**St Aubin's Bay Organic Nitrogen, Carbon and Phosphate – 2017**

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## Contents

## *1.0 Background*

The Marine Biology Section (MBS) of the Société Jersiaise was commission by the Department of Environment to collect sediment samples for an Organic Carbon, Nitrogen and Phosphate (OCNP) analysis 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.

St Aubin's Bay on the south coast of Jersey is a shallow, curving bay made up of large swathes of sands, interspersed with outcrops of primarily igneous rock. The bay forms a south-facing crescent flanked to the east by the port of St Helier and to the west by the headland of Noirmont Point. Where the beach does not back onto cliffs it is fringed with shore defences and harbour walls of either Victorian or 1940s origin. Within the bay two forts (Elizabeth Castle and St Aubin's Fort) are situated on the larger rocky heads and can be reached on foot via causeways at low tide. The majority of the coastline is given over to residential development with a few pockets of green space and some commercial activity, primarily hospitality.

The bay is host to a diverse set of substrates ranging from exposed to sheltered rock through a range of gravels and sands to fine silts and muddy sand. Associated with these substrates is a range of over 30 distinct habitats

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 OCNP values could be obtained for sediment depths of 0-5cm and 5-10cm at each site.

## *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. The cylinder was sealed at the top with an end cap custom made using a 3D printer. A metal coring frame was then used to fix the cylinders in place and extract the sediment cores (Figure 1).

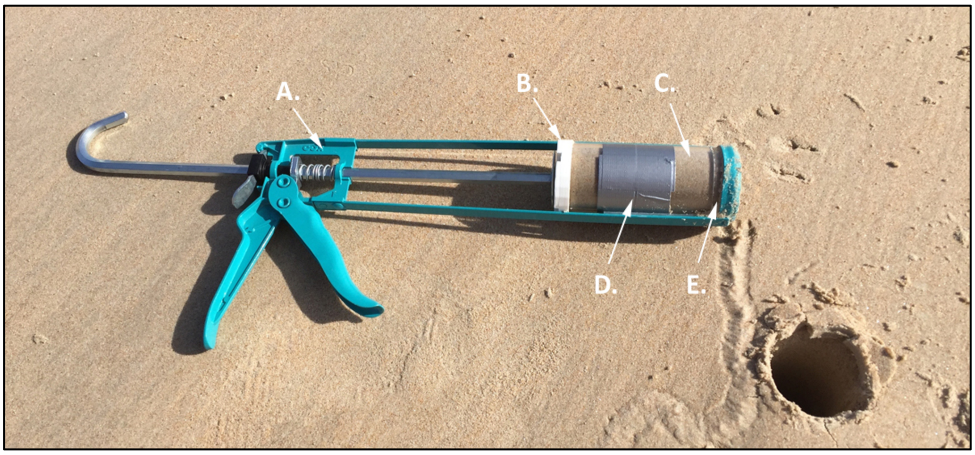


*Figure 1. Coring frame (A.) with 3D printed endcap (B.) containing a 300-micron stainless steel mesh disc, and 2 stacked 5cm high Perspex cylinders (C.) secured at the mid-point (D.) with heavy duty Duct Tape. An additional 3cm Perspex buffer (E.) was permanently secured to the end of the coring frame.*

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. Holding the cylinder endcap side down, a retractable blade knife was used to cut around the taped mid-point of each cylinder (D.), and the core sliced in two using the 5cm wide rectangular trowel. Each 5cm sample, representing 0-5cm and 5-10cm sediment depths, was then tipped out of the cylinder in to a marked sample pot and sealed for later preparation and analysis.

## 2.2 Sample Preparation

All sample pots were placed in a drying oven until completely desiccated. The dried sediment samples were then sieved (with larger particles ground down where possible) and each sample well mixed. 60g of each sample was weighed out and sealed in 125ml amber glass jars, labeled accordingly and packed ready for shipping to the UK National Laboratory Service for analysis.

# *3.0 Results*

## 3.1 Analysis Tables

*Table 1. Upper shore sample sites*

| | Upper Shore | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Depth (cm) | Lat | Long | Sample Ref. | Ammoniacal Nitrogen : Dry Wt as N | Nitrite : Dry Wt as N | Nitrogen : Total Oxidised : Dry Wt as N | Orthophosphate : Dry Wt as P | Carbon : Dry Wt | Nitrogen : Dry Wt as N | C:N Ratio | Carbon, Organic : Dry Wt as C | Dry Solids @ 30°C |
| | | | | | mg/kg | mg/kg | mg/kg | mg/kg | mg/kg | mg/kg | | % | % |
| St Aubin's Fort W. | 0-5 | 49.18373 | 2.16925 | 24A | <2 | <0.1 | <3 | 5.45 | 5520 | <200 | N/a | <0.1 | 100 |
| St Aubin's Fort W. | 5-10 | 49.18373 | 2.16925 | 24B | <2 | <0.1 | <3 | 4.48 | 11600 | <200 | N/a | <0.1 | 100 |
| La Haule | 0-5 | 49.19173 | 2.16599 | 22A | <2 | <0.1 | <3 | 1.49 | 8430 | <200 | N/a | <0.1 | 100 |
| La Haule | 5-10 | 49.19173 | 2.16599 | 22B | <2 | <0.1 | <3 | 23.4 | 14900 | <200 | N/a | <0.1 | 100 |
| Gunsite | 0-5 | 49.19519 | 2.15967 | 25A | <2 | <0.1 | <3 | 3.87 | 3730 | <200 | N/a | <0.1 | 100 |
| Gunsite | 5-10 | 49.19519 | 2.15967 | 25B | <2 | <0.1 | <3 | 2.29 | 4550 | 582 | 7.82 | <0.1 | 100 |
| Bel Royal | 0-5 | 49.19632 | 2.14619 | 35A | <2 | <0.1 | <3 | 4.38 | <2000 | <200 | N/a | <0.1 | 100 |
| Bel Royal | 5-10 | 49.19632 | 2.14619 | 35B | <2 | <0.1 | <3 | 4.83 | <2000 | <200 | N/a | <0.1 | 100 |
| Milbrook | 0-5 | 49.19551 | 2.13722 | 34A | <2 | <0.1 | <3 | 3.56 | <2000 | <200 | N/a | <0.1 | 100 |
| Milbrook | 5-10 | 49.19551 | 2.13722 | 34B | <2 | <0.1 | <3 | 2.05 | 4600 | <200 | N/a | <0.1 | 100 |
| Outfall W. | 0-5 | 49.19400 | 2.13175 | 33A | <2 | <0.1 | <3 | 3.93 | 11300 | <200 | N/a | <0.1 | 100 |
| Outfall W. | 5-10 | 49.19400 | 2.13175 | 33B | <2 | <0.1 | <3 | 4.31 | <2000 | <200 | N/a | <0.1 | 100 |
| Outfall E. | 0-5 | 49.19194 | 2.12816 | 32A | <2 | <0.1 | <3 | 11.5 | 15300 | <200 | N/a | <0.1 | 100 |
| Outfall E. | 5-10 | 49.19194 | 2.12816 | 32B | <2 | <0.1 | <3 | 7.68 | <2000 | 502 | N/a | <0.1 | 100 |
| Victoria Pool | 0-5 | 49.18773 | 2.11802 | 52A | <2 | <0.1 | <3 | 4.25 | <2000 | 1700 | N/a | <0.1 | 100 |
| Victoria Pool | 5-10 | 49.18773 | 2.11802 | 52B | <2 | <0.1 | <3 | 4.51 | <2000 | 488 | N/a | <0.1 | 100 |

*Table 2. Mid shore sample sites*

| | Mid Shore | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Depth (cm) | Lat | Long | Sample Ref. | Ammoniacal Nitrogen : Dry Wt as N | Nitrite : Dry Wt as N | Nitrogen : Total Oxidised : Dry Wt as N | Orthophosphate : Dry Wt as P | Carbon : Dry Wt as C | Nitrogen : Dry Wt as N | C:N Ratio | Carbon, Organic : Dry Wt as C | Dry Solids @ 30°C |
| | | | | | mg/kg | mg/kg | mg/kg | mg/kg | mg/kg | mg/kg | | % | % |
| St Aubin's West | 0-5 | 49.18048 | 2.16777 | 57A | <2 | <0.1 | <3 | 2.77 | 11100 | <200 | N/a | <0.1 | 100 |
| St Aubin's West | 5-10 | 49.18048 | 2.16777 | 57B | <2 | <0.1 | <3 | 2.36 | 13500 | 740 | 18.24 | <0.1 | 100 |
| St Aubin's Fort W. | 0-5 | 49.18357 | 2.16668 | 23A | 2.38 | <0.1 | <3 | 16.6 | 18000 | <200 | N/a | 0.134 | 100 |
| St Aubin's Fort W. | 5-10 | 49.18357 | 2.16668 | 23B | <2 | <0.1 | <3 | 9.86 | 20100 | <200 | N/a | 0.11 | 100 |
| St Aubin's Fort E. | 0-5 | 49.18936 | 2.16372 | 20A | 2.29 | <0.1 | <3 | 17.4 | 45200 | 669 | 67.56 | 0.148 | 100 |
| St Aubin's Fort E. | 5-10 | 49.18936 | 2.16372 | 20B | 2.18 | <0.1 | <3 | 8.92 | 40100 | 728 | 55.08 | 0.198 | 100 |
| La Haule | 0-5 | 49.19040 | 2.16273 | 51A | 2.83 | <0.1 | <3 | 15.7 | 37400 | 1180 | 31.69 | 0.207 | 100 |
| La Haule | 5-10 | 49.19040 | 2.16273 | 51B | <2 | <0.1 | <3 | 3.83 | 28600 | 1050 | 27.24 | 0.13 | 100 |
| Gunsite | 0-5 | 49.19234 | 2.15840 | 27A | <2 | <0.1 | <3 | 2.83 | <2000 | 568 | N/a | <0.1 | 100 |
| Gunsite | 5-10 | 49.19234 | 2.15840 | 27B | <2 | <0.1 | <3 | 3.28 | <2000 | <200 | N/a | <0.1 | 100 |
| Bel Royal | 0-5 | 49.19352 | 2.14576 | 39A | 2.88 | <0.1 | <3 | 19.5 | 31500 | 813 | 38.75 | 0.17 | 100 |
| Bel Royal | 5-10 | 49.19352 | 2.14576 | 39B | 2.16 | <0.1 | <3 | 9.64 | 30800 | 780 | 39.49 | 0.137 | 100 |
| Milbrook | 0-5 | 49.19242 | 2.13837 | 38A | 2.85 | <0.1 | <3 | 20.9 | 28000 | 1910 | 14.66 | 0.233 | 100 |
| Milbrook | 5-10 | 49.19242 | 2.13837 | 38B | 2.29 | <0.1 | <3 | 10.9 | 30600 | 761 | 40.21 | 0.17 | 100 |
| Outfall W. 1 | 0-5 | 49.18912 | 2.13488 | 30A | <2 | <0.1 | <3 | 15.1 | 24500 | 378 | 64.81 | 0.149 | 100 |
| Outfall W. 1 | 5-10 | 49.18912 | 2.13488 | 30B | <2 | <0.1 | <3 | 6.88 | 27100 | 567 | 47.80 | 0.141 | 100 |
| Outfall W. 2 | 0-5 | 49.19190 | 2.13467 | 56A | 2.85 | <0.1 | <3 | 18.3 | 24900 | <200 | N/a | 0.125 | 100 |
| Outfall W. 2 | 5-10 | 49.19190 | 2.13467 | 56B | 2.79 | <0.1 | <3 | 18.7 | 28200 | 433 | 65.13 | 0.123 | 100 |
| Outfall E. 1 | 0-5 | 49.18847 | 2.13265 | 31A | 2.62 | <0.1 | <3 | 17.9 | 29700 | 552 | 53.80 | 0.122 | 100 |
| Outfall E. 1 | 5-10 | 49.18847 | 2.13265 | 31B | <2 | <0.1 | <3 | 7.6 | 27000 | 588 | 45.92 | 0.113 | 100 |
| Outfall E. 2 | 0-5 | 49.18992 | 2.12801 | 55A | 3.05 | <0.1 | <3 | 19.9 | 31000 | 1030 | 30.10 | 0.143 | 100 |
| Outfall E. 2 | 5-10 | 49.18992 | 2.12801 | 55B | 2.14 | <0.1 | <3 | 7.85 | 29200 | 1370 | 21.31 | 0.167 | 100 |
| Victoria Pool E. | 0-5 | 49.18453 | 2.11802 | 53A | 3.62 | <0.1 | <3 | 32.8 | 15300 | 1130 | 13.54 | 0.201 | 100 |
| Victoria Pool E. | 5-10 | 49.18453 | 2.11802 | 53B | 4.89 | <0.1 | <3 | 16.3 | 12500 | 737 | 16.96 | 0.168 | 100 |
| Victoria Pool | 0-5 | 49.18617 | 2.12271 | 54A | <2 | <0.1 | <3 | 15.8 | 19300 | 668 | 28.89 | 0.107 | 100 |
| Victoria Pool | 5-10 | 49.18617 | 2.12271 | 54B | <2 | <0.1 | <3 | 6.76 | 21400 | 779 | 27.47 | 0.109 | 100 |
| Victoria Pool I. | 0-5 | 49.18677 | 2.12012 | 58A | 2.54 | <0.1 | <3 | 18.7 | 14000 | 1110 | 12.61 | 0.137 | 100 |
| Victoria Pool I. | 5-10 | 49.18677 | 2.12012 | 58B | 2.5 | <0.1 | <3 | 15.1 | 14300 | <200 | N/a | 0.143 | 100 |

*Table 3. Lower shore sample sites*

| | Lower Shore | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Depth (cm) | Lat | Long | Sample Ref. | Ammoniacal Nitrogen : Dry Wt as N | Nitrite : Dry Wt as N | Nitrogen : Total Oxidised : Dry Wt as N | Orthophosphate : Dry Wt as P | Carbon : Dry Wt | Nitrogen : Dry Wt as N | C:N Ratio | Carbon, Organic : Dry Wt as C | Dry Solids @ 30°C |
| | | | | | mg/kg | mg/kg | mg/kg | mg/kg | mg/kg | mg/kg | | % | % |
| St Aubin's Fort W. | 0-5 | 49.18166 | 2.16488 | 40A | <2 | <0.1 | <3 | 11.2 | 28300 | 877 | 32.27 | 0.146 | 100 |
| St Aubin's Fort W. | 5-10 | 49.18166 | 2.16488 | 40B | <2 | <0.1 | <3 | 6.97 | 31400 | 838 | 37.47 | 0.217 | 100 |
| La Haule | 0-5 | 49.18769 | 2.15640 | 41A | <2 | <0.1 | <3 | 11.9 | 23800 | 674 | 35.31 | 0.131 | 100 |
| La Haule | 5-10 | 49.18769 | 2.15640 | 41B | <2 | <0.1 | <3 | 7.18 | 24000 | 811 | 29.59 | 0.116 | 100 |
| Gunsite | 0-5 | 49.188.39 | 2.15462 | 42A | 2.13 | <0.1 | <3 | 15.3 | 25600 | 853 | 30.01 | 0.127 | 100 |
| Gunsite | 5-10 | 49.188.39 | 2.15462 | 42B | <2 | <0.1 | <3 | 8.14 | 25700 | 752 | 34.18 | 0.131 | 100 |
| Bel Royal | 0-5 | 49.19090 | 2.14550 | 36A | 2.82 | <0.1 | <3 | 20.6 | 25900 | 1100 | 23.55 | <0.1 | 100 |
| Bel Royal | 5-10 | 49.19090 | 2.14550 | 36B | 2.37 | <0.1 | <3 | 14.1 | 28000 | 1110 | 25.23 | <0.1 | 100 |
| Milbrook | 0-5 | 49.18975 | 2.13941 | 37A | 2.65 | <0.1 | <3 | 17.1 | 24800 | 2670 | 9.29 | 0.304 | 100 |
| Milbrook | 5-10 | 49.18975 | 2.13941 | 37B | <2 | <0.1 | <3 | 8.06 | 27900 | 955 | 29.21 | 0.273 | 100 |
| Outfall W. | 0-5 | 49.18775 | 2.13764 | 44A | <2 | <0.1 | <3 | 13 | 26800 | 813 | 32.96 | 0.138 | 100 |
| Outfall W. | 5-10 | 49.18775 | 2.13764 | 44B | <2 | <0.1 | <3 | 4.25 | 25100 | 784 | 32.02 | 0.114 | 100 |
| Outfall E. | 0-5 | 49.18654 | 2.13487 | 29A | <2 | <0.1 | <3 | 11.4 | 23300 | 337 | 69.14 | 0.102 | 100 |
| Outfall E. | 5-10 | 49.18654 | 2.13487 | 29B | <2 | <0.1 | <3 | 4.64 | 21500 | 216 | 99.54 | <0.1 | 100 |
| Victoria Pool | 0-5 | 49.18147 | 2.12810 | 43A | <2 | <0.1 | <3 | 13.2 | 16500 | 384 | 42.97 | 0.105 | 100 |
| Victoria Pool | 5-10 | 49.18147 | 2.12810 | 43B | <2 | <0.1 | <3 | 5.91 | 19700 | 532 | 37.03 | 0.12 | 100 |

## 3.2 Analysis Maps

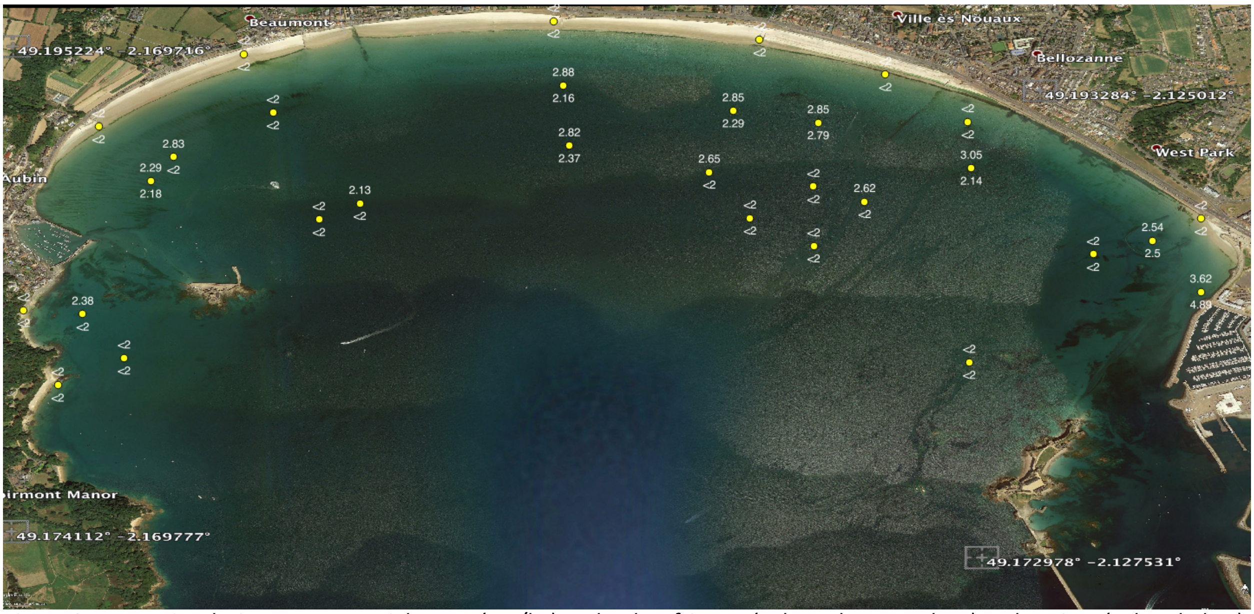


*Figure 2. Ammoniacal Nitrogen: Dry weight as N (mg/kg) at depths of 0-5cm (values above markers) and 5-10cm (values below).*

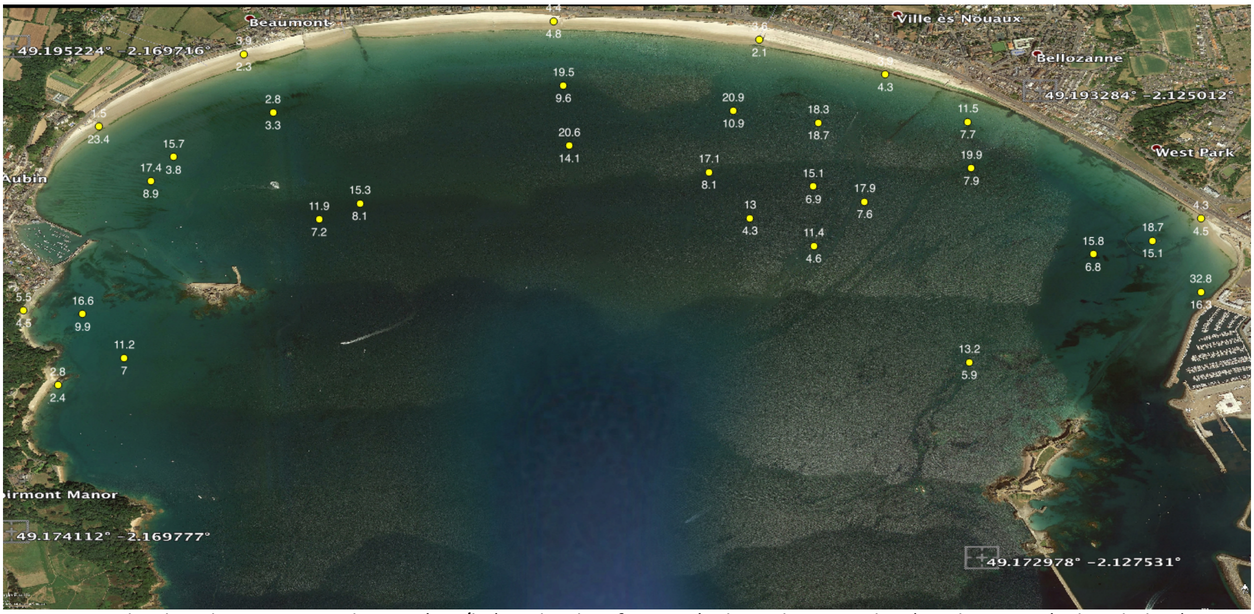


*Figure 3. Orthophosphate: Dry weight as P (mg/kg) at depths of 0-5cm (values above markers) and 5-10cm (values below).*

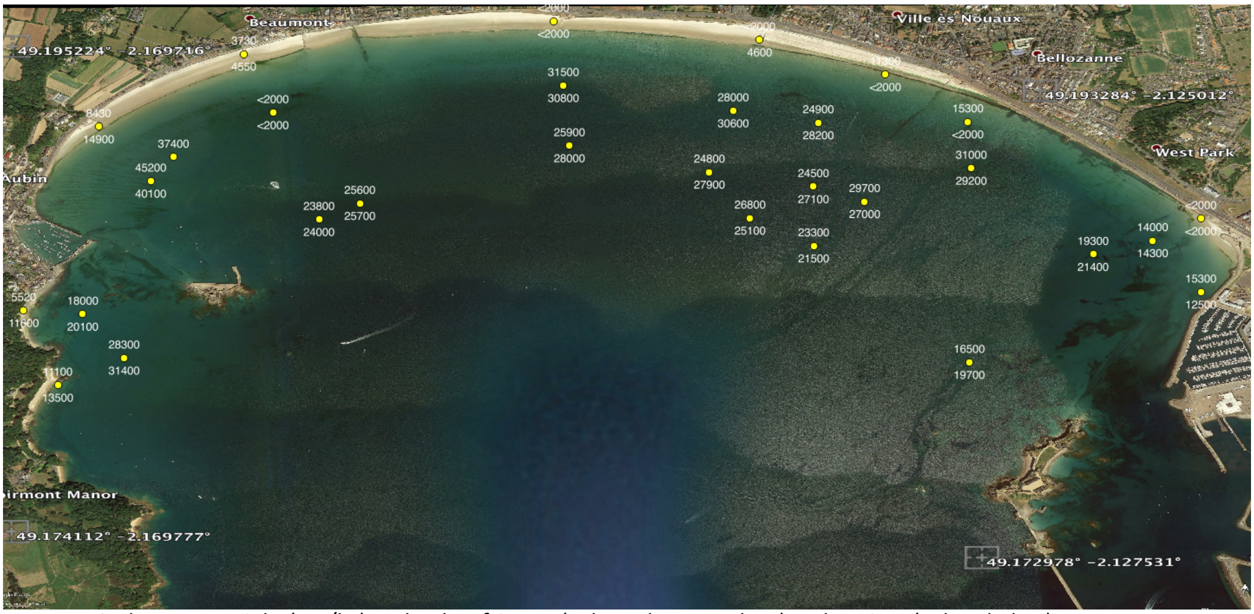


*Figure 4. Carbon: Dry weight (mg/kg) at depths of 0-5cm (values above markers) and 5-10cm (values below).*

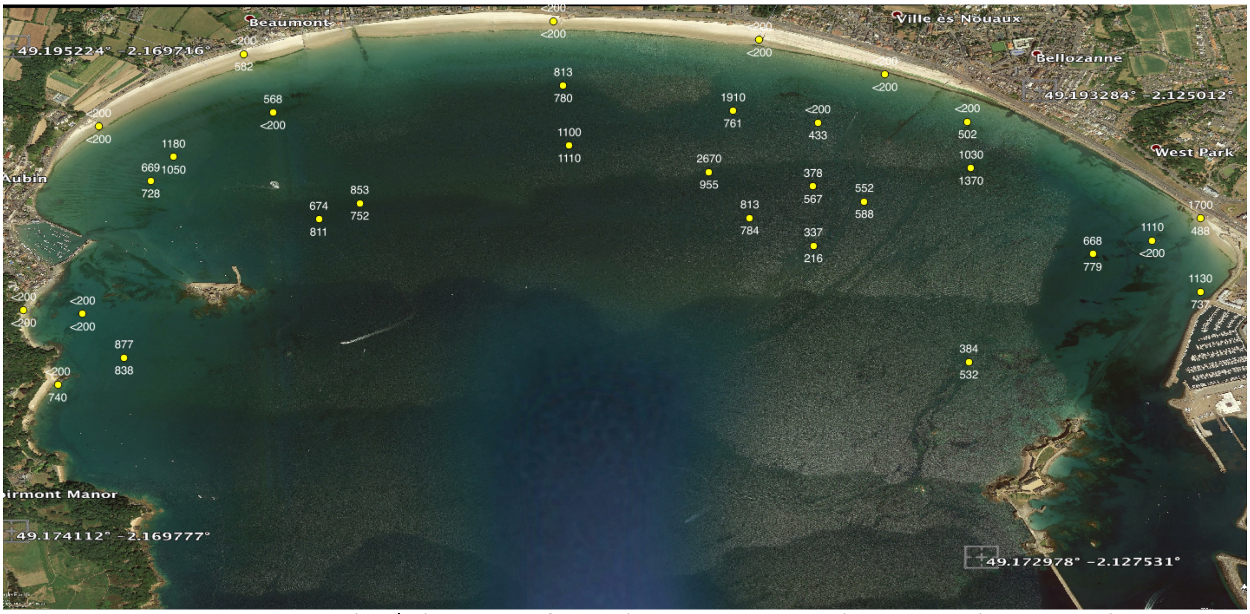


*Figure 5. Nitrogen: Dry weight as N (mg/kg) at depths of 0-5cm (values above markers) and 5-10cm (values below).*

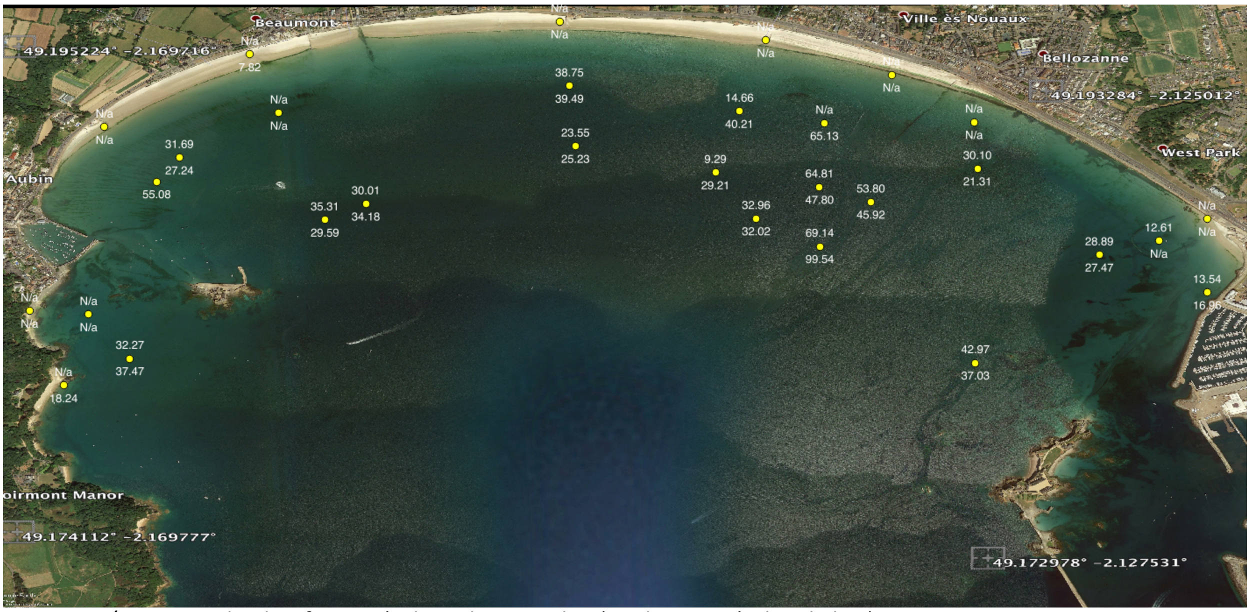


*Figure 6. C/N Ratio at depths of 0-5cm (values above markers) and 5-10cm (values below).*

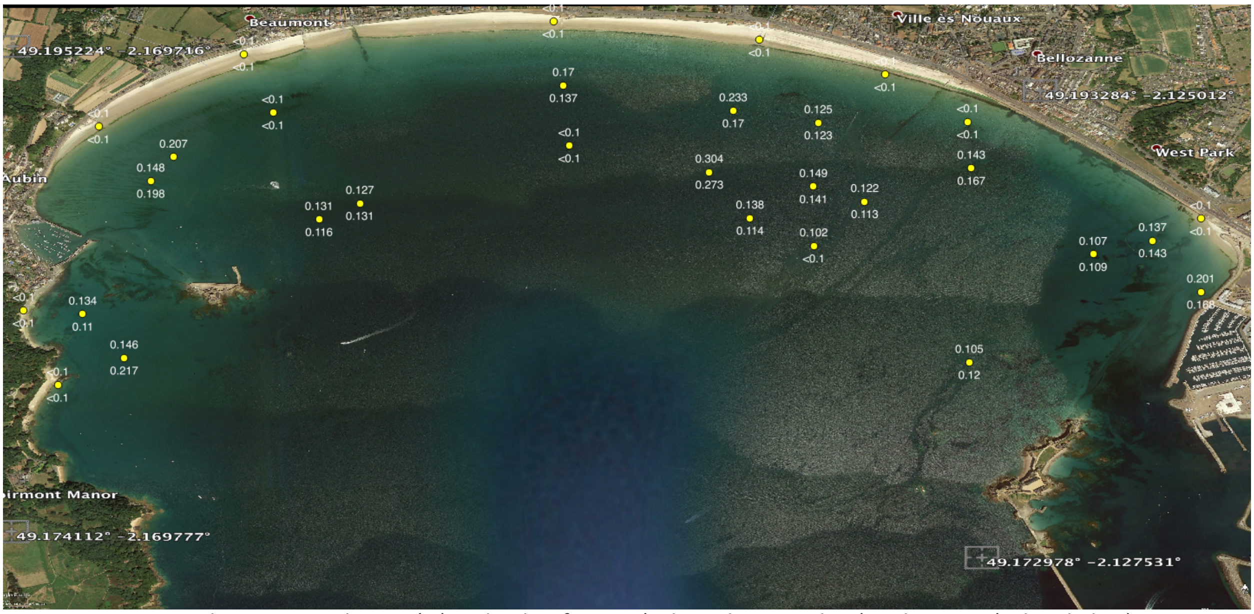

*Figure 7. Organic Carbon: Dry weight as C (%) at depths of 0-5cm (values above markers) and 5-10cm (values below).*

## 3.3 Analysis Graphs

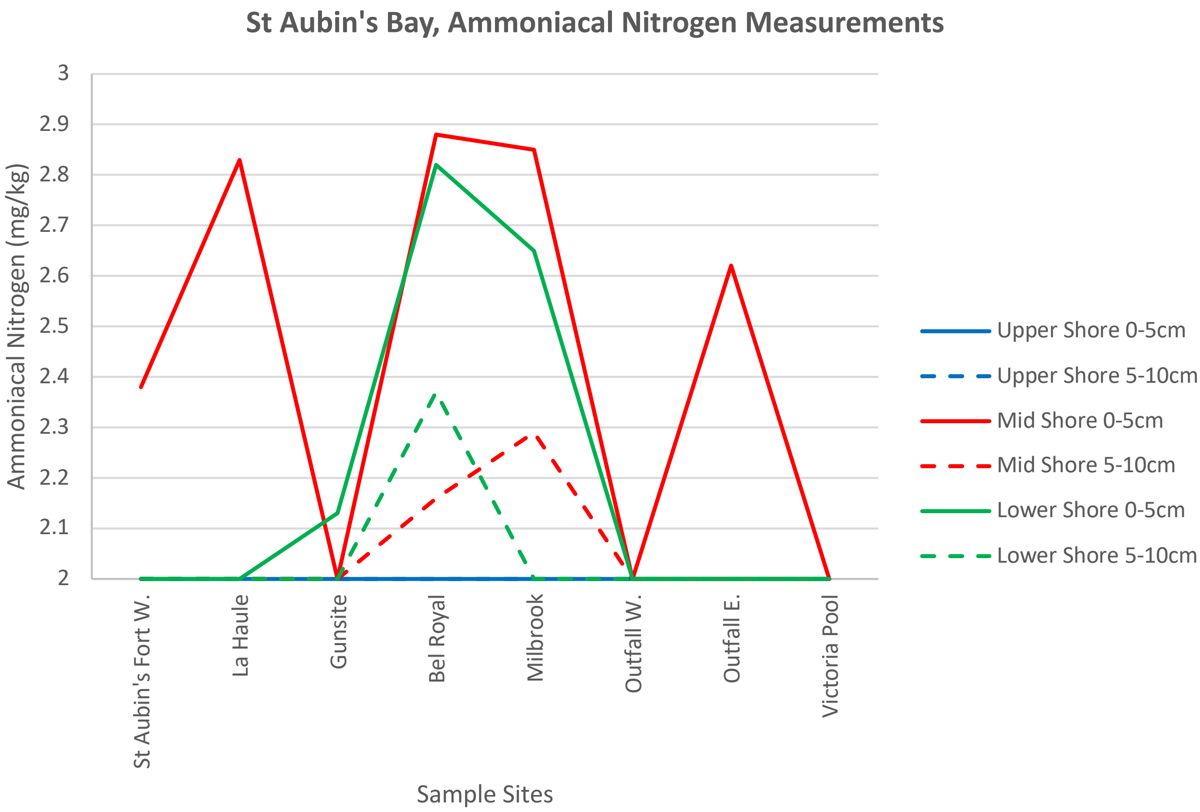


*Figure 8. Ammoniacal Nitrogen line graph. Solid lines represent 0-5cm depths and dashed lines 5-10cm. The graph visualises changes to Ammoniacal Nitrogen from west to east across the Bay at the upper, mid and lower shores.*

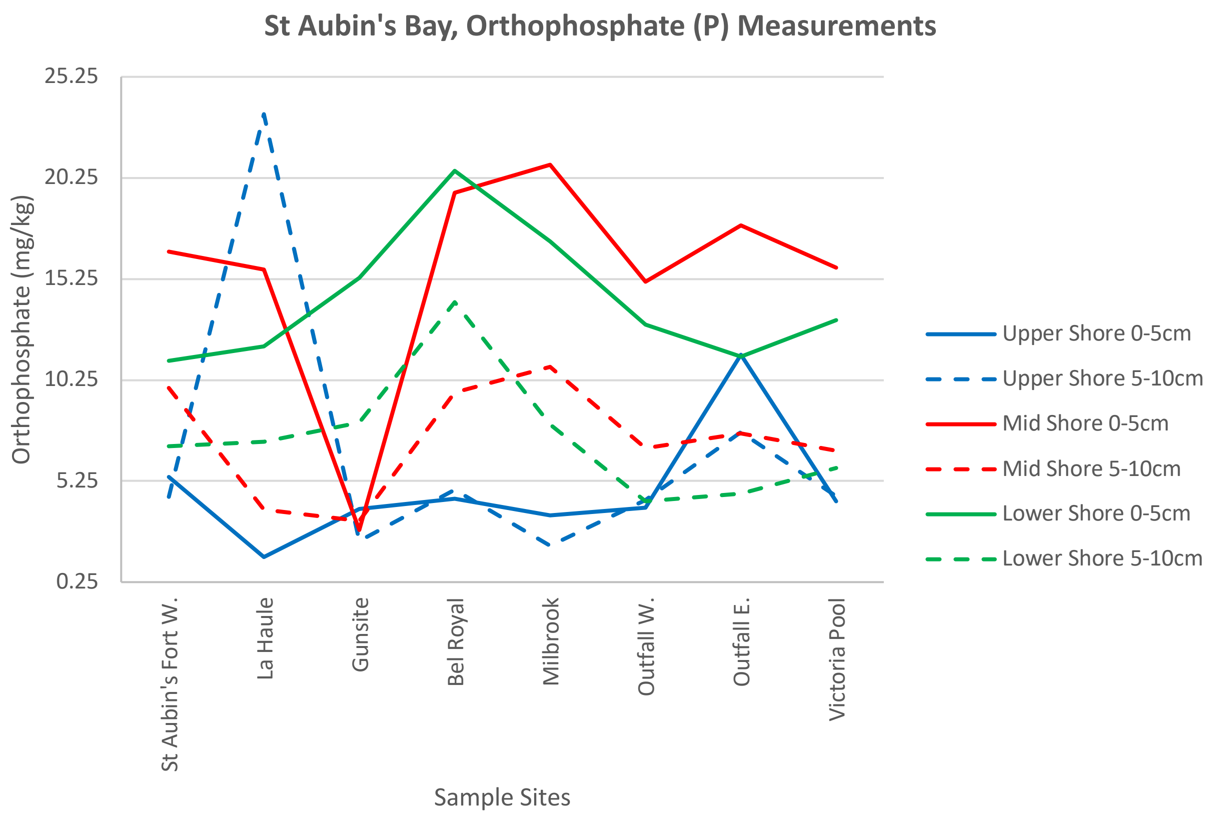


*Figure 9. Orthophosphate line graph. Solid lines represent 0-5cm depths and dashed lines 5-10cm. The graph visualises changes to P from west to east across the Bay at the upper, mid and lower shores.*

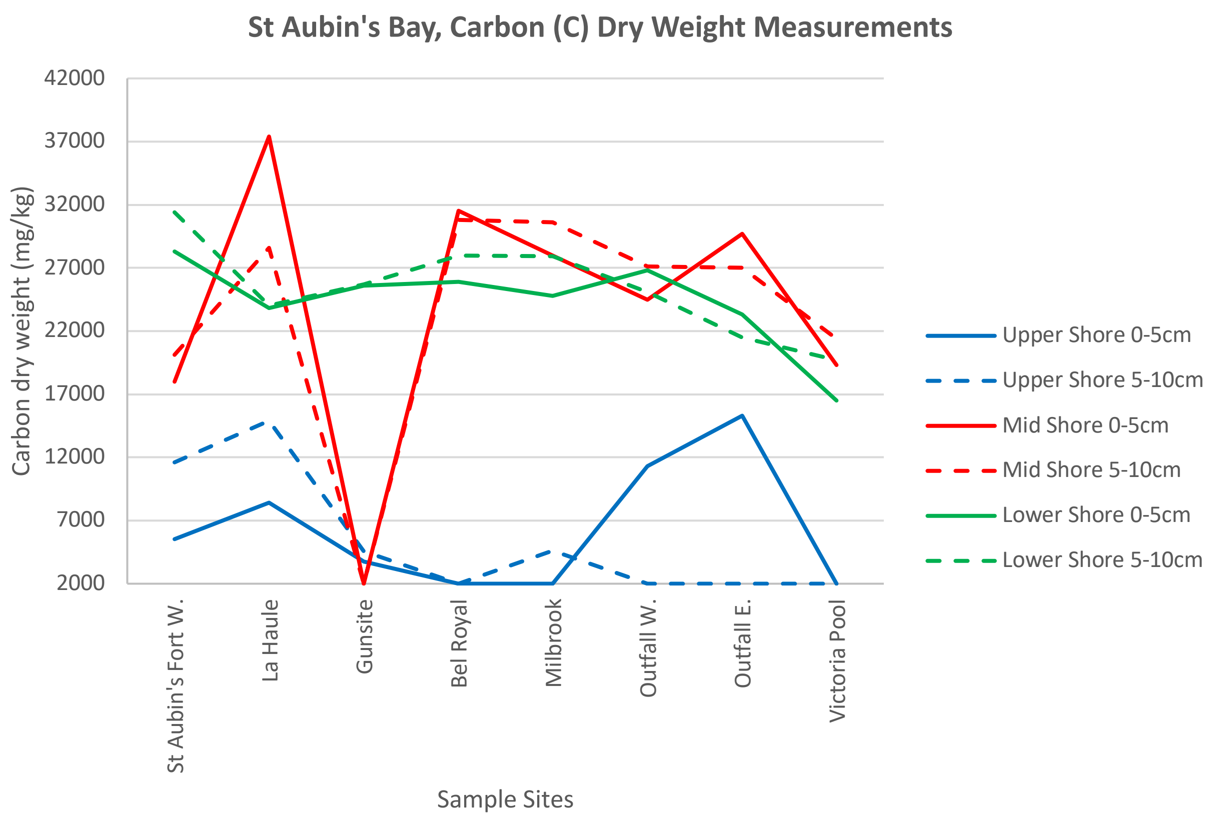


*Figure 10. Carbon line graph. Solid lines represent 0-5cm depths and dashed lines 5-10cm. The graph visualises changes to C from west to east across the Bay at the upper, mid and lower shores.*

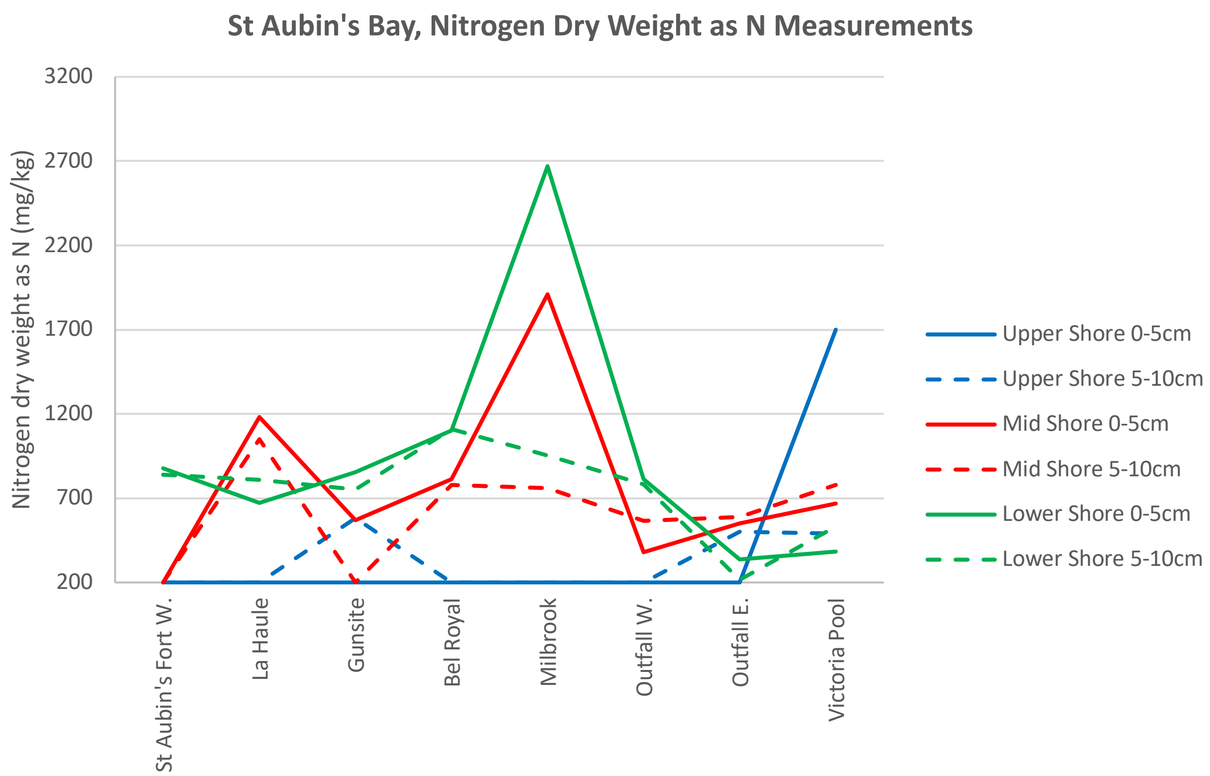


*Figure 11. Nitrogen line graph. Solid lines represent 0-5cm depths and dashed lines 5-10cm. The graph visualises changes to N from west to east across the Bay at the upper, mid and lower shores.*

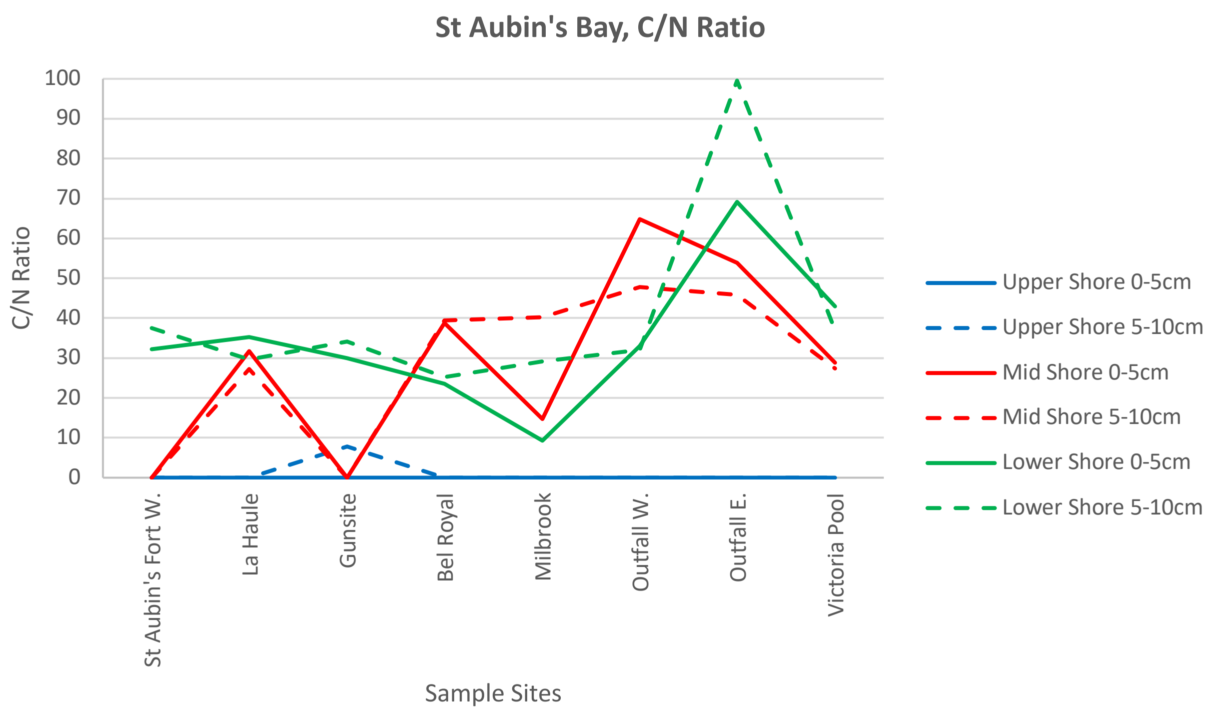


*Figure 12. C/N Ratio line graph. Solid lines represent 0-5cm depths and dashed lines 5-10cm. The graph visualises changes to the C/N Ratio from west to east across the Bay at the upper, mid and lower shores.*

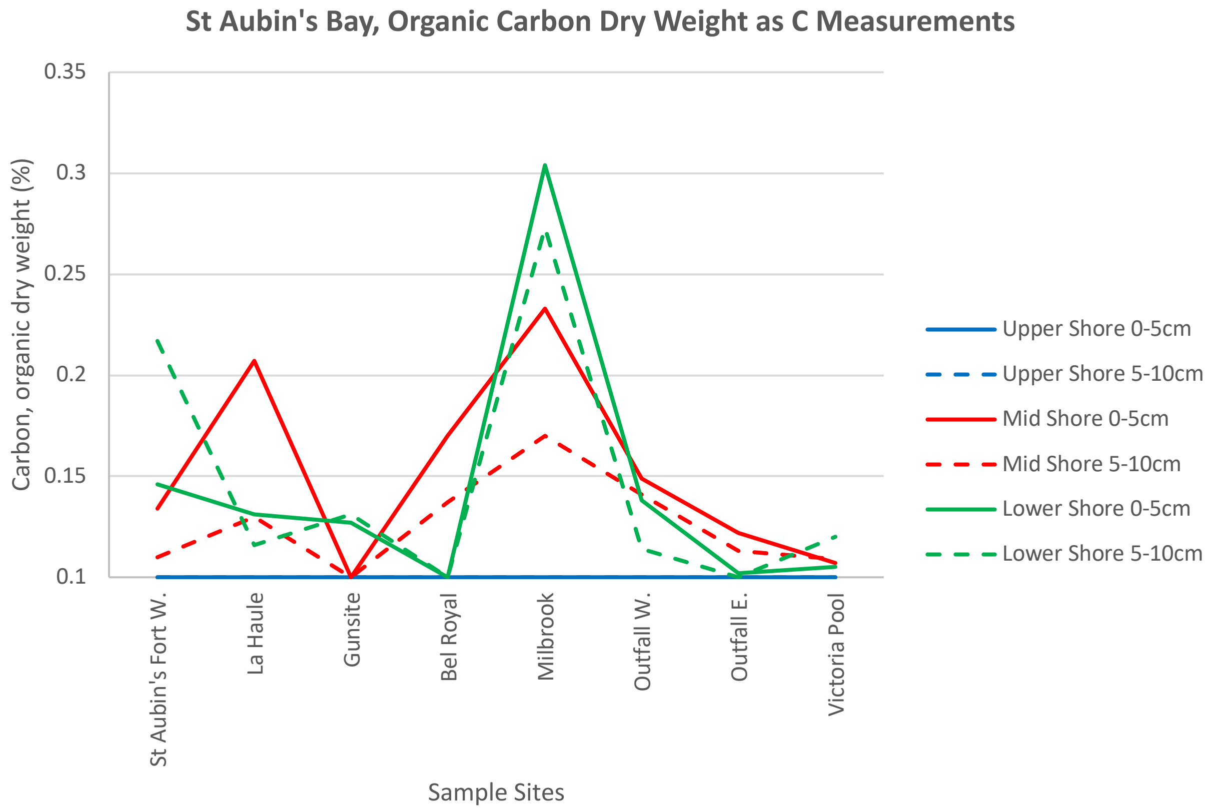


*Figure 13. Organic Carbon line graph. Solid lines represent 0-5cm depths and dashed lines 5-10cm. The graph visualises changes to Organic C from west to east across the Bay at the upper, mid and lower shores.*

## *4.0 Discussion*

### 4.1 Overview

*In situ* primary production in wave-exposed sandy beaches is very low and communities of consumers are primarily supported by organic material and nutrients imported from other systems (Dugan *et al*, 2011), with detritus derived from decaying seaweed, the faeces and remains of animals and terrigenous sources. In St Aubin's Bay, such external inputs include agricultural and waste water treatment run off, and seasonal accumulations of macroalgae deposits, predominantly *Ulva* sp..

In coastal marine ecosystems, intertidal sediments can play a major role in nearshore biogeochemical processes, particularly the decomposition of organic material and mineralization of nutrients (Dugan *et al*, 2011, Elliot *et al*, 1998). Areas of wave-exposed intertidal sands are generally characterised as being well oxygenated and having low levels of organic matter in the surface layers due to tidal pumping of the overlying seawater (Eagle, 1983), which serves to flush organic matter through the sand in the process of swash-water filtration (Mclachlan & Mcgwynne, 1986). Interstitial oxygenation is usually higher in coarser, unsorted, porous, permeable, and/or mobile sands, which in turn produces deeper anaerobic layers and higher biodegradation rates. Enabling more rapid mineralisation and cycling of nutrients back in to the water column (Mclachlan & Mcgwynne, 1986).

However, below the surface layer interstitial oxygenation may be poor, particularly where the sand is fine or unsorted and thus poorly drained or in cases of high concentrations of organic material such as decaying seaweed on the strand line (Hayward, 1994), which can lead to accumulation of nutrients within sediments.

Consequently, due to the potential for intertidal sands to rapidly cycle nutrients back in to the water column, where overall nutrient inputs in to the bay are known to be high, low nutrient concentrations at specific sample sites are not necessarily an indication of nutrient loads in that sample area. To draw further conclusions, additional analysis of particle sizes, sand permeability and anoxic depths of sediments would be required.

## 4.1 Ammoniacal Nitrogen

Nitrogen (N) is considered to be the principal limiting nutrient for algal growth in coastal water systems. Ammoniacal nitrogen is a component of N which can be adopted as an indicator to determine pollution by waste products, such as sewage, liquid manure and other liquid organic waste.

This study did not analysis nutrient loads in to the bay and therefore can't provide quantitative figures for N cycling or sedimentation. However, the low concentrations recorded at all 30 sample sites may be an indication of high N cycling and low N sink rates across all sampled areas of the bay.

## 4.2 Nitrite

Nitrite is an intermediate in the oxidation of ammonia to nitrate, which can be used as a source of nutrients for algae proliferation. High levels of ammoniacal nitrogen can lead to increased nitrite concentrations, and therefore high levels of nitrite may be an indirect indication of ammoniacal nitrogen pollution.

The nitrite concentrations in this study were below the minimum reporting value (MRV) of 0.1 mg/kg for the method of analysis at all sample sites. As with ammoniacal nitrogen, the low concentrations recorded at all 30 sample sites may therefore be an indication of high N cycling and low N sink rates across all sampled areas of the bay.

## 4.3 Total Oxidised Nitrogen

Total Oxidized Nitrogen (TON) is the sum of nitrite and nitrate. Nitrate is the measurement of the most oxidized and stable form of nitrogen and is the principle form of combined nitrogen found in natural waters, resulting from the complete oxidation of nitrogen compounds. Nitrate is the primary form of nitrogen used by algae as a nutrient to stimulate growth.

The TON concentrations in this study were again below the MRV of 3 mg/kg for the method of analysis at all sample sites. The low concentrations recorded at all 30 sample sites may therefore be an indication of high N cycling and low N sink rates across all sampled areas of the bay.

## 4.4 Orthophosphate

Phosphorus, along with N, is considered to be a limiting nutrient for algal growth. Orthophosphate (P), an inorganic phosphorous, is the most readily available form of phosphorous in seawater for uptake during photosynthesis, and high concentrations generally correlate with algal blooms. P forms are produced by natural processes, i.e. when plants die, or are eaten, the organic phosphorus is rapidly converted to orthophosphates through the action of phosphorylases within faecal material, phosphatases in plant cells, and finally by bacteria (Riley & Chester 1971), but major man-influenced sources also include partially treated and untreated sewage, and runoff from agricultural sites.

In a juxtaposition to the effects of oxygenation to the cycling of N in sediments, P is generally absorbed from pore water and accumulated in sediment in the aerobic layers and conversely desorbed from sediment particles to pore water when water is low in dissolved oxygen, i.e. in the anaerobic layers or in cases of high concentrations of decaying seaweed on the strand line. These processes allow P recycling in sediments, where the sediments act as a reservoir regulating phosphorous dynamics (Khalil & Rifaat, 2013).

Not unexpectedly therefore, unlike N the results of this study showed relatively high concentrations of P accumulation within the bay's sediments (P concentration in open seawater is generally c. 0.1 PPM, equivalent to 0.1 mg/kg, although significant variations occur especially in coastal waters (Riley & Chester, 1971)), which were in line with the above known desorption and absorption characteristics of P.

On the upper shore, although sediments are generally considered coarse and well oxygenated with deeper anaerobic layers, they can also be subject to high concentrations of decaying seaweed, especially *Ulva* sp. on the strandline during summer months. The mean concentrations of P for all sample points along the upper shore were the lowest of the three zones, with an average of 4.80 mg/kg (S.D. +/- 2.83, median 4.09 mg/kg) recorded at 0-5cm depths and 6.69 mg/kg (S.D. +/- 6.93, median 4.50 mg/kg) at 5-10cm depths. When compared to the mid-shore, where finer sand can reduce the potential for oxygenation of deeper sediments and raise anoxic depths, mean concentrations of P are distinctly higher than the upper shore. There is also a marked difference of mean concentrations between 0-5cm and 5-10cm samples suggesting a reduction of oxygenation levels. At depths of 0-5cm, the mean P concentration on the mid-shore was 16.73 mg/kg (S.D. +/- 7.31, median 17.65 mg/kg) compared to 9.14 mg/kg (S.D. +/- 4.85, median 8.39 mg/kg) at 5-10cm depths. On the lower shore, this pattern was repeated with mean concentrations of 14.21 mg/kg (S.D. +/- 3.28, median 13.10 mg/kg) at 0-5cm depths and 7.41 mg/kg (S.D. +/- 3.07, median 7.08 mg/kg) at 5-10cm depths. The total range of P was between 1.49 mg/kg, recorded at a depth of 0-5cm on the upper shore at La Haule Manor, and 32.80 mg/kg at a depth of 0-5cm for the mid-shore sample point east of Victoria Pool.

With regards to the results for P, it should be noted that some fraction of P may be strongly embedded in the mineral matrix of sediments, which can render that fraction relatively inert to biological utilisation. Fine sediment mineral matrices also have larger specific surface areas than coarser sediment particles that increases their potential for accumulating P. For this reason, some measures of P may include components that are not biologically available.

## 4.5 C/N Ratio

The ratio for total element of carbon and total nitrogen, stated as C/N, has been largely used as a proxy to explain the source of organic matter in aquatic environments, and it enables the differentiation of pollutant origins held within sediment organic matter (Nasir *et al*, 2017). The C/N ratio for marine algae is typically between 4 and 10, organic matter of soil is c.8–20, and a ratio bigger than 20 is generally for organic matter from terrigenous sources (Meyers, 1994).

When looking at the results for carbon and nitrogen dry weights, and in turn the C/N ratio, concentrations of C and N on the upper shore are generally very low, with one or both measurements being below the MRV in all but one case. Where values were reported for both C and N (at the Gunsite), the C/N ratio was 7.82, suggesting a marine source of organic matter within the sediments at that site.

When moving down to the mid and lower shores, concentrations of C and N increase, with mean and median values that are reasonably comparable with each other at both stages of the beach, despite high standard deviations between sample sites. The mid shore mean C/N ratios were 35.64 (S.D. +/- 20.44, median 30.90) and 36.80 (S.D. +/- 15.86, median 39.49), at depths of 0-5cm and 5-10cm respectively, ranging between 12.61 and 67.56 across both depths. The lower shore mean ratios were 34.44 (S.D. +/- 17.14, median 32.62) and 40.53 (S.D. +/- 24.20, median 33.10) at 0-5cm and 5-10cm depths respectively, ranging between 9.29 and 99.54 across all depths. Suggesting a general increase in the influence of terrigenous sources of organic matter below the upper inter-tidal zone (and/or a difference in the biogeochemical characteristics between zones).

When looking at the line graph representation of C/N values moving west to east across the bay, for complete transects taken, there also appears to be a spike in C/N ratios from samples taken at the mid and lower shores sites either side of the Bellozanne outfall pipe.

## 4.6 Organic Carbon

Organic carbon as a percentage of total carbon can be an indicator of organic matter inputs (both marine and terrestrial) and C cycling rates, i.e. the re-mineralisation of organic carbon to accessible inorganic forms, in coastal sediments.

As with N, this study recorded very low rates of organic carbon within the bay's sediments. 28 sites had values below the MRV of 0.1%, which included all samples taken from the upper shore. Above 0.1%, the highest percentage of organic matter recorded was 0.304% from the Milbrook lower shore, 0-5cm core. The mean value across all reported sites was 0.15% (S.D. +/- 0.05, median 0.14%), indicating high organic carbon cycling across all sampled areas of the bay.

## 4.7 Conclusion

The results of this study showed relatively low levels of N (and organic carbon) held within the sands of St Aubin's Bay, despite high nutrient inputs in to the adjacent water column and large accumulations of seaweed deposited along the strandline during summer months.

The core samples taken for analysis in this study were extracted between the months of November and December, at the end of the seasonal occurrence of *Ulva* accumulations in the year. The low nutrient values subsequently reported are a strong indication of the intertidal sand's potential to rapidly break down and cycle nutrients back in to pore water and the adjacent water column. Consequently, the re-mineralisation processes in these benthic sediments may be an important source of nutrient release that could provide a significant amount of dissolved N at critical times for sustaining productivity for algal growth over a single season (Dugan *et al*, 2011).

However, high nutrient cycling rates conversely means that N is only stored within intertidal sediments for short periods of time. It should therefore follow that if external N inputs and levels of N in to the adjacent water column were reduced, the amount and impact of N released from benthic sediments through mineralisation would also reduce over the short term.

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