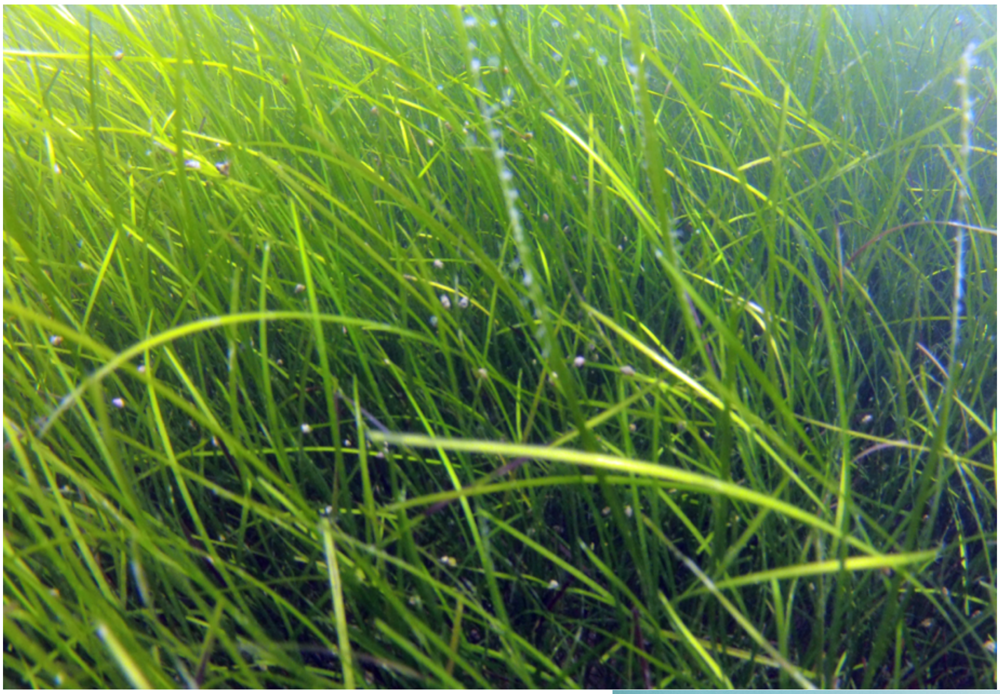
JBIM002 Fieldwork Statistics and Experimental Design

Influences of Environmental Exposure and Disturbance On Above- and Below-Ground Biomass in Jersey Seagrass Meadows



Zostera noltei (WikiSpecies, 2025)

Zostera marina (Credit: Ben Jones, Ocean image bank, 2025)

Date: 14/01/2026

ID: 760000588

Template for student declarations in AI-supported and AI-integrated assessments

From September 2024, all assessments that come under the category of AI-supported and AI-integrated will be required to include a student declaration acknowledging their use of GenAI in their assessment. **This will be included as an additional page at the front of the assessment, following this template (which should be included in the assessment brief):**

When submitting your assessment, you must include the following declaration, ticking all that apply:

AI-supported/AI-integrated use is permitted in this assessment. I acknowledge the following uses of GenAI tools in this assessment:

☐ *I have used GenAI tools for brainstorming ideas.*

☒ *I have used GenAI tools to assist with research or gathering information.*

☒ *I have used GenAI tools to help me understand key theories and concepts.*

☐ *I have used GenAI tools to identify trends and themes as part of my data analysis.*

☐ *I have used GenAI tools to suggest a plan or structure for my assessment.*

☒ *I have used GenAI tools to give me feedback on a draft.*

☐ *I have used GenAI tool to generate image, figures or diagrams.*

☐ *I have used GenAI tools to proofread and correct grammar or spelling errors.*

☐ *I have used GenAI tools to generate citations or references.*

☐ *Other [please specificy]*

I have not used any GenAI tools in preparing this assessment.

I declare that I have referenced use of GenAI outputs within my assessment in line with the University referencing guidelines.

Please note that submitting your work without an accompanying declaration, or one with no ticked boxes, will be considered a declaration that you have <u>not</u> used GenAI tools in preparing your work.

Abstract

Seagrasses are vital ecosystems that provide a wide range of ecosystem services, including biodiversity support, coastal protection and carbon sequestration, yet they are rapidly declining worldwide. Therefore, understanding how environmental conditions and recreational disturbance influence seagrass biomass allocation is critical for effective conservation and blue carbon assessment. This study compares above-ground biomass (AGB) and below-ground biomass (BGB) of seagrass meadows at two contrasting sites on the East coast of Jersey. St Catherine's Bay is highly sheltered by a breakwater and subject to high recreational activity, whereas Anne Port is more exposed and experiences less recreational activity. The three hypotheses used are:

H1: There is no difference in AGB between the two sites

H2: There is no difference in the BGB between the two sites

H3: There is no correlation between above- and below-ground biomass within sites.

Sampling occurred in summer (2021 and 2022) using standardised quadrat-based methods, and the differences between and within sites were analysed using non-parametric statistical tests. Results showed significantly higher AGB at St Catherine's, whilst BGB was not significantly different between the two sites. Both sites showed a positive correlation between AGB and BGB, although the strength of the relationships differed, with tighter coupling at Anne Port.

Higher AGB at St Catherine's was likely driven by stable, favourable environmental conditions that promote canopy health, where higher turbidity, wave exposure and sedimentation at Anne Port promote BGB investment. The differences in AGB-BGB coupling reflect the influence of recreational disturbance, particularly anchoring and mooring at St Catherine's Bay.

These findings demonstrate the plasticity of *Zostera* species and highlight how local environment shapes seagrass function and ecosystem service delivery. The relationship between AGB and BGB could be used as a non-invasive proxy for BGB, improving long-term monitoring and assessment of Jersey's blue carbon stocks, and minimising habitat disturbance.

Introduction

Seagrasses are the only marine monocotyledonous Angiosperms (flowering plants) and are found in intertidal and shallow subtidal habitats across temperate and tropical seas globally (Bujang *et al.*, 2006). Although they occupy a relatively small proportion of the global ocean floor, seagrasses provide many critical ecosystem services that both directly and indirectly benefit humans. These services include support of marine biodiversity, sediment stabilisation, nutrient cycling and climate regulation (Gomis *et al.*, 2025; Nordlund *et al.*, 2018). Despite their importance, seagrass meadows are declining globally at an estimated rate of 7% per year (Nordlund *et al.*, 2018), threatening the economic, ecological and social services they provide (Gomis *et al.*, 2025). Given the global decline, unravelling which stress factors drive changes is key to developing conservation and management strategies (Vieira *et al.*, 2020).

On a local scale, seagrass has a long historical presence in Jersey, being first recorded in 1887 as *Zostera augustifolia* (syn. *Z. Marina*) (Dunn, 2024; Marlin, 2025a). Jersey supports intertidal and subtidal seagrass meadows composed of *Zostera noltei* (dwarf eelgrass) and *Zostera marina* (common eelgrass), both of which are considered opportunistic with rapid growth and turnover rates (Dunn, 2024; Marlin, 2025a,b). While these traits allow rapid recovery following disturbance, they increase the vulnerability of these species to repeated or chronic disturbances when compared to slower-growing, longer-lived seagrasses such as *Posidonia* spp. (Unsworth *et al.*, 2017; Gomis *et al.*, 2025).

Seagrasses allocate biomass into two main compartments: above-ground biomass (AGB), including blades, leaves and sheaths, and below-ground biomass (BGB), comprising roots and rhizomes, each of which serves different functions (Bujang *et al.*, 2006). Seagrasses are habitat-building species that create structurally complex ecosystems, with higher AGB supporting increased marine biodiversity (Blampied *et al.*, 2022). Higher AGB has been linked to greater species richness and abundance, with some seagrass meadows functioning as important nursery habitats for commercially valuable fish and shellfish species, illustrating their role as keystone species (Katwijk *et al.*, 2021; Blampied *et al.*, 2022). Understanding spatial differences in AGB is therefore important for identifying areas of high biodiversity and commercial value and for informing conservation priorities.

Seagrass AGB exhibits some of the highest net primary productivity of any marine ecosystem, fixing carbon via photosynthesis at rates comparable to terrestrial rainforests and storing it in their tissues and the surrounding sediment (Gomis *et al.*, 2025; Dunn, 2024). This capacity has positioned seagrasses as key components of the blue carbon framework, which emphasises the role of coastal vegetated ecosystems in climate change mitigation (Gomis *et al.*, 2025). However, much of the blue carbon literature has focused on sediment carbon stocks, overlooking the carbon stored directly within seagrass biomass (Gomis *et al.*, 2025). Understanding patterns of biomass allocation between AGB and BGB is therefore important, as AGB is characterised by rapid turnover and short carbon residence time, whereas BGB contributes disproportionately to long-term sedimentary carbon storage and ecosystem stability (Marlin, 2025b). Sea level rise in Jersey results in a constant accumulation of sediment, which may increase sediment burial and enhance long-term carbon storage where seagrass meadows remain intact (Chambers *et al.*, 2022).

Seagrasses BGB also plays a key role in mitigating the impacts of anthropogenic climate change by stabilising sediments, while the above-ground canopy attenuates wave energy and reduces erosion, enhancing shoreline stability (Dunn, 2024; Forrester *et al.*, 2024). This is especially important for islands, which are disproportionately vulnerable to sea-level rise, increased storm intensity and associated increased wave exposure (Veron *et al.*, 2019). Quantifying the AGB and BGB in local seagrass meadows, therefore, provides valuable insights into the coastal protection services they provide and can inform coastal protection and management plans.

Seagrass biomass, productivity, and distribution are shaped by a range of environmental factors, including temperature, irradiance, water depth, hydrodynamic exposure, and sediment characteristics (Gomis *et al.*, 2025). Interactions between these and seagrass life-strategies influence biomass allocation patterns, turnover rates, and ecological functioning (Gomis *et al.*, 2025). These patterns can also be influenced by anthropogenic factors. Agricultural runoff increases nitrogen and phosphorus to the ecosystem, causing eutrophication, algal blooms and smothering of the seagrass bed (Vieira *et al.*, 2020), while physical disturbance like anchors and block-and-chain moorings can scour sediments, remove AGB and create bare scars within meadows (Chambers et al, 2022; Dunn, 2024). Such disturbances can reduce ecosystem service provision and meadow resilience (Dunn, 2024).

Despite its ecological importance, current methods of quantifying BGB are invasive and destructive, requiring physical removal of seagrass from the sediment (Paling and McComb, 2000). Developing alternative approaches to assess BGB is therefore important for improving long-term monitoring and blue carbon assessments while minimising disturbance.

This study focuses on how environmental conditions and disturbances influence seagrass biomass patterns by comparing two sites on the East Coast of Jersey. St Catherine's Bay is highly sheltered by a long breakwater and subject to long-term recreational and mooring pressure (Dunn, 2024), whereas Anne Port is less sheltered and thus subject to more diverse environmental conditions but experiences less recreational disturbance (Dunn, 2024). This report aims to assess the differences between AGB and BGB between the two sites, and to evaluate the relationship between AGB and BGB using three hypotheses:

H1: There is no difference in AGB between the two sites

H2: There is no difference in the BGB between the two sites

H3: There is no correlation between above- and below-ground biomass within sites

Methods

Study organism

The study sites are all comprised of the opportunistic temperate seagrass species *Zostera noltei* (Dwarf eelgrass) and *Zostera Marina* (Common eelgrass) (Dunn, 2024). Both these species exhibit rapid growth and high biomass turnover, resulting in temporally dynamic meadows (Wong, Bravo and Dowd, 2013). *Z. marina* is found in both intertidal and subtidal areas and has generally larger and thicker rhizomes and leaves (Marlin, 2025a). *Z. noltei* has shorter leaves with thinner rhizomes and tends to be found in intertidal zones due to high light level toleration, although it also occurs in subtidal areas (Marlin, 2025b). Both species reproduce sexually and vegetatively; however, vegetative propagation is primarily responsible for maintaining the meadow (Marlin, 2025a,b). Growth and biomass peak in summer for both species, corresponding with the sampling period of this study for both years (Marlin, 2025a,b). Although *Z. marina* usually prefers sheltered enclosed areas with low tidal ranges, its persistence in Jersey indicates tolerance of higher tidal ranges where suitable local shelter and sediment conditions occur (Marlin, 2025a; Blampied *et al.*, 2022).

Study area

Both sites are located on the East coast of Jersey (Figure 1), comprising intertidal and subtidal areas, and are protected within Jersey's south-east No Mobile Gear Zone (NMGZ) (Dunn, 2024). Jersey experiences a very large tidal range (up to 12.2m), creating a vast intertidal area, causing extensive intertidal exposure and strong tidal currents that influence seagrass distribution and disturbance regimes (Blampied *et al.*, 2022). For this analysis, Anne Port and

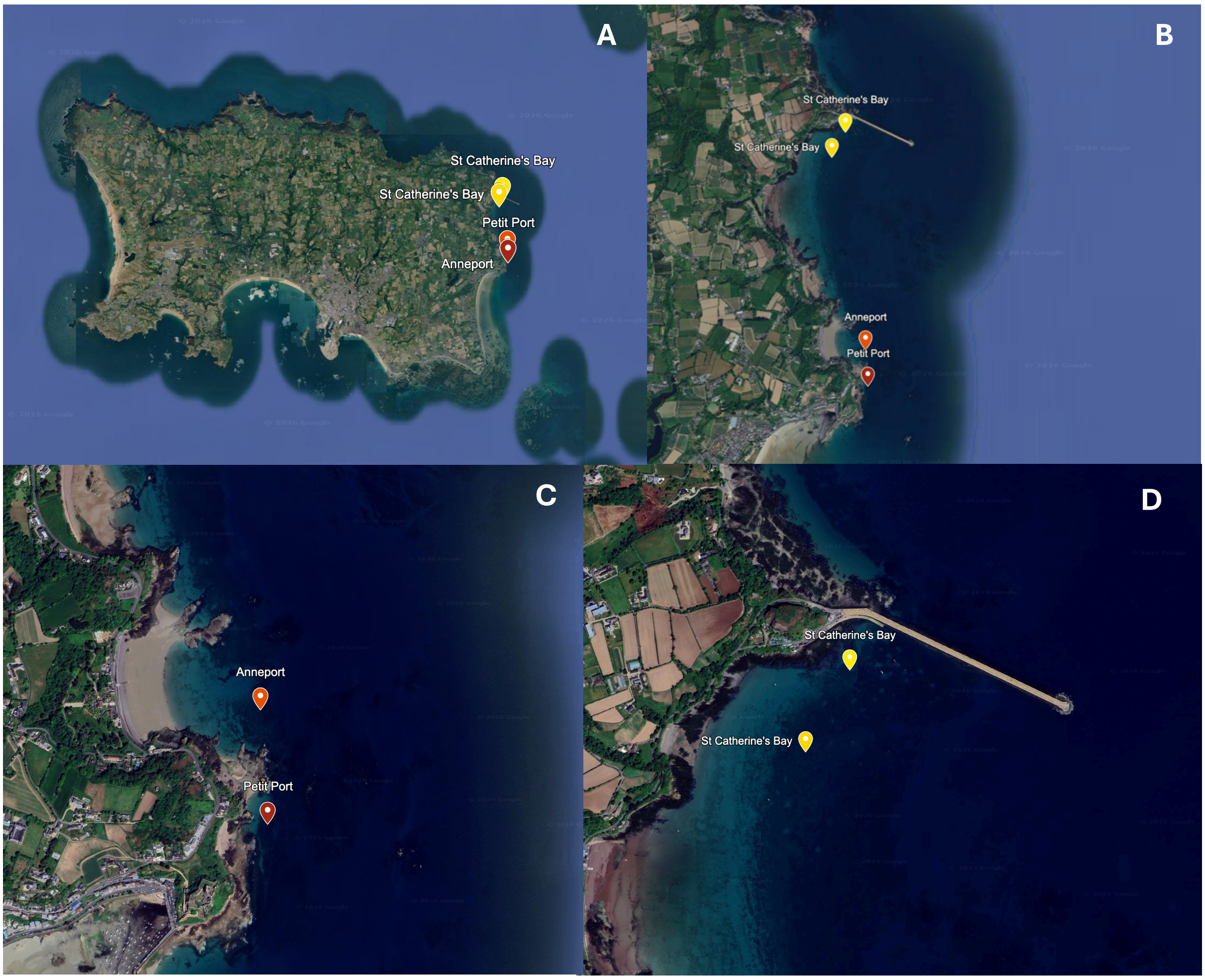


Figure 1: Shows the locations of the sampling sites used for this study. A shows sample sites in relation to Jersey, B shows sample sites in relation to each other, C shows Anne Port and Petit Port, which are combined into one site for this analysis, and D shows the two sites sampled at St Catherine's. The long breakwater (protruding feature) is evident in image D. Coordinates in Appendix 1.

Petit Port have been combined into a single dataset referred to as Anne Port, as they are in very close proximity, experience very similar environmental conditions (Dunn, 2024), and this allows for a more complete dataset for comparison.

St Catherine's Bay is commonly used recreationally for activities including dinghy sailing, swimming, snorkelling and kayaking, and is also a popular mooring site for leisure boats (Dunn, 2024). The bay is protected by a 700 m long breakwater erected in 1856 (Dunn, 2024), making it the most sheltered seagrass site in Jersey, with a Relative Exposure Index (REI) of 4.88×10^6 (Dunn, 2024). Permanent block-and-chain moorings and boat anchoring have created visible bare scars within the meadow, averaging 95 m^2 in area and reaching up to 350 m^2 in some cases, resulting in damage to approximately 6,000 m^2 of seagrass within St Catherine's Bay (Dunn, 2024).

Monitoring of the site indicates changes in seagrass coverage (including placement and size of mooring scars) at St Catherine's Bay with a decline of approximately one third between 1993 and 1997, followed by a 34% recovery (Dunn, 2024). A further smaller decline of 4.2% occurred in 2020, with a recovery of 3.8% by 2021, which corresponds to the first year of sampling used in this study.

There is less information available for Anne Port; however, the presence of an invasive red algae, *Gracilaria vermiculophylla,* is noted, and it may receive minimal indirect shelter from St Catherine's breakwater (Dunn, 2024).

Data Collection

At each of the three sites, a 30 metre transect was deployed during SCUBA collection dives. Along each transect, a 0.5 m^2 quadrat was placed at ten pre-determined random intervals. Two transects were repeated at each site. For each quadrat, the blades were pulled through and the roots excavated, keeping as much root matter as possible, and samples were placed into labelled bags. Complete removal of roots from sediment during sampling cannot be guaranteed, and thus, BGB estimates may be conservative. Post-collection samples were washed to remove any remaining sediment. AGB (blades) and BGB (roots) were placed into separate bags. The samples were dried at approximately 80 degrees Celsius in a drying oven to obtain a constant weight, then weighed to get a dry biomass (g).

These methods follow the standard stratified sampling and biomass measurement collection procedures outlined in Duarte and Kirkman (2001), although a higher temperature is used to dry the samples.

Sampling was conducted on six occasions during the summers of 2021 and 2022 (Appendix 2).

Statistical analysis

Statistical analysis was carried out in R (version 4.5.2) using tidyverse through R Studio (Wickham *et al.* 2019; R Core Team, 2024). Data were cleaned to remove missing and non-informative variables (e.g. sample bag number). Age classes were similarly represented across both sites and were not included as a factor in the analysis. Normality of AGB and BGB was assessed using Shapiro-Wilk tests, which showed significant deviation from normal distribution ($p < 0.001$). An attempted log transformation did not achieve normality; therefore, the data were analysed using raw values and non-parametric tests were employed as the assumptions of normality were not met.

Mann-Whitney U tests were used to test for differences in AGB (H1) and BGB (H2) between the two sites. The relationship between AGB and BGB at each site (H3) was assessed using a Spearman's rho correlation.

Results

A total of 85 samples remained after cleaning.

The Man-Whitney U results showed that there was a strongly significant difference ($W = 419$, $p<0.001$) in AGB between St Catherine's (median = 18.2g) and Anne Port (median = 8.18g),

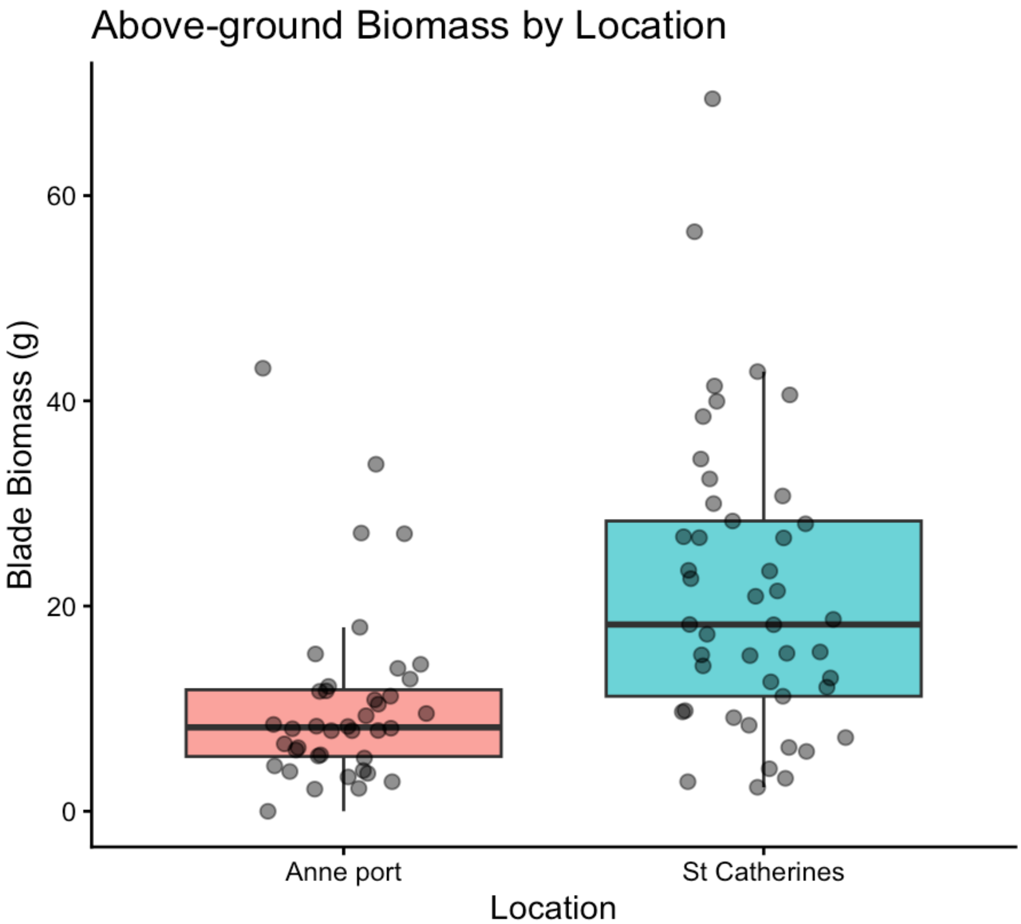


Figure 2: Illustrates the difference in above-ground biomass between St Catherine's and Anne Port, showing the medians, interquartile ranges and the raw data points. St Catherine's shows a significantly higher (p=2.331e-05) above-ground biomass than Anne Port, as well as a much larger range of dry weights. Although some points appear anomalous and may have caused a slight positive skew, they follow the general pattern of the rest of the data and are unlikely to affect significance due to the extremely low p-value.

with higher AGB observed at St Catherine's, as shown in Figure 2.

Contrastingly, there was no significant difference in BGB between St Catherine's (median = 6.28g) and Anne Port (median = 6.84g) (W 863.5, p = 0.751), as illustrated in Figure 3. The median AGB was substantially higher than the median BGB at St Catherine's, whereas AGB and BGB medians were similar at Anne Port (Figures 2 and 3).

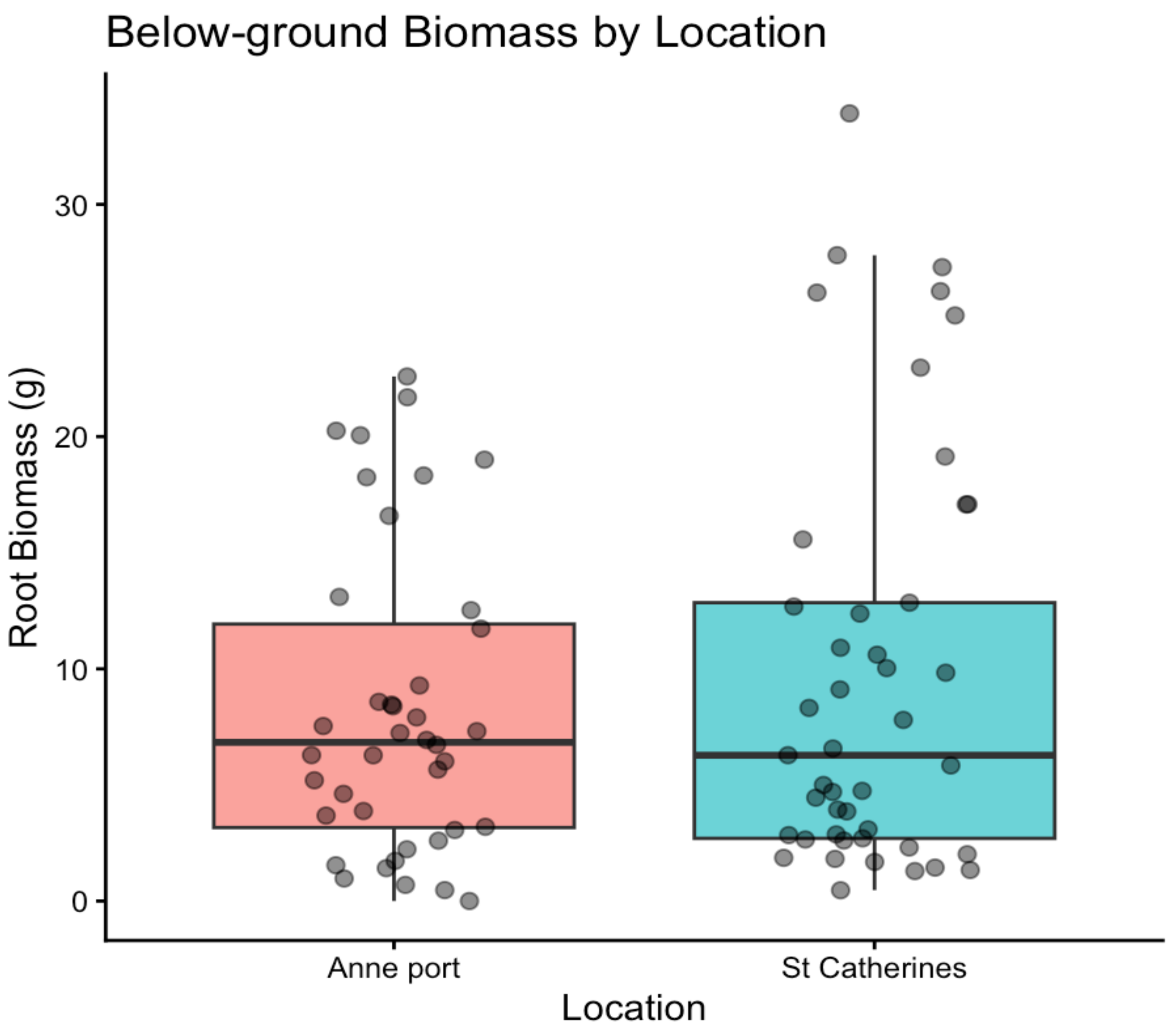


Figure 3: Shows the dry weights of below-ground biomass between St Catherine's and Anne Port, which do not show a significant difference (p=0.751). The medians are represented by the horizontal black line, and the interquartile range is represented by the vertical black lines, while the black dots represent raw data points.

Spearman's rho tests showed highly significant positive correlations between the ABG and BGB at each site (St Catherine's, $p < 0.001$ and Anne Port, $p < 0.001$). However, Anne Port exhibited a much stronger positive correlation between AGB and BGB ($\rho = 0.74$) than St Catherine's ($\rho = 0.55$), evidenced by the closer grouping of Anne Port data points around the line of best fit in Figure 4 compared with the more dispersed pattern shown for St Catherine's.

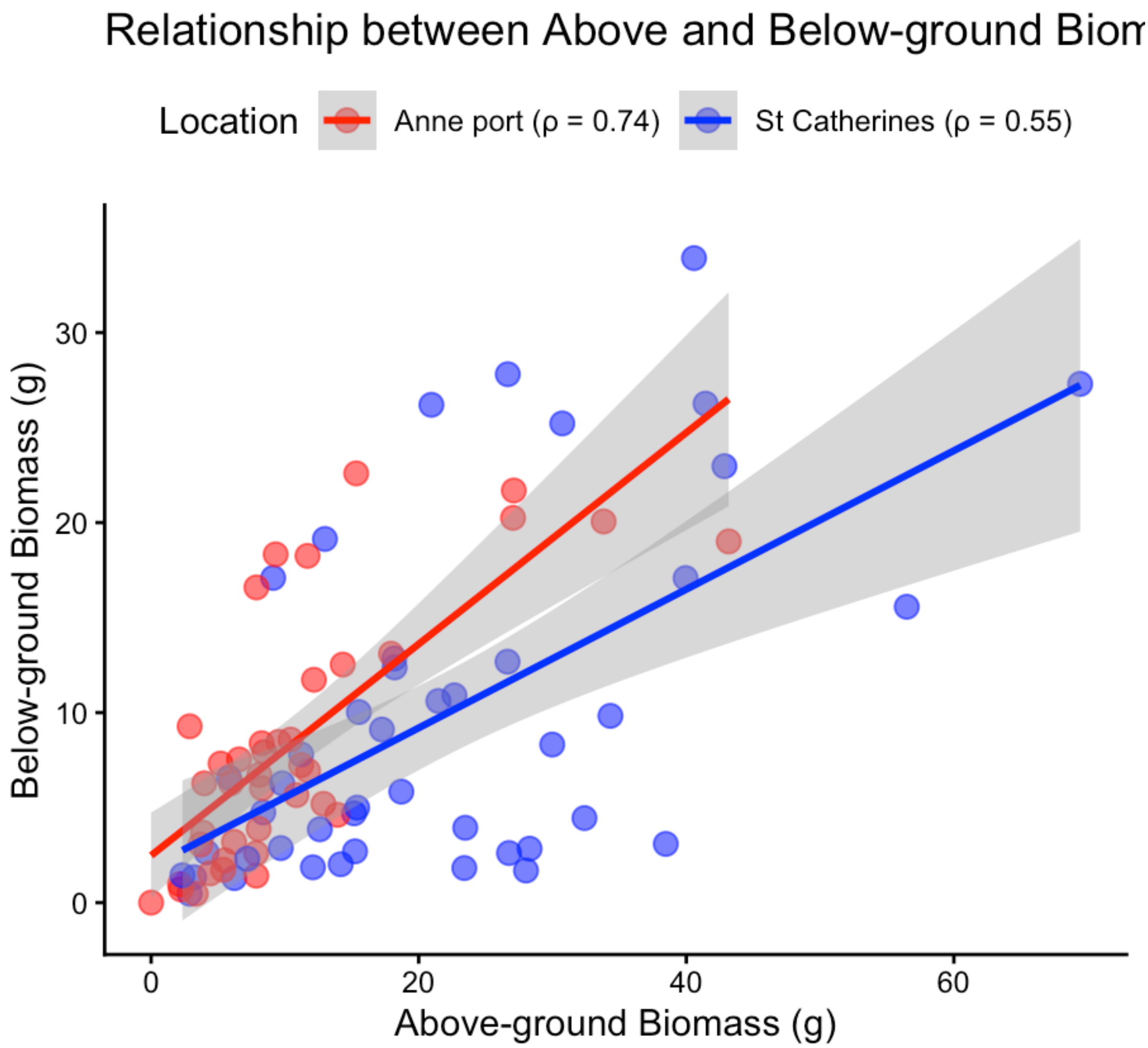


Figure 2: Shows the positive correlation between the AGB and BGB of seagrass at both sites. Anne Port (red) exhibited a strong correlation ($\rho = 0.74$, $p < 0.001$) with points clustering tightly around the regression line, while St Catherine's (blue) showed a moderate correlation ($\rho = 0.55$,

$p < 0.001$) with greater scattering of points. The grey areas present 95% confidence intervals around each regression line, where St Catherine's is wider due to the more scattered points.

Discussion

Above-ground biomass (AGB)

The differences between the AGB at the two sites are likely due to environmental factors and recreational activity levels and H1 is rejected as AGB differed significantly between sites. As both sites are of comparable age and were sampled in the summer of both years, the observed differences in AGB reflect the high plasticity of *Zostera* spp. to recent environmental conditions rather than seasonal or successional effects (Ondiviela *et al.*, 2013; Gomis *et al.*, 2025). The St Catherine's Bay breakwater (Figure 1) provides shelter for the seagrass bed, shielding it from wave action, currents and swell, hence its low REI and high AGB (Dunn, 2024) as seagrass is known to grow better in low-exposure environments, as increased wave energy and current velocity can scour sediment and uproot plants (Marbà *et al.*, 2004; Wicks *et al.*, 2009). However, breakwaters can increase sediment scour and deposition following large storms, which are becoming increasingly frequent under climate change conditions and may smother seagrass (Forrester et al 2024; Vieira *et al.*, 2020), although the high AGB at St Catherine's suggests this effect may not be limiting biomass at this site.

St Catherine's Bay is bordered by agricultural land (AECOM 2020), which may contribute to nutrient input through runoff. While it is widely reported in the literature that eutrophication causes algal blooms, which can smother seagrass, moderate anthropogenic nutrient inputs have been shown to enhance growth and health in *Zostera* spp. (Vieira *et al.*, 2020; Vasco *et al.*, 2022), potentially contributing to the significantly higher AGB at St Catherine's.

In contrast, the greater wave exposure and current velocity present at Anne Port, likely constrain seagrass canopy development, due to its lack of artificial shelter (Marbà *et al.*, 2004; Wicks *et al.*, 2009; Dunn, 2024). The soft geology above Anne Port also increases erosional risk (AECOM, 2020). This likely increases turbidity and sedimentation, which reduce light availability and negatively affect seagrass AGB creating a feedback loop where less AGB increased erosion which decreases AGB (Vieira *et al.*, 2020, Wicks *et al.*, 2009). Additionally, the presence of the invasive red algae *G. vermiculophylla* at Anne Port (Dunn, 2024) may further impact AGB. While low abundances of this algae can reduce desiccation stress, higher abundances can reduce light availability, compete for nutrients and impair gas exchange in *Z. noltei* beds (Vieira *et al.*, 2020). As *G. vermiculophylla* only arrived in Jersey in 2014, its impacts remain poorly quantified; therefore, it is not yet possible to confirm a direct negative effect at Anne Port (Department of the Environment, 2017). Nevertheless, existing evidence shows its negative effects are likely to be amplified when combined with sediment burial, which is already present at this site (Vieira *et al.*, 2020).

The higher recreational pressure at St Catherine's Bay from boating and bay use (Dunn, 2024) would be expected to reduce AGB through fragmentation and canopy damage, reducing biodiversity capacity (Jackson *et al.*, 2006), but this was not observed. This suggests that physical shelter and stable, favourable environmental conditions outweigh recreational disturbance in determining AGB differences between sites.

Overall, the combination of higher physical exposure, increased sedimentation and invasive macroalgae at Anne Port likely explains its significantly lower AGB compared to St Catherine's Bay.

Below-ground biomass (BGB)

In contrast to AGB, BGB does not show significant difference between the two sites, despite differences in AGB and environmental conditions, thus H2 is accepted. This indicates that seagrass at St Catherine's allocates proportionally more resources to AGB relative to BGB, whereas Anne Port exhibits a higher relative investment in BGB. However, interpretation of BGB patterns should be cautious, given the inherent difficulty of extracting below-ground material from sediments; therefore, BGB values may be conservative.

El-Hacen *et al.* (2019) demonstrated that as relative wave energy increased, BGB: AGB ratios also increased, indicating a greater investment in anchorage and sediment stabilisation under stressful conditions. This pattern is consistent with Anne Port, where seagrass requires stronger below-ground structures to resist erosion and uprooting (El-Hacen *et al.*, 2019). Higher BGB and thus carbohydrate stores at Anne Port enable more resilience to stressors like light-limited conditions caused by wave exposure and turbidity, enhancing their nutrient uptake and reserves and allowing the bed to 'resist' mortality (Collier *et al.*, 2021; Wicks *et al.*, 2009).

Conversely, seagrass meadows in more stable, sheltered environments allocate proportionally more resources to AGB as reliance on below-ground carbohydrate reserves is reduced when photosynthetic conditions are consistently favourable (Collier *et al.*, 2021). This supports the higher AGB allocation observed at St Catherine's, as the sheltering breakwater provides environmental stability, promoting canopy development.

Overall, the difference in environmental stability has altered the allocation of biomass at the two different sites, showing they have similar BGB despite their significantly different AGB.

Relationship between AGB and BGB

Both sites show significant positive correlations between their AGB and BGB, indicating functional coupling between biomass compartments, although this relationship cannot be interpreted as causal. This coupling is expected in this opportunistic *Zostera* species, where photosynthetically fixed carbon in leaves is translocated to rhizomes and roots for storage, clonal growth and resilience (Di Carlo and Kenworthy, 2008). Therefore, H3 was rejected, as a significant correlation between AGB and BGB was present at both sites.

Anne Port showed a stronger AGB to BGB correlation, suggesting tighter coordination between canopy production and below-ground investment under physically stressful conditions. In contrast, the weaker but still significant positive correlation at St Catherine's indicates greater variability in allocation patterns. This reduced coupling is consistent with recreational disturbance, as anchoring and mooring remove AGB whilst leaving BGB intact, fragmenting the canopy and decoupling above-and below-ground biomass at fine spatial scales (Di Carlo and Kenworthy, 2008; Unsworth *et al.*, 2017). From mooring and anchoring, 6,000 m^2 of seagrass (and subsequently 2,800kg of stored carbon) have already been lost from St Catherine's Bay (Dunn, 2024), explaining the lower AGB-BGB coupling at this site.

Overall, significant AGB-BGB coupling is present at each site, with slightly different tightness of coupling, illustrating the impacts of anthropogenic fragmentation on seagrass beds.

Broader relevance

These results have wider relevance for seagrass conservation and monitoring in Jersey. Firstly, the significant AGB-BGB coupling across differing environments suggests AGB could be used as a proxy for BGB, enabling non-invasive assessment (Collier *et al.*, 2021). This could be valuable for the long-term monitoring of Jersey's seagrass beds, replacing destructive methods that can cause cumulative damage (Paling and McComb, 2000) with aerial imagery. Although further research is required to implement this approach. This would allow increased monitoring whilst minimising disturbance to important habitats (Gomis *et al.*, 2025; Unsworth *et al.*, 2017)

These results also highlight functional differences between the two sites, with St Catherine's representing a more productivity-oriented meadow and Anne Port a more resilience-oriented system. Sheltered sites, such as St Catherine's, have higher AGB, thereby supporting higher commercially important biodiversity (including nursery habitats) and carbon accumulation through increased overall biomass (Dunn, 2024; Blampied *et al.*, 2022; Chambers *et al.*, 2022). Whereas Anne Port may prioritise structural stability, providing coastal protection (Forrester *et al.*, 2024). These findings emphasise the need for site-specific management, as some seagrass meadows contribute disproportionately to ecosystem services. Targeted protection measures, such as the increased implementation of seagrass-friendly moorings and public engagement initiatives (which are globally neglected (Nordlund *et al.*, 2018)), should be implemented at St Catherine's to further the effective conservation of this site.

Conclusions

In conclusion, the differences in AGB and BGB between the two sites in Jersey are likely driven by a combination of environmental conditions and recreational pressures that influence biomass allocation. These differences influence the ecosystem services each site provides, indicating that whilst both are ecologically important, St Catherine's supports higher productivity and a greater capacity for service provision and thus should be prioritised for targeted conservation and management. The significant correlation between AGB and BGB could enable the inference of BGB via non-invasive AGB measurements, enabling cheaper, less destructive, long-term monitoring of BGB and consequently of Jersey's blue carbon stocks.

References

AECOM (2020) Jersey Shoreline Management Plan. Revised Final, January 2020. Jersey: Government of Jersey.

Blampied, S.R., Sheehan, E.V., Binney, F.C.T., Attrill, M.J. and Rees, S.E. (2022) Value of coastal habitats to commercial fisheries in Jersey, English Channel, and the role of marine protected areas. Fisheries Management and Ecology, [online] 29(5), pp.734–744. doi:https://doi.org/10.1111/fme.12571.

Bujang, J.S., Zakaria, M.H. and Arshad, A. (2006) Distribution and significance of seagrass ecosystems in Malaysia. Aquatic Ecosystem Health & Management, 9(2), pp. 1–14. https://doi.org/10.1080/14634980600705576

Chambers, P.M., Blampied, S., Binney, F., Austin, W.E.N., Morel, G. (2022) Blue carbon resources: an assessment of Jersey's territorial seas. Government of Jersey

Collier, C.J., Langlois, L.M., McMahon, K.M., Udy, J., Rasheed, M., Lawrence, E., Carter, A.B., Fraser, M.W. and McKenzie, L.J. (2021) What lies beneath: Predicting seagrass below-ground biomass from above-ground biomass, environmental conditions and seagrass community composition. Ecological Indicators, 121, 107156. https://doi.org/10.1016/j.ecolind.2020.107156

Department of the Environment (2017) Non-native marine species in the Channel Islands: a review and assessment. Jersey: States of Jersey

Di Carlo, G. and Kenworthy, W.J. (2008). Evaluation of aboveground and belowground biomass recovery in physically disturbed seagrass beds. Oecologia, [online] 158(2), pp.285–298. doi:https://doi.org/10.1007/s00442-008-1120-0.

Duarte, C.M. and Kirkman, H. (2001). Methods for the measurement of seagrass abundance and depth distribution. In: Short, F.T. and Coles, R.G. (eds.) Global Seagrass Research Methods. Amsterdam: Elsevier Science B.V., pp. 141–153.

Dunn, K. (2024) Jersey Seagrass Report. St Helier, Jersey: Jersey Community Foundation.

El-Hacen, M., Bouma, T.J., Govers, L.L., Piersma, T. and Olff, H. (2019) Seagrass sensitivity to collapse along a hydrodynamic gradient: evidence from a pristine subtropical intertidal ecosystem. Ecosystems, 22, pp. 1007–1023.

Forrester, J., Leonardi, N., Cooper, J.R. and Kumar, P. (2024). Seagrass as a nature-based solution for coastal protection. Ecological Engineering, [online] 206, pp.107316–107316. doi:https://doi.org/10.1016/j.ecoleng.2024.107316.

Gomis, E., Strydom, S., Foster, N.R., Montemayor, D., Mateo, M.A., Serrano, E., Inostroza, K., McCallum, R., Lafratta, A., Webster, C.L., O'Dea, C.M., Said, N.E., Dunham, N., Bernasconi, R., Werner, A., Vitelli, F., PuigcorbéV., D'Cruz, A., Salinas, C. and McMahon, K.M. (2025). Global estimates of seagrass blue carbon stocks in biomass and net primary production. Nature Communications, [online] 16(1). doi:https://doi.org/10.1038/s41467-025-64667-6.

Jackson, E.L., Attrill, M.J., Rowden, A.A. and Jones, M.B. (2006) Seagrass complexity hierarchies: influence on fish groups around the coast of Jersey (English Channel), Journal of Experimental Marine Biology and Ecology, 330(1), doi:10.1016/j.jembe.2005.12.016.

Katwijk, van, Tussenbroek, van, Hanssen, S.V., Hendriks, A.J. and Hanssen, L. (2021). Rewilding the Sea with Domesticated Seagrass. BioScience, [online] 71(11), pp.1171–1178. doi:https://doi.org/10.1093/biosci/biab092.

Marbà, N., Duarte, C.M., Alexandre, A. and Cabaço, S. (2004) How do seagrasses grow and spread? In: Borum, J., Duarte, C.M., Krause-Jensen, D. and Greve, T.M. (eds.) European seagrasses: an introduction to monitoring and management. The M&MS Project (EVK3-CT-2000-00044), pp. 20 - 22

Marlin.ac.uk. (2025a). Common eelgrass (Zostera marina) - MarLIN - The Marine Life Information Network. [online] Available at: https://www.marlin.ac.uk/species/detail/1282 [Accessed 31 Dec. 2025]

Marlin.ac.uk. (2025b). Dwarf eelgrass (Zostera noltii) - MarLIN - The Marine Life Information Network. [online] Available at: https://www.marlin.ac.uk/species/detail/1409 [Accessed 31 Dec. 2025].

Nordlund, L.M., Jackson, E.L., Nakaoka, M., Samper-Villarreal, J., Beca-Carretero, P. and Creed, J.C. (2018). Seagrass ecosystem services – What's next? Marine Pollution Bulletin, [online] 134, pp.145–151. doi:https://doi.org/10.1016/j.marpolbul.2017.09.014.

Ondiviela, B., Losada, I.J., Lara, J.L., Maza, M., Galván, C., Bouma, T.J. and Belzen, J. van (2013). The role of seagrasses in coastal protection in a changing climate. Coastal Engineering, [online] 87, pp.158–168. doi:https://doi.org/10.1016/j.coastaleng.2013.11.005.

Paling, E.I. and McComb, A.J. (2000). Autumn biomass, below-ground productivity, rhizome growth at bed edge and nitrogen content in seagrasses from Western Australia. Aquatic Botany, [online] 67(3), pp.207–219. doi:https://doi.org/10.1016/s0304-3770(00)00092-9.

R Core Team (2025). R: A language and environment for statistical computing (Version 4.5.2). R Foundation for Statistical Computing, Vienna, Austria.

Unsworth, R.K.F., Williams, B., Jones, B.L. and Cullen-Unsworth, L.C. (2017) Rocking the boat: Damage to eelgrass by swinging boat moorings. Frontiers in Plant Science, 8, Article 1309. https://doi.org/10.3389/fpls.2017.01309

Vieira, R., Martin, A., Engelen, A.H., Thomsen, M.S. and Arenas, F. (2020). Interactive effects of co-occurring anthropogenic stressors on the seagrass, Zostera noltei. Ecological Indicators, [online] 109, p.105780. doi:https://doi.org/10.1016/j.ecolind.2019.105780.

Vasco, Lobo-Arteaga, J., Santos, R., Leitão-Silva, D., Veronez, A., Neves, J.M., Nogueira, M., Creed, J.C., Bertelli, C.M., Jimena Samper-Villarreal and Pettersen, S. (2022). Seagrasses benefit from mild anthropogenic nutrient additions. Frontiers in Marine Science, [online] 9. doi:https://doi.org/10.3389/fmars.2022.960249.

Veron, S., Mouchet, M., Govaerts, R., Haevermans, T. and Pellens, R. (2019). Vulnerability to climate change of islands worldwide and its impact on the tree of life. Scientific Reports, [online] 9(1). doi:https://doi.org/10.1038/s41598-019-51107-x..

Vieira, V.M.N.C.S., Lobo-Arteaga, J., Santos, R., Leitão-Silva, D., Veronez, A., Neves, J.M., Nogueira, M., Creed, J.C., Bertelli, C.M., Samper-Villarreal, J. and Pettersen, M.R.S. (2022) Seagrasses benefit from mild anthropogenic nutrient additions. Frontiers in Marine Science, 9, 960249. https://doi.org/10.3389/fmars.2022.960249

Wickham H, Averick M, Bryan J, Chang W, McGowan LD, François R, Grolemund G, Hayes A, Henry L, Hester J, Kuhn M, Pedersen TL, Miller E, Bache SM, Müller K, Ooms J, Robinson D, Seidel DP, Spinu V, Takahashi K, Vaughan D, Wilke C, Woo K, Yutani H (2019). “Welcome to the tidyverse.” _Journal of Open Source Software_, *4*(43),

1686. doi:10.21105/joss.01686 <https://doi.org/10.21105/joss.01686>.

Wicks, E.C., Koch, E.W., O'Neil, J.M. and Elliston, K. (2009). Effects of sediment organic content and hydrodynamic conditions on the growth and distribution of Zostera marina. Marine Ecology Progress Series, 378, pp. 71–80. https://doi.org/10.3354/meps07885

Wong, M.C., Bravo, M.A. and Dowd, M. (2013) Ecological dynamics of Zostera marina (eelgrass) in three adjacent bays in Atlantic Canada. Botanica Marina, 56(5–6), pp. 413–424. https://doi.org/10.1515/bot-2013-0068

Appendix

Appendix 1: Contains the coordinates of the sampled sites.

SITE NAME	LATITUDE (°N)	LONGITUDE (°W)
PETIT PORT	49.2015	−2.0163
ANNE PORT	49.2046	−2.0166
ST CATHERINE'S	49.22314	−2.01923
ST CATHERINE'S	49.2210	−2.0210

Appendix 2: Sampling dates

SAMPLING DATE	YEAR	SITE(S) SAMPLED	NOTES
31 JULY	2021	St Catherine's Bay	Old meadow samples
04 AUGUST	2021	St Catherine's Bay	Young meadow samples

10 AUGUST	2021	Anne Port; Petit Port	Anne Port (old), Petit Port (young)
02 AUGUST	2022	St Catherine's Bay	Old and young meadow samples
03 AUGUST	2022	Anne Port	Old meadow samples
04 AUGUST	2022	Petit Port	Young meadow samples

Appendix 3: R Code used for analysis

```
library(tidyverse)

library(ggplot2)



#Creating dataset

Weight <- read.csv("Data_InputSG/Seagrass_Weight_2021-22.csv") %>%

  dplyr::select(!c(Sample_bag_number, Collector)) %>%

  dplyr::filter(!Location=="N/A") %>%

  dplyr::filter(!Blades_g=="N/A") %>%

  dplyr::filter(!Roots_g=="N/A") %>%

  dplyr::mutate(Location=if_else(Location=="Petit Port", "Anne port", Location))
##changing location name for X reason



#Cleaning data

Weight$Blades_g<-as.numeric(Weight$Blades_g)

Weight$Roots_g<-as.numeric(Weight$Roots_g)
```

```
Weight$Age<-as.factor(Weight$Age)


# Test normality using shapiro-wilk test
shapiro.test(Weight$Blades_g) #Results -> W = 0.8627, p-value = 2.309e-07
shapiro.test(Weight$Roots_g) #Results -> W = 0.87268, p-value = 5.421e-07

#
#Run a Q-Q plot to visualise the data to double check normality
qqnorm(Weight$Blades_g) #Screenshot with name of file as Q-Q Plot Weight$Blades_g
qqnorm(Weight$Roots_g) #Screenshot with name of file Q-Q Plot Weight$Roots_g


#Log transform for normality as both are not normal
Weight_logged <- Weight %>%
  dplyr::mutate(
    log_AGB = log(Blades_g + 0.01),
    log_BGB = log(Roots_g + 0.01)
  )
```

#Re-test for normalisty with shapiro-Wilks with logged data t

shapiro.test(Weight_logged$log_AGB) #Results W = 0.79121, p-value = 1.238e-09, therefore still significantly abnormal

shapiro.test(Weight_logged$log_BGB) #Results W = 0.87966, p-value = 1.009e-06, also significantly abnormal, so cannot use parametric tests

qqnorm(Weight_logged$log_AGB) #Saved as Q-Q Plot (Weight_logged$logAGB) in seagrass projet in stats folder

qqnorm(Weight_logged$log_BGB) #Saved at Q-Q Plot (Weight_logged$logBGB) in seagrass project in stats folder

#Use raw data

#Man Whitney U tests

Man_whit_U_AGB_result <- wilcox.test(Blades_g ~ Location, data = Weight)

print(Man_whit_U_AGB_result) # W = 419, p-value = 2.331e-05 alternative hypothesis: true location shift is not equal to 0

Man_whit_U_BGB_result <- wilcox.test(Roots_g ~ Location, data = Weight) print(Man_whit_U_BGB_result) #W = 863.5, p-value = 0.7513 alternative hypothesis: true location shift is not equal to 0

#Get the medians

#ABG

median(St_Catherines_data$Blades_g) #18.2

median(Anne_Port_data$Blades_g)   #8.175

#BGB

median(St_Catherines_data$Roots_g)   #6.28

median(Anne_Port_data$Roots_g)   #6.835

Visualise the Man-Whitney U tests using a boxplots

library(ggplot2)

ggplot(Weight, aes(x = Location, y = Blades_g, fill = Location)) +

  geom_boxplot(alpha = 0.7, outlier.shape = NA) + # Hide outliers since we show points, alpha is transpearency value

```
  geom_jitter(width = 0.2, size = 2, alpha = 0.5) +  # Shows all data points - values are the size etc of the jitter points
  labs(title = "Above-ground Biomass by Location",
       x = "Location",
       y = "Blade Biomass (g)") +
  theme_classic() +
  theme(legend.position = "none") "AGB box and jitter point box plot with outliers"


ggplot(Weight, aes(x = Location, y = Roots_g, fill = Location)) +
  geom_boxplot(alpha = 0.7, outlier.shape = NA) +  # Hide outliers since we show points, alpha is transpearency value
  geom_jitter(width = 0.2, size = 2, alpha = 0.5) +  # Shows all data points - values are the size etc of the jitter points
  labs(title = "Below-ground Biomass by Location",
       x = "Location",
       y = "Root Biomass (g)") +
  theme_classic() +
  theme(legend.position = "none") #saved as BGB box and jitter plot by location
```

```
#Spearmans Rho correlation test

# Separate the data by site
St_Catherines_data <- subset(Weight, Location == "St Catherines")
Anne_Port_data <- subset(Weight, Location == "Anne port")

# Spearman correlation for St Catherines
spearman_St_Catherines <- cor.test(St_Catherines_data$Blades_g,
                    St_Catherines_data$Roots_g,
                    method = "spearman")
print(spearman_St_Catherines) #Results = S = 6790, p-value = 0.0001077 | alternative hypothesis: true rho is not equal to 0 | rho = 0.0.5527009

# Spearman correlation for Anne Port
spearman_Anne_Port <- cor.test(Anne_Port_data$Blades_g,
                    Anne_Port_data$Roots_g,
                    method = "spearman")
print(spearman_Anne_Port) #same data ties error, results= S = 2742.6, p-value = 4.083e-08 | alternative hypothesis: true rho is not equal to 0 | rho = 0.7427178
```

```
#present spearman correlation visuallly as a scatterplot

# St Catherines
ggplot(St_Catherines_data, aes(x = Blades_g, y = Roots_g)) +
  geom_point(size = 3, alpha = 0.6, color = "blue") +
  geom_smooth(method = "lm", se = TRUE, color = "black") +  # Adds trend line
  labs(title = "Above vs Below-ground Biomass - St Catherines",
       subtitle = "ρ = 0.55, p < 0.001",
       x = "Above-ground Biomass (g)",
       y = "Below-ground Biomass (g)") +
  theme_classic() #AGB vs BGB St Catherines scatter plot (spearman rho)

# Anne Port
ggplot(Anne_Port_data, aes(x = Blades_g, y = Roots_g)) +
  geom_point(size = 3, alpha = 0.6, color = "blue") +
  geom_smooth(method = "lm", se = TRUE, color = "black") +
  labs(title = "Above vs Below-ground Biomass - Anne Port",
       subtitle = "ρ = 0.74, p < 0.001",
       x = "Above-ground Biomass (g)",
       y = "Below-ground Biomass (g)") +
```

```
  theme_classic() #AGB vs BGB Anne Port scatter plot (spearman rho)


#Both sites together
ggplot(Weight, aes(x = Blades_g, y = Roots_g, color = Location)) +
  geom_point(size = 3, alpha = 0.6) +
  geom_smooth(method = "lm", se = TRUE) +  # Separate trend lines per site
  labs(title = "Relationship between Above and Below-ground Biomass",
       x = "Above-ground Biomass (g)",
       y = "Below-ground Biomass (g)") +
  scale_color_manual(values = c("Anne port" = "red", "St Catherines" = "blue"),
                     labels = c("Anne port (ρ = 0.74)",
                                "St Catherines (ρ = 0.55)")) +
  theme_classic() +
  theme(legend.position = "top") # saved as relationship AGB + BGB 2 locations (spearman rho)
```