St Aubin's Bay Porosity Study – 2017

Prepared by Gareth Jeffreys
Société Jersiaise, Marine Biology Section (MBS).

December 2017.

Contents

1.0 Background

The Marine Biology Section (MBS) of the Société Jersiaise was commission by the Department of Environment to undertake a porosity study of St Aubin's Bay, in respect to knowledge gaps of the bay's physical characteristics particularly pertaining to the issue of the annual *Ulva* accumulations.

Porosity (*n*) is defined as the ratio of voids to the total volume of a material, and is represented as a ratio between 0 (completely solid) to 1 (empty space). For intertidal gravel, sands and clays it is a measure of the interstitial spaces between sediment particles and consequently its capacity to fill with water. Domenico and Schwartz (1997) give typical values of porosity for gravel (0.24-0.38), coarse sand (0.31-0.46) and fine sand (0.26-0.53).

However, grain size in itself does not affect the value of porosity, as well-rounded, similarly packed sediments, notwithstanding their particle size, will maintain similar porosities. The main factors that directly influence the porosity of a sediment are packing, sorting and grain shape. Well sorted loosely packed sediments generally have higher porosity than poorly sorted sediments for the simple reason that if a sediment contains a range of particle sizes then the smaller particles may fill in the voids between the larger particles. Equally, irregular shaped particles tend not to pack as neatly as rounded particles, resulting in higher proportions of void space and consequently porosity values.

For this study, 30 sample sights were chosen across St Aubin's Bay to cover areas of varying sediment types, high, mid and low tidal areas, and areas exhibiting dense to sparse coverage of *Ulva* sp.. A single 10cm core was taken at each site, with samples subsequently split in to two equal 5cm sections so that porosity values could be obtained for sediment depths of 0-5cm and 5-10cm at each site.

Porosity was measured for the 60 individual samples using a gravimetric method suitable for sample volumes of 20cm^3 of more of sedimentary material of any grain size (Danielson and Sutherland, 1986).

2.0 Methods

2.1 Sample Collection

Core sediment samples were collected along 8 transects, encompassing upper, mid and lower shore sites, with a further 6 cores being collected at various points of interest along the mid-shore of the Bay. For the core samples, a 10cm tall clear Perspex cylinder was used with a 5cm outer diameter and 4.4cm internal diameter, that was further split in to two 5cm high sections, stacked together and secured around the circumference with heavy duty duct tape. To retain the sediment's structural integrity and void volume within the cylinders, while allowing the ingress and evaporation of water from each sample, end caps were custom made using a 3D printer with a disc of 300-micron stainless steel mesh placed between the end caps and the cylinder opening. A metal coring frame was then used to fix the cylinders in place and extract the sediment cores (Figure 1).

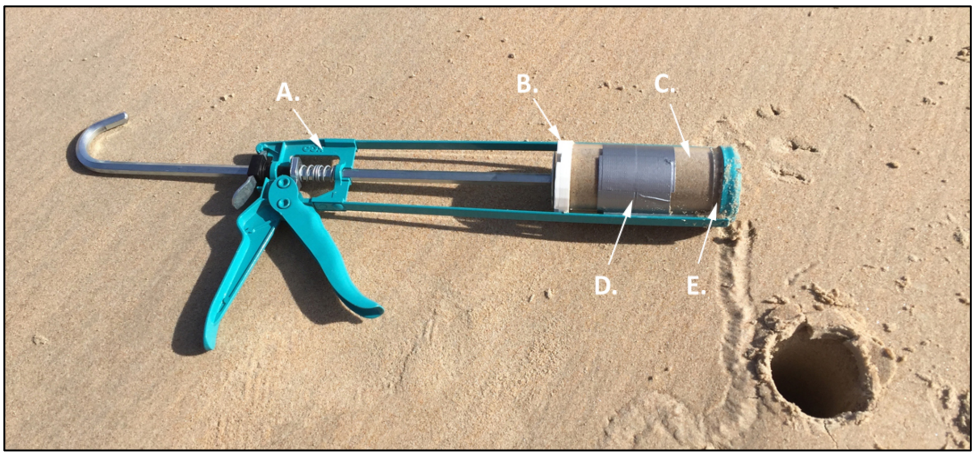

Figure 1. Coring frame (A.) with 3D printed endcap (B.) containing a 300-micron stainless steel mesh disc, and 2 stacked 5cm high Perspex cylinders (C.) secured at the mid-point (D.) with heavy duty Duct Tape. An additional 3cm Perspex buffer (E.) was permanently secured to the end of the coring frame.

Before removing the Perspex cylinders from the coring frame (A.), a 5cm wide rectangular trowel was used to slice through the sediment sample between buffer piece (E.) and the end of the coring cylinder (C.) to create a precise, flat cut through the bottom of each sample. Which was then sealed with an endcap (B.) containing a 300-micron stainless steel mesh disc. The fully sealed and intact 10cm cylinders were then transported to the laboratory for preparation and analysis.

2.2 Sample Preparation

To prepare the sealed cylinders for analysis, a retractable blade knife was used to cut around the taped mid-point of each cylinder (D.), taking care not to disturb the sediment sample, and the core sliced in two using the 5cm wide rectangular trowel. The two 5cm tall open samples (Figure 2.), representing 0-5cm and 5-10cm sediment depths, were then wiped clean of any external sand and placed in a drying oven until completely desiccated.

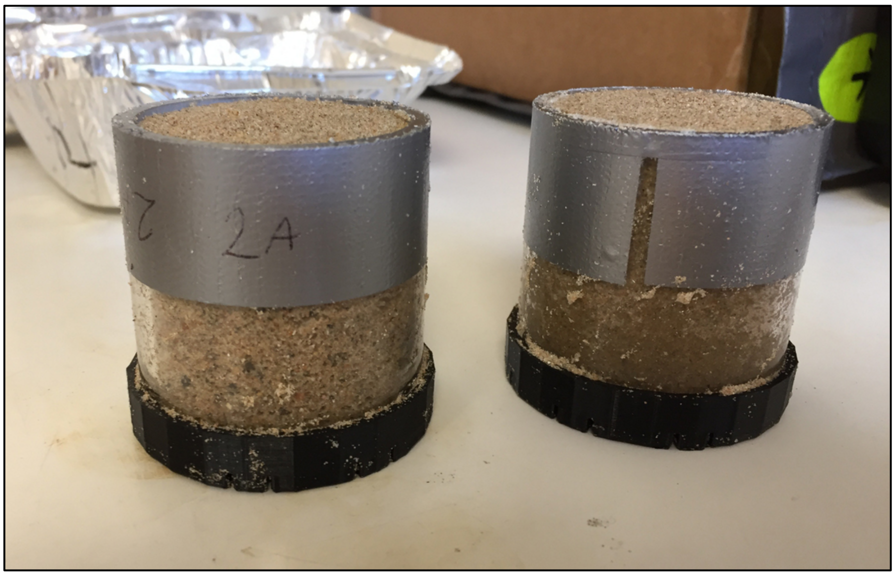

Figure 2. 0-5cm and 5-10cm cut sample cores prior to cleaning and desiccation.

2.3 Analysis

Fully desiccated samples were cooled, weighed to within 0.01g (including the weight of the Perspex cylinder and endcap) and placed in a vacuum chamber tray filled with de-aerated water. The vacuum chamber was then evacuated of air to a pressure of 20psi and the samples left to saturate.

Once saturated, each sample was re-weighed and the sediment fully extracted from each cylinder and placed in a marked sample pot. The wet and dry weights of each empty cylinder and end cap were then recorded and the amounts subtracted from the gross wet and dry weights of the full samples respectively. The volume of water uptake in each sample was then calculated in ml using the following formula:

$$v = (a - b) / c$$

Where (v) is the volume of water uptake in ml, (a) is the net wet weight of the sample in g, (b) is the net dry weight and (c) is 1.0012g, representing the weight of 1ml of de-aerated water at 20°C.

The extracted sediment from each core cylinder was then re-dried and the sediment volume (sv) measured to 0.01ml using water displacement methodology.

The porosity value (n), being the ratio of voids to total volume was then calculated as follows:

$$n = v / (v + sv)$$

3.0 Results

3.1 Porosity (*n*) Tables

	Upper Shore						
	Depth (cm)	Lat	Long	Water Volume (ml)	Sample Volume (ml)	Total Volume (ml)	Porosity (*n*)
St Aubin's Fort W.	0-5	49.18373	2.16925	29.65	43.00	72.65	0.41
St Aubin's Fort W.	5-10	49.18373	2.16925	30.49	44.00	74.49	0.41
La Haule	0-5	49.19173	2.16599	28.76	44.40	73.16	0.39
La Haule	5-10	49.19173	2.16599	32.08	47.38	79.46	0.40
Gunsite	0-5	49.19519	2.15967	30.79	45.58	76.37	0.40
Gunsite	5-10	49.19519	2.15967	30.14	46.10	76.24	0.40
Bel Royal	0-5	49.19632	2.14619	31.41	43.89	75.30	0.42
Bel Royal	5-10	49.19632	2.14619	31.51	43.75	75.26	0.42
Milbrook	0-5	49.19551	2.13722	28.16	43.34	71.50	0.39
Milbrook	5-10	49.19551	2.13722	29.30	45.00	74.30	0.39
Outfall W.	0-5	49.19400	2.13175	27.51	45.00	72.51	0.38
Outfall W.	5-10	49.19400	2.13175	24.26	52.20	76.46	0.32
Outfall E.	0-5	49.19194	2.12816	28.78	45.28	74.06	0.39
Outfall E.	5-10	49.19194	2.12816	29.12	47.80	76.92	0.38
Victoria Pool	0-5	49.18773	2.11802	29.69	43.00	72.69	0.41
Victoria Pool	5-10	49.18773	2.11802	30.08	42.00	72.08	0.42

Table 1. Upper shore sample sites.

	Mid Shore						
	Depth (cm)	Lat	Long	Water Volume (ml)	Sample Volume (ml)	Total Volume (ml)	Porosity (*n*)
St Aubin's West	0-5	49.18048	2.16777	31.41	41.20	72.61	0.43
St Aubin's West	5-10	49.18048	2.16777	30.56	43.90	74.46	0.41
St Aubin's Fort W.	0-5	49.18357	2.16668	30.79	43.00	73.79	0.42
St Aubin's Fort W.	5-10	49.18357	2.16668	29.49	45.87	75.36	0.39
St Aubin's Fort E.	0-5	49.18936	2.16372	30.24	42.37	72.61	0.42
St Aubin's Fort E.	5-10	49.18936	2.16372	26.29	47.00	73.29	0.36
La Haule	0-5	49.19040	2.16273	34.84	41.28	76.12	0.46
La Haule	5-10	49.19040	2.16273	31.93	46.90	78.83	0.41
Gunsite	0-5	49.19234	2.15840	32.31	41.00	73.31	0.44
Gunsite	5-10	49.19234	2.15840	31.25	45.50	76.75	0.41
Bel Royal	0-5	49.19352	2.14576	33.75	43.46	77.21	0.44
Bel Royal	5-10	49.19352	2.14576	31.22	43.58	74.80	0.42
Milbrook	0-5	49.19242	2.13837	33.17	40.42	73.59	0.45
Milbrook	5-10	49.19242	2.13837	29.44	44.00	73.44	0.40
Outfall W. 1	0-5	49.18912	2.13488	28.55	42.30	70.85	0.40
Outfall W. 1	5-10	49.18912	2.13488	23.99	40.80	64.79	0.37
Outfall W. 2	0-5	49.19190	2.13467	32.57	41.62	74.19	0.44
Outfall W. 2	5-10	49.19190	2.13467	34.24	42.83	77.07	0.44
Outfall E. 1	0-5	49.18847	2.13265	33.24	42.51	75.75	0.44
Outfall E. 1	5-10	49.18847	2.13265	33.94	45.35	79.29	0.43
Outfall E. 2	0-5	49.18992	2.12801	33.65	41.72	75.37	0.45
Outfall E. 2	5-10	49.18992	2.12801	33.35	42.00	75.35	0.44
Victoria Pool E.	0-5	49.18453	2.11802	35.31	42.28	77.59	0.46
Victoria Pool E.	5-10	49.18453	2.11802	33.44	45.89	79.33	0.42
Victoria Pool	0-5	49.18617	2.12271	32.73	45.20	77.93	0.42
Victoria Pool	5-10	49.18617	2.12271	30.72	45.36	76.08	0.40
Victoria Pool I.	0-5	49.18677	2.12012	32.98	42.55	75.53	0.44
Victoria Pool I.	5-10	49.18677	2.12012	32.63	47.00	79.63	0.41

Table 2. Mid shore sample sites.

	Depth (cm)	Lat.	Long.	Lower Shore Water Volume (ml)	Sample Volume (ml)	Total Volume (ml)	Porosity (n)
St Aubin's Fort W.	0-5	49.18166	2.16488	29.68	45.00	74.68	0.40
St Aubin's Fort W.	5-10	49.18166	2.16488	29.96	48.42	78.38	0.38
La Haule	0-5	49.18769	2.15640	33.03	41.80	74.83	0.44
La Haule	5-10	49.18769	2.15640	32.65	45.25	77.90	0.42
Gunsite	0-5	49.188.39	2.15462	33.24	42.16	75.40	0.44
Gunsite	5-10	49.188.39	2.15462	33.13	45.00	78.13	0.42
Bel Royal	0-5	49.19090	2.14550	32.80	40.20	73.00	0.45
Bel Royal	5-10	49.19090	2.14550	33.28	44.25	77.53	0.43
Milbrook	0-5	49.18975	2.13941	32.61	42.00	74.61	0.44
Milbrook	5-10	49.18975	2.13941	33.26	43.20	76.46	0.43
Outfall W.	0-5	49.18775	2.13764	27.02	43.00	70.02	0.39
Outfall W.	5-10	49.18775	2.13764	25.64	46.90	72.54	0.35
Outfall E.	0-5	49.18654	2.13487	28.12	42.00	70.12	0.40
Outfall E.	5-10	49.18654	2.13487	24.33	45.90	70.23	0.35
Victoria Pool	0-5	49.18147	2.12810	29.32	43.15	72.47	0.40
Victoria Pool	5-10	49.18147	2.12810	25.60	46.00	71.60	0.36

Table 3. Lower shore sample sites.

3.2 Porosity (*n*) Map

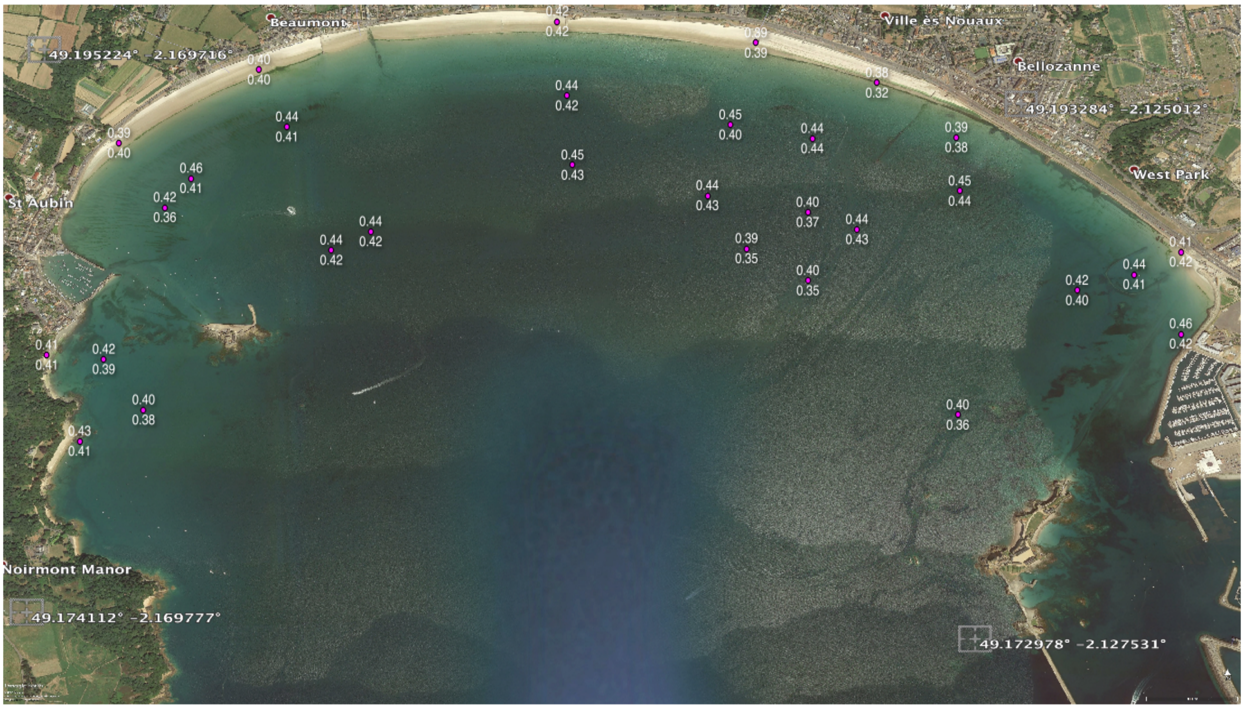

Figure 3. Porosity values (n) at depths of 0-5cm (n values above markers) and 5-10cm (n values below markers).

3.3 Porosity (*n*) Graph

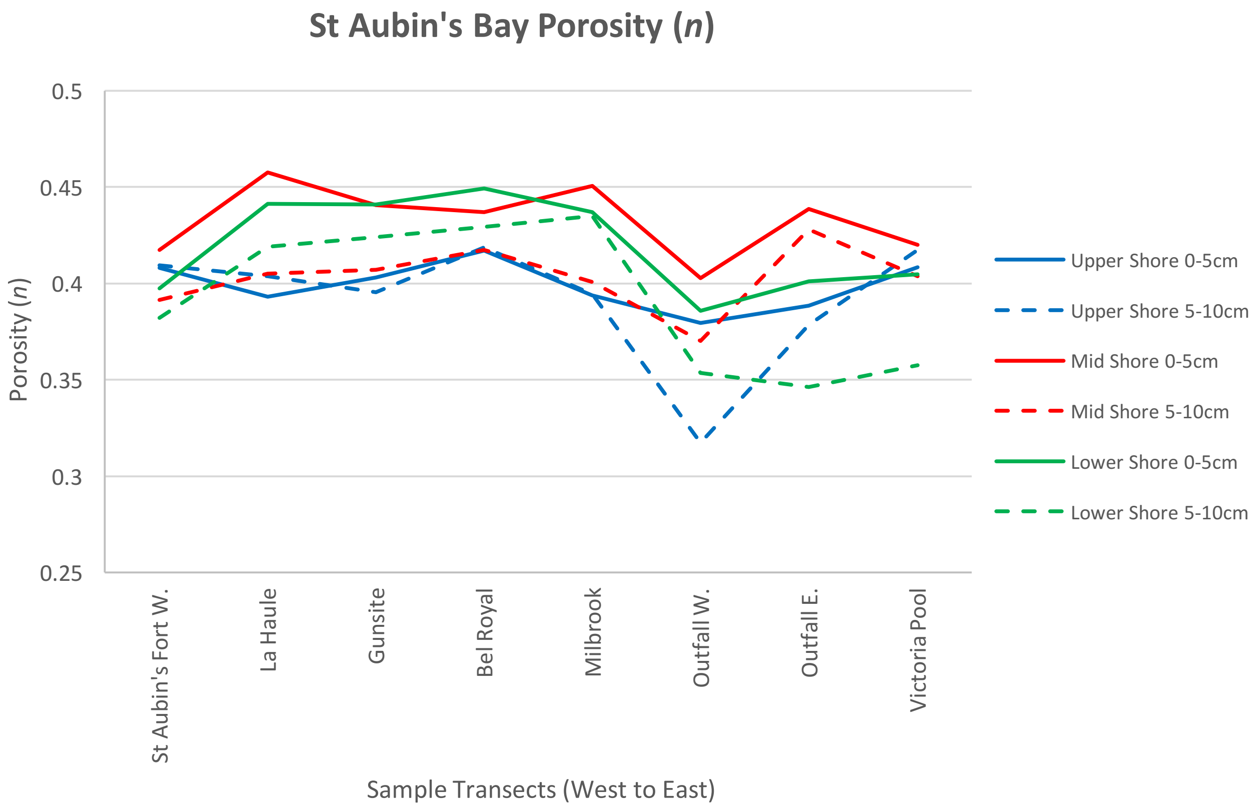

Figure 4. Porosity line graph. Solid lines represent 0-5cm depths and dashed lines 5-10cm. The graph visualises changes to porosity from west to east across the Bay at the upper, mid and lower shores.

4.0 Conclusions

Although analysis of grain size did not form part of this study, the sediment cores could generally be split in to two broad areas of sediment types; 1. coarse sand along the upper shore sample sites moving to 2. fine sand across the mid to lower shore sites. Based on the typical values as described by Domenico and Schwartz (1997) the results from Section 3.0 indicate porosity values at the upper end of expected values for such sediments, with coarse sand values typically ranging between 0.31-0.46 and fine sand between 0.26-0.53.

Despite grain sizes in themselves not directly affecting the measure of porosity, the results show that the porosity values for the upper shore right across the Bay are generally lower than those recorded at mid and lower shore sites. They are also the most consistent across both 0-5cm and 5-10cm depths. With all values falling between 0.38 and 0.42, except for a 0.32 porosity ratio recorded for the 5-10cm sample taken on the upper shore at Outfall West. Which suggests partially sorted/more regularly shaped grain sizes with lower void volumes make up the majority of the upper shore sediments at depths down to 10cm.

At 0-5cm depths, both the mid and the lower shores follow a very similar pattern from west to east across the bay on each of the 8 full transects (see Figure 4.). Which indicates a relative uniformity of sediment characteristics as pertaining to porosity up and down the mid and lower shore gradients of the beach, notwithstanding general changes to porosity values as you move from west to east across the Bay.

At 5-10cm depths, the mid and lower shore values follow a similar trend to those recorded at 0-5cm, except that at depth the porosity is lower at all sample sites across the mid and lower shore (except for Outfall West 2 on the mid shore where the values are the same). Suggesting an element of sediment grading below the upper shore with deeper sediments being more mixed/regularly shaped and tightly packed than surface sediment grains, with less potential for holding water.

With respect to the potential for holding water, although porosity provides a measure of the interstitial voids in a sediment it does not give an indication of its corresponding permeability, *K* (m/s). Which is an important factor in determining the level of uptake, seepage/drainage or retention of water across the Bay. The ease in which a fluid flows through a material can be expressed by the Carmen-Kozeny relationship where the sediment's porosity and representative grain size, together with the density and dynamic viscosity of the fluid are known.

To utilise the results of this study to provide a measure of permeability, the MBS would be able to conduct a particle size analysis (PSA) of the shore at the 30 sample sites. Which would use the same equipment and sample collection and preparation methods as described in Sections 2.1 and 2.2 above.

In terms of the limitations of this study, it should be noted that because only a single 10cm core was analysed at each sample site and due to the possibility of random rocks/shells that are not indicative of the wider area forming part of the core sample collected, there is the potential for outlier measurements being presented in the results (such as the 0.32 value recorded at the Outfall West upper shore site).

It should also be noted that due to the mechanics of the sediment corer, sites could only be sampled in areas where there was at least a coarse sand/gravel mix present to a depth of over 13cm.

5.0 Works Cited

Blanco, B.L., (2003). *Dynamics of gravel and mixed, sand and gravel, beaches*: Master's Thesis - Imperial College of Science Technology and Medicine, London UK.

Danielson, R.E. and Sutherland, P.L. (1986). Porosity, in *Methods of Soil Analysis Part 1. Physical and Mineralogical Methods*, Agronomy Monograph no. 9, Soil Science Society of America, Madison, WI, USA, p. 443-461.

Domenico, P. and Schwartz, F.W. (1997). *Physical and Chemical Hydrogeology (2nd edition)*. John Wiley, Chichester.