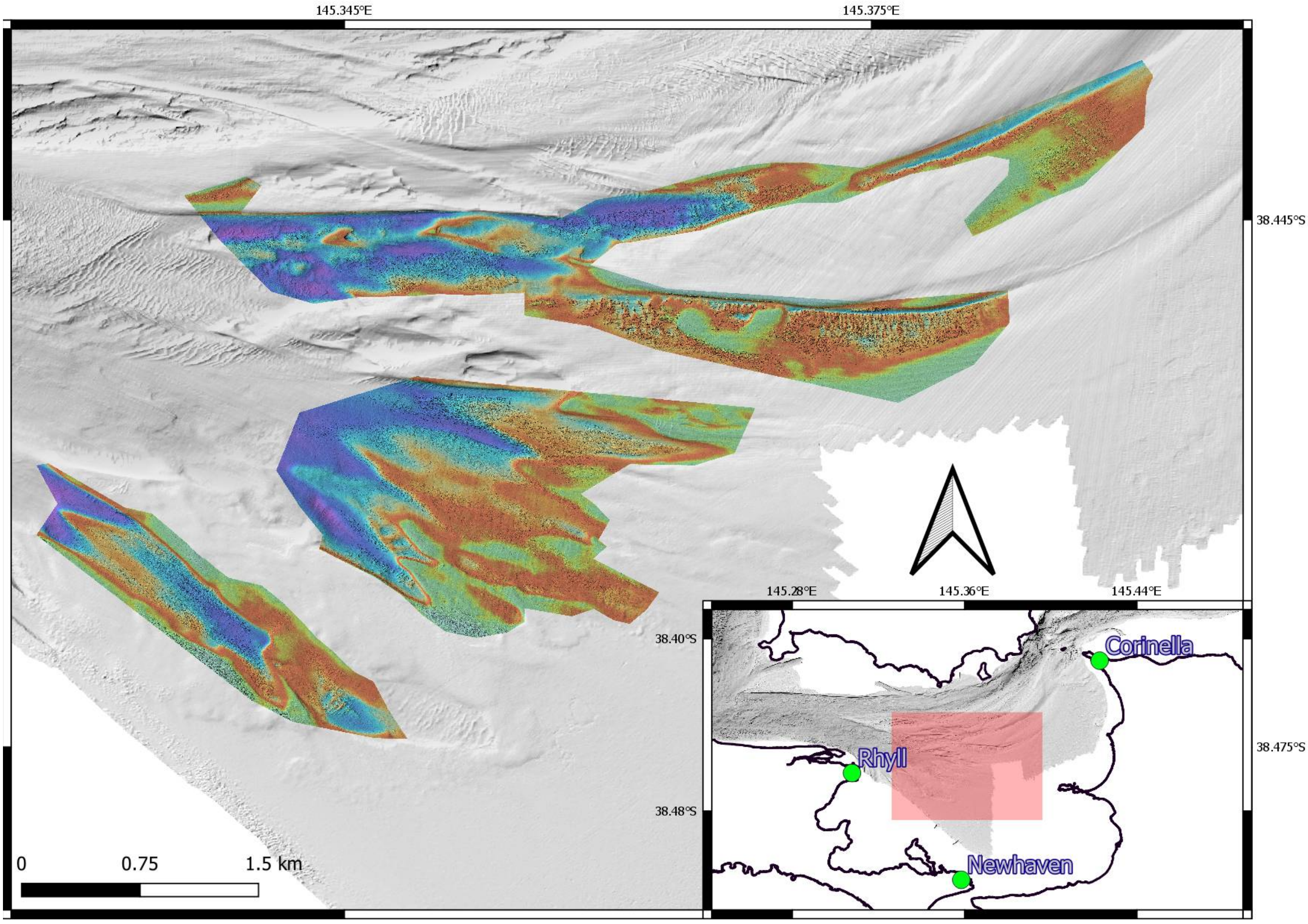

Figure 1 Location of the bryozoan reefs, in Western Port Bay. Northern, Middle and Southern cells are highlighted.

2.2. Data Collection

The concept for monitoring is that there would be two classes of data: (1) echosounders installed on recreational fishing boats recording data throughout normal fishing activities of citizens, thus representing random transects through the areas of interest, and (2) echosounders installed on research or agency vessels recording dedicated transect data focussed on areas of interest. This trial program collected both types of data using echosounders installed on a Fathom Pacific research vessel and a Victorian Fisheries Authority vessel used for compliance and enforcement in Western Port (Figure 2). The transects therefore covered reef and non-reef substrates.

Sonar data was recorded using a Simrad NSS EVO3 echo sounder and a Lowrance TotalScan transducer installed on both vessels. Echosounder transmission frequency was set to 200 kHz, vessel speed kept below 5 knots. Raw sonar data were uploaded to BioBase®, a cloud-based sonar data processing facility to extract data on the so-called "second echo" which is relatable to acoustic energy absorption and reflectance and therefore seabed hardness.

2.3. Monitoring Method Development

The concept for monitoring would generate large numbers of transects that intersect the bryozoan reefs. It was recognised that detection of changes at reef boundaries, potentially caused by processes such as sediment encroachment is an important aspect of extent monitoring. However, it was also recognised that boundary conditions are potentially variable in reef cover and that the method is likely to generate sparse data at boundaries. Therefore, the key consideration for monitoring investigated in the present study was the detection of changes within high value reef areas (e.g. areas of reef impacted by anchor damage causing structural collapse and conversion to rubble/sediment substrate).

Due to the fact that any one transect traversing a particular reef feature contains relatively few data points (a function of ping rate of the echosounder and speed of the vessel), there was a need to establish an analysis method that amalgamates data over a spatial scale (monitoring site) that is relevant to ecological function over time. The concept for monitoring is that transects would progressively transit through monitoring sites (either as random transits by fishers or planned transects by agencies) and establish a baseline seabed hardness index that is unique to that site. Changes in the seabed hardness index in that site would be monitored over time and a change beyond a certain threshold would be identified as a trigger for more detailed investigation.

Data analysis therefore focussed on:

1. Testing the system's ability to detecting the gradients in seabed structure.
2. Establishing a robust method for analysing data and detecting change.

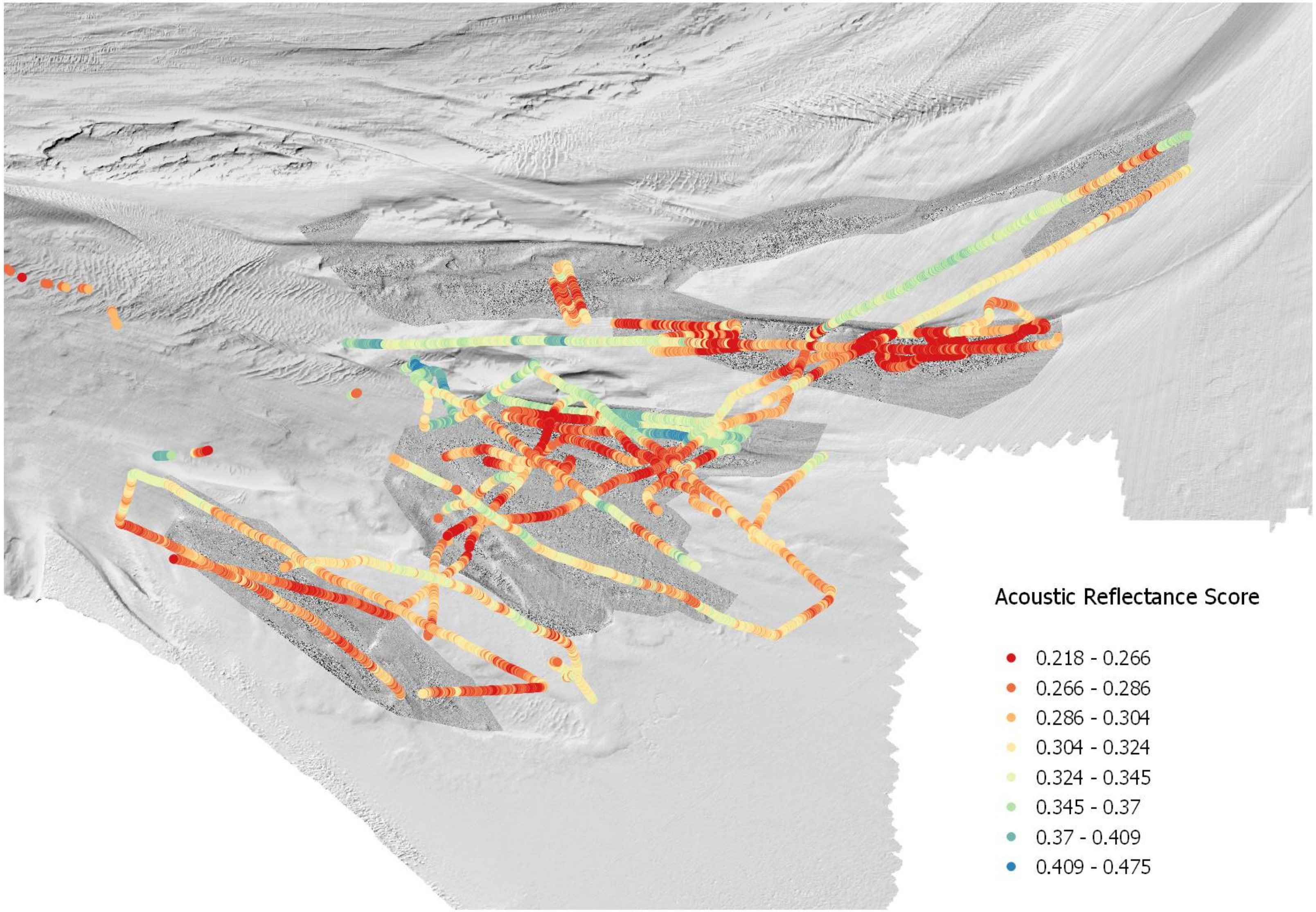

Figure 2. Transects conducted by Fathom Pacific and VFA between February 2018 and January 2020, showing derived hardness index from red ('hard') to blue ('soft').

2.4. Seabed Hardness Data Processing and Monitoring Block Selection

Recorded file outputs (.sl2) from the Simrad NSS EV03 were processed using the online BioBase® software (www.biobasemaps.com). The .sl2 files are processed to extract acoustic ping number, latitude and longitude and a "hardness" index (a value ranging from 0 to 1). The "hardness" index is derived from the second echo return detected by the transducer and can be conceptualised as a relative index of seabed structure.

Hardness index values were mapped against the known location of bryozoan reefs at the sub-meter scale to confirm the ability of the system to detect reef and sediment classes. Hardness data was clipped to the spatial extents of the Northern, Middle and Southern cells. A spatial join was made to categorise points as bryozoan reef (using the polygons of known reef location, Fathom Pacific 2020a) and sediment in each cell.

A number of methods were considered for the selection of monitoring blocks, from regular grids to random patches at various spatial scales. After some testing, and consideration of the multibeam data available, it was decided to place monitoring blocks over mapped intact linear reef areas and over representative patch reefs.

A series of functions were written in Python to clip the hardness values to monitoring site extents. The functions utilised the *Standard*, *Pandas* and *Geopandas* Python libraries (Van Rossum & Drake 2011; McKinney 2010; GeoPandas contributors 2019). The distribution of hardness values within each monitoring block were then compared to the distribution of values on neighbouring sediments. To visualise these frequency distributions, a series of Python functions were developed that utilised the *MatPlotLib* Python library (Hunter 2007). For all the bryozoan monitoring blocks and sediments of the Northern, Middle and Southern cells, the mean, median, standard deviation, excess kurtosis and skewness values were calculated using the *SciPy* and *Statistics* libraries in Python (Oliphant 2007; Van Rossum & Drake 2011). Additionally, to directly compare the distribution of values within the monitoring sites with the neighbouring sediments a two-sample Kolmogorov-Smirnov test and a two-sample Anderson-Darling test were conducted using the *SciPy* library.

3. Results and Discussion

3.1. Bryozoan Reef Detection and Monitoring Site Selection

Visual interrogation of the data returned by BioBase® indicated that the bryozoan linear and patch reefs can be detected and visually distinguished from the surrounding sediments (**Figure 3**). Acoustic reflectance correlated with the location of reefs mapped in the multibeam echosounder survey. The acoustic reflectance/absorption properties of bryozoan skeletal structure, based on the hardness index, was vastly different from the surrounding sediments.

The multibeam survey acquired high resolution definition of continuous reef, patch reefs and individual bryozoan mounds. This enabled the direct identification of reef features that are a suitable size to be designated as the monitoring sites. This placement of monitoring sites on mapped features was considered more advantageous than other area-based site selection methods such as random or regular grids to the creation of a random grid. Macrofauna biodiversity studies (Fathom Pacific 2020b) suggested that the most intact reefs are likely to correspond to highest biodiversity values. Thus, monitoring the regions of intact reef will translate to one method of effectively monitoring biodiversity. The sites identified for the monitoring bryozoan reef extent and condition are shown in Figure 4 and Figure 5. A full list of monitoring sites names, associated reef type and spatial occupancy is given in

Table **1**.

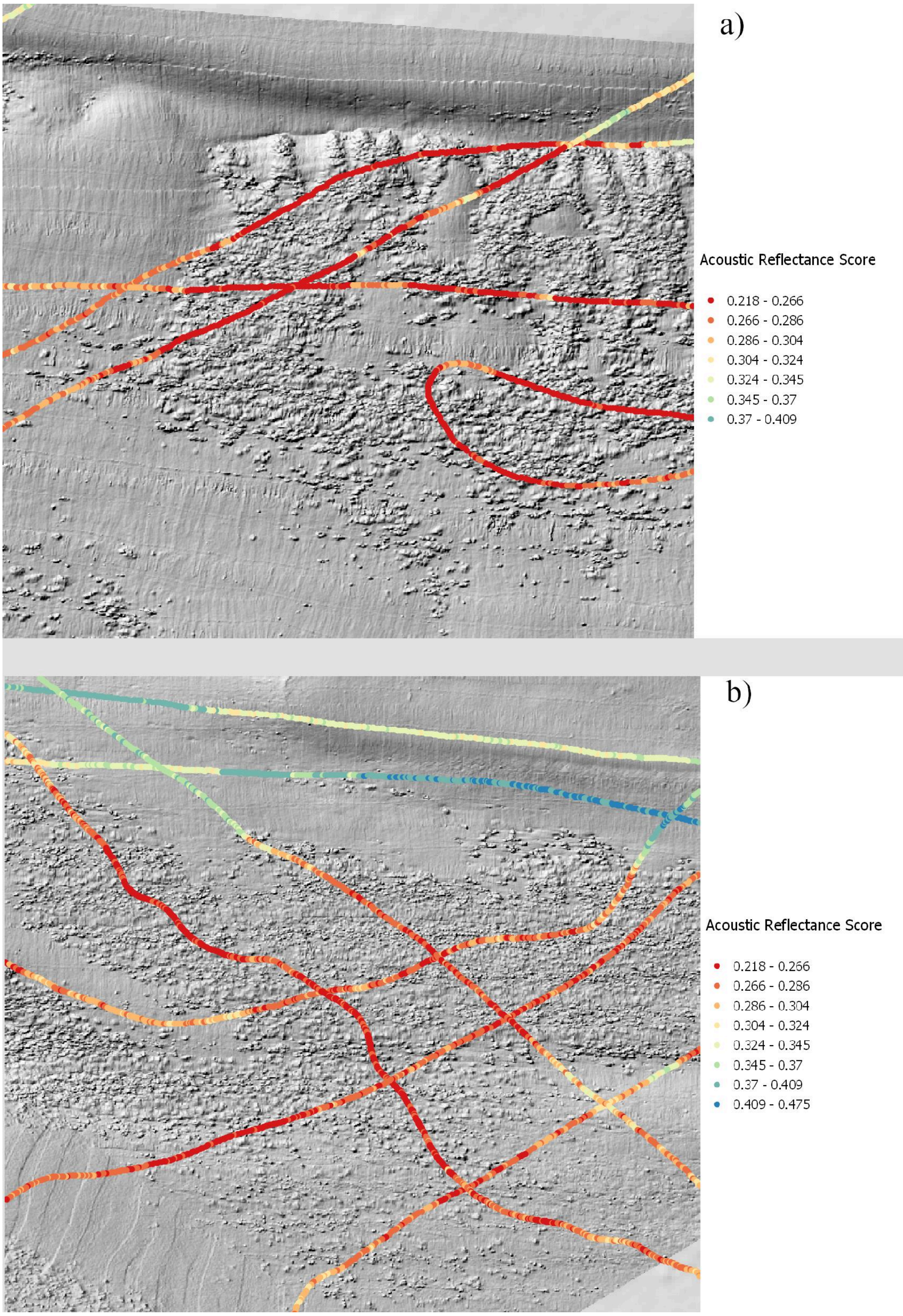

Figure 3. Examples of bryozoan reef detection using the acoustic reflectance score results from BioBase®. Bryozoan reef indicated by red to dark orange. Surrounding sediments indicated by light orange to blue. (a) Linear bryozoan reef, (b) bryozoan patch reef.

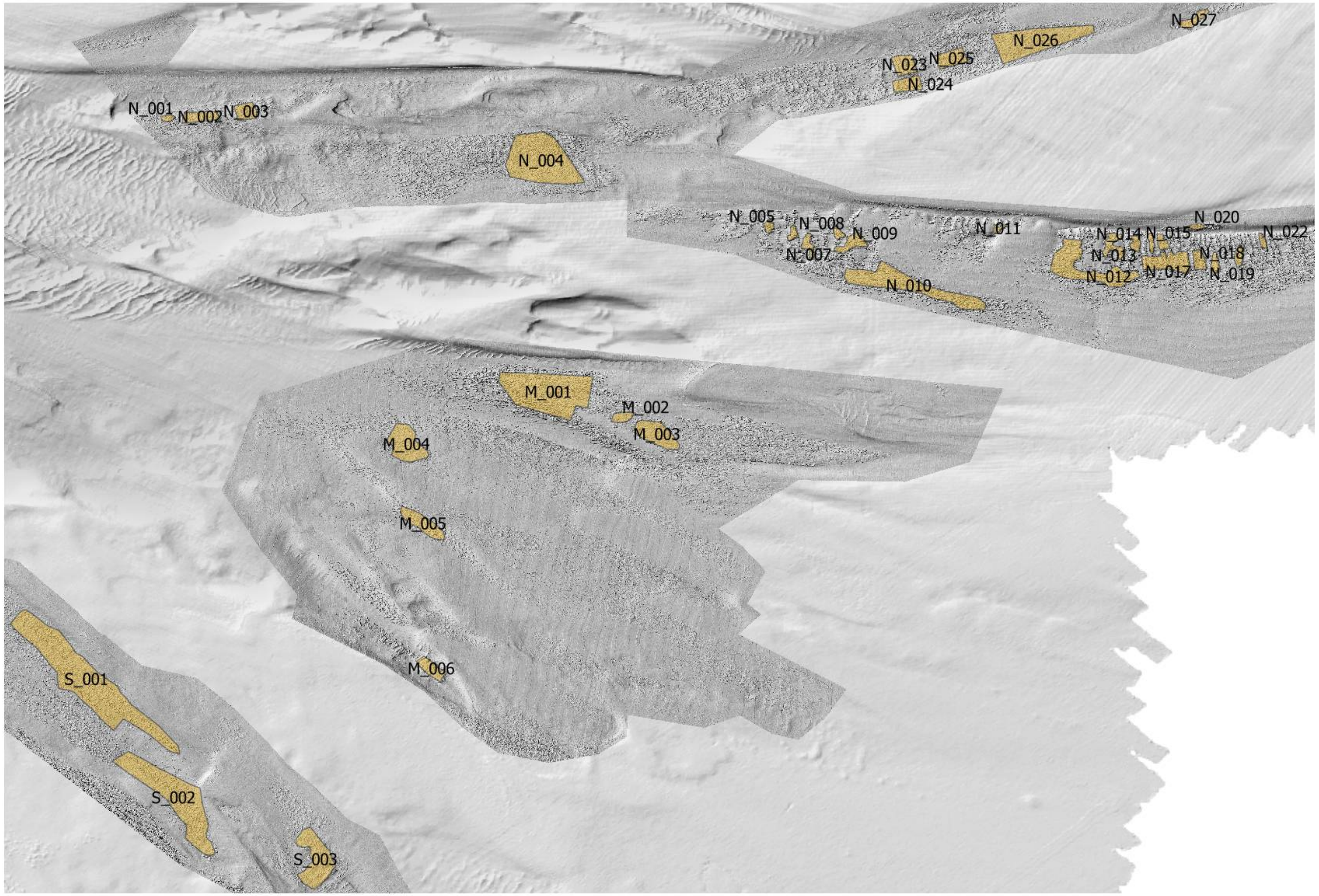

Figure 4. Bryozoan reef monitoring patches located within the Northern, Middle and Southern cells.

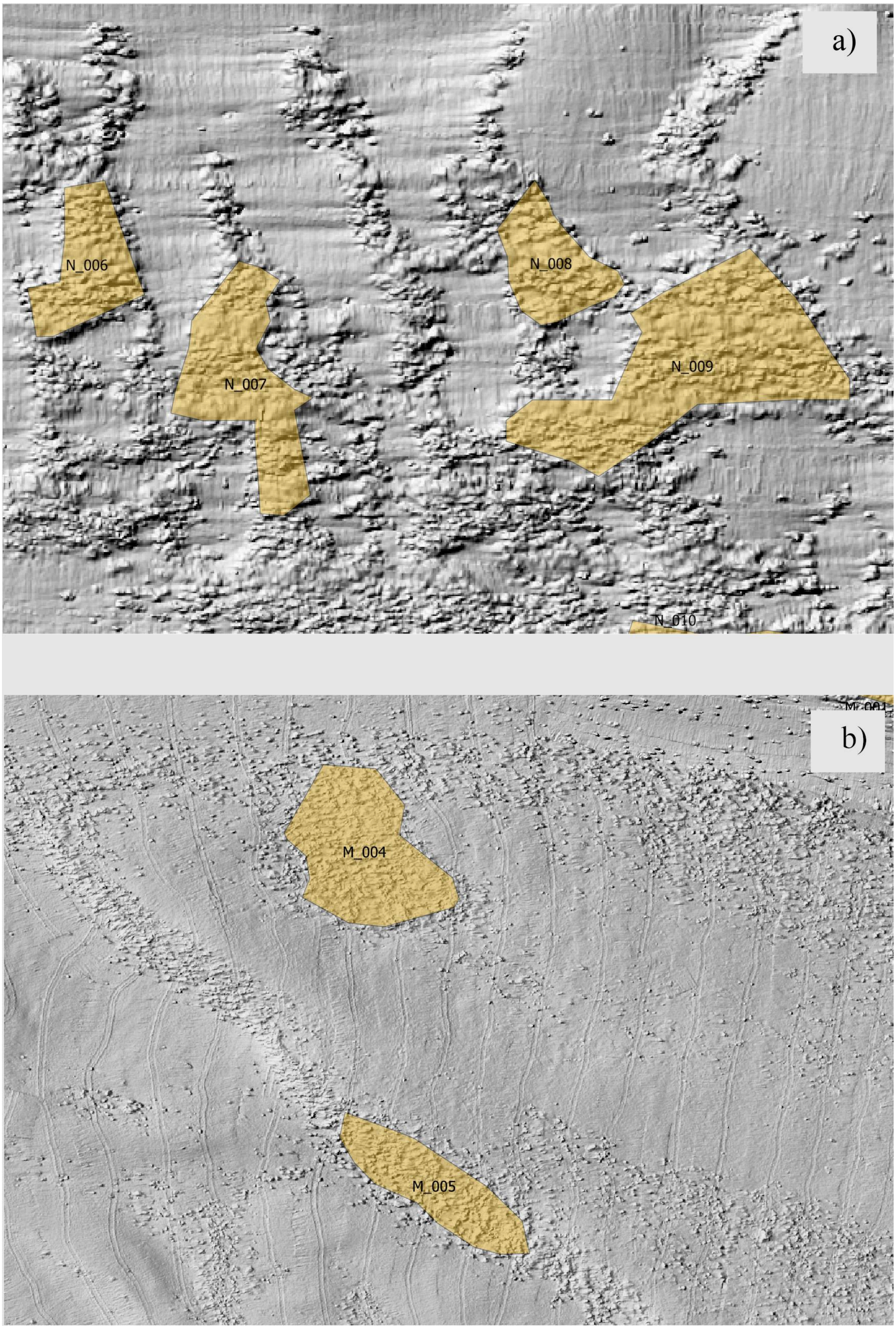

Figure 5. Zoomed in examples of monitoring sites encompassing contiguous reef features. (a) Monitoring sites situated within Linear bryozoan reef. (b) Monitoring sites situated within bryozoan patch reef.

Table 1. Monitoring site descriptions.

Site Name	Reef Type	Area (ha)
N_001	Patch Reef	0.081
N_002	Patch Reef	0.385
N_003	Patch Reef	0.363
N_004	Patch Reef	3.316
N_005	Patch Reef	0.103
N_006	Linear Reef	0.112
N_007	Linear Reef	0.191
N_008	Linear Reef	0.107
N_009	Linear Reef	0.372
N_010	Linear Reef	2.363
N_011	Linear Reef	0.072
N_012	Linear Reef	1.853
N_013	Linear Reef	0.353
N_014	Linear Reef	0.151
N_015	Linear Reef	0.112
N_016	Linear Reef	0.155
N_017	Linear Reef	0.892
N_018	Linear Reef	0.248
N_019	Linear Reef	0.161
N_020	Patch Reef	0.102
N_021	Linear Reef	0.17
N_022	Linear Reef	0.094
N_023	Linear Reef	0.464
N_024	Patch Reef	0.427
N_025	Patch Reef	0.514
N_026	Patch Reef	2.384
N_027	Patch Reef	0.277
M_001	Patch Reef	3.674
M_002	Patch Reef	0.208
M_003	Patch Reef	0.935
M_004	Patch Reef	1.165
M_005	Patch Reef	0.716
M_006	Patch Reef	0.39
S_001	Patch Reef	6.079
S_002	Patch Reef	3.587
S_003	Patch Reef	1.527

3.2. Acoustic Reflectance Distributions

Graphical analysis, two-sample Kolmogorov-Smirnov and the two-sample Anderson-Darling test all revealed that there was a difference in the distribution of the acoustic reflectance ("hardness") values between the bryozoan reef monitoring sites and surrounding sediments. Examples of the graphical analysis can be seen in Figure 6 and a full examination of the individual monitoring sites can be seen in Appendix 1. In the Northern and Middle cells, acoustic data from the bryozoan reef had markedly different distribution (Figure 6a and Figure 6b), consistent with field observations of large intact patches of seafloor covering bryozoan skeletal matrix in the Northern cell and moderately dense patch reef in the Middle cell. In the Southern cell, there was more overlap between the bryozoan and sediment data distributions (Figure 6c), which is also consistent with the multibeam echosounder data and limited field observations in this cell that showed relatively sparse patch reef dispersed on sediments.

Hardness index of sediments show similar values among all cells (Table 2). Hardness index among the bryozoan reef monitoring sites was more variable (Table 3) consistent with the observations of differential density of bryozoan skeletal matrix in the three cells. The results indicate that monitoring must be cell-specific, with monitoring sites stratified by cell.

Results from the two-sample Kolmogorov-Smirnov and two-sample Anderson-Darling tests show that all acoustic reflectance ("hardness") values within the monitoring sites were significantly different to those on neighbouring sediments (Table 3). All p-values for the two-sample Anderson-Darling and Kolmogorov-Smirnov tests were ≤ 0.01.

The analysis showed that mean and median acoustic reflectance values were not suitably sensitive statistics to define baseline conditions or detect change. This is likely to be due to the fact that the bryozoan reef biotope has a sediment component and that data points in a bryozoan monitoring site (acoustic "pings") are likely to integrate both skeletal matrix and interspersed sediments. Examination of the frequency distribution of hardness data to detect the significant differences in excess kurtosis and skewness. Statistical methods designed to test for differences in sample distributions, rather than means, were required (Stephens 1974, 1986).

Reflectance values within the bryozoan reef monitoring sites have more skewed distribution with higher excess kurtosis than that of the surrounding sediments. By progressively increasing the number of data points in each monitoring site in each cell over time by planned transects or random intersection with the sites by citizen scientists, the acoustic reflectance distributions can be updated and compared to that of the surrounding sediments. Statistical tests will identify trends that would indicate a change to the composition of the seabed that may be related to differential cover of bryozoan skeleton and sediment. This would be intended to trigger more detailed assessment using other higher resolution acoustic or optical sensing methods.

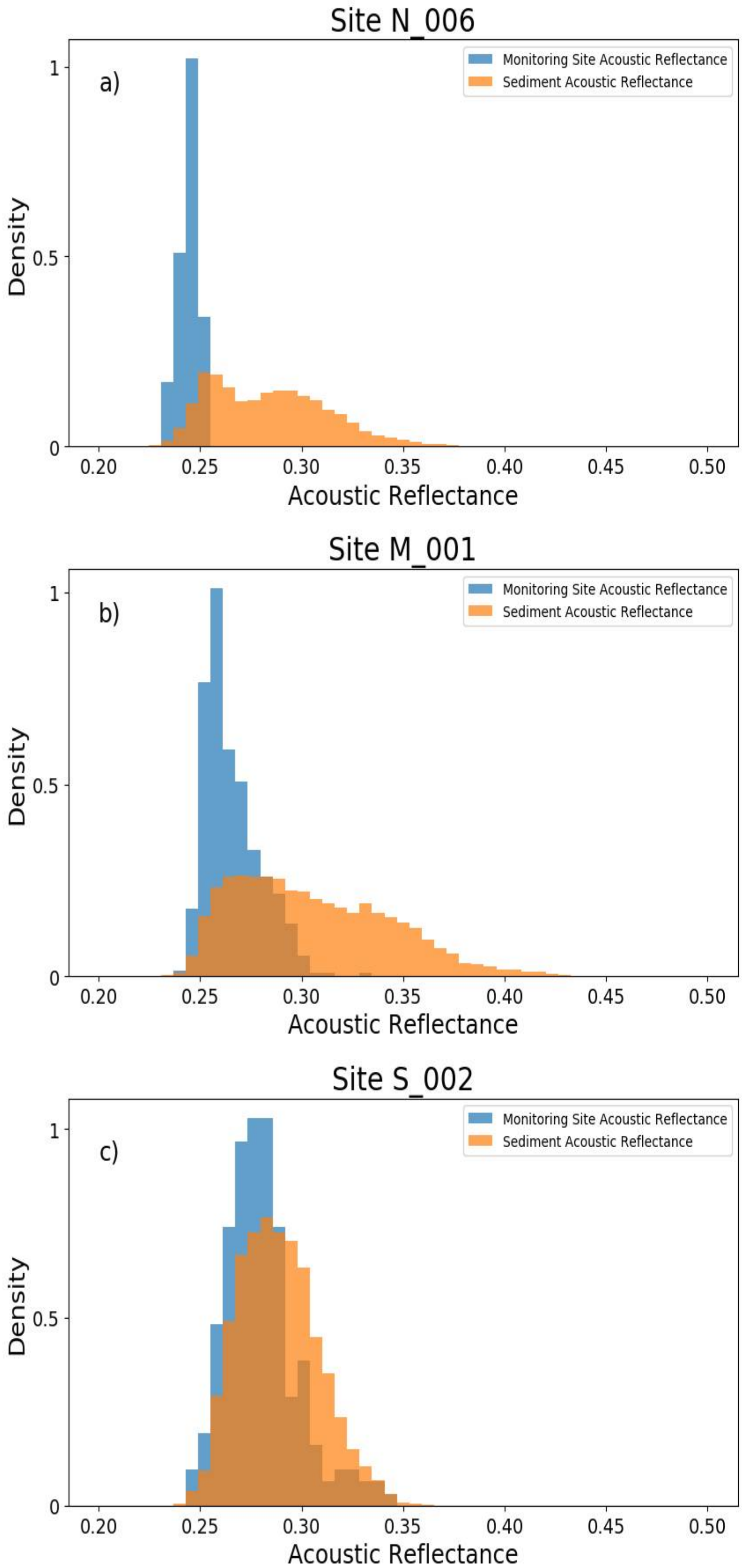

Figure 6. Acoustic reflectance values associated with bryozoan reefs (blue) and surrounding sediments (orange) within each cell. (a) Site N_006, Northern cell (b) Site M_001, Middle cell (c) Site S_002, Southern cell.

Table 2. Statistical characteristics of the acoustic reflectance points returned from the sediments in the Northern, Middle and Southern cells.

Cell	Mean acoustic reflectance	Median acoustic reflectance	Acoustic reflectance Standard Deviation	Excess kurtosis	Skewness
Northern	0.284	0.282	0.0289	-0.111	0.539
Middle	0.306	0.3	0.0378	-0.307	0.565
Southern	0.289	0.287	0.0197	-0.209	0.381

Table 3. Statistical characteristics of the acoustic reflectance points returned from the bryozoan reefs in the individual monitoring sites.

Site Name	Mean acoustic reflectance	Median acoustic reflectance	Acoustic reflectance Standard Deviation	Excess kurtosis	Skewness	AD Crit	AD p value	KS Crit	KS p value
N_004	0.275	0.272	0.0163	0.455	0.873	114.2	≤ 0.01	0.245	≤ 0.01
N_006	0.243	0.243	0.0055	0.01	-0.007	27.7	≤ 0.01	0.841	≤ 0.01
N_007	0.252	0.25	0.0111	-0.504	0.242	35.5	≤ 0.01	0.573	≤ 0.01
N_008	0.253	0.25	0.0102	-0.831	0.384	14.6	≤ 0.01	0.593	≤ 0.01
N_009	0.246	0.244	0.0096	-0.285	-0.165	48.0	≤ 0.01	0.697	≤ 0.01
N_010	0.259	0.254	0.0191	1.52	1.27	59.8	≤ 0.01	0.419	≤ 0.01
N_012	0.25	0.25	0.0091	0.342	-0.0228	346.1	≤ 0.01	0.648	≤ 0.01
N_013	0.245	0.243	0.0086	-0.203	0.634	73.9	≤ 0.01	0.732	≤ 0.01
N_017	0.254	0.25	0.0123	1.918	1.205	146.7	≤ 0.01	0.54	≤ 0.01
N_018	0.254	0.253	0.0081	-0.124	0.329	30.5	≤ 0.01	0.612	≤ 0.01
N_019	0.253	0.253	0.0095	3.021	1.273	25.2	≤ 0.01	0.661	≤ 0.01
N_020	0.256	0.255	0.0115	0.364	0.763	45.4	≤ 0.01	0.51	≤ 0.01
N_021	0.252	0.251	0.0105	2.222	1.326	44.1	≤ 0.01	0.57	≤ 0.01
M_001	0.266	0.262	0.0136	0.976	1.007	502.5	≤ 0.01	0.537	≤ 0.01
M_003	0.258	0.257	0.0091	0.079	0.158	284.0	≤ 0.01	0.741	≤ 0.01
M_004	0.262	0.261	0.0092	1.146	0.895	373.9	≤ 0.01	0.678	≤ 0.01
M_005	0.262	0.261	0.0082	-0.576	0.054	51.9	≤ 0.01	0.711	≤ 0.01
S_001	0.271	0.267	0.0161	3.24	1.728	152.2	≤ 0.01	0.498	≤ 0.01
S_002	0.28	0.278	0.018	1.151	0.922	25.1	≤ 0.01	0.23	≤ 0.01
S_003	0.276	0.278	0.0133	0.147	0.017	11.7	≤ 0.01	0.403	≤ 0.01

Footnote: In the *AD Crit* and *AD p value* column; AD is shorthand for Anderson-Darling, Crit is shorthand for Critical Value. In the *KS Crit* and *KS p value* columns; KS is shorthand for Kolmogorov-Smirnov, Crit is shorthand for Critical Value.

4. Conclusions

This report outlines a novel technique to monitor bryozoan reef extent and condition using low cost recreational fish finders. The technique provides a tractable method to engage citizen scientist recreational fishers and agencies in the collection of high-quality data. A data processing and analysis pipeline has been developed, the results of which, over time, can link to management objectives and actions.

Threats to the bryozoan reefs have been identified (Fathom Pacific 2020a) and the method developed in the present study applies to monitoring changes associated with potential anchor damage, sediment influx/impact and introduction of algae to the reefs. Given that future management of the bryozoan reefs may include some form of protection and/or education, the involvement of recreational fishers in monitoring is considered advantageous. During the course of this project we have discussed this monitoring technique with fishing club presidents, volunteer groups and advocacy groups. We have also conceptualised arrangements that can be used to support monitoring, such as sponsorship by tackle shops (e.g. BCF) to supply the required equipment, fishing competition prizes, equipment loans to trusted fishers and equipment buy-back schemes. Data exchange and cloud processing is a streamlined process and Fathom Pacific maintain the required software licenses and code for statistical analysis.

With sites now established, this monitoring solution is available for implementation. Fathom Pacific and VFA vessels will continue to operate in the area and collect data but the opportunity to increase data yield by engaging citizen scientists is identified.

5. Acknowledgements

This work is a part of the Western Port Bryozoan Reefs Research Project funded by La Trobe University, AGL, Port Phillip and Westernport Catchment Management Authority and Fathom Pacific Pty Ltd. The project has benefitted greatly from the collaborations with Port of Hastings Development Authority, Victorian Fisheries Authority and the Western Port Biosphere, Western Port Seagrass Partnership and Parks Victoria. Total Hydrographic Pty Ltd completed the multibeam studies and The Port of Hastings Development Authority and Department of Environment, Land, Water and Planning allowed access to the original 2009 multibeam data.

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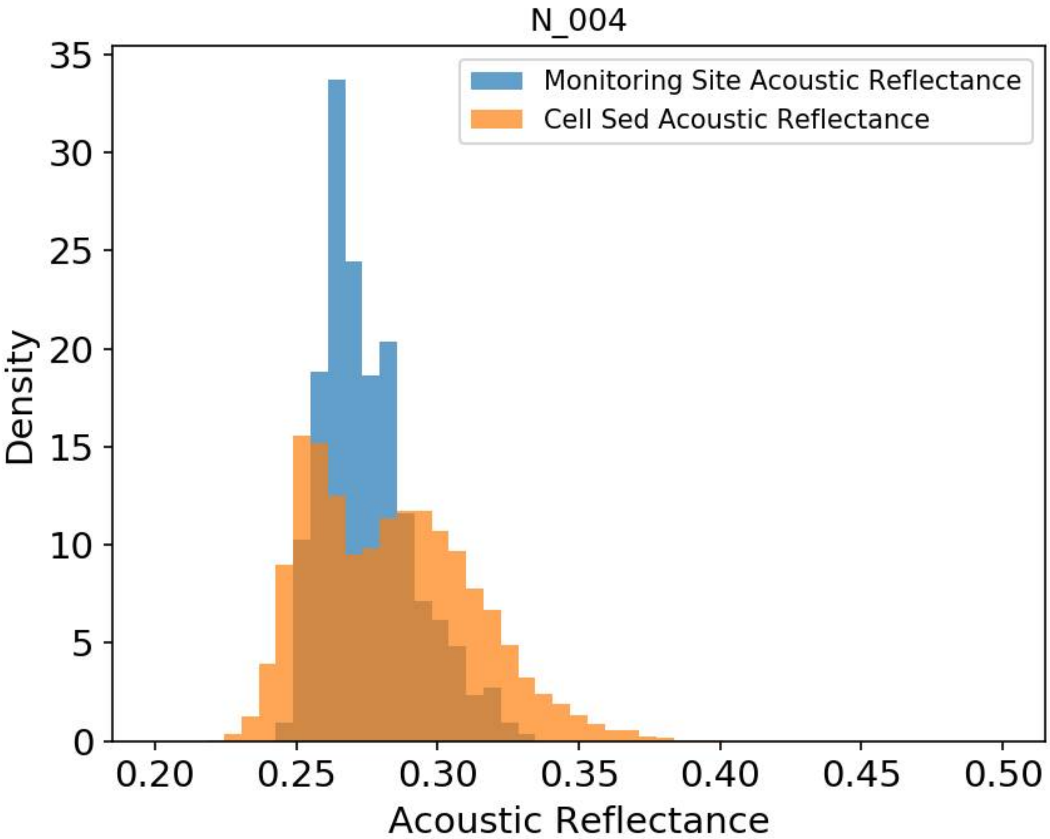
APPENDIX 1

Bryozoan reefs vs Sediments: Acoustic reflectance plots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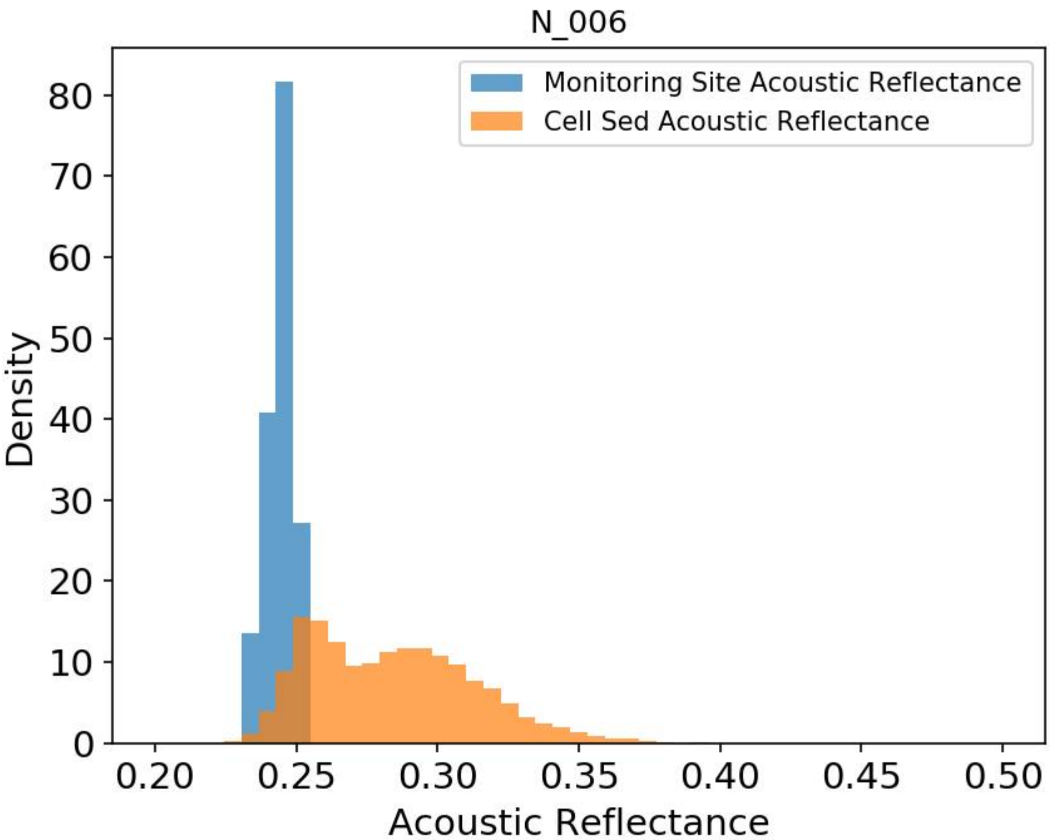
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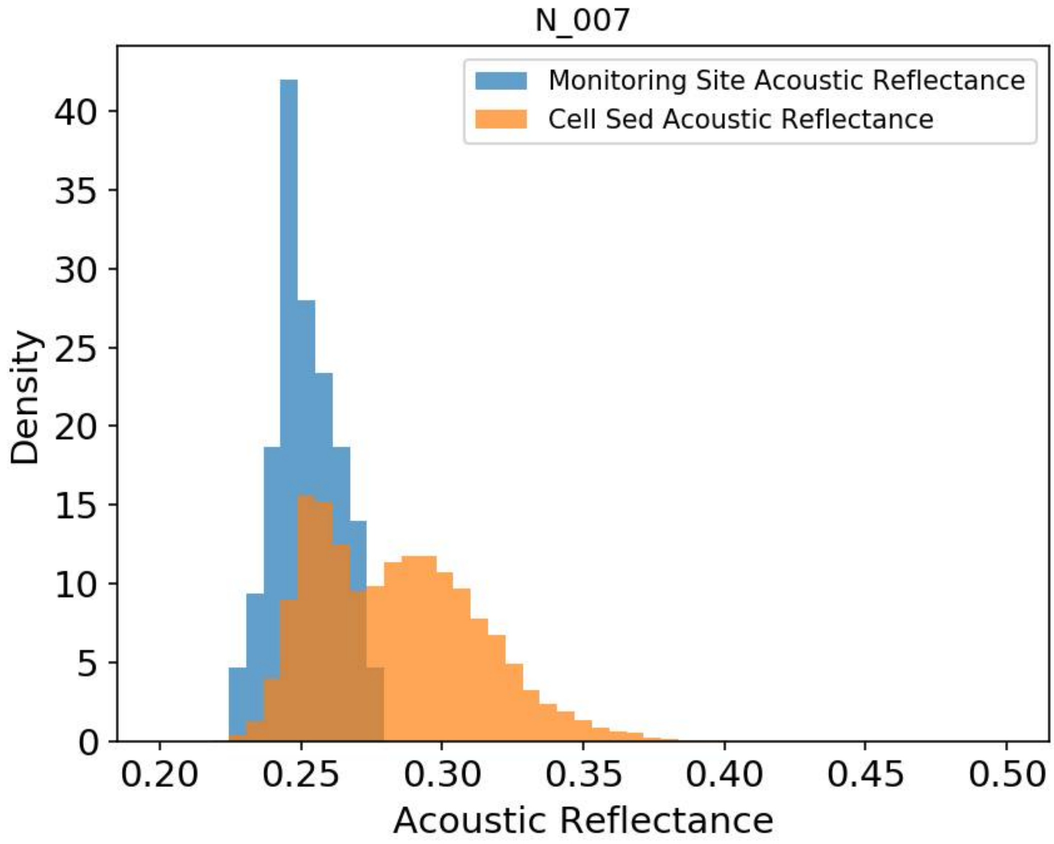
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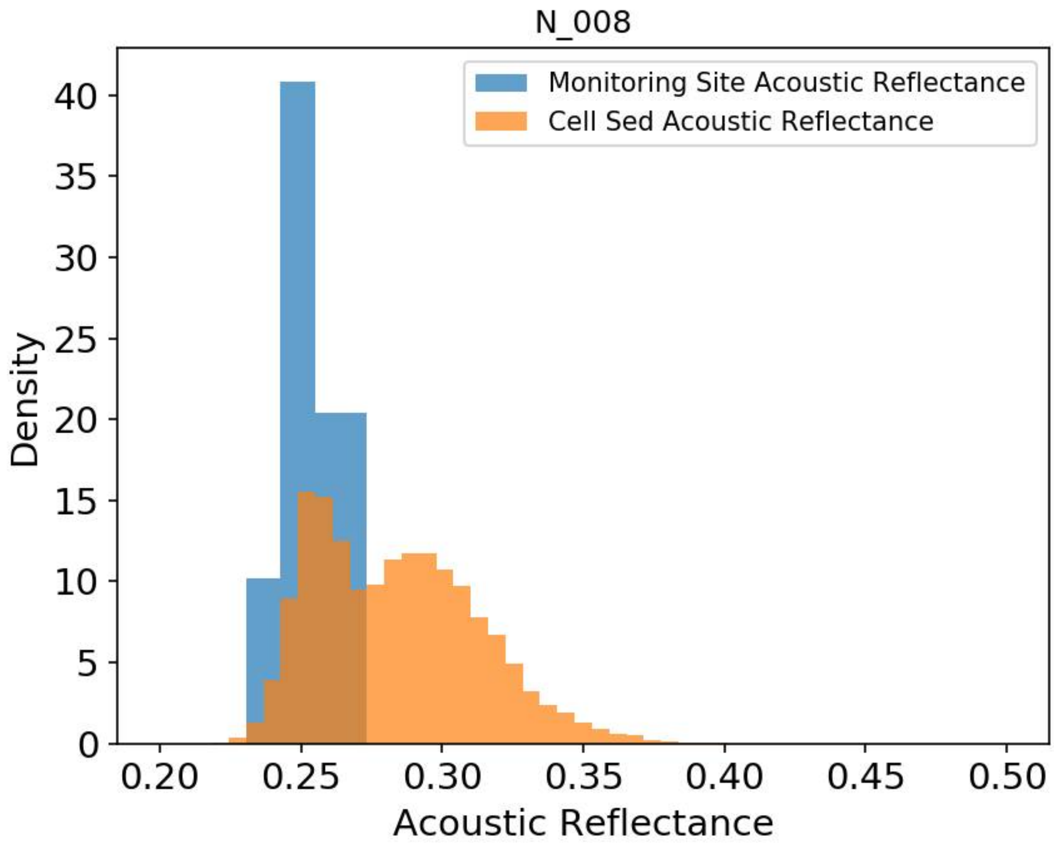
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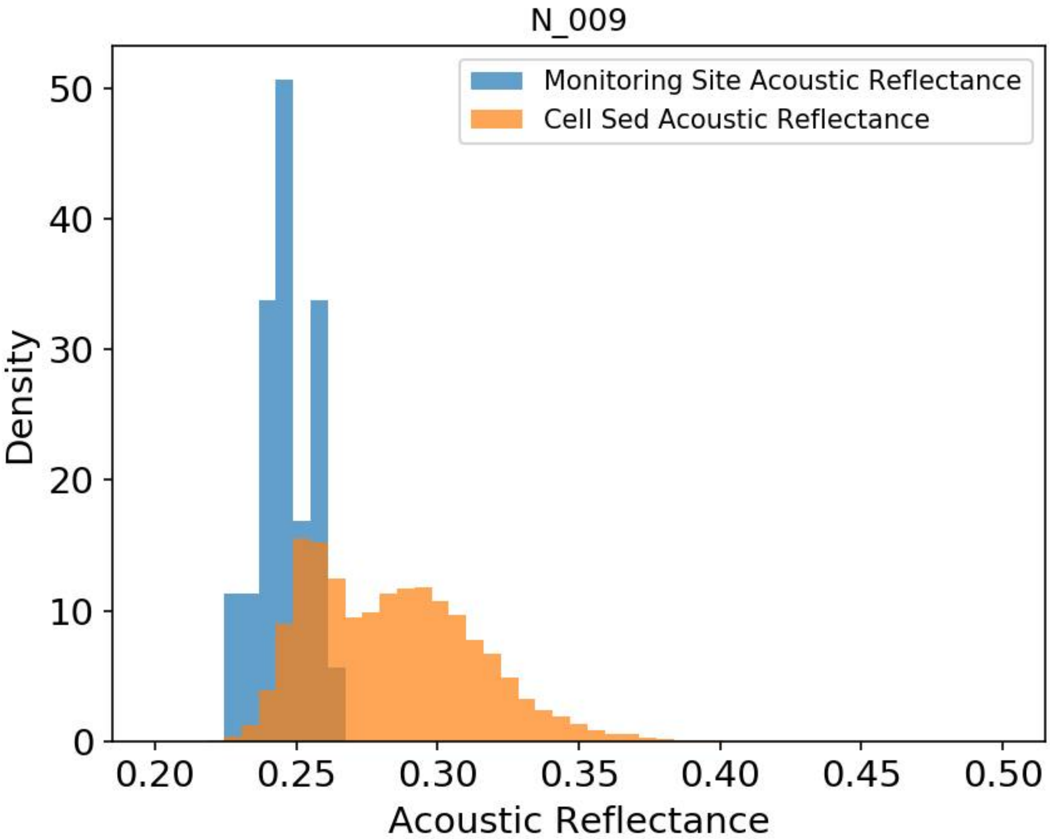
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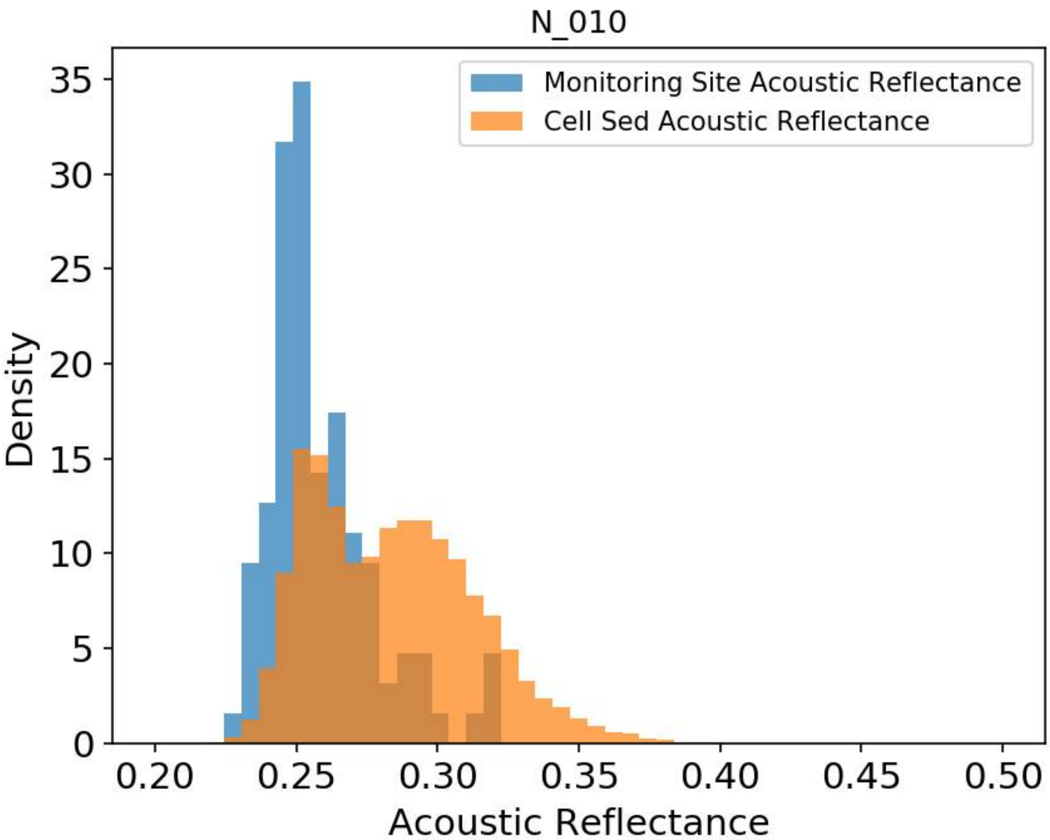
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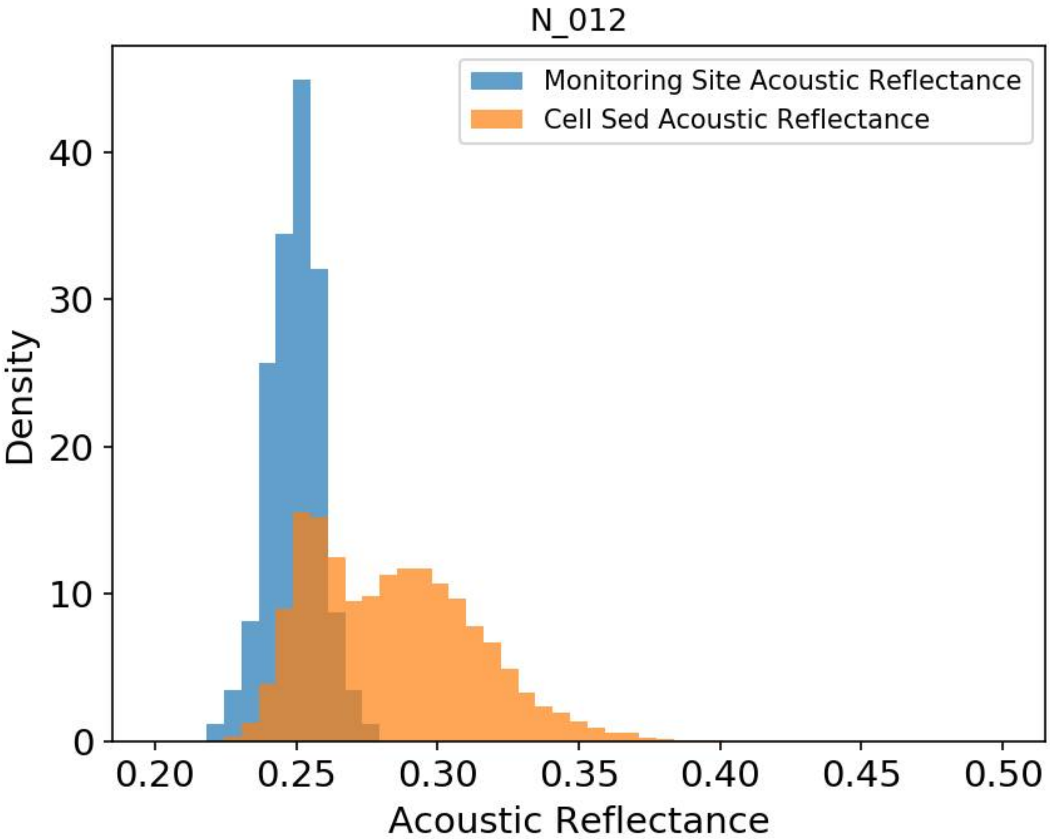
N_012
Monitoring Site Acoustic Reflectance
Cell Sed Acoustic Reflectance
Density
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20
30
40
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0.25
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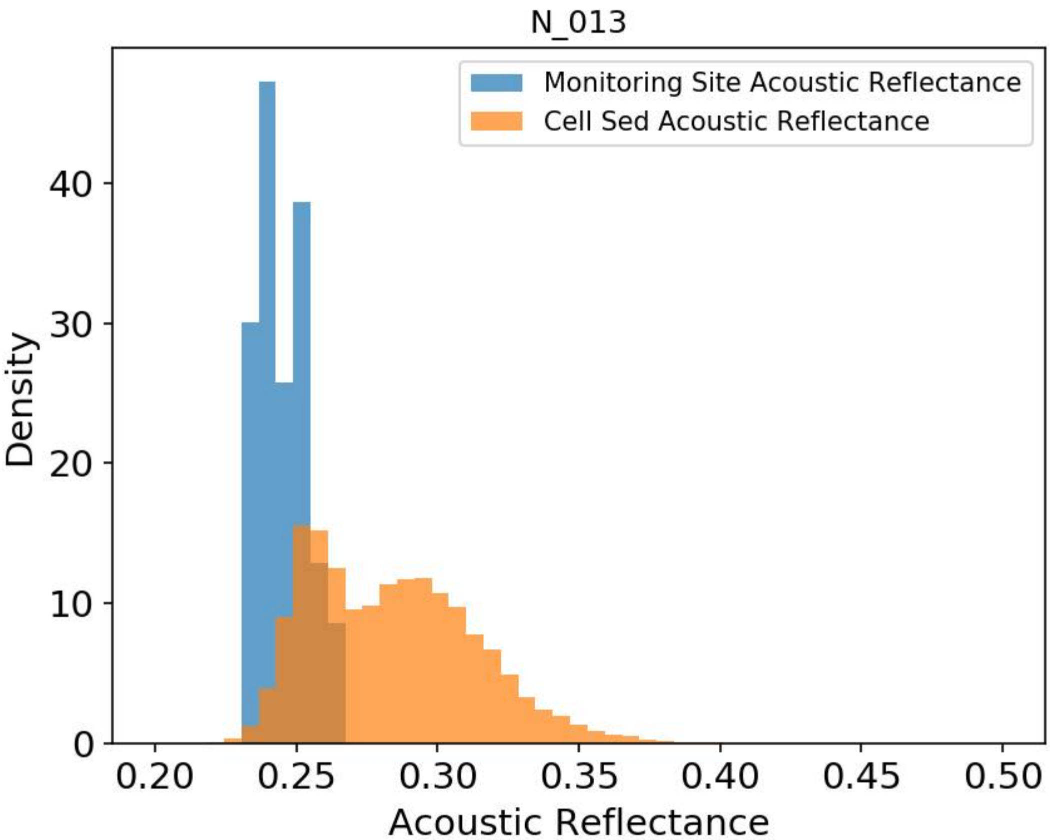
0.40
0.45
0.50
Acoustic Reflectance


N_013
Monitoring Site Acoustic Reflectance
Cell Sed Acoustic Reflectance
Density
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30
40
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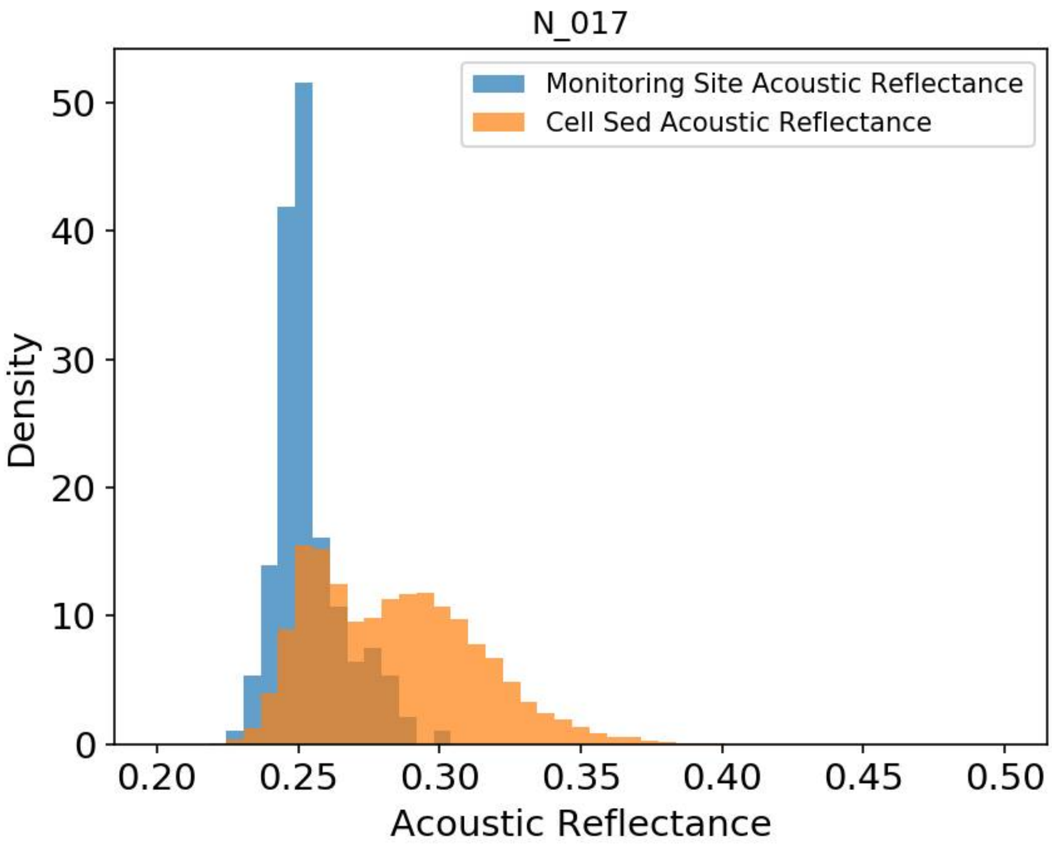
0.25
0.30
0.35
0.40
0.45
0.50
Acoustic Reflectance


N_017
Monitoring Site Acoustic Reflectance
Cell Sed Acoustic Reflectance
Density
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0.20
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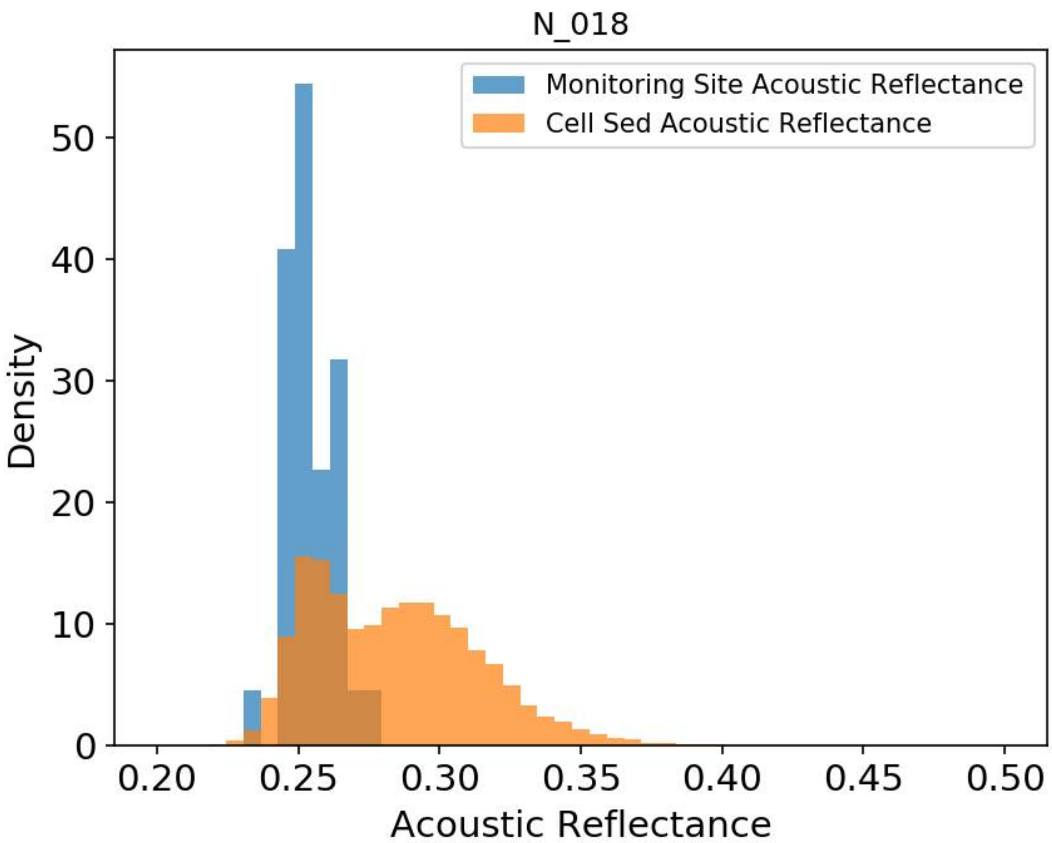
0.40
0.45
0.50
Acoustic Reflectance


N_018
Monitoring Site Acoustic Reflectance
Cell Sed Acoustic Reflectance
Density
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30
40
50
0.20
0.25
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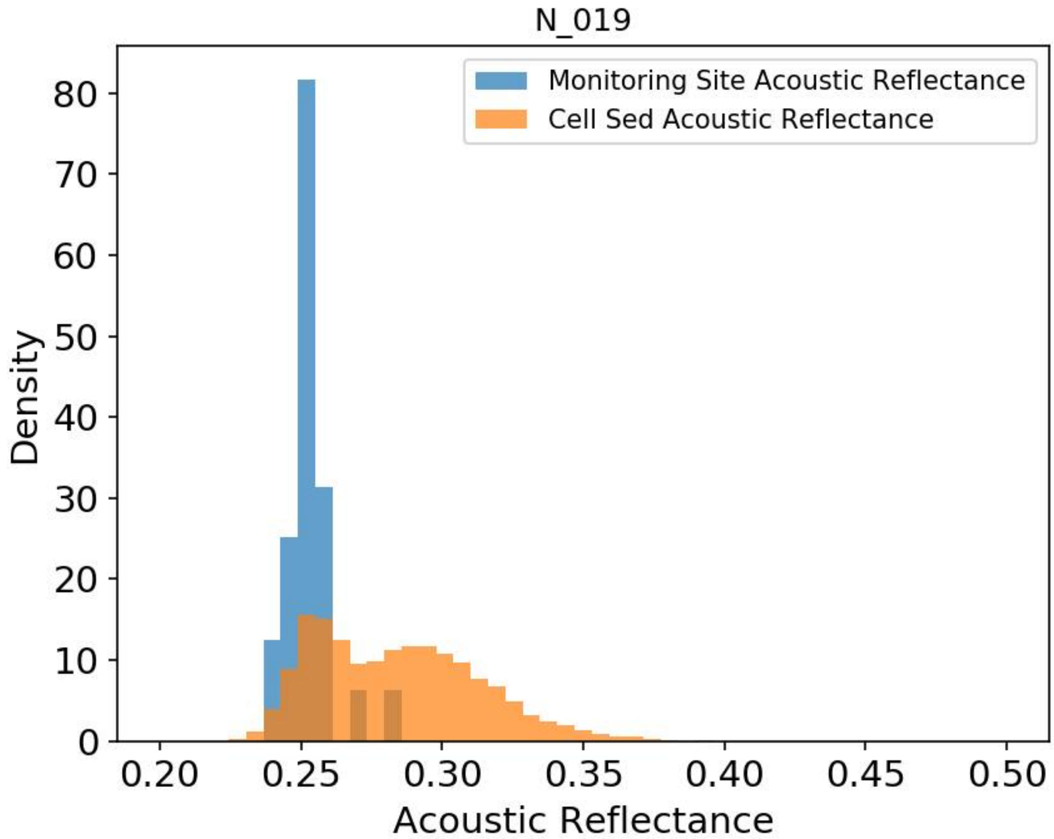
0.35
0.40
0.45
0.50
Acoustic Reflectance


N_019
Monitoring Site Acoustic Reflectance
Cell Sed Acoustic Reflectance
Density
0
10
20
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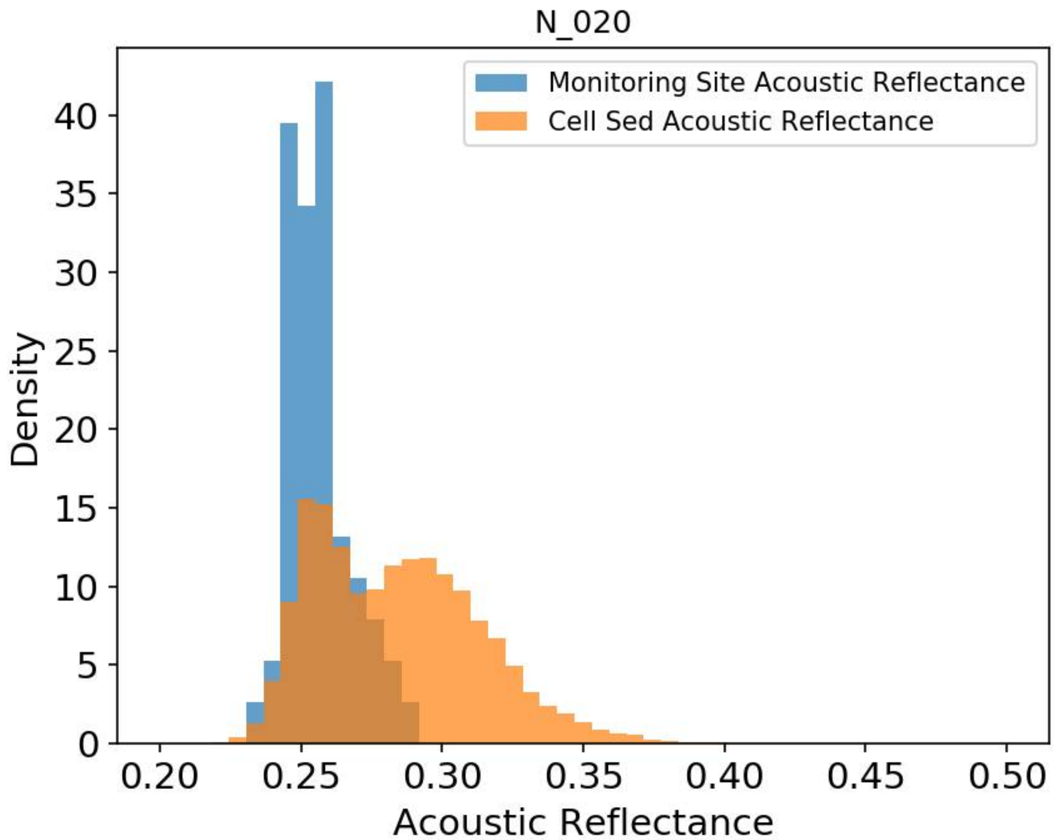
40
50
60
70
80
0.20
0.25
0.30
0.35
0.40
0.45
0.50
Acoustic Reflectance


N_020
Monitoring Site Acoustic Reflectance
Cell Sed Acoustic Reflectance
Density
0
5
10
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20
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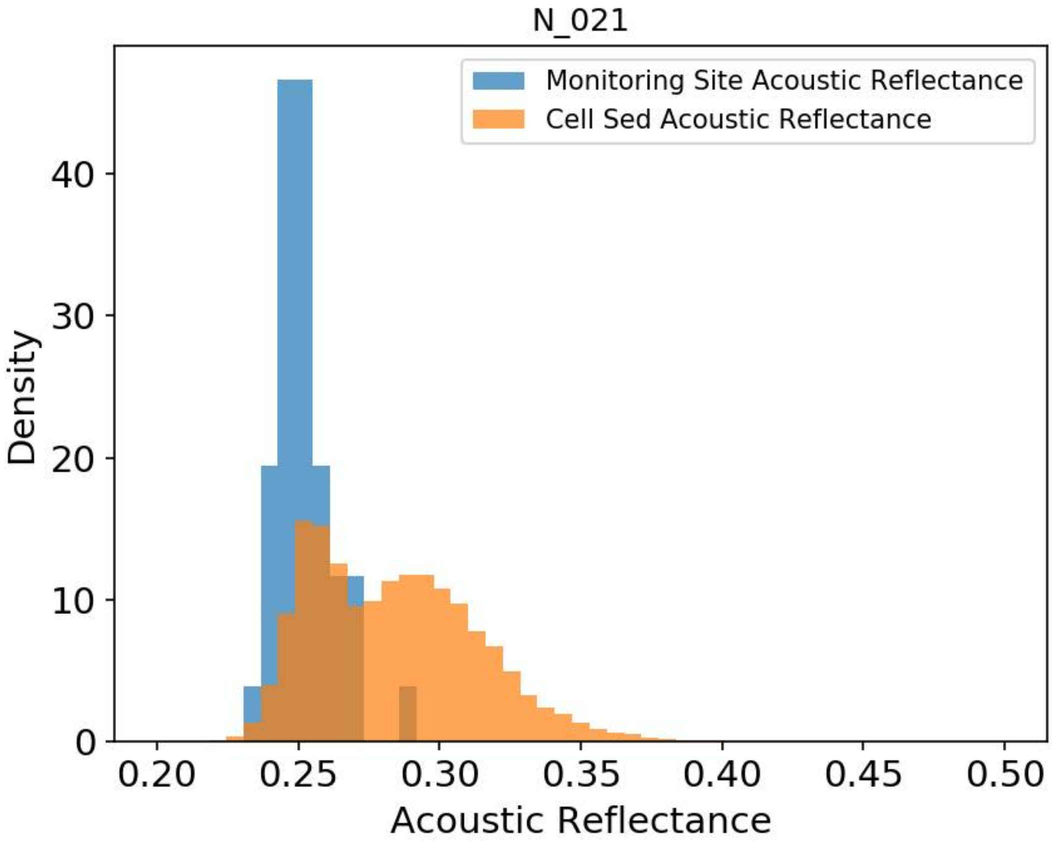
35
40
0.20
0.25
0.30
0.35
0.40
0.45
0.50
Acoustic Reflectance


N_021
Monitoring Site Acoustic Reflectance
Cell Sed Acoustic Reflectance
Density
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0.25
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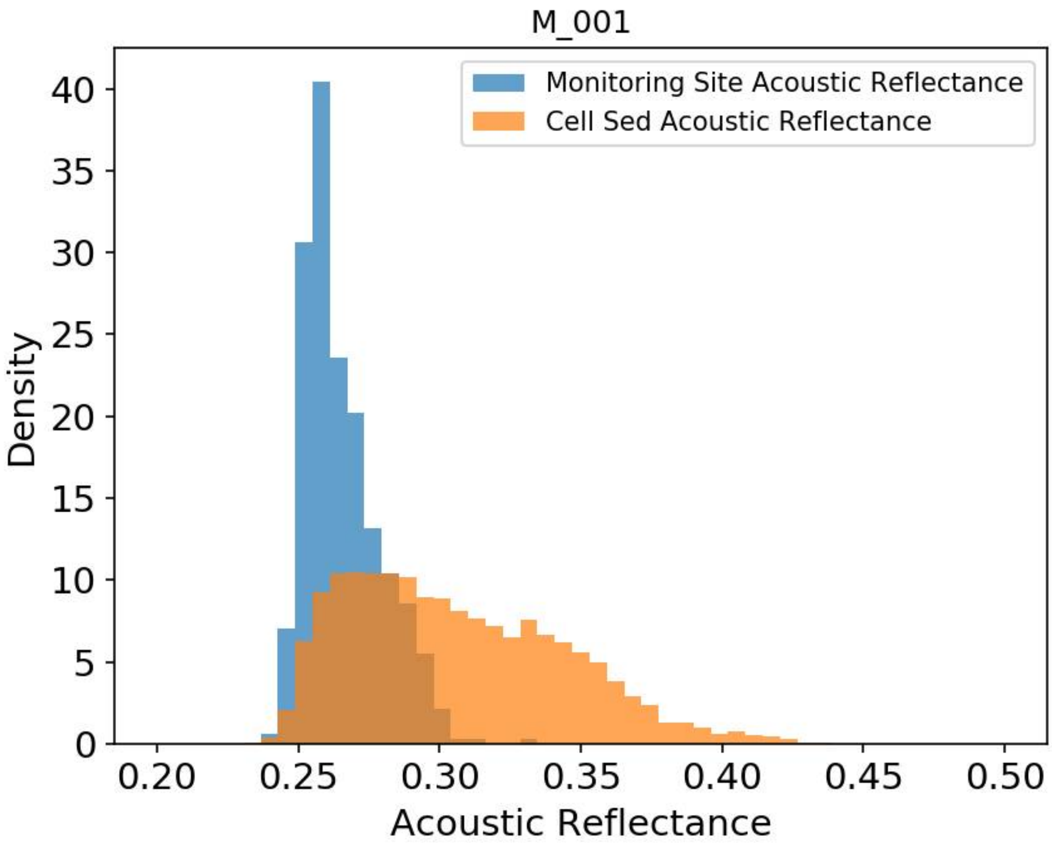
0.40
0.45
0.50
Acoustic Reflectance


M_001
Monitoring Site Acoustic Reflectance
Cell Sed Acoustic Reflectance
Density
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5
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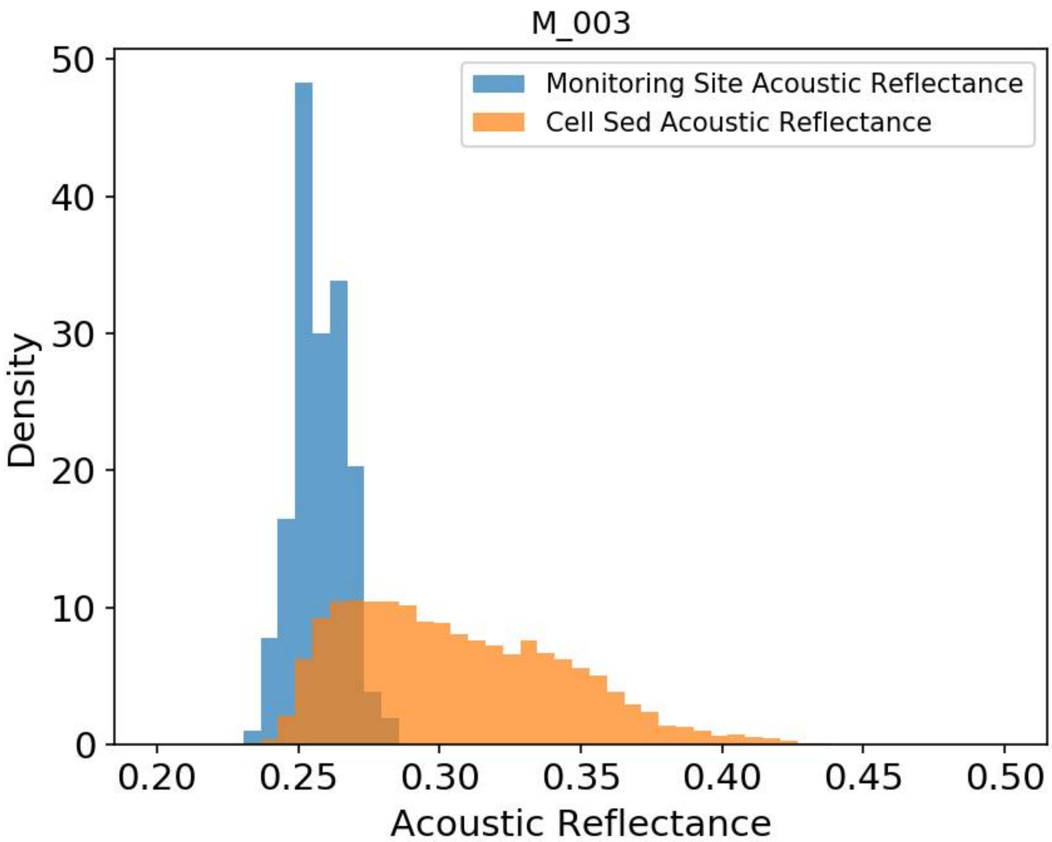
0.25
0.30
0.35
0.40
0.45
0.50
Acoustic Reflectance


M_003
Monitoring Site Acoustic Reflectance
Cell Sed Acoustic Reflectance
Density
Acoustic Reflectance
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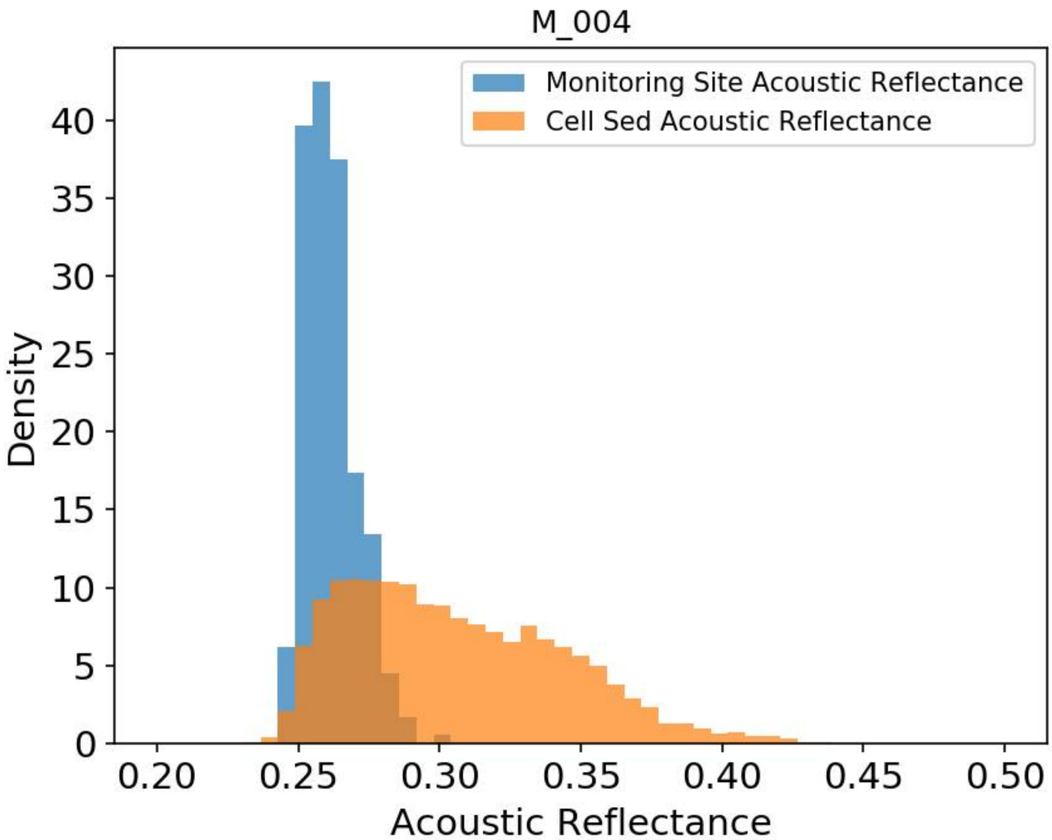
0.20
0.25
0.30
0.35
0.40
0.45
0.50


M_004
Monitoring Site Acoustic Reflectance
Cell Sed Acoustic Reflectance
Density
Acoustic Reflectance
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10
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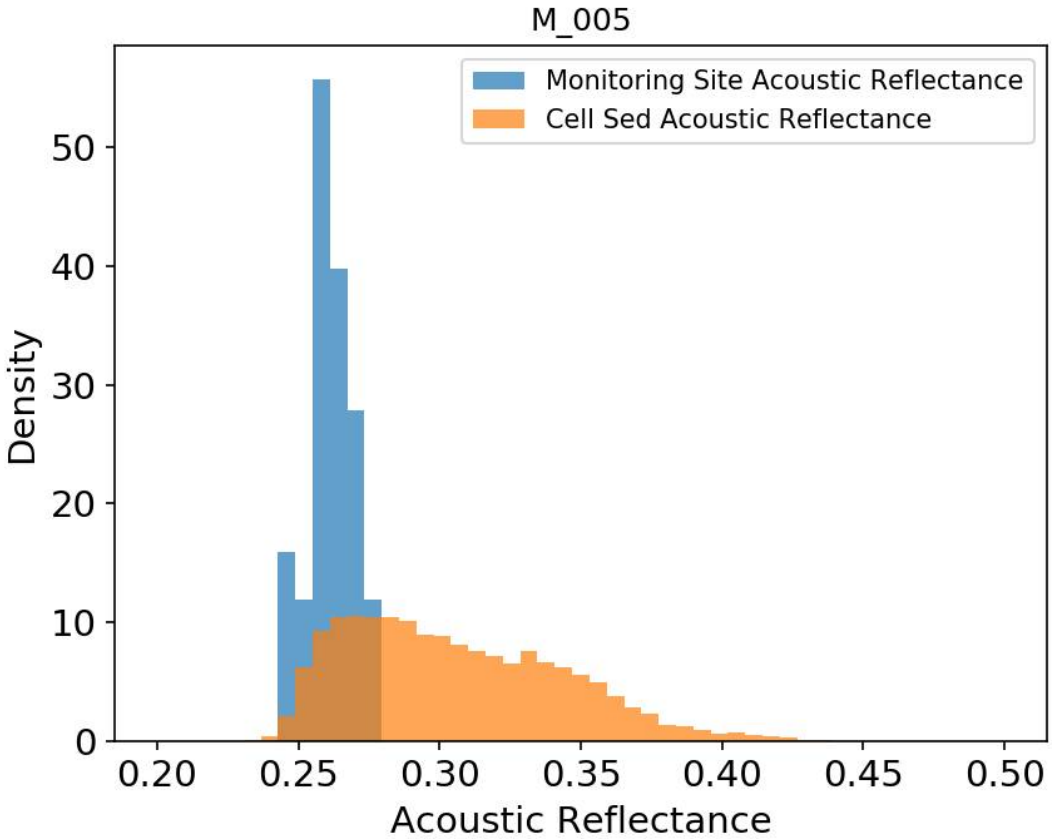
20
25
30
35
40
0.20
0.25
0.30
0.35
0.40
0.45
0.50


M_005
Monitoring Site Acoustic Reflectance
Cell Sed Acoustic Reflectance
Density
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50
0.20
0.25
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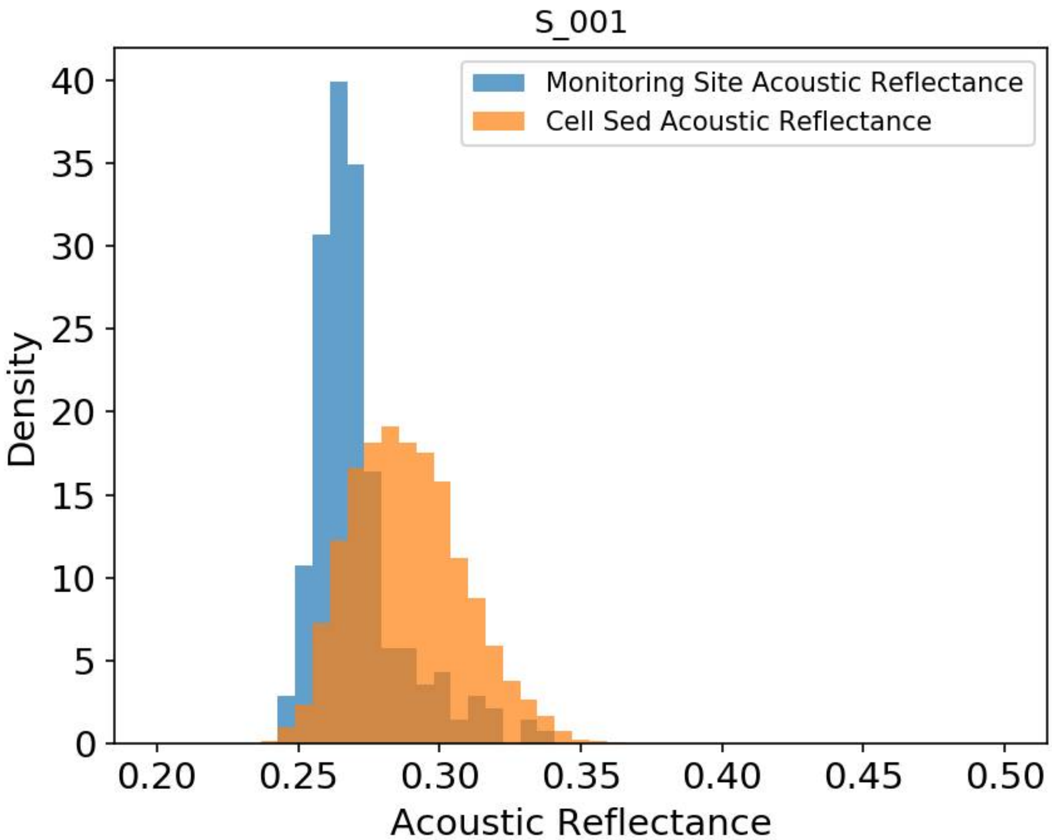
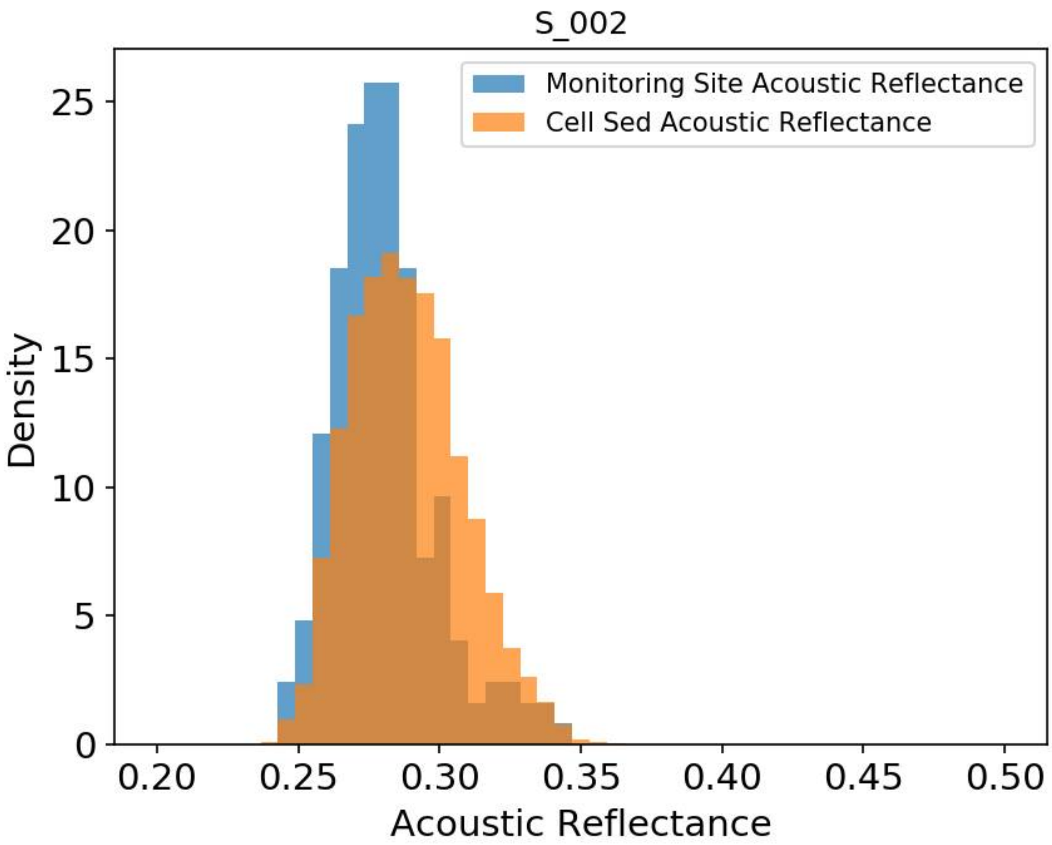
0.40
0.45
0.50
Acoustic Reflectance


S_001
Monitoring Site Acoustic Reflectance
Cell Sed Acoustic Reflectance
Density
0
5
10
15
20
25
30
35
40
0.20
0.25
0.30
0.35
0.40
0.45
0.50
Acoustic Reflectance


S_002
Monitoring Site Acoustic Reflectance
Cell Sed Acoustic Reflectance
Density
Acoustic Reflectance
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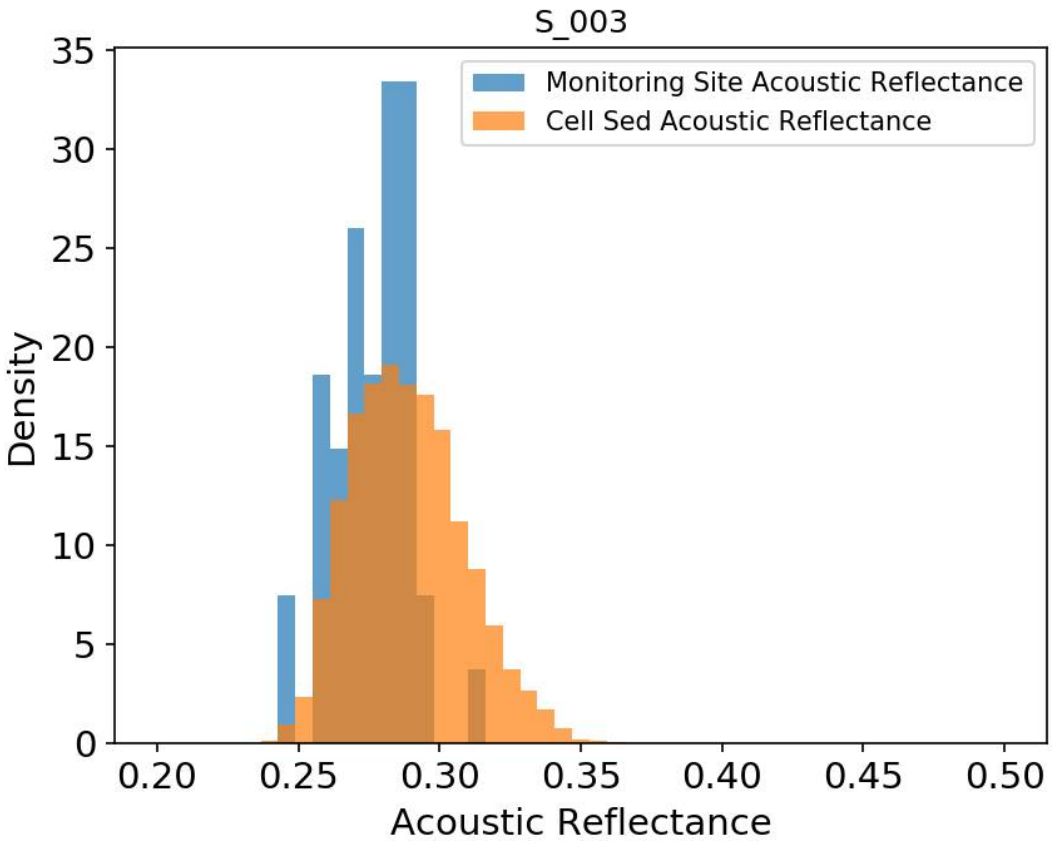
10
15
20
25
0.20
0.25
0.30
0.35
0.40
0.45
0.50


S_003
Monitoring Site Acoustic Reflectance
Cell Sed Acoustic Reflectance
Density
Acoustic Reflectance
0
5
10
15
20
25
30
35
0.20
0.25
0.30
0.35
0.40
0.45
0.50