# Distribution, Extent, Condition and Potential Seed Bank Use of *Zostera noltii* Beds at Roa Island, Cumbria, UK

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## Summary

Seagrass ecosystems have experienced catastrophic declines in the past century on a global scale, due to disease outbreaks compounded by anthropogenic activity which has further hampered their natural recovery. As important ecosystems conferring numerous benefits on the environment, including fisheries support, flood defence and carbon sequestration, their conservation and recovery is of the utmost importance. Considerable efforts worldwide have begun in recent years to restore actively areas of seagrass meadow which existed historically, with the most efficient methods for doing so still under development.

This study aimed to quantify the extent and report on the condition of the *Zostera noltii* bed to the west of Roa Island in Cumbria, North West England, as well as attempt to quantify seed spathe density as a basis for understanding whether the bed was in a resilient enough condition to withstand seed collection as part of potential future restoration projects. Extent mapping of the meadow boundary reported seagrass bed coverage of 23.31 Ha, which did not include all seagrass present at Roa Island as further seagrass coverage was observed further west of the study area. *Z. noltii* condition was studied through quadrat surveys and reported to be generally in good condition across the survey area, with mean *Z. noltii* coverage recorded at 36.41% (±21.02) of the quadrat area, though this average varied considerably between quadrats. Mean spathe count was calculated to be 26.97 (±33.26) within quadrats containing spathes. Little to no geographic association was observed for any factor recorded, nor were any correlations observed between seed spathe density and seagrass condition factors.

Seed density and seagrass condition within certain areas of the *Z. noltii* bed was deemed to be at a condition which was sufficient to enable seed collection without impacting the longevity/continued persistence of the existing bed, based on existing data for *Z.noltii* meadow resilience and the preference of a vegetative reproduction strategy within established beds. It is recommended that further, more comprehensive surveys of the bed be conducted to identify areas within the bed which exhibit the high spathe densities and good condition as reported within this survey. It is also recommended that an assessment of environmental conditions be conducted within the area prior to any seed removal, to ensure that abiotic conditions of the area are not at stressful levels for *Z.noltii* which may trigger a shift towards sexual reproduction and the requirement of seeds to support the persistence of the existing bed, as *Z. noltii* has been observed to shift towards a sexual reproduction strategy under stressful conditions.


## Introduction

Seagrasses are the only marine flowering plant and form sparse to dense meadows in the intertidal and shallow subtidal areas of the seabed (Bunker & Foster-Smith, 1996), providing a sheltered habitat for numerous species (Davison et al., 1998). They provide several additional ecosystem services, including but not limited to protection from coastal erosion through sediment stabilisation, fisheries support (Cullen-Unsworth et al., 2014; Mtwana Nordlund et al., 2016), carbon sequestration at a rate 35 times faster than tropical rainforests (McLeod et al., 2011) and a food source for wintering wildfowl (Ganter, 2000).

Despite their importance and utility, seagrass ecosystems worldwide have experienced severe global declines over the past century, with estimates for seagrass declines in the United Kingdom ranging from 44% to as high as 98% over longer timescales (Green et al., 2021). Though the cause of this decline in the United Kingdom is often primarily attributed to the incidence of a severe “wasting disease" outbreak in the 1930s (Butcher, 1934), anthropogenic disturbances including pollution, ocean warming through climate change, ocean acidification and physical disturbances such as boat moorings and bottom trawling have all contributed to the decline of seagrass meadows and, critically, have hampered their natural recovery (Davison et al., 1998).

In response to the need for marine nature recovery in line with a reduction in net $CO_2$ emissions, numerous independent seagrass restoration projects have been developed and are currently underway in the UK (e.g. Project Seagrass, Seagrass Ocean Rescue, Seawilding). Projects either focus on one or both of the two species native to the UK, *Zostera marina* or *Zostera noltii*, though projects focusing on *Z. noltii* are comparatively in the early stages of research and development. Active restoration methods have historically focused on the collection of seeds from a "healthy" area of the target seagrass species and the subsequent planting of seeds onto another suitable or historic location for seagrass, either as seeds or as seedlings after a controlled germination and "rotting out" period (e.g. Yorkshire Wildlife Trust). Understanding of optimal seed germination conditions, planting strategy and meadow resilience to seed removal is still poor, and many projects are trialling methods by which to understand more confidently the ideal parameters by which to conduct restoration (e.g. Seeding Change Together, Cornwall Wildlife Trust). Additionally, our knowledge of seagrass meadow coverage and condition around the UK is far from comprehensive, and ongoing research is required to more fully comprehend the areas of healthy seagrass which we currently have from which to source seeds for future restoration efforts.

The North West of England has two known locations where seagrass beds have been recorded. One such area is the coast of Barrow-In-Furness, Cumbria, which supports several seagrass beds of both *Z. marina* and *Z. noltii*. The focal area for the survey in this report was the intertidal mud areas in Pike Stones Bed and Concle Bank, situated between Roa Island and Westfield Point on the southern coastline of Barrow-In-Furness, Cumbria (Figure 1).

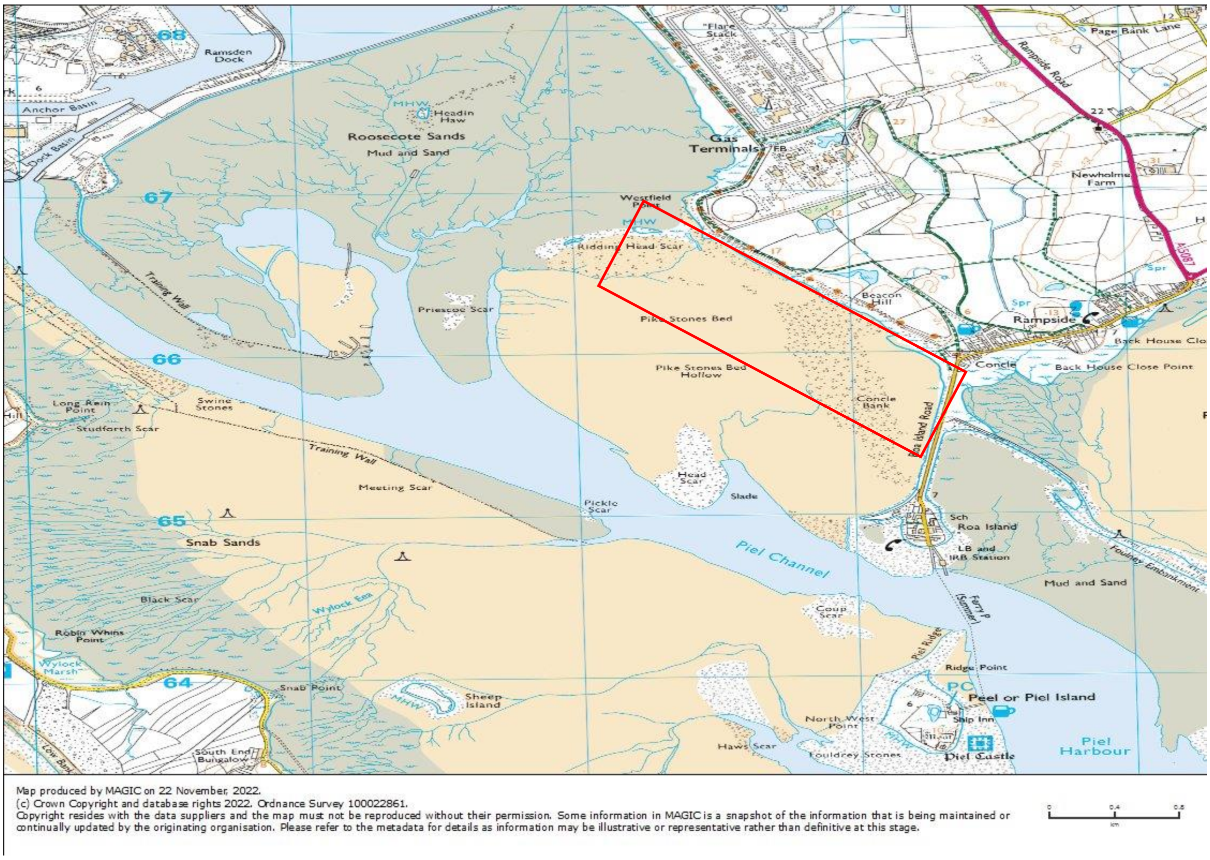



*Figure 1: OS Map showing the survey location, outlined in red.*

# Survey methodology

## Survey location

Surveys were conducted within Pike Stones Bed and Concle Bank, two areas of mudflat to the west of Roa Island, Barrow, to the south-east of Roosecote Sands (Figure 1).

## Consents, Licenses and Permissions

### Access Permissions

As this was classified as a non-intrusive survey with no material removed from the site, no access permissions were required.

### Licenses

As this survey did not involve the collection of samples or specimens, as per the Wildlife and Countryside Act 1981, no license was required to conduct the survey.

### Habitats Regulations Assessment (HRA)

No HRA was required as the survey was non-intrusive with no samples being taken.

## Survey Dates

Extent mapping of the surveyed beds was conducted during the low tide on the 16th of August, 2022. The site was revisited during the low tide on the 17th of August, 2022. Survey dates were chosen around the peak blooming time for *Zostera* species, to attempt to capture the maximum seeds present for the bed.

## Survey Techniques

### Walkover and extent mapping survey

The outer boundary of continuous *Z. noltii* bed (any area with higher than 5% cover, (OSPAR, 2009)) was walked by surveyors. A combination of different GPS tracking softwares were used to record the boundaries of meadow areas. GPS routes were uploaded to QGIS (version 3.26.1) in order to generate digital representations of the seagrass areas and randomly select points within the areas of seagrass for quadrat surveys.

### Intertidal mudflats quadrat survey

60 random points within the larger bounded areas of mapped seagrass meadow were generated using the **"Random Points in Layer Bounds…"** function in QGIS (version 3.26.1). Points were assembled into two routes of 30 points each (A and B), labelled and exported using EasyGPS software to portable GPS units. Owing to time pressures experienced on the day, the quadrat survey was shortened to 50 points, with alternate points of the final 10 points of each route surveyed in order to still achieve coverage of the full survey area

A 0.5m by 0.5m quadrat was placed at each survey point, at which point the following information was recorded:

1. Sediment type within the quadrat.
2. Water depth within the quadrat area – recorded as an average by taking three random measurements of water depth where water was present.
3. Bare sediment cover (recorded as a percentage of the total quadrat).
4. Seagrass cover (recorded as a percentage of the total quadrat). The percentage coverage of within each quadrat was agreed by both surveyors.
5. Proportionate cover of seagrasses *Z. marina* and *Z. noltii* (recorded as a percentage of the total seagrass cover in the quadrat).
6. Number of spathes within a quadrat; where spathes were predicted to be fewer than 20 within the whole quadrat, spathes within the entire quadrat were counted. When spathes were considered, upon observation, to have a higher number than 20, a 10cmx50cm strip of the quadrat was searched for spathes and this count multiplied by 5 to give a value for the full quadrat. Spathes are used as a proxy for seed counts, where spathes are estimated to contain between 2-3 seeds each (Hootsmans et al., 1987).
7. Spathe length; the length of three randomly selected individual spathes from the quadrat. Where three spathes were not present, the maximum number of spathes possible within the quadrat were recorded.
8. Blade length in canopy – the length of three individual *Z.noltii* blades was recorded within each quadrat and the mean value given as the final recorded value.
9. Condition of *Z.noltii* within the quadrat (categorised as good, partially blackened or blackened)
10. Algae cover (recorded as a percentage of the total quadrat).
11. Notation of anything of additional interest e.g. notable associated species.

Photographs of each quadrat were taken alongside a label to relate them to individual survey points. A copy of the original survey sheet and examples of the quadrat photographs taken have been included in the Appendix of this report (Appendices 1 and 2).

# Results

## Z. noltii extent

Extent mapping identified 2 apparently continuous beds of *Z. noltii* within the survey area, with a total area of 23.31 Hectares (Figure 2). Comparison of recorded extent with areas recorded during extent mapping surveys in 2016 (36.91 Ha) and 2017 (34.34 Ha) show that the total area of mapped seagrass within the survey area has decreased by 16.6 Ha and 11.03 Ha respectively (Figure 3). The majority of loss of *Z. noltii* coverage was confined to three particular areas; two areas where the bed extends towards the channel and one area intersecting the bed (see Figure 3). Other areas where *Z. noltii* was present were noted both west and east of the survey area; however, extent mapping was not attempted in these regions owing to time constraints.


*Figure 2: Mapped extent of the* Z. noltii *beds present at the Roa Island survey site.*


*Figure 3: Extent comparisons between surveys conducted in 2016 (red), 2017 (orange) and 2022 (blue). Mapped area at the far North-West of the survey area was not mapped within the 2022 survey.*

## Seagrass cover and condition

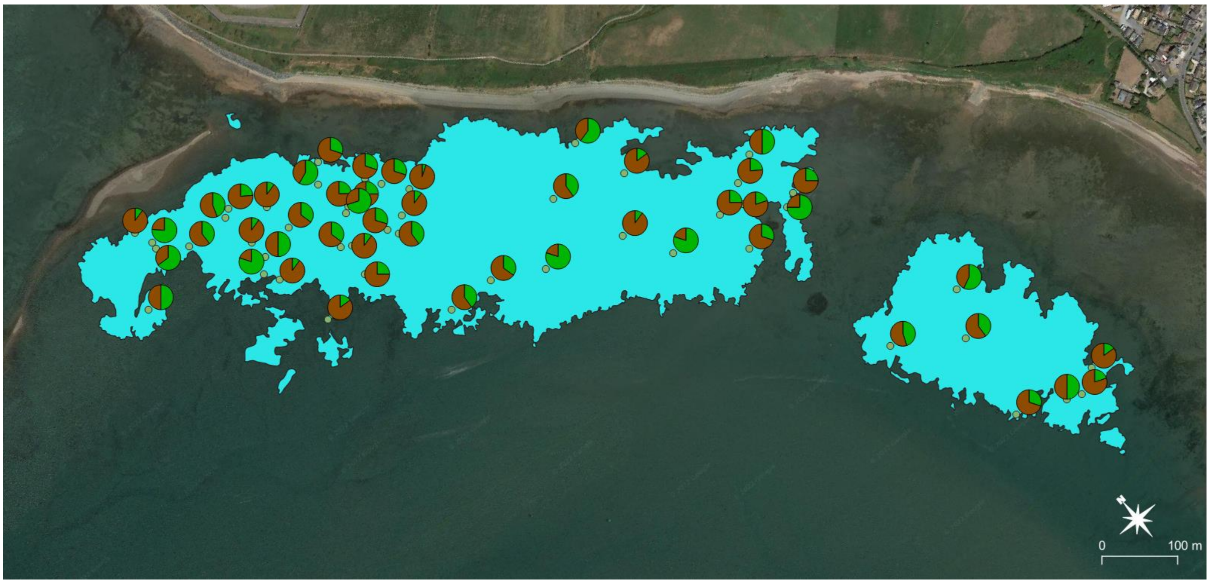
Sediment type within survey quadrats was predominantly recorded as muddy sand (48/50, 96%), with one quadrat recorded as muddy sand and gravel and one quadrat containing muddy sand mixed with cobble mussels. Mean water depth varied from 0mm to 21.7mm across quadrats, but was observed to vary within quadrats due to uneven terrain (see Appendix 2).

Both *Zostera* species were recorded within the survey at variable frequencies; *Z. noltii* was present in 100% of quadrats whereas *Z. marina* was observed in 16% (8/50) of quadrats. Total *Zostera* cover varied considerably between quadrats, with lowest total coverage estimated at 5% and highest cover estimated as 80% coverage. Mean total *Zostera* coverage of quadrats was calculated as 36.4%. Mean *Z. marina* cover was calculated to be 0.258% (±0.77) with a highest cover of 3% and a lowest cover of 0%. Mean *Z. noltii* cover was calculated to be 36.14% (±21.02), with a highest coverage of 80% and lowest coverage of 5% (Figure 4). *Z. noltii* condition was predominantly recorded as "good" (29/50, 58%), followed by "partially blackened" (20/50, 40%), meaning that there was some evidence of blackening within the quadrat, but without blackening occurring for the majority of seagrass within the quadrat, and fully blackened within one quadrat (Figure 5). Mean canopy length was calculated to be 85.14mm (±103.52).

Spathes were present within 78% (39/50) of the quadrats surveyed (Figure 6). Mean spathe counts across all quadrats totalled 21.04 (±31.51), whereas mean spathe counts for quadrats found to contain spathes totalled 26.97 (±33.26). As some spathes were observed partially buried in the sediment, which upon uncovering revealed further fully buried spathes, seed spathe density is predicted to be underestimated by this survey. Mean spadice length was calculated as 12.02mm (±2.58).

Algae was observed within 11 (22%) of quadrats, however cover was generally low. Mean algae cover across all quadrats was calculated as 2.41% (±5.4), whereas mean algae cover within quadrats containing algae was calculated as 5.18% (±8.39).

In order to better understand potential indicators of seed density, comparisons were drawn between spathe counts and shoot length, seagrass cover and seagrass condition within quadrats. No correlations were observed between shoot length and any of these factors. Additional analysis of map data showed no particular pattern of seagrass condition, cover, shoot length or spathe count across *Z. noltii* beds (Figures 4, 5 and 6).




*painFigure 4: QGIS map showing percentage cover of Z. noltii (green) compared to bare sediment cover (brown) within quadrats surveyed at Roa Island. Quadrat survey location points are shown as grey circles.*

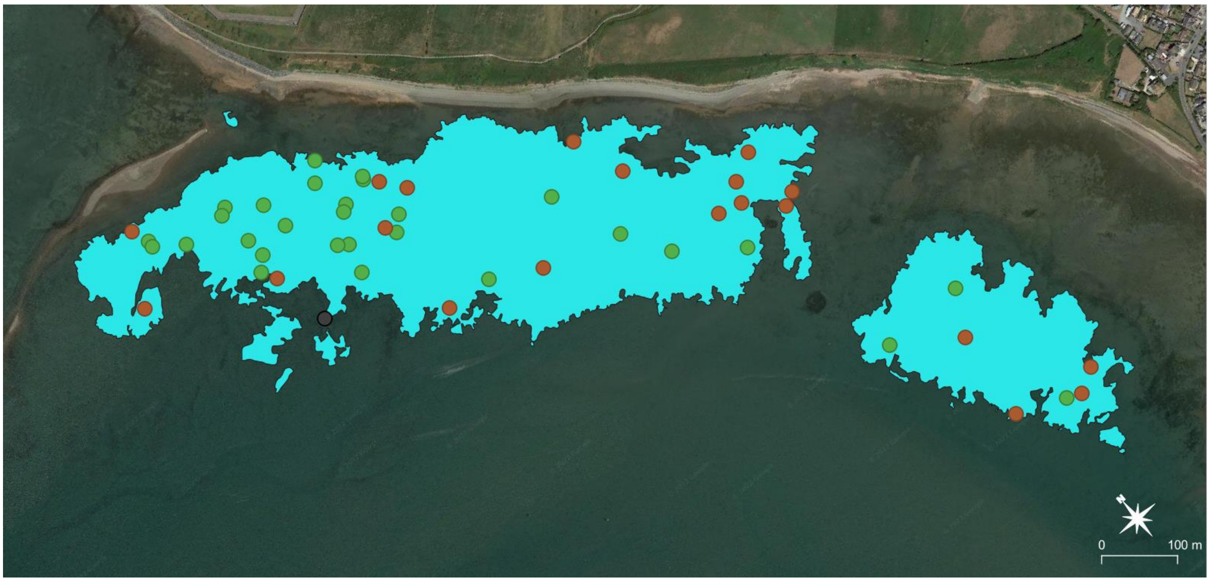



*Figure 5: QGIS map showing seagrass condition in quadrat surveys. Green circles represent "good" condition, brown circles represent "partially blackened" and black circles represent "blackened" condition.*

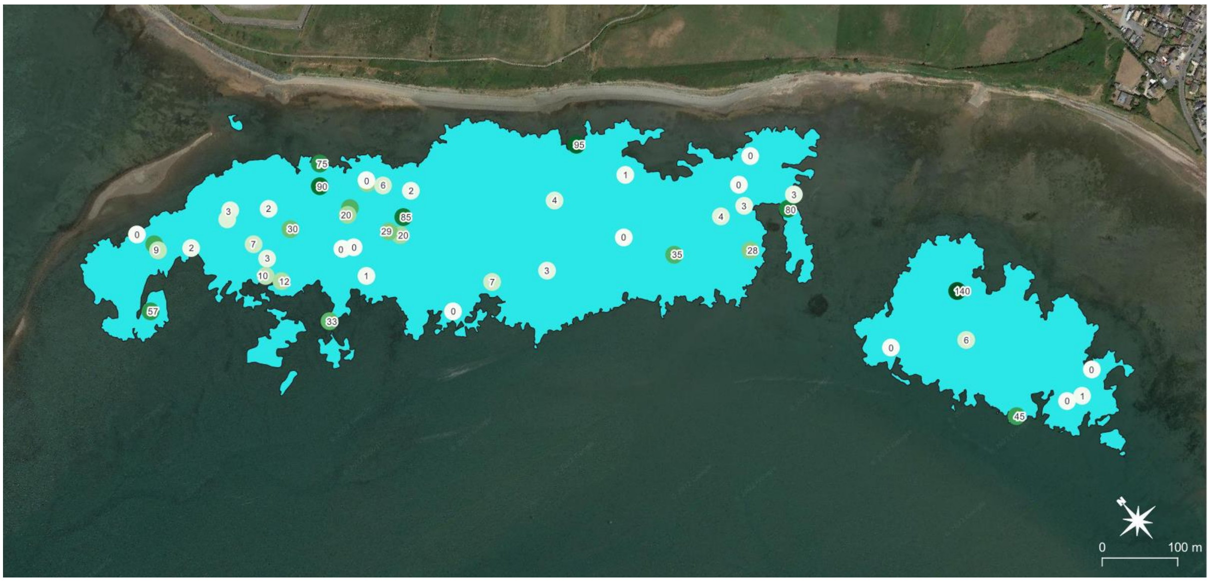



*Figure 6: QGIS map showing spathe counts in quadrat surveys at Roa Island. Counts are represented by numbers, with a white to dark green colour scale further visualising spathe density at each quadrat location.*

## Discussion

Extent mapping of the *Z. noltii* bed showed a decline in cover when compared to surveys undertaken in 2016 and 2017 (Figure 3). A lack of data from the years between 2017 and 2022 poses a difficulty in understanding whether there has been a consistent decline or fluctuation between *Z. noltii* bed growth and decline over this timespan. Three distinct areas of the bed account for the majority of *Z. noltii* decline (Figure 3). For the two areas extending southward, this may be due to changes in environmental condition which would occur as a bed extends towards the subtidal zone e.g. light exposure, which could affect *Z. noltii* growth (Jiménez et al., 1987). Additionally, there is a possibility that patchy areas of seagrass where continuous bed previously existed (as observed in other areas of the bed) may have been present but not recorded. Access to detailed previous extent records was not gained prior to the extent mapping within this report; as such, it is possible that remaining patches within this area were missed as surveyors were not aware of the bed's previous extension into this area. Additionally, considerable losses of seagrass *Z. Noltii* bed were noted adjacent to a map feature that may indicate some human activity (Figure 3, Appendix 3). Further investigation is required to ascertain whether some human disturbance is occurring within this area which may be affecting the persistence of the *Z. noltii* meadow. It is unclear whether anthropogenic or environmental stressors are affecting the growth and condition of *Z. noltii* at Roa Island; in general, the effects of different stressors on *Z. noltii* are poorly understood. However, individual studies have reported declines in *Z. noltii* condition or growth in response to stressors or limiting factors such as low light intensities, nutrient overloading, nutrient deficiencies and organic loading (Brun et al., 2008; Govers et al., 2014; la Nafie et al., 2012). It is also possible that grazing by wintering wildfowl may have affected *Z. noltii* cover, though as overwintering wildfowl populations often migrate later in the year, this is unlikely (Davison et al., 1998). Studies investigating the environmental conditions of areas supporting *Z. noltii* meadows, such as sediment and water conditions, could shed light on the effect of environmental perturbations on *Z. noltii* and help to understand the causes of *Z. noltii* bed decline in the survey area. Additionally, comparisons of environmental conditions between areas currently supporting *Z. noltii* meadow and areas without *Z. noltii* within the survey area may uncover differences in condition between these areas, which may indicate potential stressors for *Z. noltii* at the Roa Island site.

Comparisons between different indicators of condition taken from quadrat survey data showed no correlation between seed spathe density and any other recorded seagrass characteristic (e.g. canopy length, blackening or *Z. noltii* cover*).* Conclusions drawn from mapping condition results onto the survey bed area indicated that there is no obvious pattern to occurrence of high-density areas of *Z. noltii* or *Z. noltii* seeds within the survey bed (Figures 4 and 6); however, more intensive and comprehensive surveying of these factors should be carried out to either reinforce or contradict this result. Due to time pressures, repeated surveys of all *Z. noltii* bed areas around Roa Island were not completed in 2022. It is recommended that, if time and research effort is sufficient, surveys of all bed areas in this region continue on an annual basis to allow for more precise and accurate monitoring of changes to the bed extent and condition.

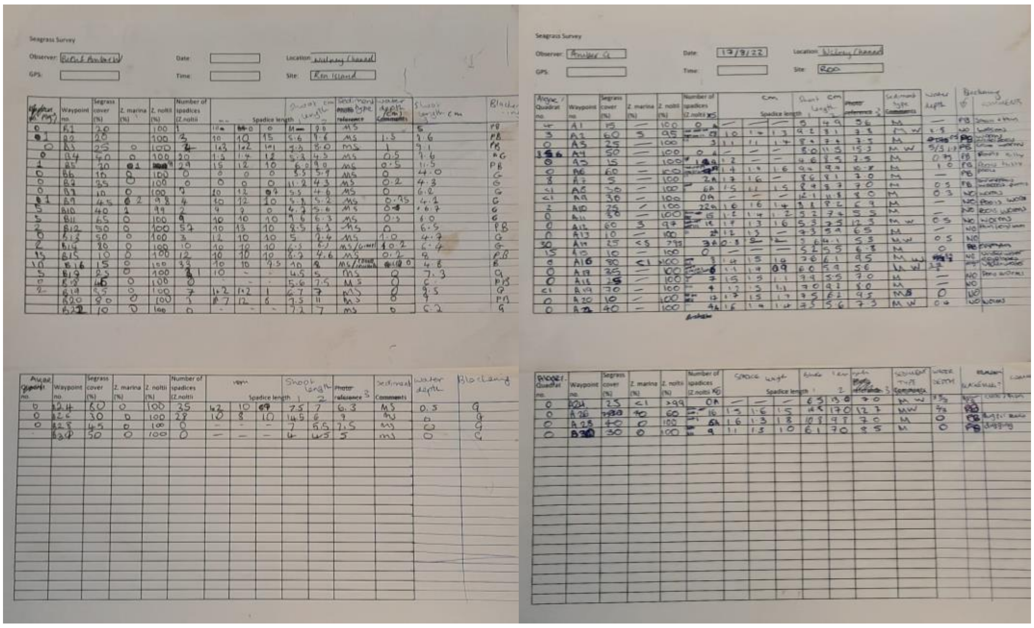
The high seagrass seed densities observed within some quadrats indicate that it may be possible to collect considerable numbers of seed from the survey bed in an effort to restore other areas of degraded *Z. noltii* bed. However, seed spathe densities obtained within this survey varied considerably and the data collected is not sufficient to accurately estimate the proportion of the bed which contains these high densities. The collection of a greater number of quadrat samples in future surveys would improve upon the results within this survey and enable a more accurate prediction of the quantity of seed present within the Roa Island beds.

Regarding the use of Roa Island as a seed bank, it is important to first understand the general conditions of the existing bed and the reasons behind observed declines in seagrass cover. *Z. noltii* has been observed to prefer a vegetative reproduction strategy over seed recruitment, despite prolific seed production (Cleater, 1993; Rae, 1979; van Lent & Verschuure, 1994a, 1994b). However, this reproductive strategy preference may fluctuate between beds, and there is some evidence to suggest that *Z. noltii* seeds persist within the sediment for several years and may act as an "insurance" against significant disturbances to the existing bed, allowing the bed to shift towards a sexual reproduction strategy when necessary (Zipperle, 2012). Therefore, removing seeds from a bed undergoing stress may hamper its ability to recover either during, or in the event of, a future stress event. It is therefore critical that the environmental conditions of the area supporting the *Z. noltii* bed at Roa Island be understood before the site is used as a seed donor for restoration efforts. Additionally, if research efforts allow, studies into the preferred reproductive strategy of the Roa Island beds specifically (likely through genetic analysis of the bed, see Zipperle, 2012) would shed more light on the reliance of the Roa island *Z. noltii* beds on seed availability.

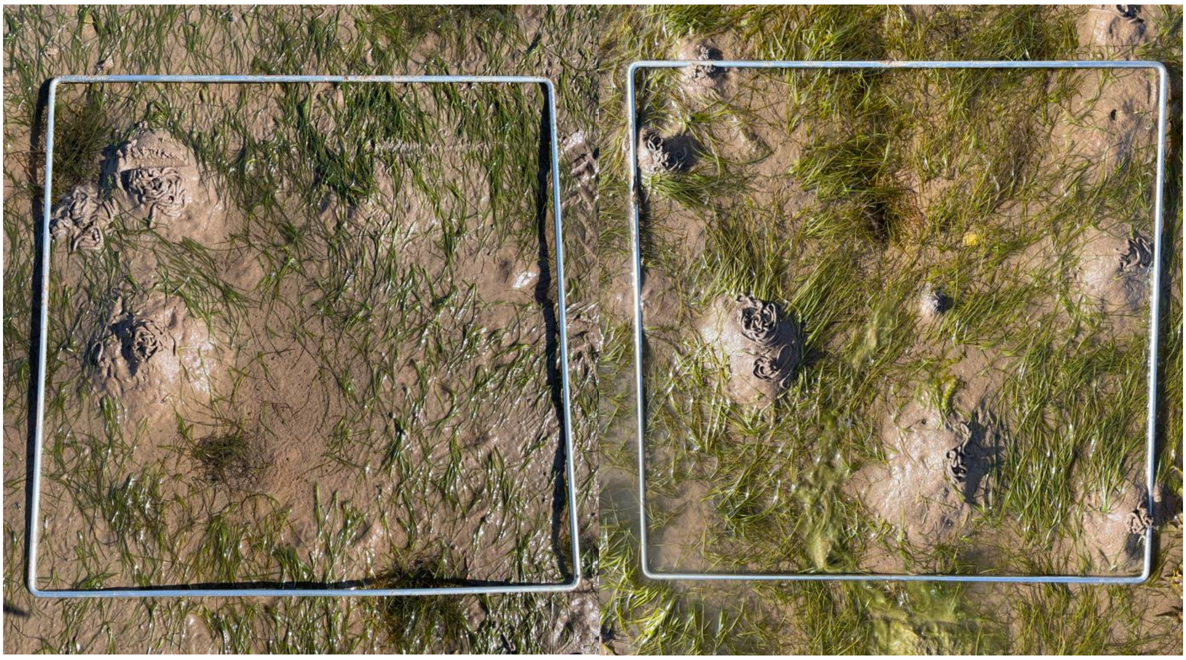
## Conclusion

This survey updated existing records of the extent of *Z. noltii* beds at Roa Island and provided an assessment of *Z. noltii* condition and seed spathe density. Seagrass cover, condition and spathe density all varied considerably between quadrats and no correlation between these factors was observed. These data suggest that there is potential to utilise the seed banks at Roa Island as a resource by which to restore degraded *Z. noltii* meadow elsewhere, however it is strongly advised that further research into the bed condition, seagrass spathe density and environmental conditions of the bed be conducted before doing so.

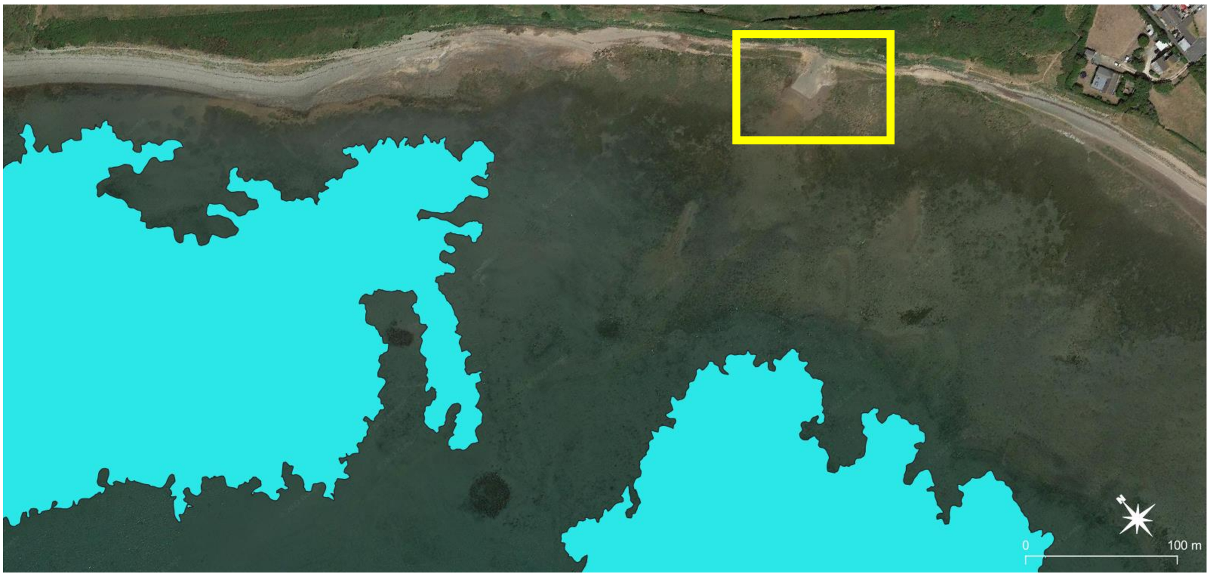
# Appendix



*Appendix 1: Survey sheets from quadrat surveys at Roa Island, 2022*



*Appendix 2: Example quadrat photos from quadrat surveys at Roa Island*



*Appendix 3: QGIS Map screenshot of degraded area of* Z. noltii*, with an apparently man-made feature to be investigated highlighted by a yellow box.*