UKSeaMap 2010 Technical Report 3

Substrate data

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1.1 Introduction

Substrate data was a key component in the construction of the UKSeaMap 2010 predictive habitat model. It was used in combination with light, wave, current and depth data to model EUNIS seabed habitats for UK waters. It is necessary to examine the way substrate information is categorised to determine appropriate boundaries and classes to be used in the substrate data layer.

Sediment classification systems, such as Wentworth (1922) and Folk (1954) have been designed by geologists (Table 1). As part of the Marine Nature Conservation Review Connor and Hiscock (1996) aggregated the Wentworth sediment categories to make them more biologically relevant for use in observational field recording (Table 1), including an equivalency to the Folk (1954) system and Friedman & Sanders (1978). These biologically relevant classes are part of the Marine Habitat Classification for Britain and Ireland (Connor et al, 2004), at Level 4 and more detailed levels (5, 6 etc). At Level 3, the Marine Habitat Classification for Britain and Ireland, and the European equivalent (Davies & Moss, 2004; Connor *et al*, 2004) group these detailed classes into four coarse classes using a modification of the Folk system, with one boundary change between the **sand and muddy sand** and **mud and sandy mud** category (muddy sand boundary changed from 10 - 50% to 10 - 20% mud) (Figure 1). The original UKSeaMap project (Connor *et al*, 2006) used these four sediment groups to classify their sediment information (Figure 1).

UKSeaMap 2010 revisited the original UKSeaMap classification to see if it could be refined using additional biological and sediment data available through the Marine Recorder database (Version 20090520)[1].

[1] The Marine Recorder package was developed by JNCC as a collect and collate piece of software designed to hold and manage marine survey data including Marine Nature Conservation Review surveys. The JNCC database holds benthic sample data from a variety of organisations including the JNCC, the Country Conservation Agencies, MEDIN, Seasearch and Local Record Centres

Table 1: Sediment particle sizes and equivalent classification terms

Mm	µm	phi	*Wentworth (1922)*	*Friedman & Sanders (1978)*	*Connor & Hiscock (1996)*	*Folk (1954)*	*EUNIS v2004*
2048		-11	Boulder gravel	Very Large Boulders	Very large boulders	Gravel	**Rock** **e.g. A1, A3, A4, A6.1**
1024		-10		Large Boulders			
512		-9		Medium Boulders	Large boulders		
256		-8		Small Boulders	Small boulders		
128		-7	Cobble gravel	Large Cobbles	Cobbles		*** If highly mobile = Sediment A2.11, A5.121**
64		-6		Small Cobbles			
32		-5	Pebble gravel	Very coarse Pebbles	Pebbles		*** If stable and/or mixed with cobble, boulder, little sediment = Rock**
16		-4		Coarse Pebbles			
8		-3		Medium Pebbles	Gravel		
4		-2		Fine Pebbles			
2	2000	-1	Granule gravel	Very fine Pebbles	Coarse sand		Sediment e.g. A2, A5, A6.2-A6.6 See Folk triangle for subdivisions
1	1000	0	Very coarse Sand	Very coarse Sand		Sand	
0.5	500	1	Coarse Sand	Coarse Sand	Medium sand		
0.25	250	2	Medium Sand	Medium Sand			
0.125	125	3	Fine Sand	Fine Sand	Fine sand		
0.063	63	4	Very fine Sand	Very fine Sand			
0.031	31	5	Silt	Very coarse Silt	Mud	Mud	
0.016	16	6		Coarse Silt			
0.008	8	7		Medium Silt			
0.004	4	8		Fine Silt			
0.002	21	9	Clay	Very fine Silt Clay			

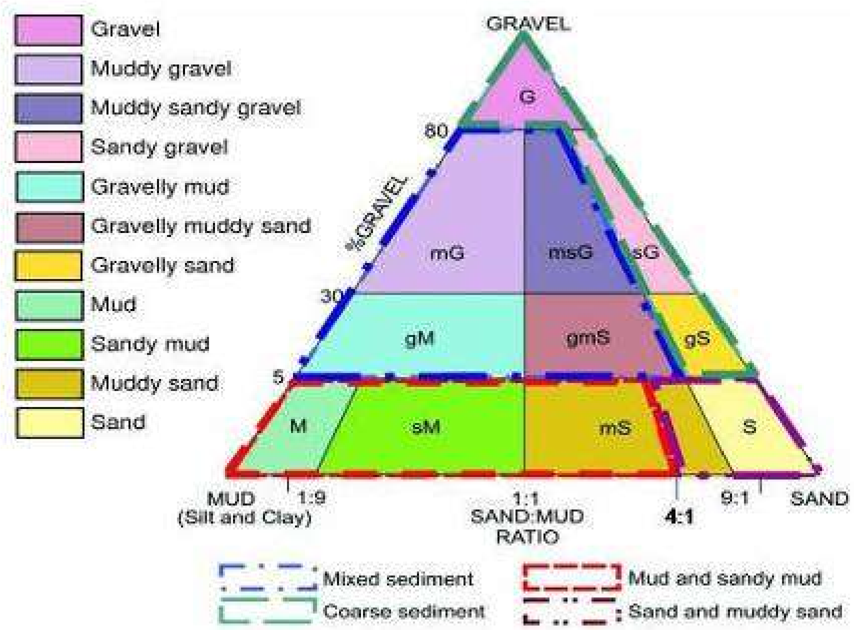


Figure 1: UKSeaMap sediment trigon, modified to show the aggregation of classes into four UKSeaMap 2006 sediment classes (coarse, mixed, sand and muddy sand, mud and sandy mud).

This study used data for sublittoral sediments only (infralittoral, circalittoral and deep circalittoral) and did not analyse data for littoral or deep sea areas because of a lack of available data. Littoral areas are not included in the BGS DigSBS250 seabed sediments map, and deep sea areas lack a sufficient volume of biological and physical samples against which to compare the sediment map.

This study examined the number of sediment classes currently used for broad-scale modelling, to determine whether the qualitative resolution of the substrate layers used in modelling could be increased while maintaining clear links to the structure of the habitat classification system, and hence the ecological validity of the sediment classes. This involved examining sediment classes at more detailed levels of the EUNIS hierarchy. Sublittoral sediment categories at EUNIS Level 3 to 5 were identified from the EUNIS 2007-11 classification (Table 2). Table 2 shows the sediment classifications used at EUNIS Levels 3 and 4 and the 38 sediment descriptions used at EUNIS Level 5. Before starting the analysis it was decided that it was not feasible to attempt to test the biological relevance of the EUNIS Level 5 classes, or to derive them from the available substrate information. Hence the analysis was restricted to sediment classes at Level 3 and 4 only. The eight EUNIS Level 4 sediment classes are still relatively broad groups and were expected to occupy significant areas of the seabed, which is important for clarity in the modelled outputs.

Table 2: EUNIS level 3, 4 & 5 sublittoral sediment categories (EUNIS 2007 classification).

EUNIS Level 3 Code	EUNIS Level 3 classes	EUNIS Level 4 classes	EUNIS Level 5 Sediment descriptions
A5.1	Coarse sediment	Coarse sediment	Gravel Shell gravel Stone gravel Shingle (cobbles and pebbles) Fine gravels Gravel & sand Gravelly sand Sand and mixed gravely sand Coarse sand Medium-coarse sands Silted cobbles
A5.2	Sand & muddy sand	Sand Fine Sand Muddy sand	Sand with cobbles or pebbles Sand Medium to very fine sand Fine sand Fine & muddy sands Fine muddy sands Slightly mixed sediment Facies
A5.3	Mud & sandy mud	Mud Sandy Mud Fine Mud	Muddy sediment Firm mud or clay Sandy mud Sandy or shelly mud Mud Fine mud Silty sediments Clayey mud White calcareous muds Facies
A5.4	Mixed sediments	Mixed sediments	Mixed sediment Coarse mixed sediment Muddy mixed sediment Stones and mixed sediment Sandy mixed sediment
A5.6 – A5.8	Others	Maerl beds	Cobbles and pebbles Gravel and pebbles Muddy gravel Shelly gravel & boulders

1.1.1 Aim

- To test the biological relevance of various ways of grouping sediment types into sediment classes equivalent to EUNIS level 3 or 4.
- To decide on appropriate sediment classes and their boundaries for use in UKSeaMap 2010

1.2 Methods

1.2.1 Analysis of seabed sediment types in the UK

The projection of the BGS seabed sediments map DigSBS250 was converted to the Europe Albers Equal Area Conic coordinate system (Standard Parallel 1 = 50.2, Standard Parallel 2 = 58.5).The projection was changed to ensure that area values could be calculated in metres. Area values were calculated in the attribute table of the DigSBS250 shapefile using in ArcMap™ 9.2. This work was completed to examine the proportions of different sediment types present in the UK. This was used to show how changes in the substrate classes and their boundaries might change the substrate types in the UKSeaMap 2010 map. DigSBS250 uses the BGS modified Folk classification (Figure 2).

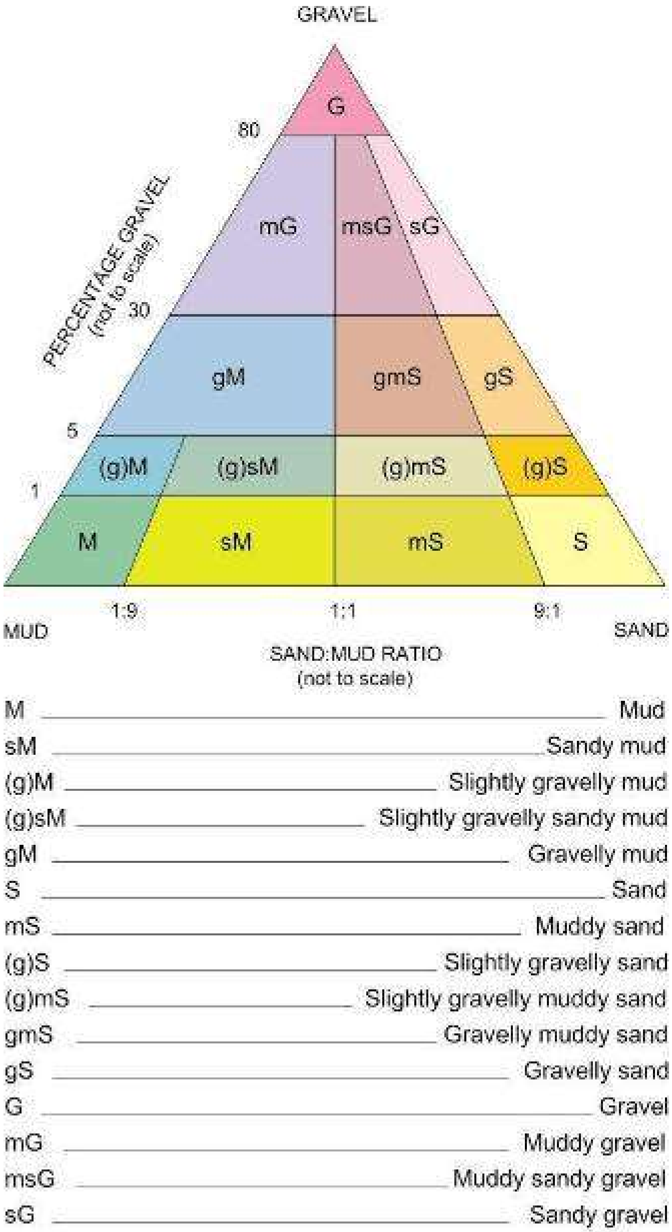


Figure 2: BGS modified Folk sediment classification.

1.2.2 Habitat point data analysis

Sediment Classifications used

Three sediment classification systems were analysed by UKSeaMap 2010; BGS modified Folk (Figure 2), Wentworth (1922) and UKSeaMap 2006 (Figure 1). For each classification system, full-coverage sediment maps in that classification were compared to point samples containing physical or biological information. The patterns produced were examined in order to determine which sediment classification system had the strongest relationship to the point sample data.

Data extraction

Data were extracted from the JNCC Marine Recorder database (All20090520 Version). Biotope points which fitted into one of four EUNIS Level 3 categories (A5.1, A5.2, A5.3 and A5.4) were extracted (Table 3). Two subsets of data were extracted from this larger dataset:

- Biotope data points from the relevant parts of the habitat classification which had associated particle size data (e.g. sieved sediment samples)
- Biotope data points from the relevant parts of the habitat classification which had associated subjective sediment information (e.g. sediment descriptions from dives or video footage).

This significantly reduced the number of available habitat data points as many biotope points did not have associated sediment samples or descriptions. Data points from dives or video data where the total substrate cover did not add up to 100% were eliminated from the analysis; this also reduced the total number of available data points.

To avoid confusion in the following sections when the same terms are used to describe EUNIS Level 3 sublittoral sediment categories and data which fall into UKSeaMap sediment classifications, italics have been used to refer to *EUNIS Level 3 sediment divisions* and bold text is used to refer to the **UKSeaMap 2006 sediment classes**.

Data analysis

The Gradistat programme (Blott & Pye, 2001) was used to classify particle size data into Folk and Wentworth (1922) sediment classes. BGS modified Folk was required (rather than Folk) as this is the classification used by BGS in their seabed sediments map DigSBS250 which provided the basis for the UKSeaMap 2010 substrate map. Gradistat classifies sediments into Folk (1954) categories which uses a trace amount (0.1%) of gravel to distinguish slightly gravelly sediments rather than BGS modified Folk categories (Cooper *et al*, 2005) which uses 1% gravel to distinguish slightly gravelly sediments. The difference between these classifications is the boundary between ‘slightly gravelly’ sediments and sediments containing little or no gravel, e.g. the boundary between ‘muddy sand’ and ‘slightly gravelly muddy sand’. Folk categories were manually adjusted after Gradistat analysis to BGS modified Folk categories.

Table 3: Total number of available data points in Marine Recorder (All20090520). Biotope data points which had associated subjective sediment information were only included if the total substrate cover added up to 100%. The habitat classes are colour coded to match the sediment types from Table 2.

EUNIS Level 3 substrate class	EUNIS 2007-11 Code	Britain & Ireland 04.05 Code	Number of data points		
			Biotope	Biotope & PSA	Biotope & subjective sediment data
Coarse sediment	**A5.1**	**SS.SCS**	**2,312**	**362**	**1,184**
	A5.12	SS.SCS.SCSVS	12	2	6
	A5.13	SS.SCS.ICS	746	294	230
	A5.14	SS.SCS.CCS	1,304	63	826
	A5.14	SS.SCS.OCS	133	0	110
Sand & Muddy Sand	**A5.2**	**SS.SSa**	**2,827**	**690**	**697**
	A5.21	SS.SSa.SSaLS	8	3	7
	A5.22	SS.SSa.SSaVS	166	57	0
	A5.23	SS.SSa.IFiSa	830	273	158
	A5.24	SS.SSa.IMuSa	970	222	269
	A5.25	SS.SSa.CFiSa	160	32	68
	A5.26	SS.SSa.CMuSa	269	69	92
	A5.27	SS.SSa.OSa	130	12	70
Mud & Sandy Mud	**A5.3**	**SS.SMu**	**2,898**	**692**	**978**
	A5.31	SS.SMu.SMuLS	58	5	36
	A5.32	SS.SMu.SMuVS	511	258	97
	A5.33	SS.SMu.ISaMu	447	226	76
	A5.34	SS.SMu.IFiMu	470	34	235
	A5.35	SS.SMu.CSaMu	727	98	274
	A5.36	SS.SMu.CFiMu	592	58	253
	A5.37	SS.SMu.OMu	18	5	4
Mixed sediment	**A5.4**	**SS.SMx**	**3,174**	**352**	**1,074**
	A5.41	SS.SMx.SMxLS	8	5	0
	A5.42	SS.SMx.SMxVS	188	55	54
	A5.43	SS.SMx.IMx	582	79	175
	A5.44	SS.SMx.CMx	2,019	210	826
	A5.45	SS.SMx.OMx	31	2	19

The sediment classification categories were graphically explored using two different methods; barcharts and ternary plots. Barcharts were constructed in Excel 2007 and used to show the proportions of different sediment categories (e.g. Folk – mud or muddy sand) at each EUNIS level. Ternary plots were constructed in R 2.9.1 and used to show the distribution of EUNIS habitats or biotopes on the BGS modified Folk triangle. The 95% median confidence intervals were calculated for percentage values of gravel, sand and mud. Median confidence levels were used instead of mean confidence levels as median values are less affected by outlier values. This analysis was used to look at the ranges of gravel, sand and mud for categories at EUNIS Levels 3 and 4.

1.2.3 EUNIS Level 3

Sublittoral sediment records from the JNCC Marine Recorder database were assigned to habitats within one of the following four EUNIS level 3 categories:

- *sublittoral coarse sediment*

- *sublittoral mixed sediment*
- *sublittoral sand and muddy sand*
- *sublittoral mud and sandy mud*.

Only records with both a Marine habitat classification for Britain and Ireland classification and accompanying particle size data were selected. In order to investigate the relationships between the biological data and the sediment classifications, particle size data were categorised according to one of three sediment schemes; BGS modified Folk, Wentworth (1922), and the UKSeaMap 2006 classification system (Connor, 2006). The different categories in the sediment classifications were examined to see if the actual categories matched their expected categories.

1.2.4 EUNIS Level 4

Sublittoral habitat records from the JNCC Marine Recorder database were assigned to EUNIS Level 4 sublittoral sediment categories. Only two EUNIS Level 3 sublittoral habitats were examined at Level 4, *sublittoral sand and muddy sand* and *sublittoral mud and sandy mud* as no additional sediment classes appear in the *coarse sediment* and *mixed sediment* habitat categories at EUNIS Level 4. *Sublittoral sand and muddy sand* splits into three categories: *fine sand*, *sand* and *muddy sand* (Table 4). *Sublittoral mud and muddy sand* also splits into three categories: *fine mud*, *mud* and *sandy mud* (Table 4). Circalittoral and Infralittoral categories of the same sediment type were combined into the one group. EUNIS Level 4 categories were examined using two different sediment classifications systems; BGS modified Folk and UKSeaMap 2006. The different categories in the sediment classifications were examined to see if the actual categories matched the expected categories

EUNIS Level 4 sublittoral sediment records from Marine Recorder (All20090520 version) were assigned to one of the EUNIS Level 5 sublittoral sediment categories. EUNIS Level 5 categories were examined using ternary plots only in order to assess whether the variation in EUNIS Level 4 sediment types could be attributed to the spatial aggregation of certain EUNIS Level 5 biotopes, e.g. if a EUNIS Level 4 coarse sediment habitat had many data points occurring in ‘mixed sediment’ area of the sediment trigon, could these occurrences be attributed to one particular EUNIS Level 5 biotope. Not every EUNIS Level 5 category contained a sufficient number of samples to be analysed in this way (Table 4).

Table 4: 'Sand and muddy sand' and Mud and sandy mud' split by EUNIS Level 4 sediment categories and by MNCR habitat type.

	EUNIS Level 4 sediment categories	EUNIS 2007 - 11 CODE	Marine habitat classification of Britain and Ireland 04.05 Code	N
Sand and muddy sand	Fine sand	A5.23	SS.SSa.IFiSa	19
		A5.231	SS.SSa.IFiSa.IMoSa	42
		A5.23.	SS.SSa.IFiSa.ScupHyd	11
		A5.233	SS.SSa.IFiSa.NcirBat	52
		A5.234	SS.SSa.IFiSa.TbAmPo	8
		A5.25	SS.SSa.CFiSa	13
		A5.251	SS.SSa.CFiSa.EpusOborApri	16
		A5.252	SS.SSa.CFiSa.ApriBatPo	1
			Total	162
	Sand = both fine sand and muddy sand	A5.21	SS.SSa.SSaLS	3
		A5.221	SS.SSa.SSaVS.MoSaVS	25
		A5.222	SS.SSa.SSaVS.NcirMac	13
		A5.223	SS.SSa.SSaVS.NintGam	1
		A5.27	SS.SSa.OSa	12
			Total	54
	Muddy Sand	A5.24	SS.SSa.IMuSa	4
		A5.241	SS.SSa.IMuSa.EcorEns	34
		A5.242	SS.SSa.IMuSa.FfabMag	132
		A5.243	SS.SSa.IMuSa.ArelSa	4
		A5.261	SS.SSa.CMuSa.AalbNuc	37
		A5.262	SS.SSa.CMuSa.AbraAirr	4
			Total	215
Mud and muddy sand	Fine mud	A5.34	SS.SMu.IFiMu	17
		A5.343	SS.SMu.IFiMu.PhiVir	4
		No EUNIS code	SS.SMu.IFiMu.Beg	1
		A5.36	SS.SMu.CFiMu	1
		A5.361	SS.SMu.CFiMu.SpnMeg	6
		A5.3611	SS.SMu.CFiMu.SpnMeg.Fun	1
		A5.362	SS.SMu.CFiMu.MegMax	11
			Total	41
	Mud = both fine mud and sandy mud	A5.31	SS.SMu.SMuLS	5
		A5.321	SS.SMu.SMuVS.PolCvol	16
		A5.322	SS.SMu.SMuVS.AphTubi	75
		A5.323	SS.SMu.SMuVS.NhomTubi	30
		A5.324	SS.SMu.SMuVS.MoMu	2
		A5.325	SS.SMu.SMuVS.CapTubi	24
		A5.326	SS.SMu.SMuVS.OlVS	12
		A5.327	SS.SMu.SMuVS.LhofTtub	1
		A5.375	SS.SMu.OMu.LevHet	5
			Total	170
	Sandy Mud	A5.33	SS.SMu.ISaMu	4
		A5.331	SS.SMu.ISaMu.NhomMac	60
		A5.333	SS.SMu.ISaMu.MysAbr	32
		A5.334	SS.SMu.ISaMu.MelMagThy	51
		A5.336	SS.SMu.ISaMu.Cap	12
		A5.35	SS.SMu.CSaMu	2
		A5.351	SS.SMu.CSaMu.AfilMysAnit	25
		A5.352	SS.SMu.CSaMu.ThyNten	17
		A5.354	SS.SMu.CSaMu.VirOphPmax	1
		A5.3541	SS.SMu.CSaMu.VirOphPmax.HAs	5
		A5.355	SS.SMu.CSaMu.LkorPpel	11
			Total	252

1.2.5 Comparisons between subjective data and PSA data

Median confidence levels (95%) were calculated for percentage values of gravel, sand and mud for sediment categories derived both from particle size data and those derived from subjective data analysis in Minitab ® 15.1.30.0 (Table 3). The aim was to investigate whether differences could be observed between the ranges for gravel, mud and sand for the UKSeaMap sediment classes from the different categories.

1.3 Results

1.3.1 Analysis of seabed sediment types in the UK

Analysis of the BGS modified Folk sediment categories from DigSBS250 showed that the area was clearly dominated by sandy sediments with 'sand', 'gravelly sand' and 'slightly gravelly sand' comprising 56.5% of the area (Table 5). In contrast, Folk sediment types such as 'muddy gravel' and 'slightly muddy gravel' together comprise only 0.3% of the total area. This indicates that at the broad mapping scale, accurately subdividing the sandy sediments (e.g. S, gS and (g)S) may be more useful in describing the variety of habitats around the UK than trying to subdivide habitats which in reality are very spatially restricted.

Table 5: Areas (km^2) of BGS DigSBS250 sediment categories.

BGS Folk categories	km^2	%
S	52,801	20.1
gS	51,990	19.8
(g)S	43,469	16.6
sG	33,382	12.7
mS	23,404	8.9
sM	10,789	4.1
(g)mS	10,632	4.0
G	8,115	3.1
gmS	6,416	2.4
Undifferentiated solid rock.	6,233	2.4
msG	5,491	2.1
M	3,533	1.3
gM	1,767	0.7
(g)sM	1,623	0.6
Diamicton	1,039	0.4
rock and sediment	662	0.3
rock or diamicton	439	0.2
(g)M	420	0.2
mG	188	0.1
gravel, sand and silt	138	0.1
mussel deposit (marine, biological deposit)	6	0.0
clay and sand	4	0.0
Total	**262,542**	**100.0**

1.3.2 Habitat point data analysis

EUNIS Level 3

Both the BGS modified Folk and UKSeaMap 2006 classifications are based on percentages of gravel, sand and mud and thus show similar results. Figure 3 and Figure 4 show that EUNIS Level 3 *sublittoral sand and muddy sand* and *sublittoral mud and sandy mud* habitats relate well to the UKSeaMap classifications. The *sublittoral coarse sediment* and *sublittoral mixed sediment* habitats do not relate to the UKSeaMap 2006 sediment classes, with less than 50% of the particle size data falling into the expected sediment classes. Figure 4 shows 51% of EUNIS level 3 habitat points designated as *sublittoral coarse sediment* actually had accompanying particle size data which fell into the **sand and muddy sand** category. From Figure 3, we can see that these are mostly from the 'slightly gravelly sand' (14%) and 'sand' (35%) BGS modified Folk classifications. The EUNIS level 3 habitat points designated as *sublittoral mixed sediment* actually have particle size data which fall into every UKSeaMap sediment category, ranging from 15% for **mud and sandy mud** to 35% for **mixed sediments**. This may be something which can not necessarily be resolved due to the nature of the description.

Table 6 shows the 95% confidence intervals for the median values of percentage gravel, mud and sand. These differ substantially to the current boundaries being used to delineate these classes. **Coarse sediment** and **sand and muddy sand** appear quite similar, indicating that further exploration of the sublittoral *sand and muddy sand* category at Level 4 might be useful. Surprisingly, **coarse sediment** appears to contain very low amounts of gravel. This is most likely due to the nature of the sediment sampling as conventional grab samplers will often fail to work in **coarse sediments**.

Table 6: 95% Confidence intervals for the median for percentage gravel, mud and sand for EUNIS Level 3 habitats based on particle size sediment data. N = number of samples.

UKSeaMap 2006 Categories	*Gravel (%)*	*Sand (%)*	*Mud (%)*	*N*
Coarse Sediment	0.2 – 0.5	90 - 96	3 - 8	271
Mixed Sediment	9 – 18	59 - 71	8 - 13	231
Sand & Muddy Sand	0 - 0.1	96 - 98	1.6 - 2.2	454
Mud & Muddy Sand	0	33 - 42	52 - 64	434

The Wentworth (1922) classification is based on median grain size (Figure 5 and Table 1). The **mud and sandy mud** habitat is dominated by silts and very fine sands and the **sand and muddy sand** category by fine and medium sands. Again, there is less of a clear distinction between categories for the **coarse sediment** and **mixed sediment** categories. Both the Wentworth (1922) and Connor and Hiscock (1996) classification show much more overlap between categories within habitats, e.g. medium or fine sands having high proportions in several categories. This indicates that it may make more sense to spilt sediments based on percentages of mud, sand and gravel rather than by median grain size.

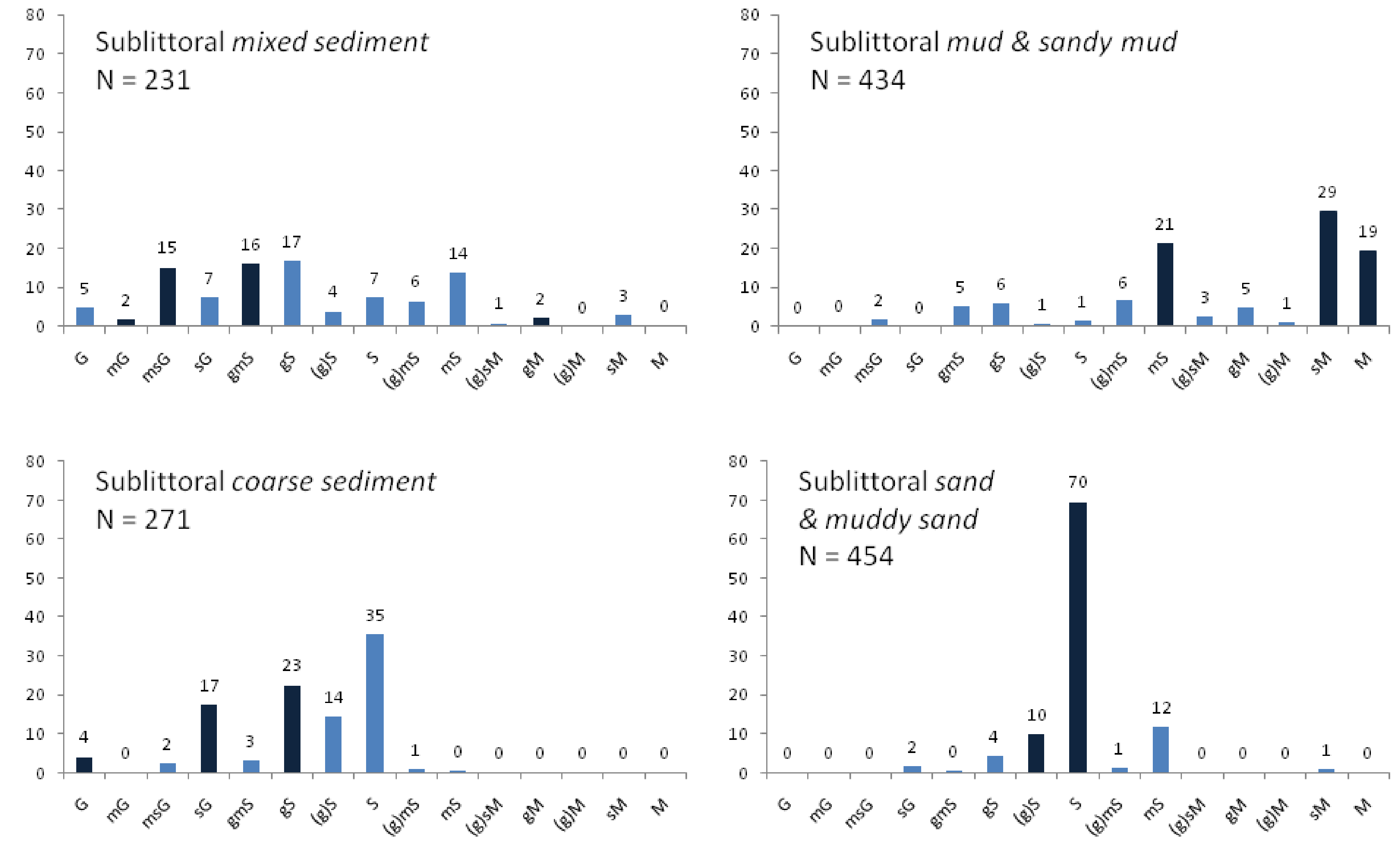


Figure 3: Folk sediment categories for EUNIS Level 3 sublittoral habitats based on PSA data. All values in percentages. The darker areas indicate the Folk categories you would expect to find in the biotope to fall into based on the original UKSeaMap classification. N = number of samples included.

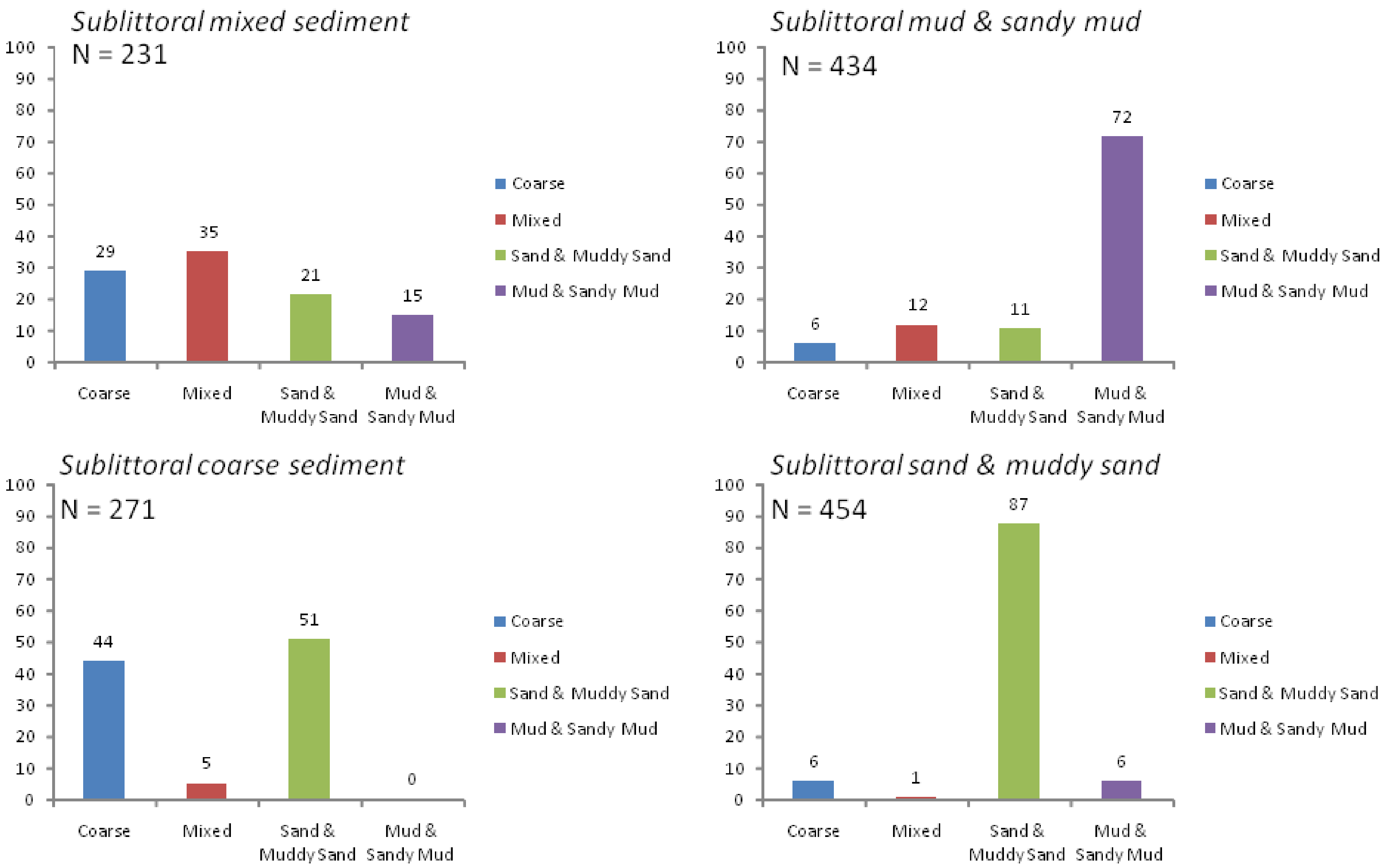


Figure 4: Original UKSeaMap sediment categories for EUNIS Level 3 sublittoral habitats. All values in percentages. N = number of samples included.

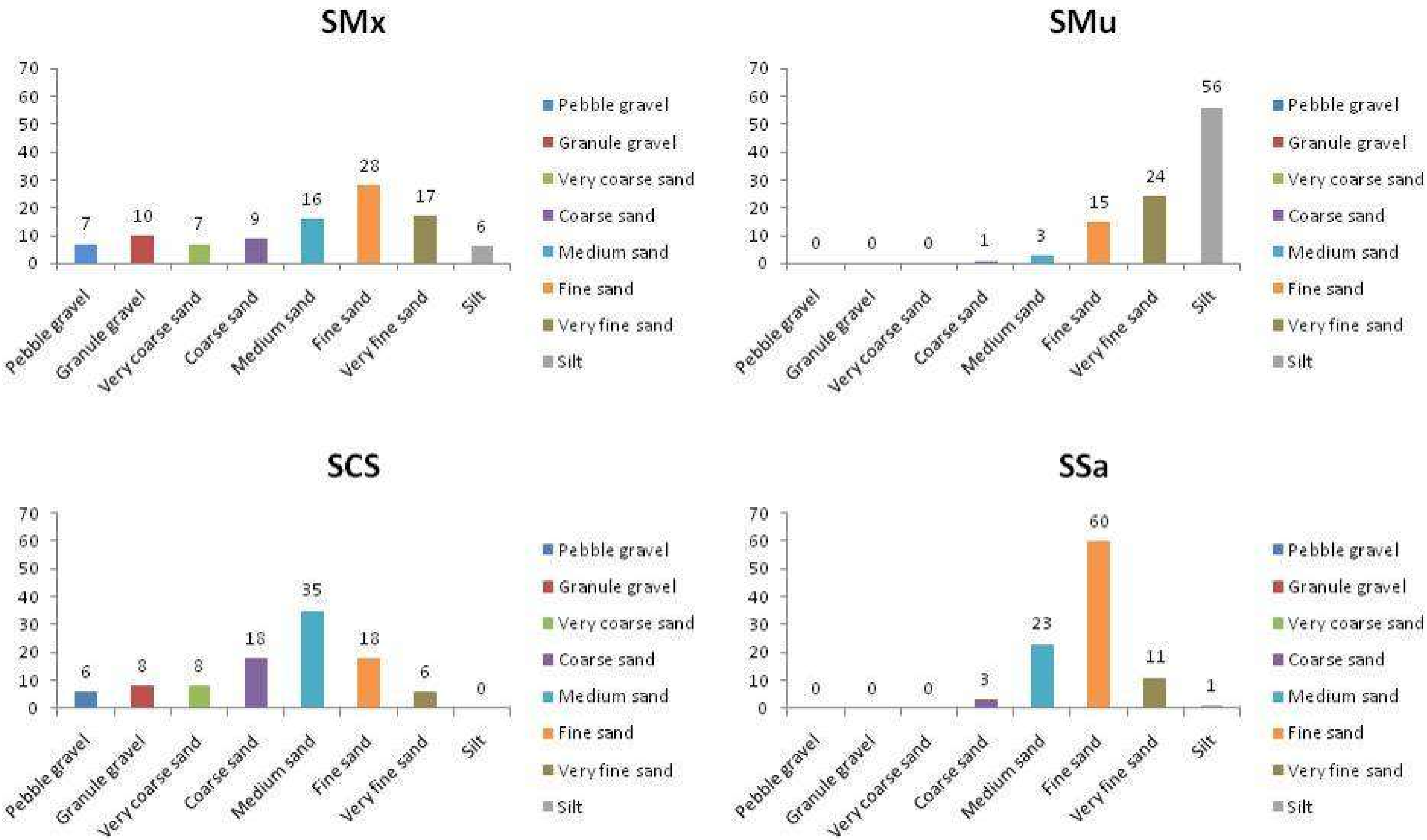


Figure 5: Median grain size particle Size data split by the Wentworth classification. Data separated into EUNIS Level 3 sublittoral sediment habitats. N = number of samples included.

EUNIS Level 4

Figure 6 shows the *sublittoral mud and sandy mud* categories into the sediment categories at EUNIS Level 4. The majority of the data falls in to the expected original UKSeaMap category (64 – 88%). The '*sandy mud*' category does show more variation than the '*muds*' and '*fine muds*'. Figure 6 also shows the Folk categories for each EUNIS Level 4 sediment type. '*Fine muds*' and '*muds*' show similar results as both are dominated by a mixture of 'muds' and 'sandy muds'. '*Sandy muds*' show a much lower number of habitats falling in the 'mud category' (6%) and are instead dominated by 'sandy muds' and 'muddy sands'. This result would support the idea of possibly separating this category into 'muds' and 'sandy muds'.

Figure 7 shows that for each EUNIS level 4 *sublittoral sand and muddy sand* habitat, a very high proportion of the habitats fell into the expected original UKSeaMap category of **sand and muddy sand** (86 – 95%). The Folk categories show that for all of these categories the bulk of the sediments fall within the 'sand' Folk class (Figure 6). '*Muddy sands'* do not clearly differ from the '*sand*' or '*fine sand*' categories as might be expected.

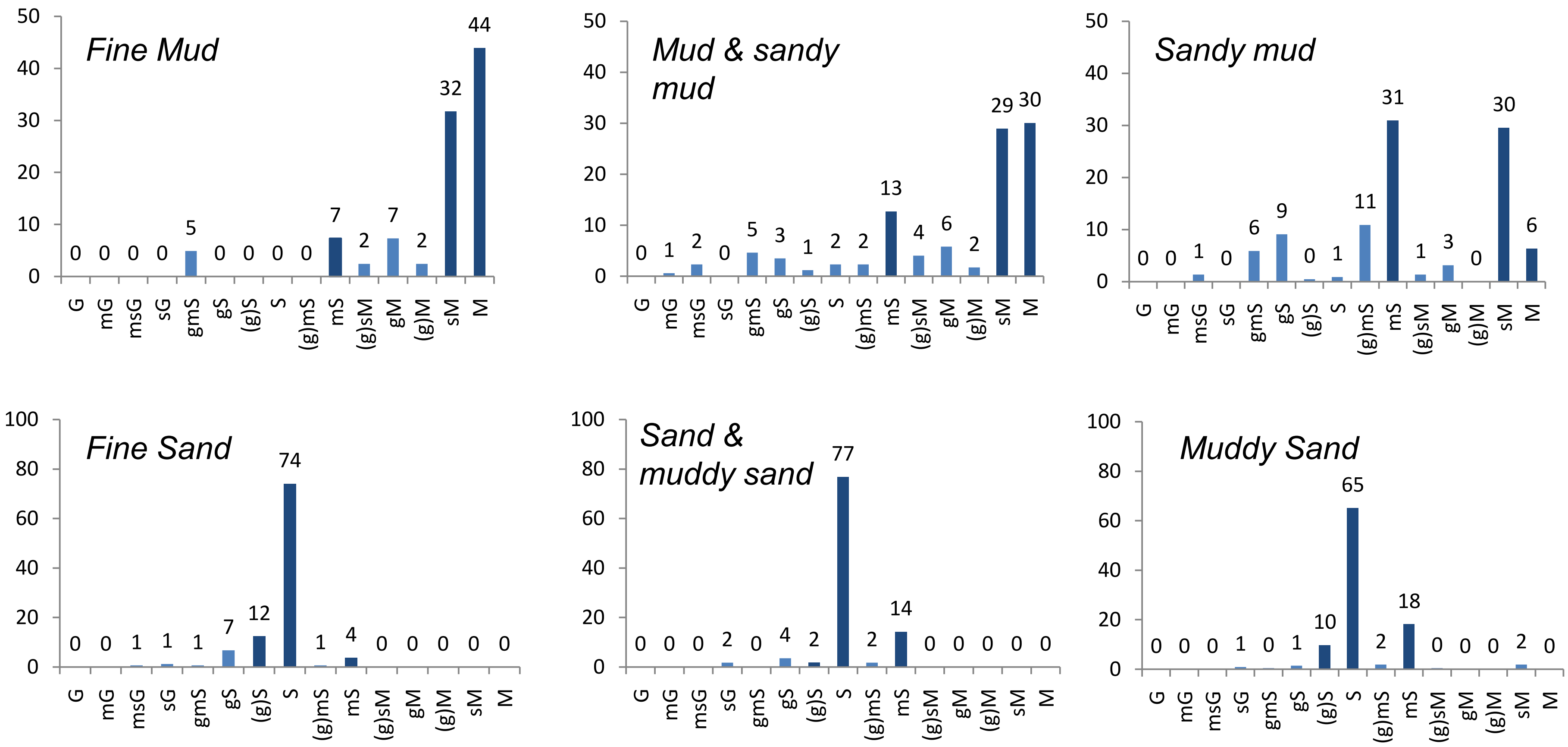


Figure 6: BGS modified Folk categories for EUNIS level 4 sublittoral sediment categories. All values in percentages. N = number of samples included.

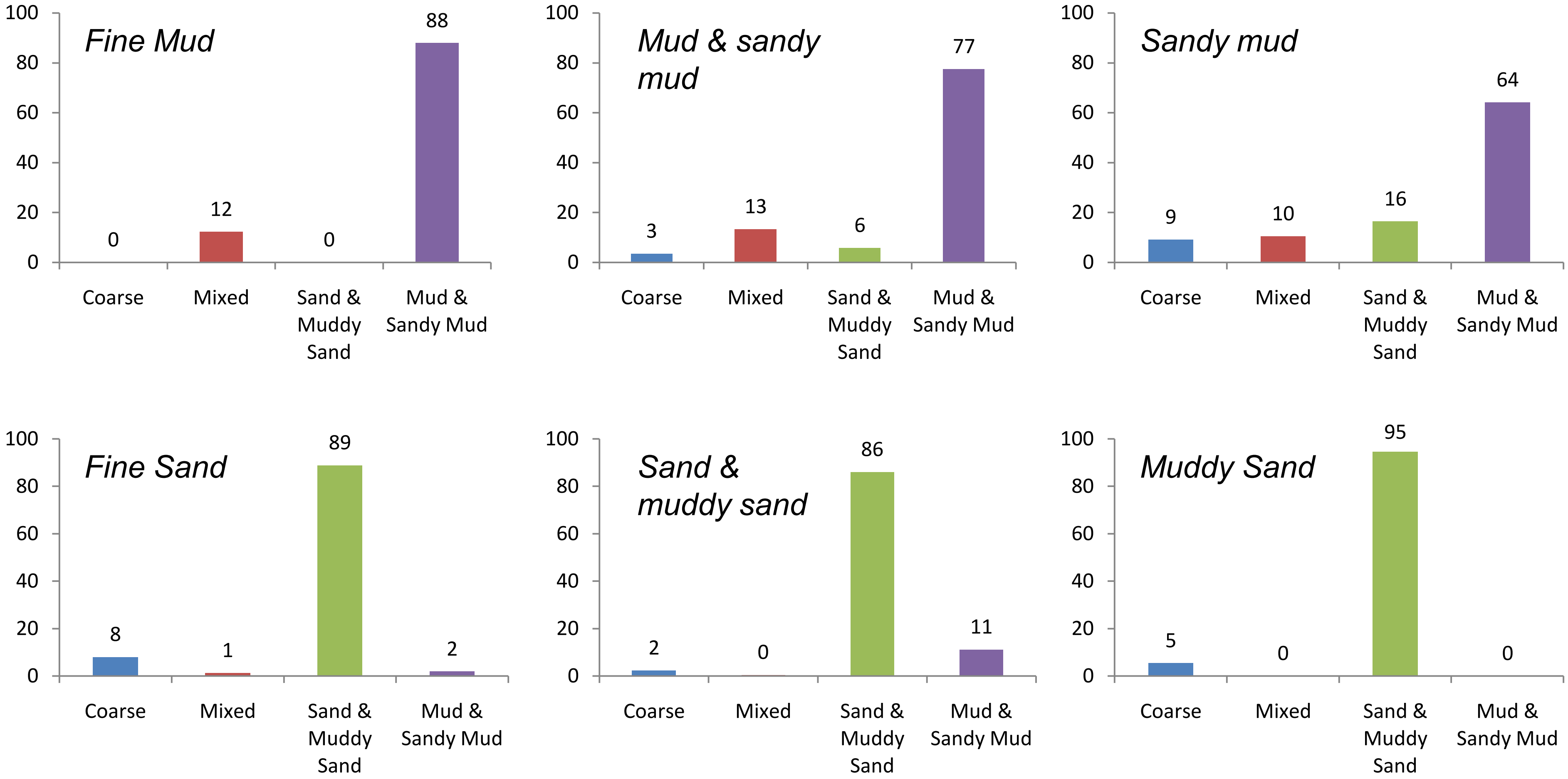


Figure 7: Original UKSeaMap sediment categories found in EUNIS Level 4 sublittoral sediments. All values in percentages

EUNIS Level 5 ternary plots

EUNIS level 5 habitats were plotted on ternary plots to examine whether biotopes at Level 5 can be distinguished based on sediment type. These graphs have been attached in a separate appendix at the end of this document (Appendix 1) due to their volume. There is considerable scatter in the distribution of the EUNIS level 5 biotopes and clear delineations between the biotopes are not observed. The biotopes in the 'sand and muddy sand' categories do appear to be less variable than those in the 'mud and sandy mud' categories.

While Ternary plots can be useful to show the sediment range of EUNIS habitats and biotopes, they can be misleading as they do not show the density of the data and therefore outliers can appear to be more important than they actually are.

1.3.3 Comparisons between subjective data and PSA data

Subjective sediment data (e.g. from videos and dives) and particle size data were compared to see if the same conclusions were being reached using both types of data (Table 7 and Table 8). Percentages of gravel, sand and mud were examined using the 95% confidence interval of the medians. Both analyses revealed there seemed to be little difference between the *sand* and *muddy sand* categories, indicating that it would not be possible to subdivide these categories based on percentages of gravel, sand and mud. Both results indicate that if an attempt were to be made to separate *mud* from *sandy mud* that the mud boundary between these categories should be moved from 90% mud to somewhere between 65 - 70% mud.

Table 7: 95% Confidence intervals for the median for percentage gravel, mud and sand for EUNIS Level 3 habitats based on PSA.

Categories	% Mud	% Sand	% Gravel	N
Coarse Sediment	0 - 1	90 - 100	0 - 10	269
Mixed Sediment	5 - 15	55 - 75	10 - 20	225
Fine sand	1 – 4	96 -98	0	53
Sand	0.2 - 0.7	98 – 99	0.3	162
Muddy Sand	2 – 5	94 – 97	0	215
Fine Mud	72 – 94	5 – 25	0	41
Mud	69 – 81	17 -27	0	173
Sandy Mud	30 - 46	50 – 65	0	220

There seems to be little difference between the categories of sand, fine sand and muddy sand for the particle size data, indicating that these cannot be split based on the Folk triangle. While fine mud and mud categories overlap, in general, fine mud seems to have higher levels of mud and less of sand than the mud category. BGS have indicated that there would not be sufficient data to split the fine mud and mud categories. Table 7 and Table 8 show clear differences in the amounts of sand between the 'mud' and 'fine mud' categories. This difference is likely to be due to the nature of the way the data was collected with subjective analysis recording a muddy habitat as having no sand or gravel, where more detailed particle analysis may reveal the samples also contain fine sand. This shows the pitfalls of comparing data which is collected using two different methods.

Table 8: 95% Confidence intervals for the median for percentage gravel, mud and sand for EUNIS Level 3 habitats based on subjective data.

Categories	% Mud	% Sand	% Gravel	N
Coarse Sediment	0	75 - 95	0 - 10	88
Mixed Sediment	10 - 26	20 - 50	10 - 24	103
Fine sand	0	90 - 96	0	226
Sand	0 - 2	95 - 100	0	70
Muddy Sand	2 - 4	90 - 95	0	361
Fine Mud	99 - 100	0	0	488
Mud	90 - 99	0	0	133
Sandy Mud	41 - 50	15 - 30	0 - 1	350

1.4 Conclusions

The sediment analysis indicated that users of the Marine habitat classification of Britain and Ireland are assigning biotopes to samples based on biological data rather than a combination of biological and physical (e.g. PSA) data. For many biotopes for which samples are available in the Marine Recorder database, there is a huge variability in sediments recorded at the same site as the biotope. This does not necessarily mean that the biotope assignments are incorrect, but may be because biotopes occur across a wider range of sediment than previously thought. Thus the sediment descriptions associated with each biotope in the classification may be too narrow.
It was decided that there was insufficient evidence to merit changing the sediment categories from those used in UKSeaMap 2006, and their boundaries, but it is recommended that this issue be examined in further detail in the context of amendments to the marine habitat classification. Future analysis should also look at the littoral habitat classification. The data supported the 20% mud boundary between 'mud and sandy mud' and 'sand and muddy sand'. The available data do not show any difference between the muddy sands and sands at EUNIS Level 4. It will not be possible to get a full coverage EUNIS Level 4 map.

More detailed sediment classes are available for most areas of the UK through the BGS Seabed sediment map DigSBS250. Unfortunately, these more detailed classes do not enhance the predictive habitat modelling process. This is due to the structure of the EUNIS classification scheme. At Level 4 in the EUNIS classification system, sediment classes use two different types of terminology, e.g. mud and sandy mud which are terms from the BGS modified Folk classification (Long, 2006) and fine sand and fine mud which are terms more associated with Wentworth (1922) or Friedman and Saunders (1978) classifications. The integration of these two classifications systems at Level 4 and higher levels of the habitat classification systems makes it impossible to use more detailed substrate classes to consistently maps to higher levels of the classification system. It is recommended that the seabed habitat classification systems should adopt a consistent method of describing sediments at EUNIS Level 4.

2 UKSeaMap 2010 substrate layer

Five datasets were used in the construction of the UKSeaMap 2010 substrate layer: DigSBS250; the MB0103 rock/hard substrate layer (Gafeira *et al*, 2010); the Water Framework Directive (WFD) typology layer (Rogers *et al*, 2003); the NOC deep sea sediment layer (Jacobs & Porritt, 2009) and MNCR substrate data.

BGS will release version 2 of their digital seabed sediments map DigSBS250 in 2011. Version 1 of DigSBS250 provided the basis for the original UKSeaMap substrate map. This project used a pre-release version of DigSBS250 version 2 which used additional particle size analysis (PSA) data (where available) to change polygon boundaries.

There were several areas of UK seas within the DigSBS250 dataset which were blank, reflecting the absence of data when this data set was compiled. These areas include the shallow near-shore coastline where the BGS programme did not extend, and also areas in the Atlantic Northwest approaches and the Faroe-Shetland Channel. The coastal fringe was updated using the 1nm gridded coastal seabed substrata data collated (by BGS) for the Water Framework Directive typology project (Rogers *et al*, 2003). UKSeaMap 2006 did *not* use the transitional waters dataset, gridded to 0.1 nm, from Rogers *et al* because the resolution of the final UKSeaMap 2006 product was too coarse to justify inclusion of these fine-scale data. Data for coastal (1nm grid) and transitional waters (estuaries, 0.1 nm grid), collated by BGS for the Water Framework Directive typology project (Rogers *et al*, 2003), have not been updated since UKSeaMap 2006. The coastal dataset, as well as the transitional waters dataset, were used for UKSeaMap 2010 in inshore areas not covered by DigSBS250 version 2.

In the original UKSeaMap project, some offshore blank areas were reduced by including data from the BGS 1:1,000,000 seabed sediment maps (BGS 1987) and more recent unpublished data. Recent work carried out by the National Oceanography Centre, Southampton (Jacobs & Porritt, 2009) has produced a deep sea substrate map which stretches from the Atlantic North West Approaches, through Rockall Trough and Bank, to the most easterly extent of the Scottish Continental Shelf and Faroe-Shetland Channel. The study area also includes the deep waters of the Atlantic South West Approaches. The substrate map was based on existing interpretation of several acoustic deep-water datasets and further interpretation of newly released acoustic data. BGS seabed sediment maps were combined with and modified by these interpretations. The substrate types identified were the four sediment classes from the modified Folk sediment classification (Cooper *et al*, 2005) and used in UKSeaMap 2006 (Connor *et al*, 2006), plus rock.

Several geological data layers were available for the UK seabed surface and sub-surface (e.g. DigSBS250; DigRock; Quaternary maps). However, none of these data layers comprehensively represented the distribution of rock or hard substrate at, or near, the seabed surface. The physical character and bathymetric environment at the sea bed play a key role in determining the composition of benthic biological communities. Rock and hard substrates are of particular importance as they provide suitable habitats for a range of sessile organisms.

The existing seabed geology maps produced by BGS focus on the distribution of seabed sediments in terms of lithology (the structure and formation of the rock) and grain size. The maps make no distinction between thin and patchy sediment cover and exposed rock or boulders. MB0103 hard substrate mapping undertaken for DEFRA, concentrates on mapping this hard substrate within 0.5m of the seabed. This is in contrast with DigSBS250 (version 1) that maps sediments within 0.1m and only maps rock where no sediment occurs however patchy. The MB0103 workflow involved reinterpreting existing sample records, integrated with new digital bathymetry and existing high resolution seismic to provide a new map that distinguishes areas of likely rock outcrop more clearly than is currently possible (Gafeira *et al*, 2010).

Marine Nature Conservation Review habitat (MNCR) data included field surveys of the shores and nearshore subtidal zone to describe biotopes[2]. Comparable data from other organisations have been added to provide information on over 1000 sites within the region and analysed to classify the biotopes present. The information was presented as areas summaries.

The substrate input data layers were combined using the order of precedence set out in Table 9.

Table 9: Order of precedence given to UKSeaMap 2010 substrate layers.

Order of precedence	Justification
MB0103 Rock/ hard substrate layers (BGS)	Extensive use of additional sample information and acoustic data. JNCC to erase sediments in areas mapped as rock by regional rock layers contract (SF0255; MB0103).
Deep sea substrate dataset (NOC)	Extensive use of acoustic data
DigSBS250 pre-release version 2 (BGS)	Raw data used to re-draw boundaries for UKSeaMap 2010
WFD typology data layers (coastal and transitional) (BGS)	Derived data based on point samples
MNCR data (JNCC)	Used to fill in gaps between DigSBS250 and the WFD typology layers

[2] http://jncc.defra.gov.uk/page-1596

3 Confidence

Substrate confidence was assessed using a modified version of the MESH confidence assessment tool for habitats. The confidence assessment was based on four input sediment datasets: the updated DigSBS250 version 2; the NOC Deep Sea substrate layer (Jacobs & Porritt, 2009); Water Framework Directive coastal and transitional water datasets (Rogers *et al*, 2003); MB103 hard substrate map (Gafeira *et al*, 2010).The British Geological Survey (BGS) was contracted to create a MESH substrate confidence map based on the underlying substrate datasets and a sample density and sample variability maps for the area (Cooper *et al*, 2010).

The MESH confidence assessment tool, associated spreadsheet and assessment guidance are available for download from http://www.searchmesh.net/Default.aspx?page=1635. The tool evaluates a map by scoring factors according to agreed rules. The factors are grouped according to three main questions:

- How good is the remote sensing?
- How good is the ground-truthing?
- How good is the interpretation of the overall map?

A map is scored using a value from 1 - 3 for each factor (Table 10). Based on the weighting assigned to each factor, individual scores are multiplied by a weighting factor and then added together to create group scores. This process is completed in the MESH confidence Excel score sheet. The overall score is calculated by using an average of the three group scores for remote sensing, ground-truthing and interpretation.

Table 10: Breakdown of the MESH confidence assessment tool.

Questions	Factor	Scores	Final value
How good is the remote sensing?	Remote Techniques	Remote score	Overall score
	Remote Coverage		
	Remote Positioning		
	Remote Standards Applied		
	Remote Vintage		
How good is the ground-truthing	Biological Ground-truthing Technique	Ground-truthing score	
	Physical Ground-truthing Technique		
	Ground-truthing Position		
	Ground-truthing Sample Density		
	Ground-truthing Standards Applied		
	Ground-truthing Vintage		
How good is the interpretation of the overall map?	Ground-truthing Interpretation	Interpretation score	
	Remote Interpretation		
	Detail Level		
	Map Accuracy		

The criteria for categories in the MESH confidence assessment tool have been slightly modified, as in this case it is assessing a map based on substrate data only. The biological ground-truthing technique score is always zero as the substrate map does not involve any biological ground-truthing. The physical ground-truthing sample density score has been modified to include elements of both sample density and sample variability. The sample density map produced by BGS is based on substrate samples which either had particle size data or sample descriptions. Both the sample density and sample variability maps produced scores based on search areas of 314km^2 (radius: 10km) (Figure 8). The two variables were combined using a matrix of sample density versus sample variability (Table 11).

Table 11: Substrate confidence matrix combing sediment sample density and sediment sample variability to produce a score for ground-truthing sample density. Values are based on a circle with a search radius of 10km and an area of 314km2.

		Sediment Variability	
		<= 2 EUNIS classes	>= 3 EUNIS classes
Combined sediment sample density	No samples	0	0
	<= 10 samples	1	0
	11 – 50 samples	2	1
	> 50 samples	3	2

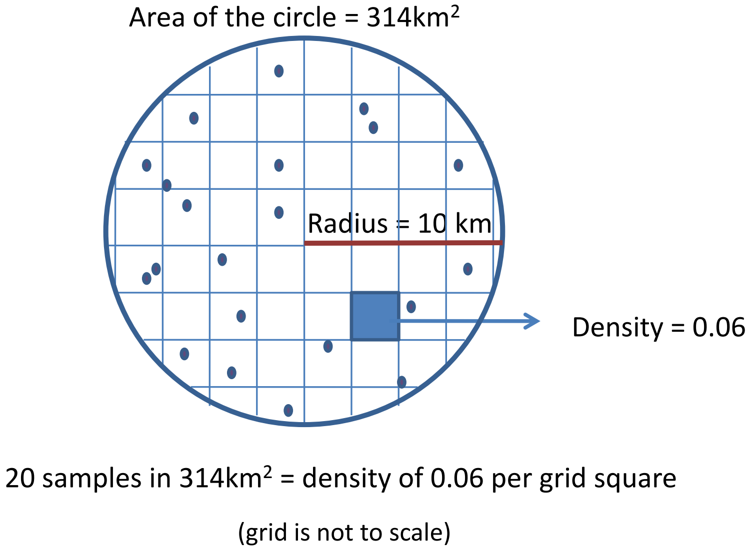


Figure 8: Example of substrate sample density and sample variability search areas

The sample density / sample variability matrix score was used to replace the Ground-truthing density scores in the MESH substrate confidence model. MESH confidence scores for the MNCR habitat maps were used for areas where the substrate map had been supplemented by data from this source. The biological ground-truthing score for the MNCR maps were changed to 0 as the data was used for a substrate map.

The final substrate confidence map is shown in Figure 13. MESH scores are produced on scales of 0 – 100, these were changed to scale of 0 – 1 to ensure the layers use the same scale as other confidence scores. By showing the maps for the group scores, it enables the map user to see where high and low scores in the final map originate from.

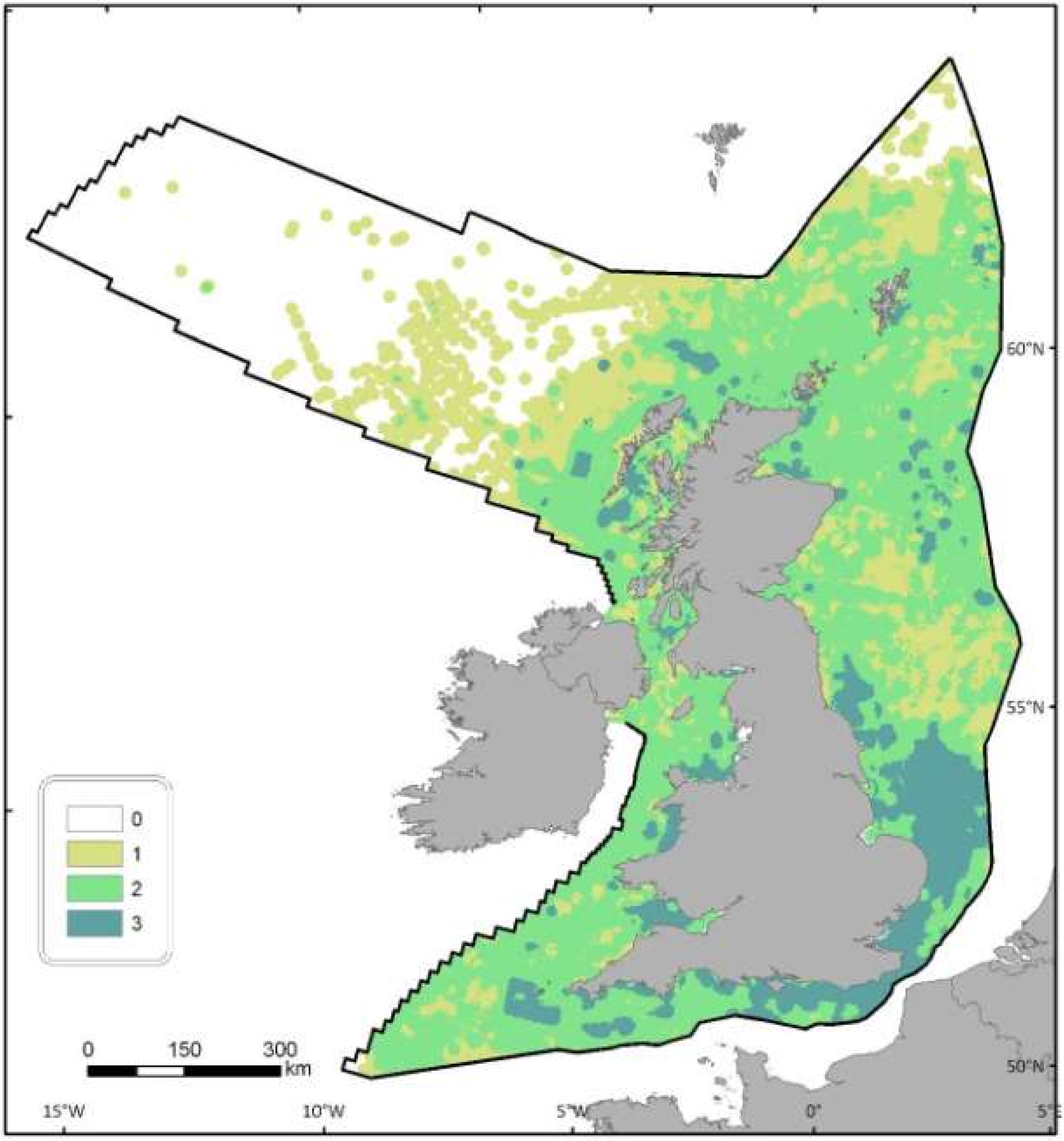


Figure 9: Sample density and sample variability matrix scores for the model area.

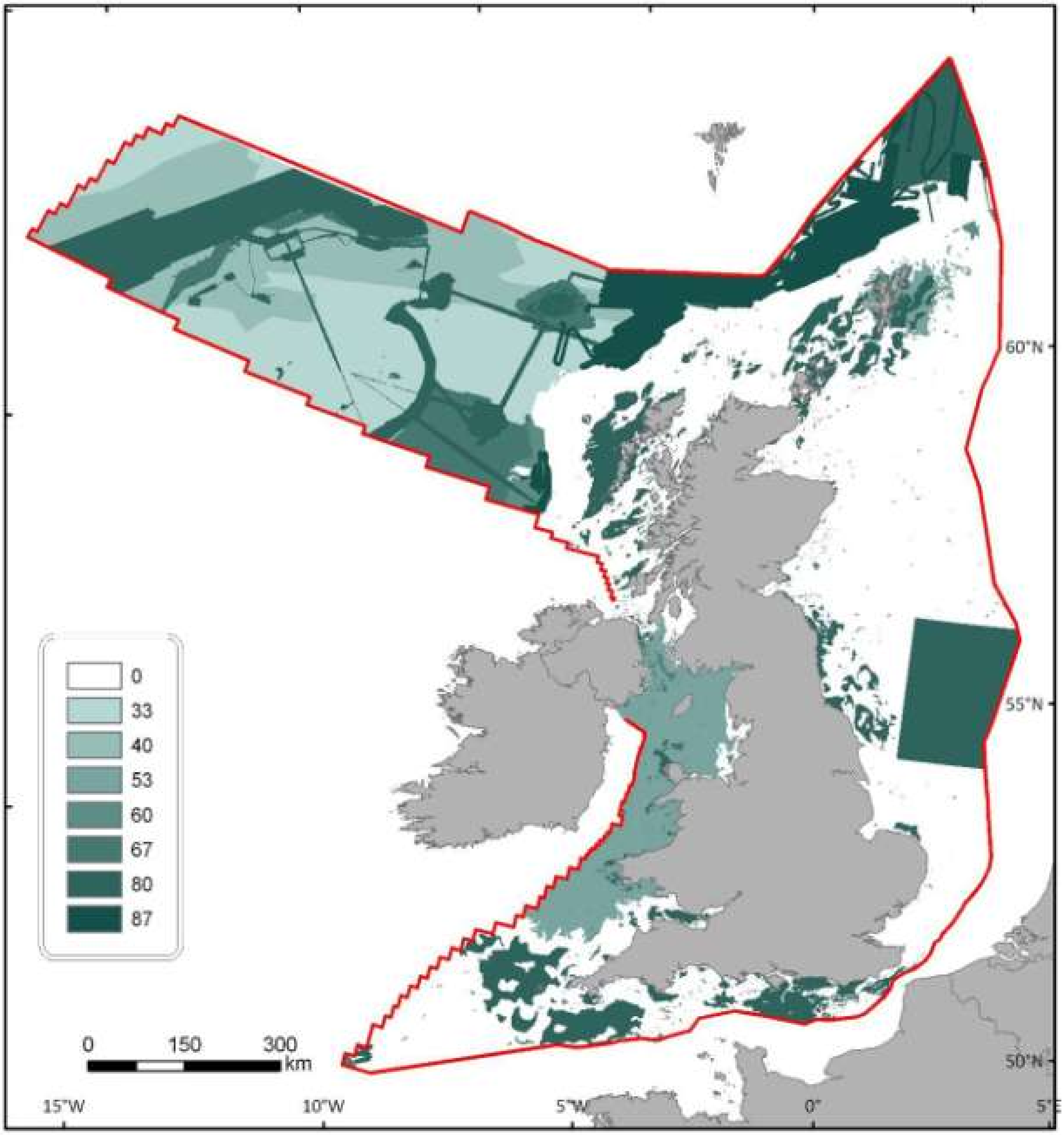


Figure 10: MESH remote sensing group scores

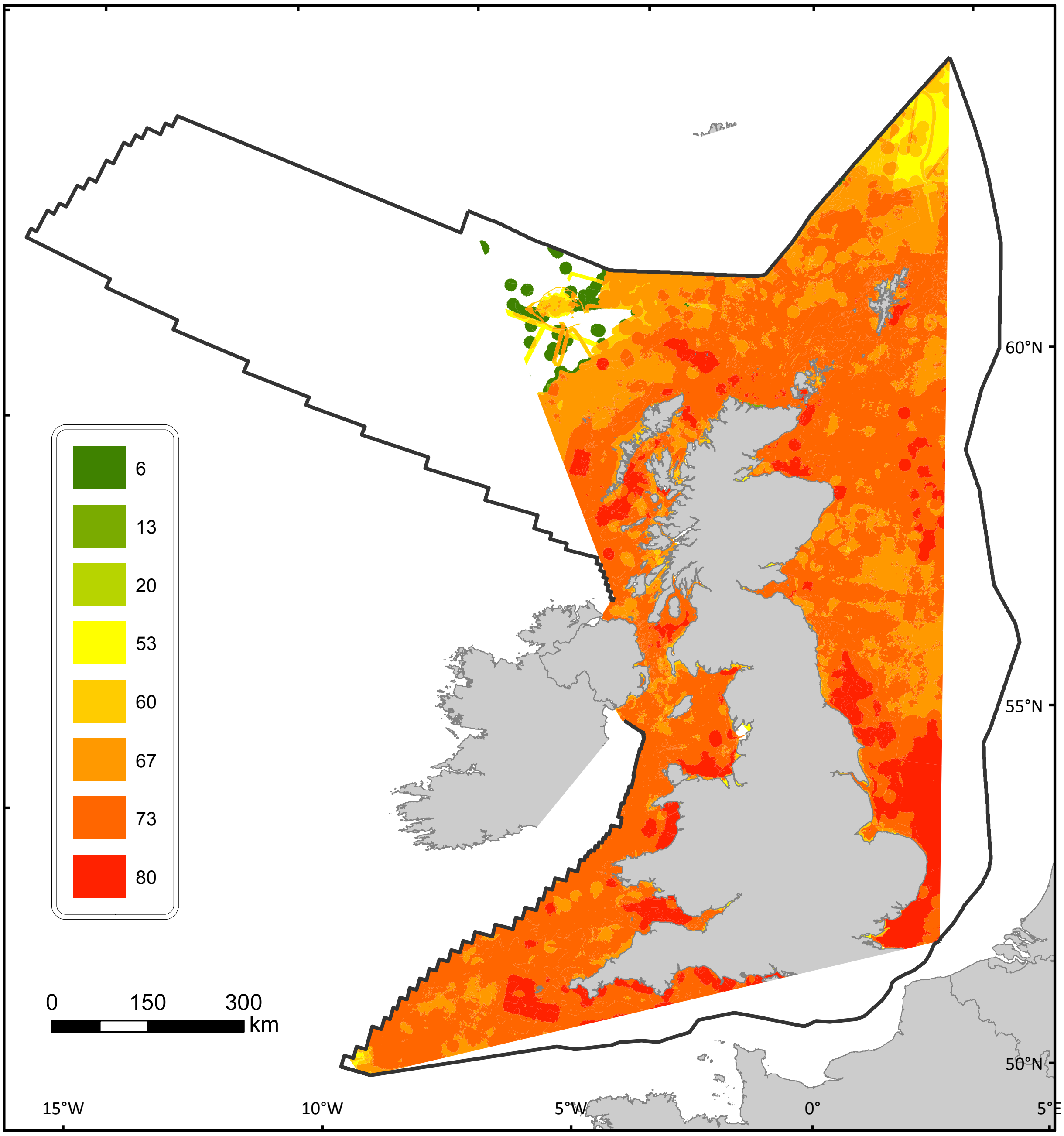


Figure 11: Ground-truthing group scores

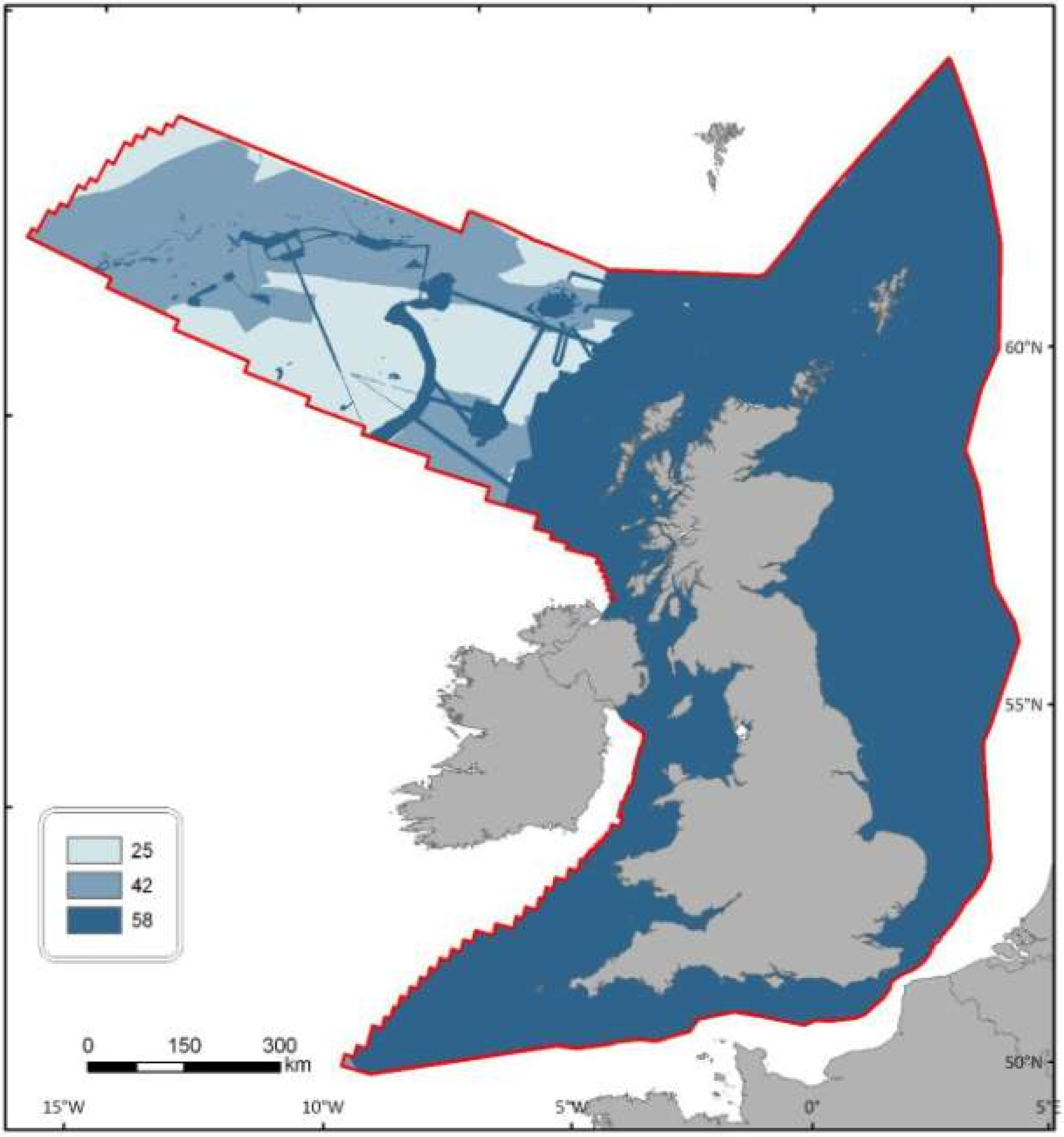


Figure 12: Interpretation group scores

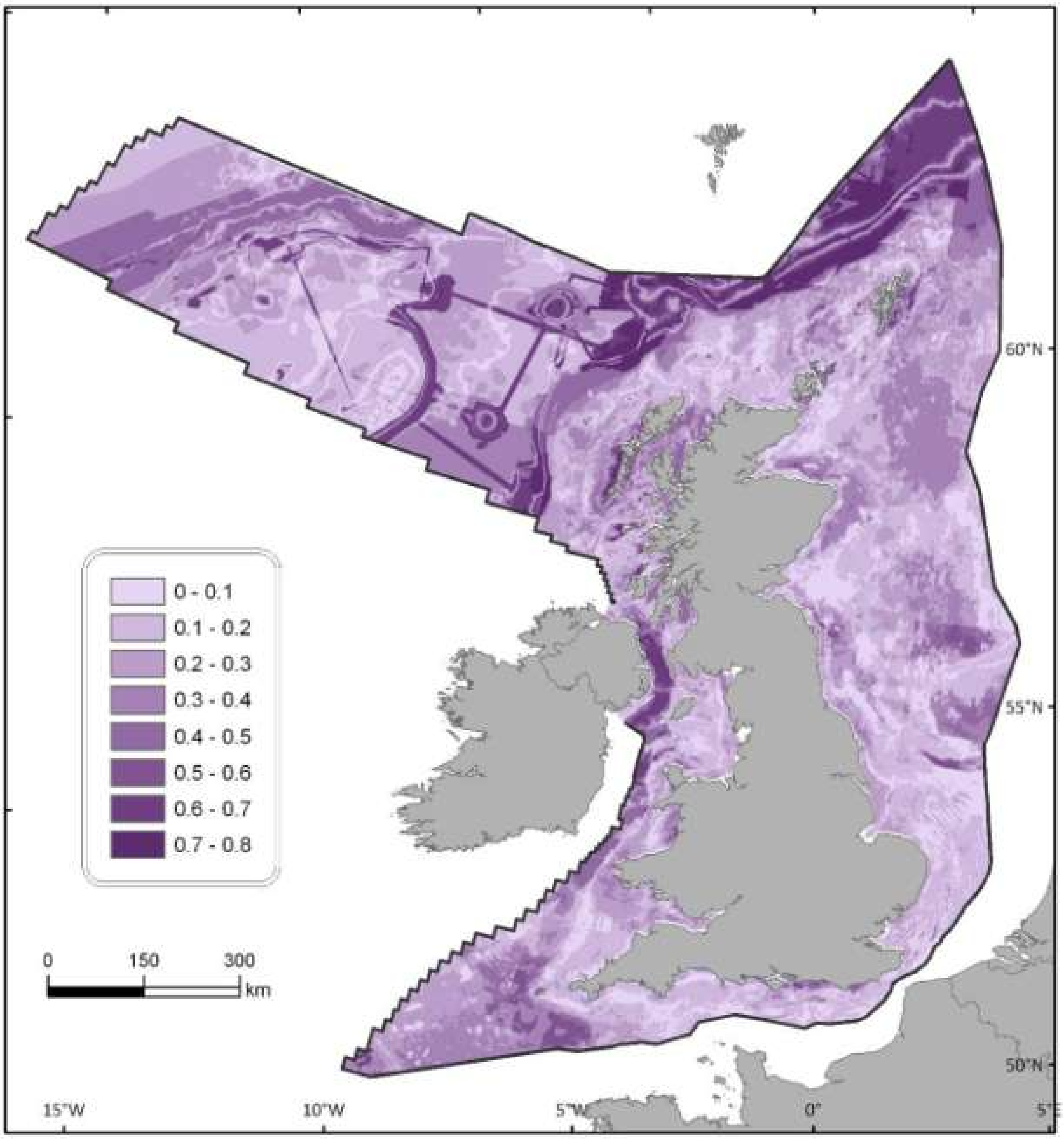


Figure 13: Overall MESH substrate confidence scores. Values were divided by 100 to ensure that the scale corresponded to the energy and biological zone probability scores which all have a possible maximum scale of 1.

Reference List

BLOTT, S. J. and PYE, K., 2001. GRADISTAT: A grain size distribution and statistics package for the analysis of unconsolidated sediments. *Earth Surface Processes and Landforms*, **26,** 1237 - 1248

CONNOR, D. W., ALLEN, J. H., GOLDING, N., HOWELL, K. L., LIEBERKNECHT, L. M., NORTHEN, K. O., & REKER, J. B., 2004. The marine habitat classification for Britain and Ireland version 04.05. *Joint Nature Conservation Committee Report, Peterborough, UK*,

CONNOR, D. W., GILLILAND, P., GOLDING, N., ROBINSON, P., TODD, D., & VERLING, E., 2006. UKSeaMap: The Mapping of Seabed and Water Column Features of UK Seas.

CONNOR, D. W. & HISCOCK, K., 96. Data collection methods (with Appendices 5 - 10) *In:* HISCOCK, K., ed. *Marine Nature Conservation Review: rationale and methods.* Peterborough: Joint Nature Conservation Committee, 51 - 65, 126

COOPER, R., HENNI, P., LONG, D., & PICKERING, A., 2005. Draft report explaining BGS data input to the UKSeaMap project - Broadscale mapping of the seas around the UK. *British Geological Survey Commissioned Report*.

COOPER, R., LONG, D., DOCE, D., GREEN, S., & MORANDO, A., 2010. Creating and assessing a sediment data layer for UKSeaMap 2010. *British Geological Survey Commercial Report*. CR/09/168

DAVIES, C. E. & MOSS, D., 2004. EUNIS Habitat Classification Marine Habitat Types: Revised Classification and Criteria. C02492NEW

FOLK, R. L., 1954. The distinction between grain size and mineral composition in sedimentary nomenclature. *Journal of Geology*, **62,** 344 - 359

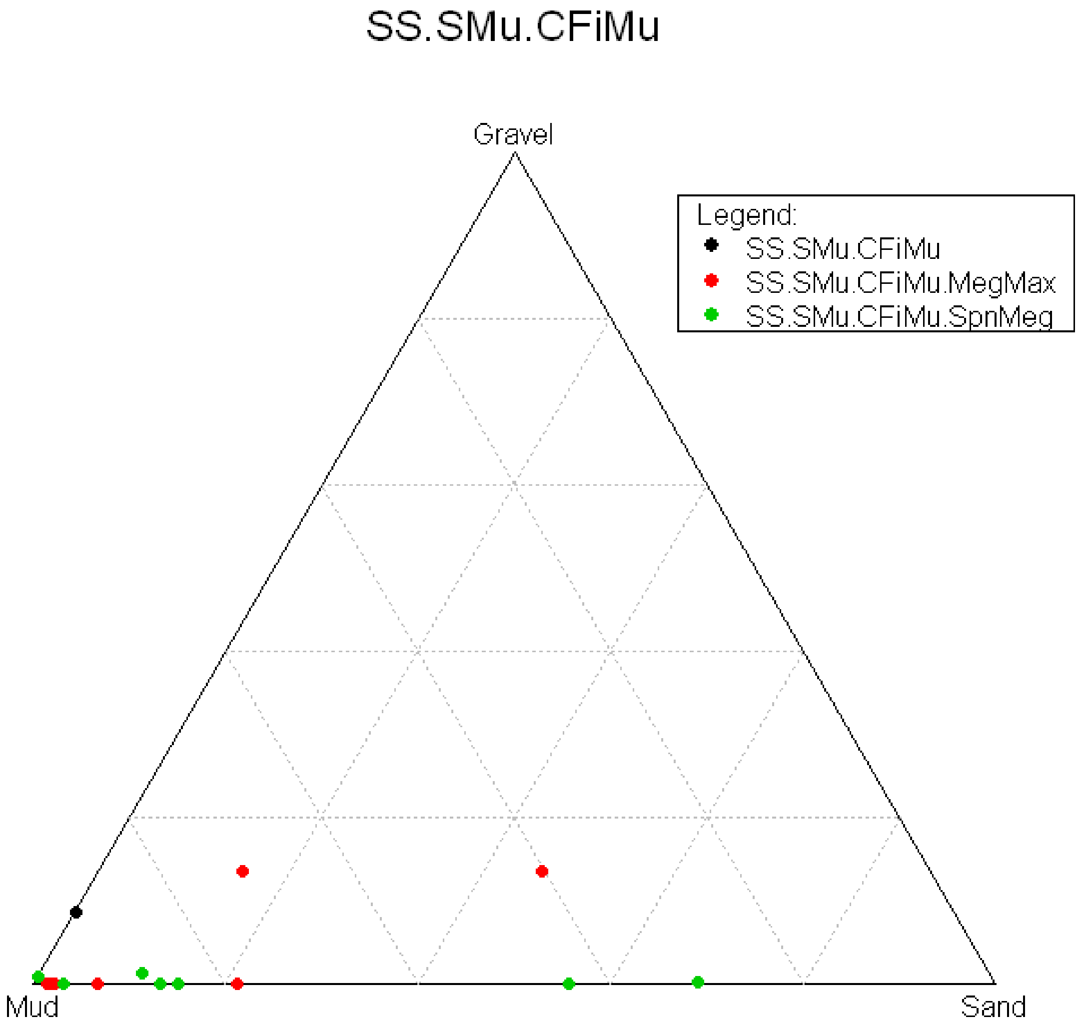
GAFEIRA, J., GREEN, S., DOVE, D., MORANDO, A., COOPER, R., LONG, D., & GATLIFF, R. W., 2010. Developing the necessary data layers for Marine Conservation Zone selection - Distribution of rock/hard substrate on the UK Continental Shelf.

JACOBS, C. L. & PORRITT, L., 2009. Deep Sea Habitats - Contributing Towards Completion Of a Deep Sea Habitat Classification Scheme. NOCS Research & Consultancy Report No. 62

ROGERS, S., ALLEN, J., BALSON, P., BOYLE, R., BURDEN, D., CONNOR, D., ELLIOTT, M., WEBSTER, M., REKER, J., MILLS, C., O'CONNOR, B., & PEARSON, S., 2003. Typology for Transitional and Coastal Waters for the UK and Ireland. WFD07

WENTWORTH, C. K., 1922. A scale of grade and class terms for clastic sediments. *Journal of Geology*, **30,** 377 - 392

Appendix 1



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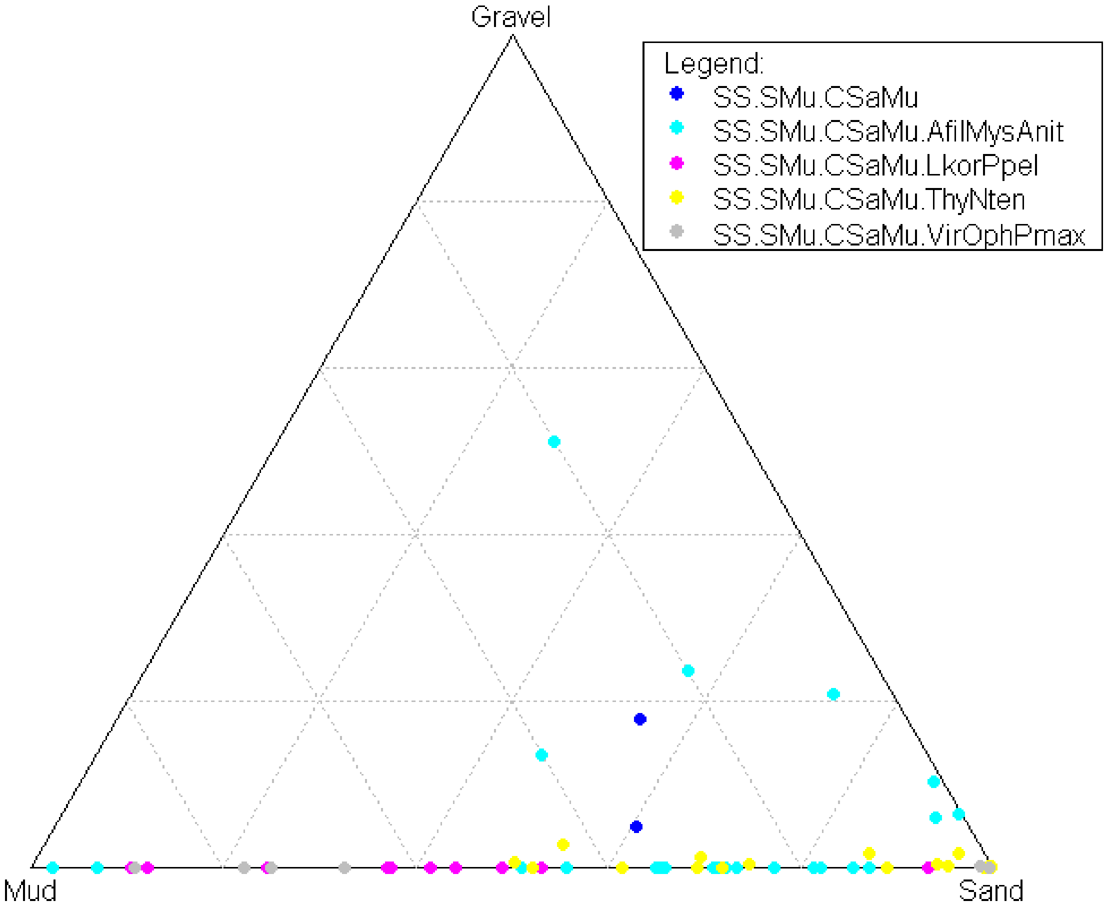

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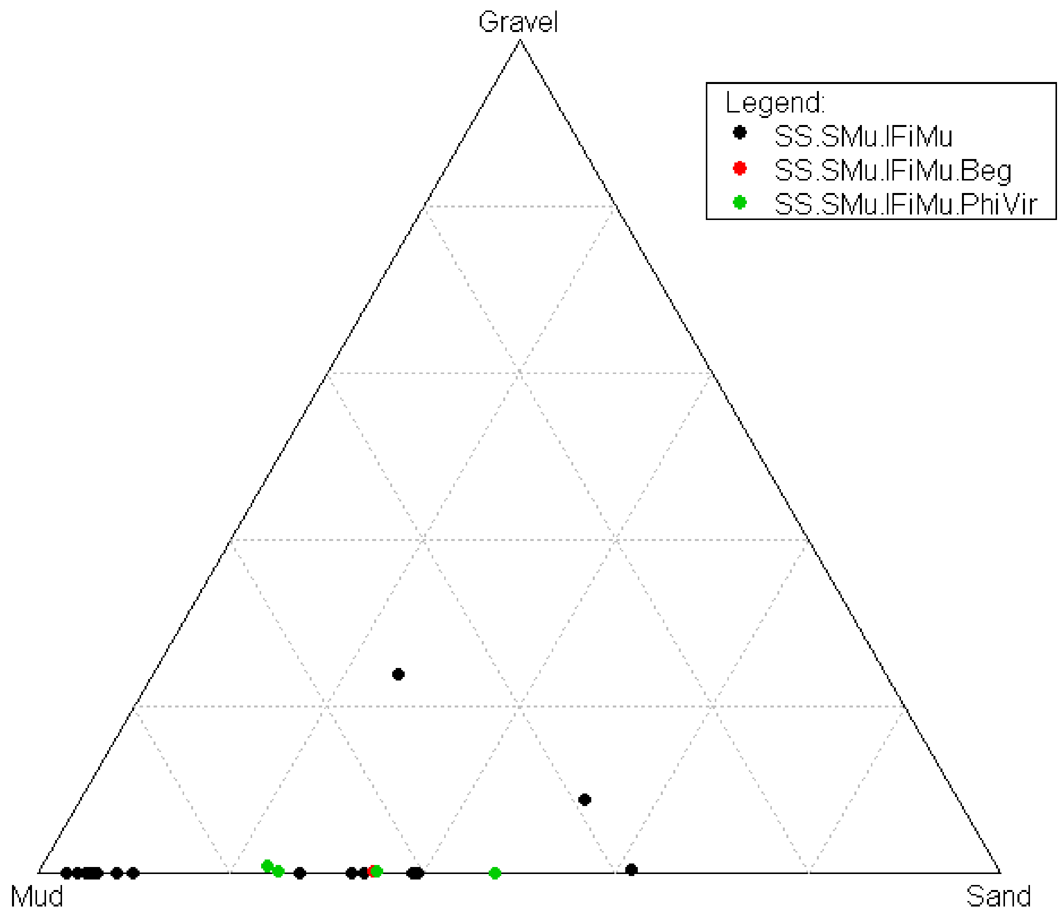
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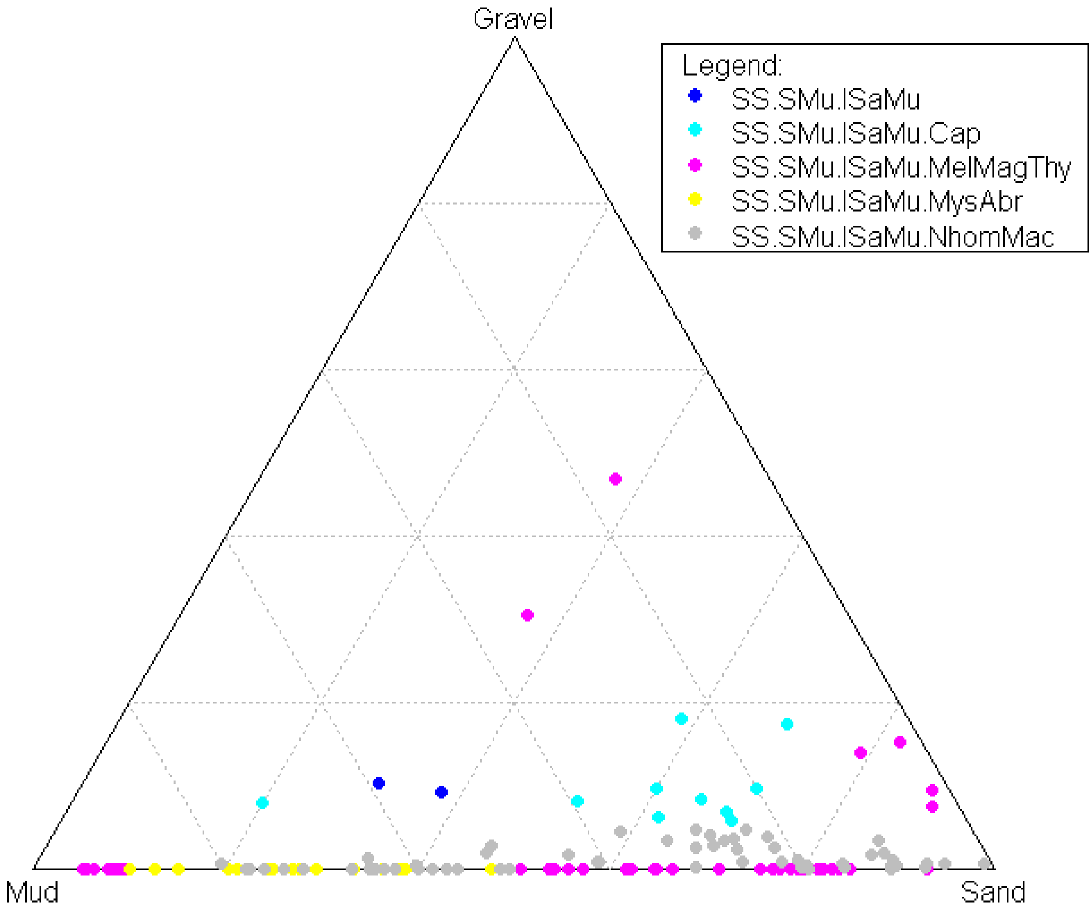
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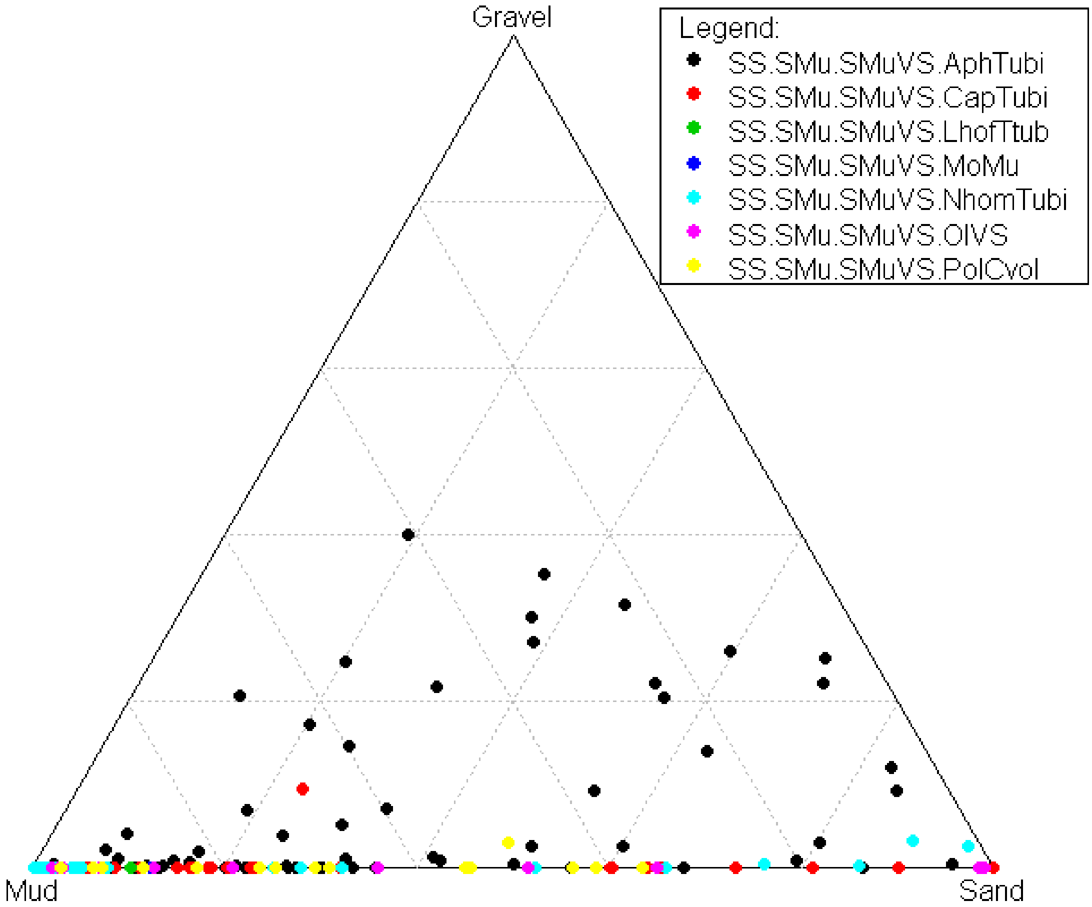

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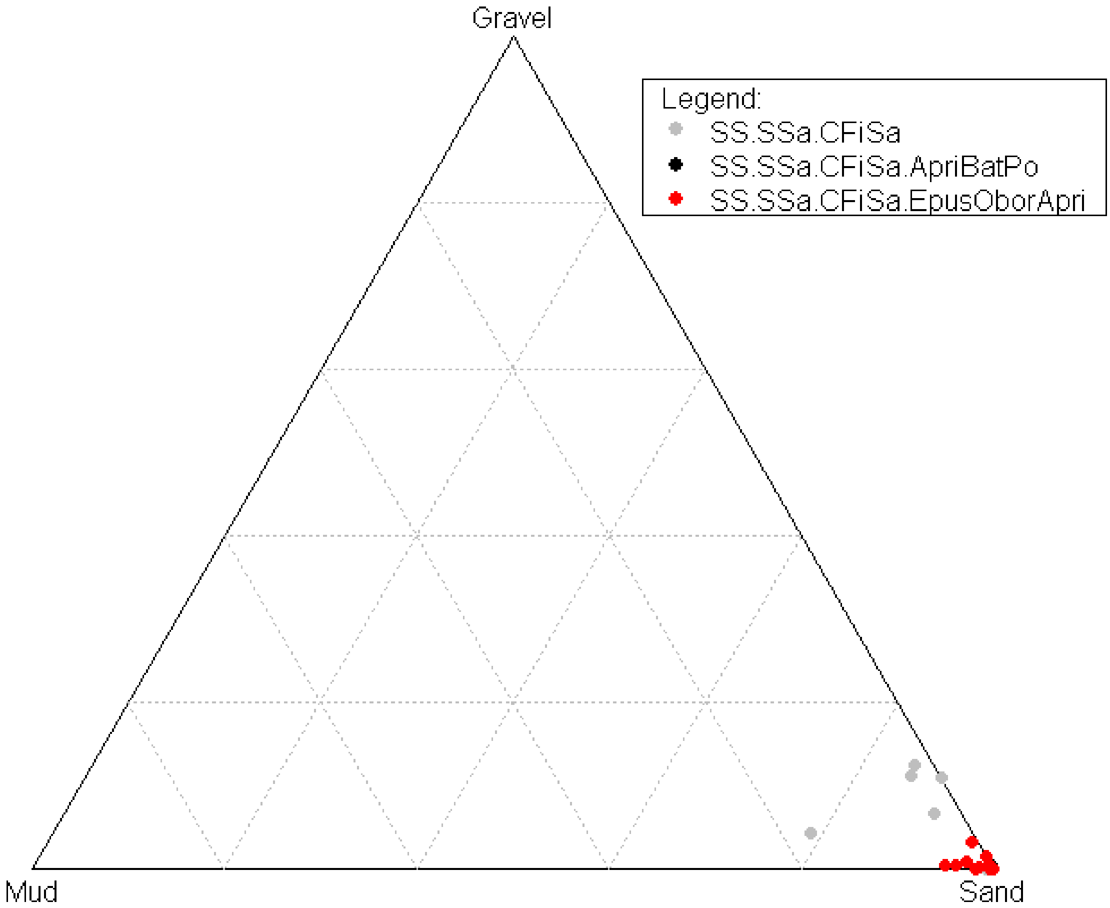
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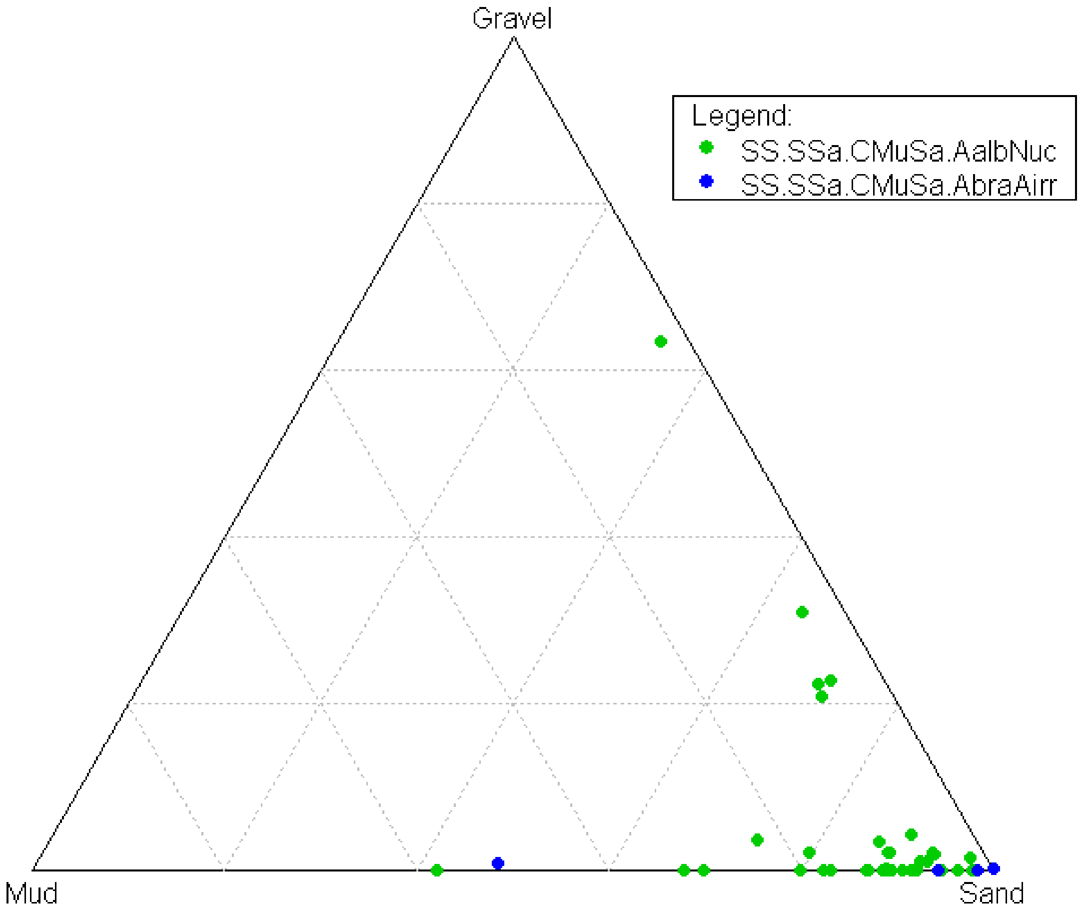
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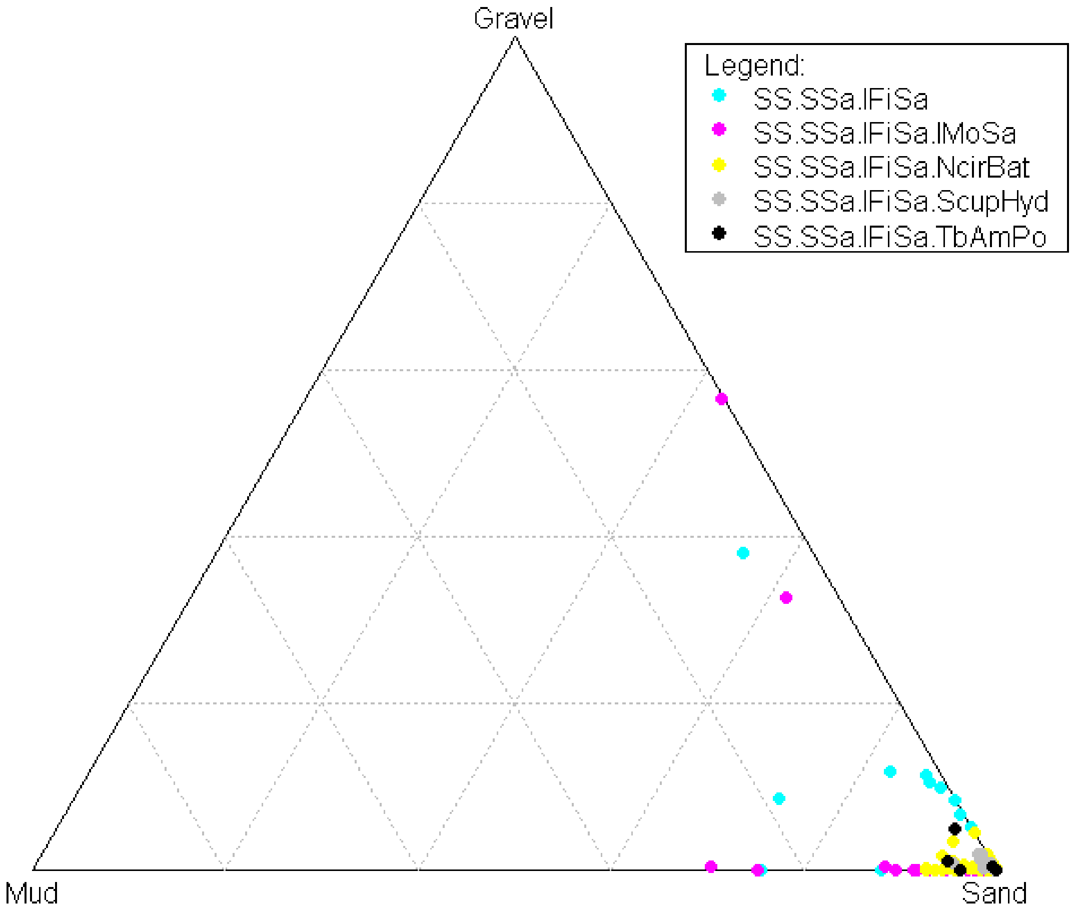
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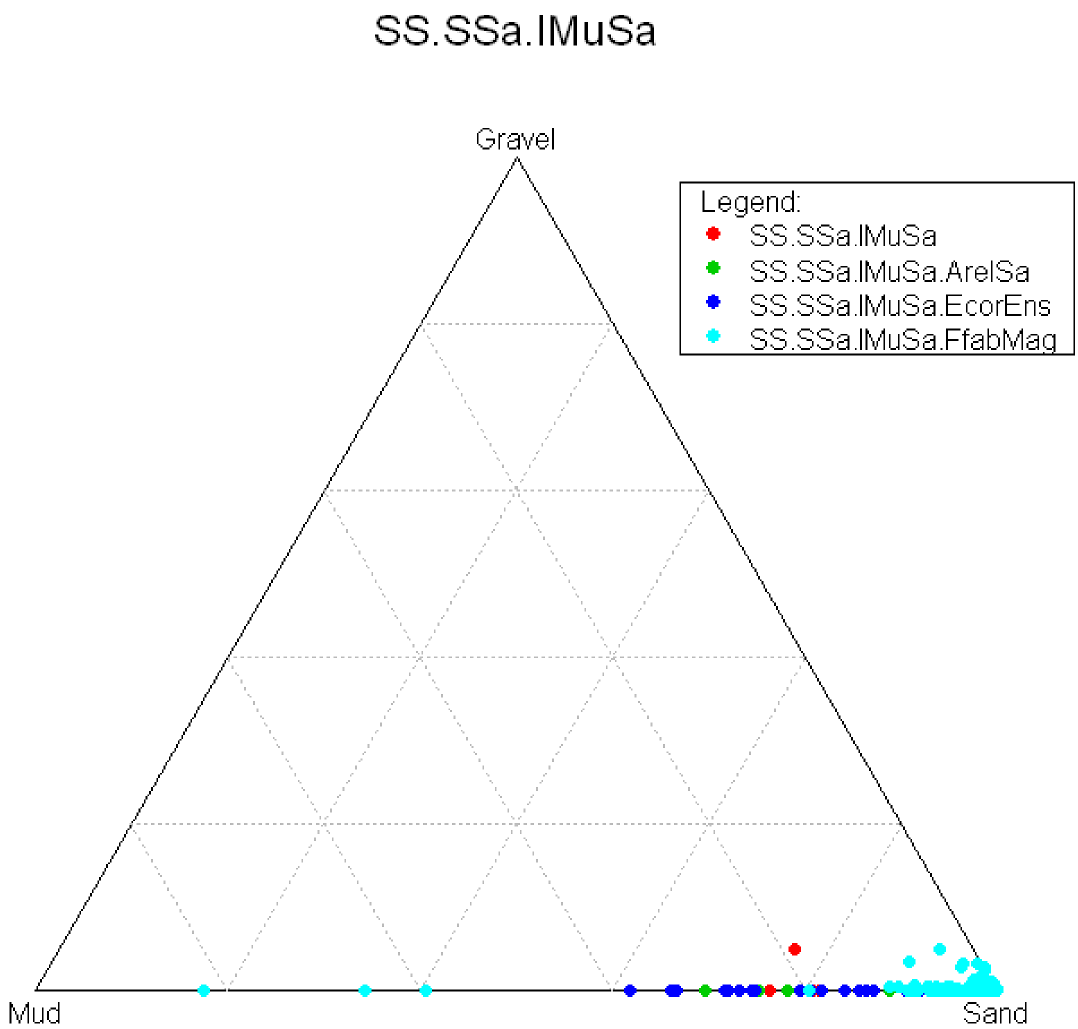
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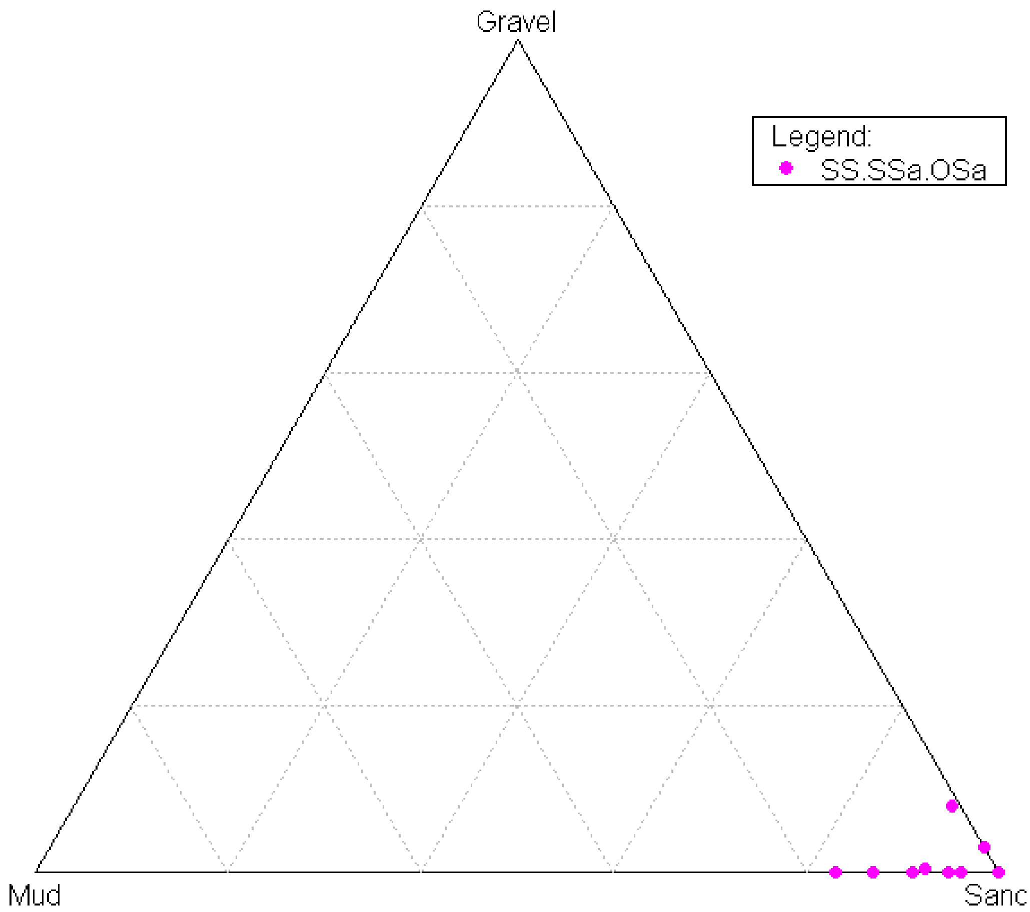

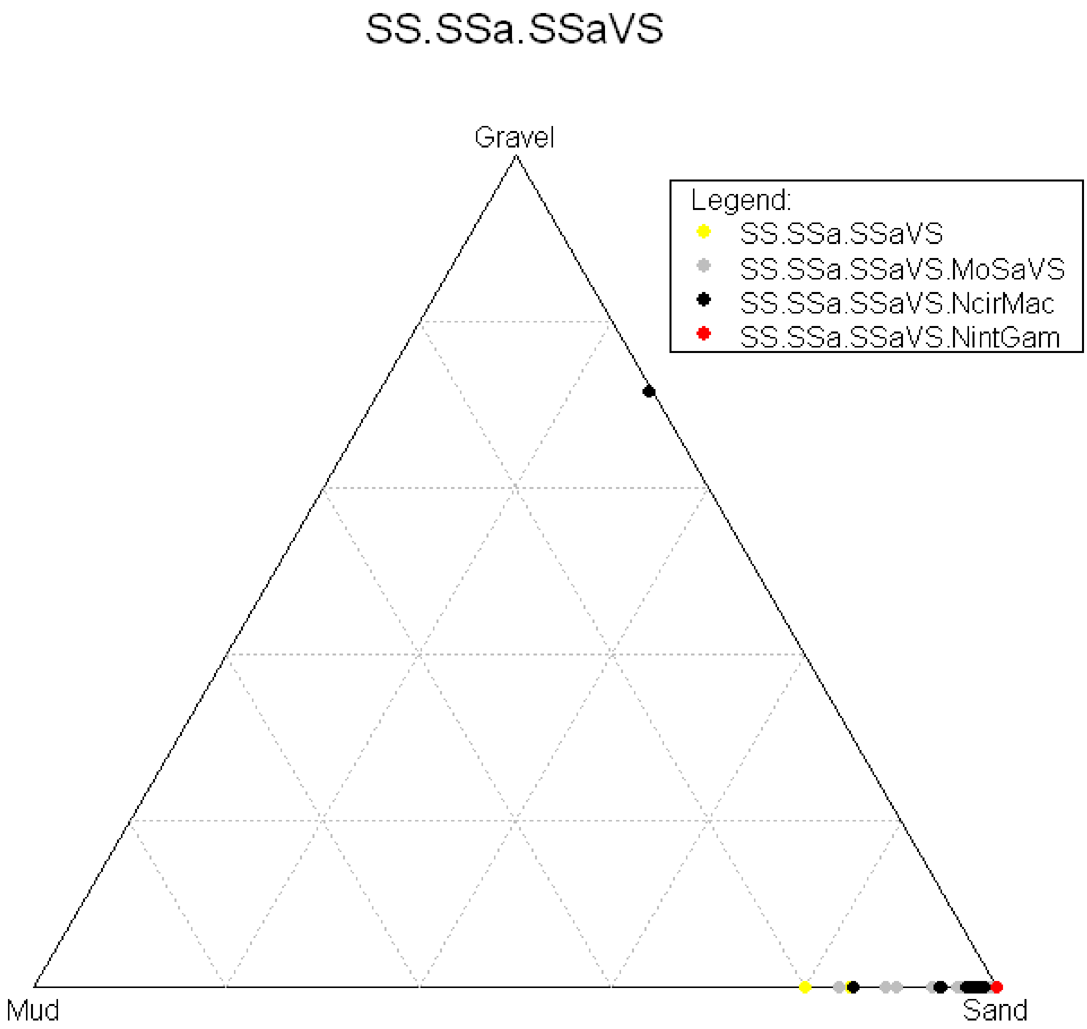
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