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Searching for Shetland's lost seagrass: establishing the baseline distribution and abundance of seagrass in the Shetland Islands

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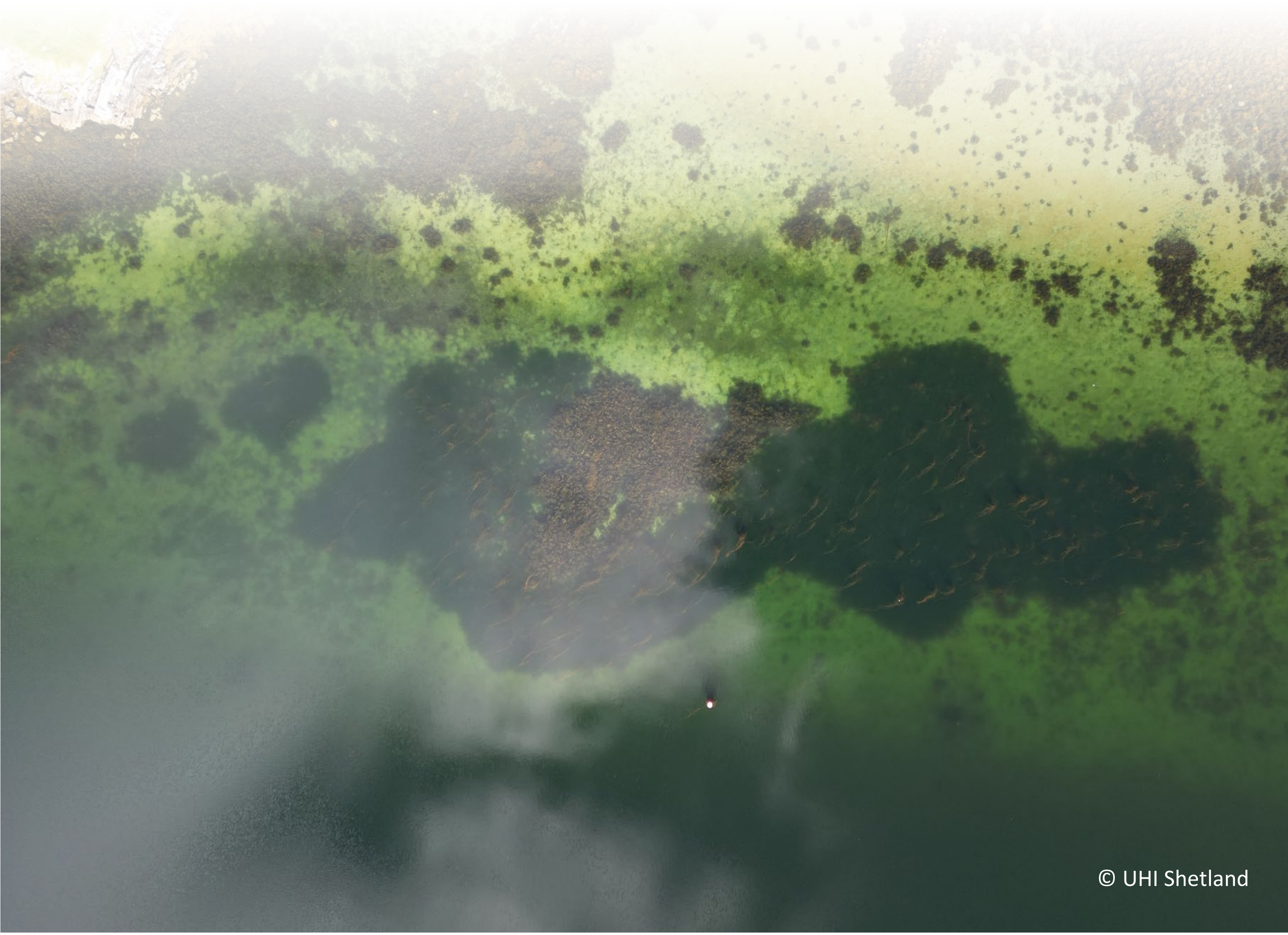

Searching for Shetland's lost seagrass: establishing the baseline distribution and abundance of seagrass in the Shetland Islands

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Executive summary

Seagrass habitats are important productive and biodiverse marine habitats, but their status is vulnerable as a result of extensive loss throughout the UK. Accurate knowledge of the current distribution of seagrass habitat is important to inform management, restoration assessments and blue carbon storage calculations. This study investigated the historic and current distribution of seagrass in the Shetland Islands.

Historic records of seagrass from across Shetland were reviewed to identify prioritised areas to assess for presence of subtidal *Zostera marina* (eelgrass) beds. To map the current extent of subtidal eelgrass beds, small Unmanned Aircraft Systems (UASs or drones) were used to survey identified sites. The use of UASs to map and monitor seagrass is rising in popularity, as they offer a time- and cost-effective means to gather high-resolution aerial imagery across large areas. Manual analysis of aerial images identified suspected seagrass bed locations which were ground-truthed via paddleboard and snorkel surveys with photo and video transects carried out by community volunteers.

The review of historic accounts identified 73 records of *Z. marina* at 12 sites in the Shetland Islands from 1837 to 2020. Analysis of the aerial images from UAS surveys provided no evidence for *Z. marina* presence at 10 of the 12 sites with historic records of *Z. marina* beds. Extant *Z. marina* beds were recorded only in Whiteness Voe and Weisdale Voe, with seagrass beds at Burra the most recently lost. There were 37 sites with historic records of *Ruppia* spp. from Yell, Whalsay, Fetlar, Unst, and Mainland Shetland, mainly from vadills and small lagoons. Further work is needed to understand the current extent of *Ruppia* spp. and how extensive *Ruppia* sp. beds are.

The total area of subtidal *Z. marina* bed habitat in the Shetland Islands is currently estimated to be 1.62 hectares, over 14 beds in the upper part of Whiteness Voe and one bed on the western shore of Weisdale Voe. The seagrass beds in Whiteness Voe are considered to be in good condition, with high densities of *Z. marina* in summer months in all beds. The *Z. marina* bed in Weisdale Voe is sparser and less dense, with more algae intermingled within the bed. Flowering was observed in beds in Whiteness Voe, but reproductive shoot density was low, and no seed-bearing shoots recorded.

This study documents the continued decline of seagrass in Shetland, with further loss of seagrass habitat since surveys were last conducted in the early 1990s. Despite this general trend, seagrass beds in Whiteness Voe appear to have remained relatively stable in the last 30 years. Further work to ground truth absences at historic sites is needed and could be explored through further engagement with the community and recreational water sport groups.

This project demonstrated the applicability of small, relatively inexpensive UASs to cost- and time-effectively survey and map subtidal seagrass habitats. This method is particularly useful in remote and hard to access areas with highly complex coastlines such as the Shetland Islands. The benefits of accessible historic survey reports and local records for informing current surveys and identifying historic baseline distributions are emphasised, and it is important that all contextual information is preserved if historic data is to be used to guide future restoration efforts.

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Acknowledgements

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1 Introduction

Seagrasses are marine flowering plants which occur in shallow coastal areas in every continent apart from Antarctica. They can form dense meadows or beds growing in sheltered, shallow waters on sandy or muddy substrates. These vital ecosystems are highly biodiverse and provide important structural habitat for a wide variety of invertebrate and fish species. The shelter afforded by seagrass meadows acts as nursery habitats for commercially important fish and shellfish species, contributing to the productivity of global fisheries (Bertelli and Unsworth, 2014; Unsworth *et al.*, 2019). Seagrass beds also provide other important ecosystem functions, contributing to nutrient storage and cycling, including the sequestration of carbon (Duarte and Krause-Jensen, 2017). Seagrass shoots can trap particles suspended in the water column, and the complex rhizome root structures stabilise sediments and help protect against erosion (Ondiviela *et al.*, 2014).

Seagrass meadows range in size from small patches one to two metres-square, to large meadows covering thousands of hectares (Unsworth and Cullen-Unsworth, 2017). Seagrasses are principally found in sheltered areas with limited wave exposure in areas with suitable nutrient availability. As aquatic plants, seagrasses require sunlight to photosynthesise, so their distribution is restricted to shallow waters from the intertidal to around 10 m deep.

As flowering plants adapted to marine conditions, seagrasses can reproduce through the production of flowering shoots and seeds, with pollination facilitated by water movement (den Hartog and Kuo, 2007). However, spread can also occur through vegetative clonal growth of new shoots from the rhizome system which anchors seagrass plants within the sediment. Rafting of both flowering and vegetative shoots on ocean currents may help disperse seagrasses to new habitats (Kendrick *et al.*, 2012).

Seagrasses are sensitive to environmental changes, particularly those that affect the availability of light and nutrient availability in coastal systems. Rapid coastal change caused by anthropogenic activity are contributing to continued decline of seagrass species across the globe. There is estimated to have been a 7% loss in global seagrass extent across all species every year since 1990, and a 29% loss since 1879 (Waycott *et al.*, 2009). Declines have been attributed to disease as well as the impact of human activities, including spread of invasive species, aquaculture, increases in turbidity, eutrophication from terrestrial run-off, and coastal development (Jones and Unsworth, 2016; Orth *et al.*, 2006).

1.1 Seagrass in Scotland

1.1.1 Eelgrasses (Zostera spp.)

In the UK there are two species of fully marine seagrass, common eelgrass (*Zostera marina Linnaeus, 1753*) and dwarf eelgrass (*Zostera noltii* Hornemann, 1832). *Zostera noltii* is found in the intertidal zone and has short leaves about 20 cm long. *Zostera marina* is characterised by longer blades between 20 to 50 cm, but up to 2 m long. It primarily forms subtidal beds, extending from the low intertidal zone to as much as 10 m deep (OSPAR, 2009). *Zostera marina* demonstrates flexible growth patterns depending on environmental conditions, which led to distinction between *Z. marina* and characterisation of intertidal populations with shorter broader stems as *Z. angustifolia*. However, *Z. angustifolia* is now considered to be a taxonomic synonym of *Z. marina* and they are considered one species (d'Avack *et al.*, 2024).

Zostera marina or eelgrass is the most abundant species of seagrass in the Northern hemisphere distributed from the Mediterranean to the Arctic, and found as far north as 70 °N in northern Norway (Boström *et al.*, 2014). In Scotland, *Z. marina* is typically found in sheltered, shallow areas from the lower shore to 6 m, but may be found deeper where light conditions allow (Davison, 1998; Kent *et al.*, 2021). While both species of *Zostera* are found across Scotland, there is variation in their geographic distribution between the species. Subtidal *Z. marina* eelgrass beds are widely recorded across the west coast of Scotland, in the Outer Hebrides, Orkney and in Shetland, as well as within the Firth of Clyde (Cleator, 1993; Kent *et al.*, 2021). Intertidal eelgrass beds of both *Z. noltii* and *Z. marina* are found predominantly in firths and estuaries on the east coast of Scotland.

1.1.2 Widgeon grasses (*Ruppia* spp.)

Widgeon grasses (*Ruppia* spp.) are occasionally grouped within seagrass habitats, although they are not considered true seagrasses (Kuo and den Hartog, 2001). *Ruppia* spp. are a genus of aquatic freshwater plants which have a high salinity tolerance, and also form beds or meadows and occupy similar habitats to eelgrass (Gamble *et al.*, 2021). *Ruppia* spp. are found in very shallow sheltered soft muddy-sand and mud in estuarine and brackish environments, and on occasion can be found interspersed with *Z. marina* (Tyler-Walters and d'Avack, 2015). The species considered to be present in the UK are the beaked tasselweed (*Ruppia maritima* Linnaeus, 1753) and spiral tasselweed (*Ruppia cirrhosa* (Petagna) Grande, 1918). However, there are several taxonomic challenges in identifying and classifying species within the genus, which may lead to confusion in separating records of *R. maritima*, *R. cirrhosa* and *Ruppia spiralis* (den Hartog and Triest, 2020). Most of the UK's records of *Ruppia* spp. beds are from Scotland (Tyler-Walters *et al.*, 2016).

1.1.3 Seagrass decline

The distribution and abundance of seagrass habitats has declined across the UK in the last century (Jones and Unsworth, 2016). Eelgrass beds suffered catastrophic losses in the UK around the 1930s, at the same time as mass dieback of eelgrass across western Europe. The primary cause of the decline was attributed to seagrass wasting disease, caused by *Labyrinthula zosterae*, but was likely exacerbated by other anthropogenic pressures and changes to environmental conditions (Green *et al.*, 2021).

Eelgrass extent has continued to decline across the UK since this time, with a variety of estimates as to the scale of the loss (Gamble *et al.*, 2021). Green *et al.* (2021) estimate loss of 44% of seagrass extent in the UK since 1936, and 39% since the 1980s. However, these estimates are challenging due to limited data on changes in seagrass extent. Assessment of the environmental health of seagrass beds in the UK suggests that many beds are in poor condition as a result of poor water quality (Jones and Unsworth, 2016).

As a result of this decline, seagrass beds are considered degraded across the UK and are listed as an OSPAR threatened and/or declining habitat (Finger and Lilley, 2023). Seagrass is listed as an Annex I habitat under the EU Habitats Directive and is thus a protected feature in some Special Areas of Conservation (SACs) in the UK. In Scotland, seagrass beds are also identified as Priority Marine Features (PMFs). PMFs are marine species and habitats identified as of priority conservation importance in Scotland, and the PMF list is used to focus marine conservation efforts (Tyler-Walters *et al.*, 2016). The seagrass biotopes included within the PMF list are *Zostera marina*/*angustifolia* beds on lower shore or infralittoral clean or muddy sand (SS.SMp.SSgr.Zmar), *Zostera noltii* beds in littoral muddy sand (LS.LMp.LSgr.Znol), and *Ruppia maritima* in reduced salinity infralittoral muddy sand (SS.SMp.SSgr.Rup).

In the whole of Scotland, the extent of subtidal seagrass habitat has been estimated at 1,504 ha using data from the Geodatabase of Marine Features in Scotland (GeMS); however, this is not a comprehensive estimate of the full extent of seagrass beds within Scottish waters (Cunningham and Hunt, 2023). Seagrass habitat in Scotland is thought to be less well mapped than in other areas of the UK, in part due to the challenges of mapping seagrass in areas with complex coastline such as those found in the Western Isles, Orkney and Shetland (Bekkby *et al.*, 2008; Thomson *et al.*, 2014).

The distribution of seagrass within shallow, clear waters means that remote sensing of marine habitats can be used as an alternative to costly dive surveys. Unmanned Aircraft Systems (UASs or drones) are becoming an increasingly popular spatial survey tool, capable of covering large areas cost- and time-effectively and collecting high resolution aerial images (Svane *et al.*, 2022). Most of the applications of UASs for mapping seagrass habitat have been in tropical regions or for intertidal seagrass beds (Elma *et al.*, 2024), but recent research has demonstrated that it is possible to map and detect change in subtidal eelgrass extent in temperate marine regions as well (Nahirnick *et al.*, 2019a; Nahirnick *et al.*, 2019b). UAS's may be especially useful in mapping seagrass habitat in remote island archipelagos, where traditional survey methods such as dive surveys are challenging to deliver in a cost-effective way (Thomson *et al.*, 2014).

Understanding the distribution and health of seagrass habitats is vital to their protection and restoration. Obtaining current estimates of seagrass extent is essential to inform blue carbon assessments, improve the accuracy of habitat suitability, and inform assessment of restoration potential (Cunningham and Hunt, 2023). To assess the need and viability of seagrass restoration to aid in reversing seagrass decline, it is useful to know both the historic and current extent of seagrass beds.

1.2 Historical distribution of seagrass in Shetland

In Shetland dialect, the name 'marlok'[1] or 'marlie'[2] is given to eelgrass (*Zostera marina*) beds (Jakobsen, 1932), a name of Norse origin potentially derived from 'marlauk' meaning 'sea onion' (Torbjørn, 2003). Eelgrass beds have been recorded at the head of sheltered shallow voes on the west coast of Shetland, and from Balta sound in Unst, although there have been no records at this location since the 1800s (Scott and Palmer, 1987). Widgeon grass is more commonly distributed, with records for both *Ruppia maritima* and *Ruppia cirrhosa* (syn. *Ruppia spiralis*) in coastal lagoons and pools cut off from the sea by shingle beaches, but also occasionally in shallow sheltered areas of tidal lochs (Druce, 1922; Scott and Palmer, 1987).

The last review of the distribution of seagrass in Shetland was undertaken by W. Scott and R. Palmer as part of their flora 'The Flowering Plants and Ferns of the Shetland Islands' published in 1987. Scott and Palmer (1987) note that the earliest reference to both *Z. marina* and *Ruppia* spp. is in Unst by the Shetland botanist Thomas Edmondston in 1837. In Edmondston's Flora of Shetland (1845), *Z. marina* is described as inhabiting "Sandy sea shores, generally covered unless at very low tides, common". There are further references to *Zostera marina* as 'common' in the published flora and survey notes of visiting botanists including Alexander Craig-Christie, William Hadden Beeby, and George Claridge

[1] Also spelt 'marlik' or 'marklak' (Anugs (1914), Jakobsen (1932))

[2] Also spelt 'marli' or 'marlee' (Jakobsen (1932))

Druce in the late 1800s and early 1900s (Craig-Christie, 1870; Druce, 1922; Druce, 1925; Scott and Palmer, 1987). The same sources also document the occurrence of *Ruppia* spp., with the earliest record for *Ruppia maritima* found in Edmonston's Flora (Edmondston, 1845), although later versions give the same location references for *Ruppia spiralis* and a novel location record for *R. maritima* (Edmondston, 1903).

The historic high abundance of *Z. marina* during this early period is documented by Scott and Palmer (1987), to whom Weisdale Voe and Marlee Loch in the Vadills, Brindister Voe were identified as particularly abundant:

> *"The late W. H. Robertson told us that the 'marlie' used to be so abundant towards the head of Weisdale Voe that a channel was sometimes needed to be cut to allow the passage of small boats. At very low tides the plant would become exposed, allowing whelks to be gathered from its bottle-green leaves. The autumn gales would drive masses of eelgrass on to the beaches from where it was harvested for bedding cattle and for stuffing mattresses; for the latter purpose it had to be very carefully dried. In the Weisdale area these practices continued into the early 1920s."* (Scott and Palmer, 1987)

Indeed, the name 'Marlee Loch' is a direct reference to the prevalence of *Z. marina* at this site from the Shetland 'marlie' (Jakobsen, 1932). The practice of collecting seagrass after autumn storms for use in mattresses is documented from Shetland more generally and was reportedly believed to protect against fleas (Fenton, 1997). These practices were also seen in Denmark and elsewhere in the UK (Gamble *et al.*, 2021; Torbjørn, 2003).

Zostera marina appears to have drastically declined in Shetland around the same time as general loss across the North Atlantic. Scott & Palmer (1987) reference the drastic decline of colonies at Weisdale Voe and Marlee Loch in the 1930s, attributing the loss to seagrass wasting disease (*Labyrinthula* spp.). Whether seagrass decline is attributable purely to disease, or a combination of other factors including environmental conditions and eutrophication is hard to determine.

Starting in 1986, several in-depth field surveys were conducted around the coast of Shetland as part of the Marine Nature Conservation Review (MNCR) of Great Britain (Hiscock 1989). The results of the MNCR and other surveys during the early 1990s in Shetland are summarised in Howson (1999). These surveys included detailed dive surveys of the upper part of Whiteness Voe, between 1987 to 1989 to identify the sublittoral habitats and associated communities (Hiscock, 1989). The survey identified the *Zostera marina* seagrass beds as the most extensive in Shetland, at the time (Hiscock, 1989).

Since the high marine survey effort in the late 1980s and 1990s there has been no dedicated survey to understand the current distribution of seagrass in Shetland. In the 2017 Shetland Islands Marine Region State of the Environment Assessment, seagrass beds in Shetland were assessed to be deteriorating, with findings constrained by lack of evidence on current status (Shucksmith, 2017). Anecdotal accounts suggests that seagrass has continued to decline across Shetland.

1.3 Study Aims

The aim of this study was to determine the current distribution and extent of seagrass beds in the Shetland Islands. The key objectives of this study were as follows:

- Collate historic records and public observations of seagrass habitat in Shetland to identify survey search areas.
- Trial the use of UASs and community snorkel surveys as a cost-effective means to locate and map subtidal *Z. marina* seagrass beds.
- Determine the exact location and map the boundaries of subtidal *Z. marina* beds in Whiteness Voe.
- Assess the status of *Z. marina* in the Shetland Islands and make recommendations for marine management and future restoration needs.

Figure 1 – Aerial image of Marlee Loch at the head of Brindister Voe in the Vadills SAC. The name Marlee Loch is a reference to the historic presence of seagrass beds at this site.

2 Methods

2.1 Study area

The Shetland Islands are Scotland's most northerly island group, situated approximately 150km north of the Scottish mainland between Scotland and Norway. Lying between 59° and 61° North, the Shetland Islands have an extensive, deeply indented coastline of over 2730 km in length characterised by many voes (narrow inlets) and firths (NatureScot, 2019). Shetland's outer coast is exposed to the full force of Atlantic waves and storms, but these narrow voes provide shelter for varied marine assemblages. This project reviewed seagrass records across the whole of the Shetland Islands, while surveys of the current extent of seagrass were restricted to the Shetland Mainland (Figure 1).

2.2 Review of historic seagrass distribution

A review of seagrass records was conducted through an initial search of the National Biodiversity Network (NBN) gateway, NMPi, and DASSH for both *Zostera* spp. and *Ruppia* spp. within the Shetland Islands area. This search was used to identify survey records in the Government Database portal, primarily those associated with the Marine Nature Conservation Review (MNCR) surveys in the late 1980s and early 1990s. The search included examination of published literature, survey reports and herbarium collections held by the Shetland Museum and Royal Botanic Gardens Edinburgh. The full list of reviewed databases and literature is provided in Appendix 1.

Records were compiled and cross-referenced to identify duplicate records across different data repositories. Records were imported into ArcGIS Pro and the point locations were cross-referenced with OS Maps and satellite imagery using Digimap Ordnance Survey and Aerial Imagery Collection (https://digimap.edina.ac.uk/). Where no latitude and longitude were given, or where the latitude and longitude did not match the described location, the location was updated using Edina Digimap OS Map based on the record location description, coordinates of other records from the same site, or based on the habitat description (e.g. presence of coastal lagoons).

Information was also sought from the local community on historic or current sightings of seagrass through outreach events and materials circulated via the Shetland Community Wildlife Group. This identified two sites (Saltness and North Collafirth) with potential sightings of seagrass, although it was not known if this was *Ruppia* spp. or *Z. marina* based on descriptions (Table 1).

2.3 Current extent of *Zostera marina*

2.3.1 Survey locations

The compiled list of historic *Z. marina* records was used to identify a prioritised list of survey locations within the Shetland Islands (Figure 1, Table 1). Surveyed areas were limited to Mainland Shetland as there have been no confirmed sightings of *Z. marina* in Unst since 1887. Sites with records from the 1980s onwards were prioritised, including Whiteness Voe, Weisdale Voe, the Loch of Hellister, the Burra isles and the Vadills & Marlee Loch. The location of three extant seagrass beds in Whiteness Voe (Z1-A,Z1-G, and Z1-H) was known prior to the start of surveys due to sightings by community members while either swimming or snorkelling (S. White, R. Shucksmith (*pers. comm.*) 2023). Two additional sites (Bay of Scousburgh and St Ninian's) were surveyed in south Mainland following the discovery of a large volume of drifted seagrass washed ashore on the south side of St Ninians beach in October 2024. A total of 13 areas were surveyed in Mainland Shetland from 19th April 2023 to 12th February 2025 (Appendix 2).

Table 1 – List of *Z. marina* sites identified from historic records and potential survey areas from community reports and drift records. Full details from source records can be found in Appendix 1.

Location	Site	Date of last historic record	Most Recent Source
Whiteness Voe	Z1	2020	1994 SNH sublittoral survey of Whiteness Voe
Weisdale Voe	Z2	1978	Scott & Palmer 1987
Loch of Hellister	Z3	1993	1993 MNCR Shetland lagoons survey
Marlee Loch	Z4	1983	Scott & Palmer 1987
Head of the Vadills	Z5	1988	1988 MNCR Shetland littoral and sublittoral survey
Papil, Burra Isles	Z6	1986	1986-87 MNCR Shetland, Foula and Fair Isle survey
South of Holms, Burra Isles	Z7	1987	1986-87 MNCR Shetland, Foula and Fair Isle survey
Effirth Voe	Z8	1980	Scott & Palmer 1987
Semblister	Z9	1927	Scott & Palmer 1987
Tresta Voe	Z10	1912	Scott & Palmer 1987
Balta Sound, Unst	Z11	1839 to 1887	Scott & Palmer 1987
Saltness, Brae	Z12	1996	Entec 1996/Community report of seagrass
North Collafirth	n/a	n/a	Community report of seagrass
St Ninian's Tombolo	n/a	n/a	2024 Drift record of *Z. marina* at St Ninian's Tombolo
Bay of Scousborough	n/a	n/a	2024 Drift record of *Z. marina* at St Ninian's Tombolo

2.3.2 UAS Surveys

Initial explorative surveys of prioritised sites were conducted with an UAS (drone) to identify marine features that could indicate the presence of subtidal seagrass beds. A search area was planned based on the details of historic survey reports and records, analysis of satellite imagery, and water depth. UAS surveys were conducted with a DJI Mini 3 Pro or DJI Mavic 3E, with flights conducted in a semi-systematic pattern accounting for weather, light, and water visibility conditions. Flights were limited to days with low wind, and preferably sunshine with limited cloud cover. Between April 2023 and March 2025, 24 UAS surveys were conducted at 13 locations covering an area of approximately 9.59 km^2 (Table A 4).

Aerial photographs were taken of any notable features with the UAS camera facing directly down, with the UAS on-board GPS used to georeference the photos. Images were assessed manually for presence of subtidal marine features and any suspected seagrass bed locations recorded for future ground truthing surveys. Aerial images of known reference *Z. marina* beds in Whiteness Voe and known features such as kelp and macroalgae beds were used for comparison and to guide analysis. Aerial photographs were also taken of habitat features in the context of other landmarks such as notable shore features and the approximate location also noted on an OS Map in the field to guide community ground truthing surveys (Figure 6).

Where *Z. marina* beds were suspected or confirmed, further UAS flights were conducted at 70 m to provide aerial photographs of the full extent individual beds, and at 30 m to provide aerial photographs to produce georeferenced photomosaic images. Flights with the DJI Mavic 3E utilised flight planning software to fly pre-programmed routes to capture images for photogrammetry. No ground control points (GCPs) were deployed due to difficulties in accessing suitable shore locations in remote areas. The in-built UAS GPS was used to directly georeferenced the orthomosaics, using the open-source software WedODM Lightning.

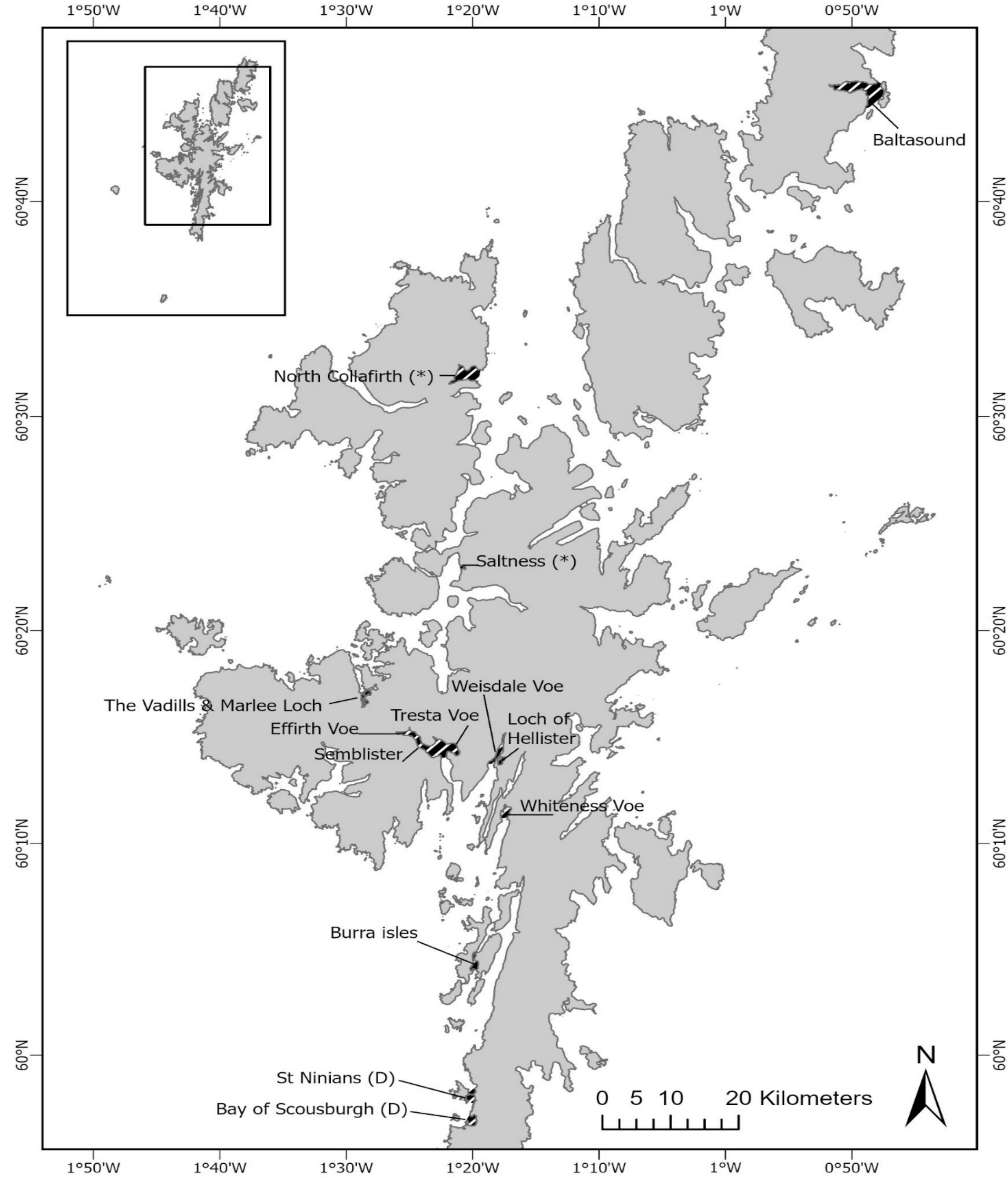

Figure 2 - Areas identified from historic records of Z. marina in the Shetland Islands, records of drift seagrass (D) or community observations (*). All sites were searched between 2023 and 2025 apart from Balta Sound, Unst.

2.3.3 In situ verification of seagrass presence and bed extent

Suspected seagrass beds were verified by swim, snorkel or paddleboard surveys to confirm presence and distribution of *Z. marina*. Local swimming and paddle groups aided in the verification and mapping of seagrass beds. Aerial photographs and the location of potential beds were shared with community members to guide searches (e.g. see Figure 2), and seagrass presence and location was confirmed using underwater cameras and a handheld Garmin GPS (ETREX 22x).

In Whiteness Voe, where UAS surveys identified multiple *Z. marina* beds, the extent of individual beds was mapped between April 2023 and September 2024 (Table 7), following protocols based on those designed by Seawilding and BSAC for 'The Great Seagrass Search'. Teams of two people snorkelled the outer edge of the seagrass beds supported by a team member on shore. The lead snorkeller identified the edge of the bed, with the second team member following with a GPS device in a tow float. The GPS device was set to save a waypoint every 2 seconds, with a waypoint saved manually at the start and end of the track. An underwater camera was used to take pictures of the seagrass to confirm ID and provide an indicator of the health of the beds. All beds bar Z1-I and Z1-L were mapped via snorkel, and a similar method was trialled using a paddleboard to map the edge of bed Z1-L. A paddleboard survey confirmed the rough distribution of bed Z1-I, but the edge extend was derived from the orthomosaic image generated through UAS flights.

2.3.4 Data analysis

GPS tracks and waypoints were processed in ArcGIS Pro with GPS tracks trimmed based on timestamps to remove waypoints from the survey approach or where points overlapped due to variation in snorkeller speed. The point data from the GPS track was joined using straight lines to create a polygon of the bed perimeter using ArcGIS Pro Geoprocessing tools.

2.3.5 *Z. marina* bed health and biodiversity

Data on seagrass bed density was collected by snorkellers at two of the Whiteness Voe beds (Z1-A and Z1-H). Five haphazardly placed 0.25 m^2 quadrats were photographed and the percentage cover of seagrass, algae and presence of wasting disease noted. Photographs and observations of seagrass health were also collected opportunistically during surveys of edge extent.

Observations of wider biodiversity were not systematically collected, but records of species observed by snorkellers and recreational swimmers in Whiteness Voe were collected over the course of the project period. A Baited Remote Underwater Vehicle (BRUV) deployment was trialled in Whiteness Voe in May 2024, using a lander placed from shore in the shallowest seagrass bed (Z1-D) at approximately 1m below chart datum at low tide. The BRUV was baited with mackerel and deployed for 60 minutes, fitted with a GoPro Hero in an underwater housing and two underwater lights.

2.3.6 Environmental Data

A conductivity, salinity and temperature logger (Star Oddi DST CT) was deployed in Whiteness Voe at 1m from the seabed attached to a mooring located within 3m of the *Z. marina* bed Z1-A in June 2024 with the last retrieval in March 2025. In Weisdale Voe, the logger was deployed attached to an oyster trestle within 30m of the seagrass bed (60.244379, -1.298479). The loggers were set to a measurement interval of 1 hour. Data was downloaded using Star-Oddi Seastar software and the average temperature and salinity data per day was calculated.

3 Results

3.1 Review of historic seagrass records

3.1.1 Zostera spp.

Location data on *Z. marina* from the Shetland Islands was compiled from 28 sources. The review of historic records identified 73 records of *Z. marina* and one record of *Zostera sp.* at 12 sites in the Shetland Islands from 1837 to 2020. Most of these records are from sheltered voes on the west side of Shetland mainland, except for records from Balta Sound, Unst (Figure 3). At some locations there are multiple records per site from different sources, but there are also duplicate records per site as MNCR survey datasets include both habitat and individual species point records. There were five records of drifted plants, including two records from North Haven, Fair Isle. In addition, a large quantity of *Z. marina* plants (>25 plants) washed up on the south side of St Ninian's tombolo in November 2024. The source of these drifted *Z. marina* plants is uncertain, but plants were bright green and appeared alive (Giesler RJ *pers. obs.* 09/11/2024).

Zostera noltii was recorded in the Loch of Hellister in 1993 from the MNCR Shetland Lagoon Survey. However, a later record from 2007 states that genetic work carried out on suspected *Z. noltii* specimens at this location identified them as *Ruppia* sp.[3] Cleator (1993) also identify an unauthenticated record from Gott, east Mainland, but again this may be a misidentification as there are numerous records of *Ruppia* sp. from this site.

3.1.2 *Ruppia* spp.

The review identified 126 records for *Ruppia* spp. spanning the period from 1888 to 2016, with records for *R. maritima*, *R. cirrhosa*, and *Ruppia spiralis*. There were 37 sites with records of *Ruppia* sp. from Yell, Whalsay, Fetlar, Unst, and Mainland Shetland (Figure 4). Most records are from small lagoons or houbs (lagoons at the head of voes), of which there are numerous examples across Shetland. The recorded distribution is likely an underestimate of the distribution of *Ruppia* sp. in Shetland as there are other locations which would appear suitable for *Ruppia* sp. but do not have survey records. These records are a mix of point species observations and seagrass bed habitat records.

During the project period, presence of *Ruppia* sp. was noted at the Loch of Hellister (05/07/2023) and at The Brigs, Clousta (25/05/2024). No other areas were surveyed.

[3] Record: 2cd4p9h.dzbksc | Occurrence record | NBN Atlas Scotland

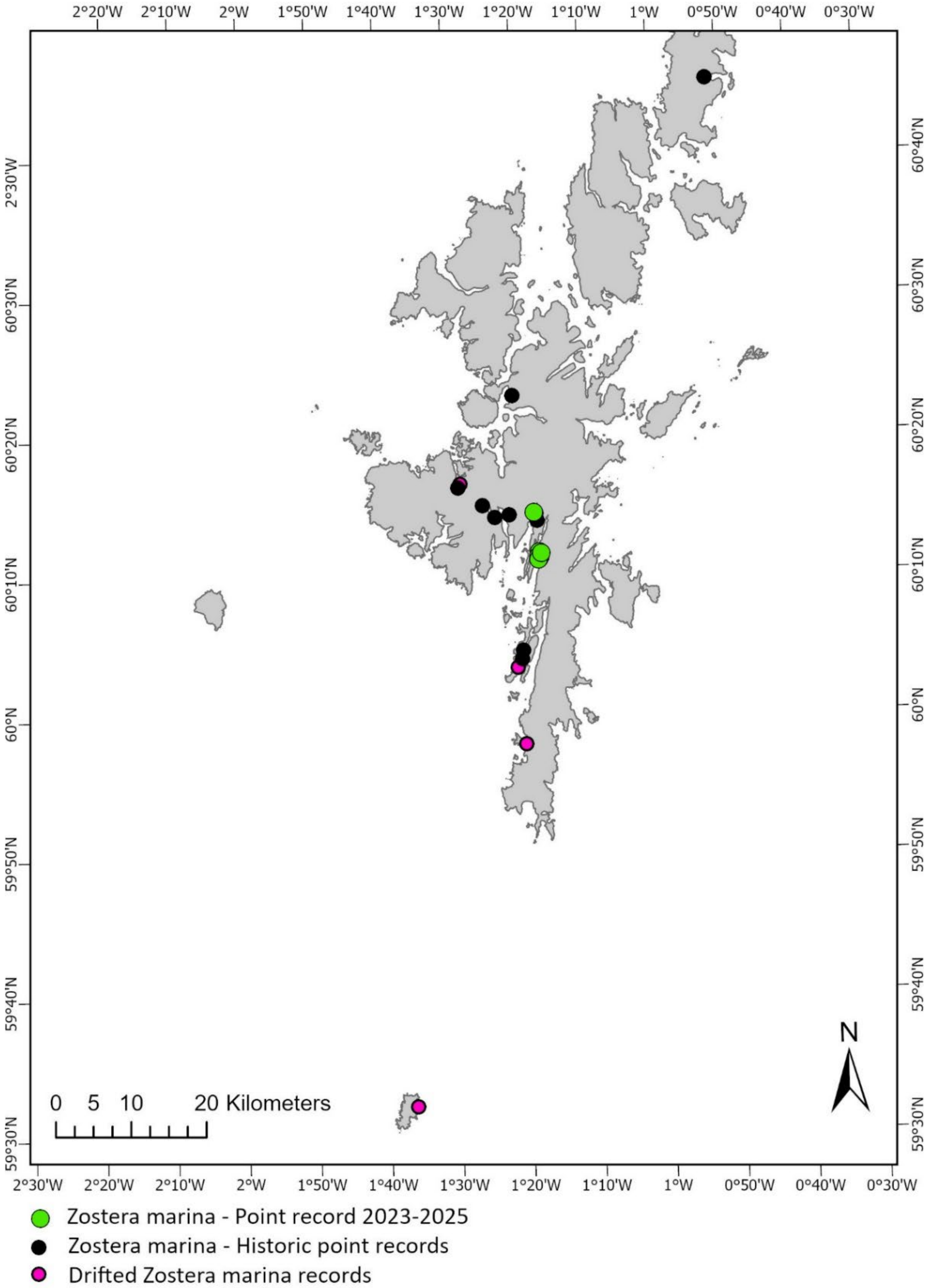

Figure 3 - Historic and current point records of *Zostera* sp. from the Shetland Islands from 1888 to 2025. Positions have been corrected for some records where they could be derived from location description.

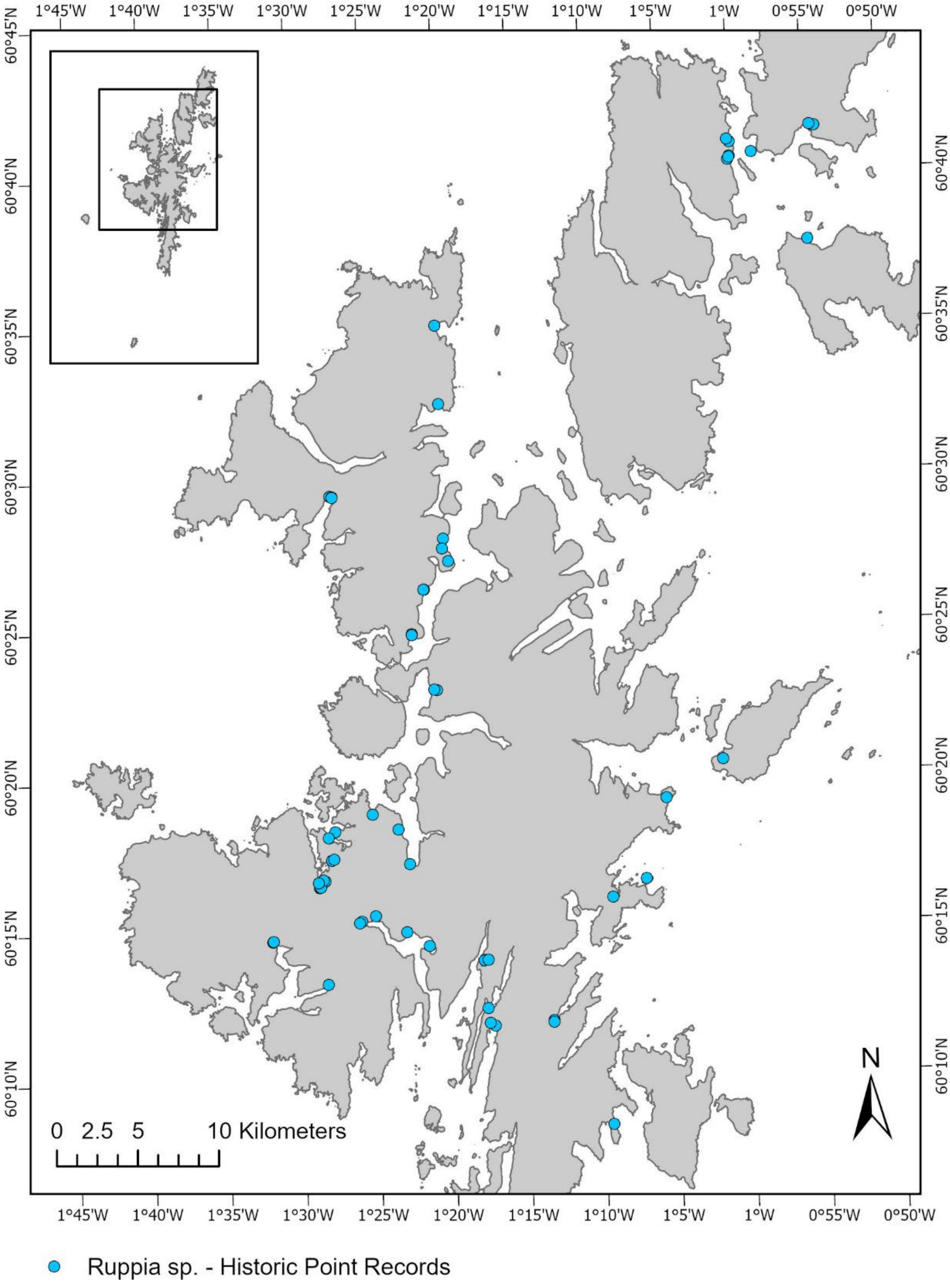

Figure 4 – Historic point records of *Ruppia* spp. from the Shetland Islands from 1888 to 2016. Positions have been corrected for some records where they could be derived from location description.

3.2 Current extent and condition of *Zostera marina* beds in Shetland

Z. marina was found at two sites: Whiteness Voe where it was known extant beds were present, and Weisdale Voe where *Z. marina* was last recorded in 1980. Analysis of aerial footage from UAS surveys did not suggest presence of extensive *Z. marina* beds at any other site. It is possible that small sparse beds may have been missed in analysis of aerial photos, especially at the Loch of Hellister where water visibility was limited. Three additional sites were surveyed based on community reports of seagrass presence (North Collafirth and Saltness) and following sightings of drifted specimens (Bay of Scousburgh and St Ninian's) but there was no evidence for *Z. marina* presence in aerial photos.

There are fourteen confirmed subtidal *Zostera marina* beds in Whiteness Voe and one bed in Weisdale Voe (Table 1). All beds were greater than 25 m^2 with greater than 5% cover confirmed by in-situ observations and thus meet the OSPAR definition of a *Zostera* bed (OSPAR, 2009). In Whiteness Voe, the beds are mainly located around the 2 m bathymetry line on the eastern shore of the voe in relatively shallow depths (Figure 5). However, the largest bed (Z1-I, 7707 m^2) is in the centre of the voe between two skerries (rocky islets only uncovered at low tide). The total spatial bed extent of all confirmed eelgrass beds is 16,184 m^2 (1.62 ha or 0.016 km^2). The only *Z. marina* bed found in Weisdale Voe was relatively small, at 292.5 m^2, and notably sparser and patchier than beds in Whiteness Voe. The size of the bed was derived from aerial photos and may have been overestimated as the seagrass was interspersed with algae (Giesler RJ *pers. obs.* 29/05/2024).

Subtidal *Z. marina* beds in Whiteness Voe appear healthy, with high stalk density in the summer months. The percentage cover of seagrass in beds Z1-A and Z1-H varied from 30% to 80%, with an average cover of 61 ± 17% in site Z1-A (07/05/2023) and 40 ± 7% in site Z1-H (26/05/2024). Epiphyte cover across all beds was assessed as low based on visual assessment by snorkellers and comparison with reference photos in Gamble *et al.* (2021). The presence of seagrass wasting disease (*Labyrinthula* spp.), indicated by blackened shoot tips, was noted in all Whiteness beds but did not appear to be negatively impacting the overall health of sites. Flowering shoots were observed in beds Z1-B and Z1-C during community snorkel surveys undertaken in August 2023 and in Z1-A, Z1-H and Z1-J in May 2025. There was no indication of seed formation, just the presence of flowering inflorescences.

Loss of seagrass shoots during autumn gales resulted in beds having significantly sparser densities during winter months, with shoot length observed to be much shorter (Giesler RJ *pers. obs.* 17/01/2025). Seagrass density peaked during late summer, and differences in seagrass density between summer and winter were notable on UAS aerial footage with gaps in the seagrass bed visible in winter months (Figure 3).

High Resolution (25cm) Vertical Aerial Imagery (2021) [JPG geospatial data], Scale 1:500, Tiles: hu3944,hu3945 Updated: 21 October 2020, Getmapping, Using: EDINA Aerial Digimap Service, <https://digimap.edina.ac.uk>, Downloaded: 2024-08-06 11:09:03.629

Figure 5 - Aerial image of Whiteness Voe with locations of surveyed *Z. marina* beds (labelled A to L). Exact central coordinates are provided in Table 1.

Table 2 – Estimated area of *Zostera marina* beds in Shetland, mapped by UAS and confirmed by snorkel and paddleboard surveys.

Bed	Location	Central Point (DD - WGS84)	Survey Type	Survey Date (YYYY-MM-DD)	Area (m^2)	Perimeter (m)
Z1-A	Whiteness Voe	1.2874110°W 60.1961862°N	GPS Track - Snorkel	2023-07-05	1060.5	209.07
Z1-A1	Whiteness Voe	1.2881361°W 60.1962044°N	GPS Track - Snorkel	2023-07-05	40.8	26.84
Z1-A2	Whiteness Voe	1.2882810°W 60.1961551°N	GPS Track - Snorkel	2023-07-05	27.3	21.11
Z1-B	Whiteness Voe	1.2845640°W 60.1940742°N	GPS Track - Snorkel	2023-08-30	846.1	147.20
Z1-C	Whiteness Voe	1.2851805°W 60.1933729°N	GPS Track - Snorkel	2023-08-30	625.5	118.82
Z1-D	Whiteness Voe	1.2871174°W 60.1905164°N	GPS Track - Snorkel	2023-09-13	323.5	96.95
Z1-E	Whiteness Voe	1.2875769°W 60.1904541°N	GPS Track - Snorkel	2023-09-13	211.5	57.10
Z1-F	Whiteness Voe	1.2877423°W 60.1902450°N	GPS Track - Snorkel	2023-09-13	297.3	79.25
Z1-G	Whiteness Voe	1.2889484°W 60.1884166°N	GPS Track - Snorkel	2023-09-06	1463.1	241.26
Z1-H	Whiteness Voe	1.2889749°W 60.1877237°N	GPS Track - Snorkel	2023-09-06	1892.5	257.4
Z1-I	Whiteness Voe	1.2909937°W 60.1912252°N	UAS Aerial Photo	2023-09-13	7703.4	873.82
Z1-J	Whiteness Voe	1.2902224°W 60.1874588°N	UAS Aerial Photo	2024-02-05	1072.9	146.03
Z1-K	Whiteness Voe	1.2903841°W 60.1871858°N	UAS Aerial Photo	2024-02-05	200.6	57.46
Z1-L	Whiteness Voe	1.2837486°W 60.1951133°N	GPS Track - Paddleboard	2024-09-22	126.5	48.8
Z2-A	Weisdale Voe	1.2990132°W 60.2436975°N	UAS Aerial Photo	2024-10-02	292.5	97.1
				Total Area:	**16,184**	

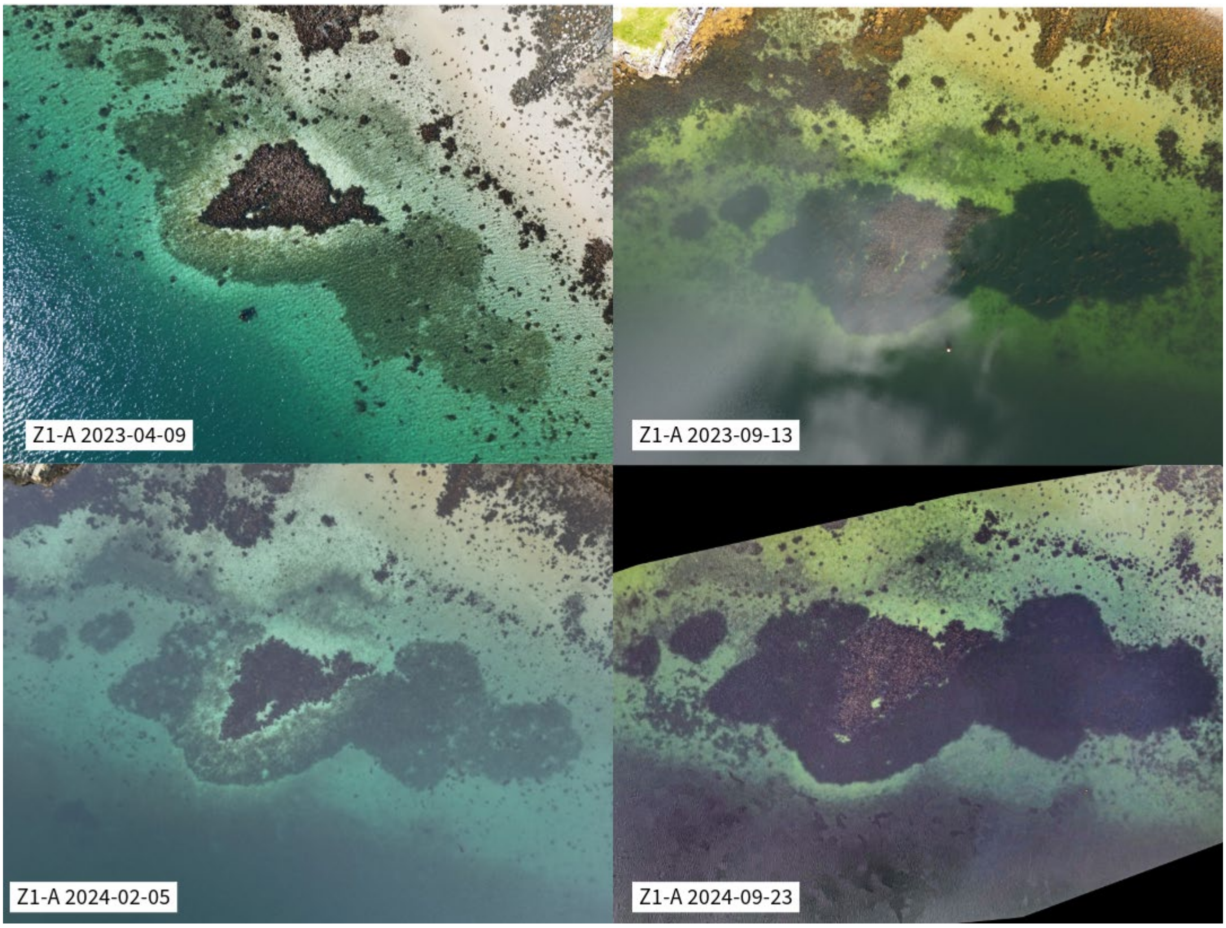

Figure 6 - Aerial photographs of subtidal *Z. marina* bed Z1-A in Whiteness Voe in late winter/early spring and late summer across 2023 to 2024. Photo 4 is a photomosaic from multiple aerial photos and was edited to remove haze caused by weather conditions.

3.2.1 Environmental conditions

The daily average temperature measured in Whiteness Voe at site Z1-A is shown in Figure 7, and the daily average salinity is shown in Figure 6. Challenges in retrieving and redeploying the loggers meant that there were gaps in the Whiteness log between August and November 2024 and at the start of February 2025. The minimum temperature recorded was 4.40°C on 11/01/2025 and the maximum temperature was 17.83°C on 04/08/2024. The minimum salinity (PSU) was 24.46 on 03/12/2024 and the maximum 34.8 on 11/07/2024. Analysis of the data trends suggests that the logger captured the full temperature range at this site.

The daily average temperature in Weisdale Voe near site Z2-A is also shown in Figure 5, and the daily average salinity is shown in Figure 8. Between August 2024 and April 2025, the minimum temperature recorded was 3.27°C on 03/01/2025 and the maximum temperature was 17.44°C on 06/08/2024. Salinity at Weisdale Voe was significantly more variable than at Whiteness with a minimum salinity below the lower limit of the logger (<3 PSU) on 18/09/2024 and a maximum of 34.23 on 06/09/2024, likely because of the proximity of the logger to a small burn near the southern extent of the oyster farm trestles. The dramatic change in salinity within a 12-day period is attributable to the onset of autumn storms in Shetland.

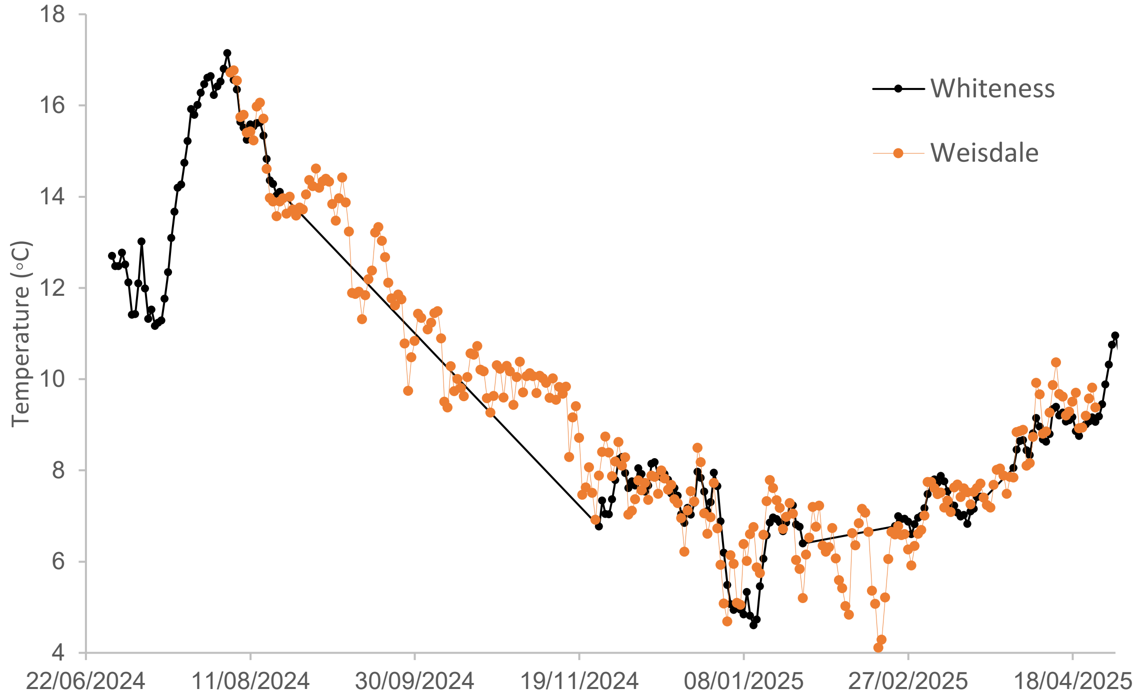

Figure 7 – Average daily temperature (°C) at 1 m from the seabed in Whiteness Voe (Z1-A) from June 2024 until April 2025 (black) and in Weisdale Voe (Z2) from August 2024 to April 2025 (orange). Gaps in the temperature record are from periods where it was not possible to retrieve or deploy the CT logger.

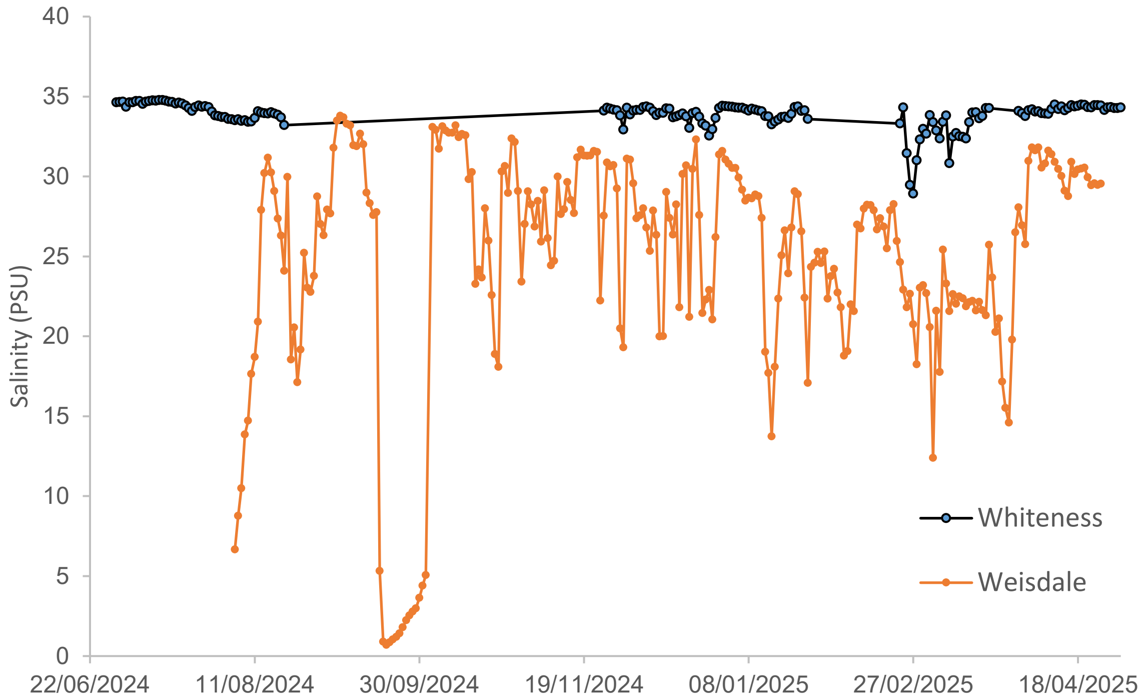

Figure 8 - Average daily salinity (PSU) at 1 m from the seabed in Whiteness Voe (Z1-A) from June 2024 to April 20252025 (black) and in Weisdale Voe (Z2) from August 2024 to April 2025 (orange). Gaps in the salinity record are from periods where it was not possible to retrieve or deploy the CT logger.

3.2.2 Associated biodiversity

Eelgrass beds In Whiteness Voe were observed to have a wide variety of associated species during snorkel surveys, with high numbers of Rissoid snails, dog whelks, sea hares, hermit crabs, spider crabs and green crabs, pipefish, and sand eels. Notable species records in the wider upper voe include observations of native oyster (*Ostrea edulis*), flapper skate (*Dipterus intermedius*) and the royal flush sea slug (*Akera bullata*) which is typically found with *Zostera marina*. A full description of the associated benthic biotopes and species found in Whiteness Voe is provided in Hiscock (1989).

Figure 9 - Image of a pipefish in a seagrass bed in Whiteness Voe, recorded in BRUV footage.

Figure 10 – Images of notable species associated with *Z. marina* beds or nearby sediment in Whiteness Voe ©M. McAllister/R.J. Giesler

3.3 Site descriptions

3.3.1 Whiteness Voe

Whiteness Voe is a 3.3 km long inlet running north to south on the west side of Mainland, Shetland. The inner part of the voe is very sheltered, protected by the relatively narrow south facing entrance, which also partly restricts water exchange (Howson, 1999). Hiscock (1989) extensively surveyed the upper part of Whiteness Voe in 1986-87, and reports *Z. marina* beds as occurring in mud or muddy sand between 0.5 m and 2.5 m depth (Figure 13). They describe the beds as patchy in occurrence with high abundance of *Chorda filum* within the beds. The current extent of *Z. marina* beds in Whiteness Voe is described in Section 3.2 and shown in Figure 13.

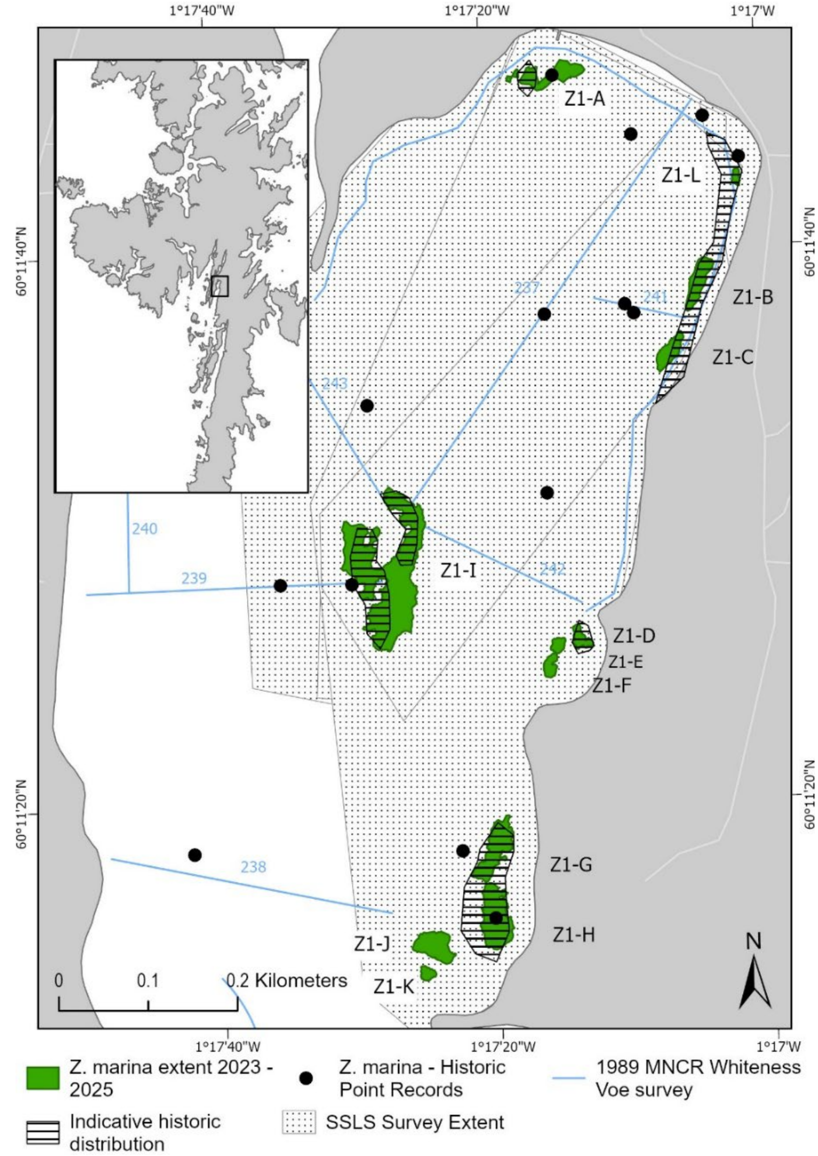

Figure 11 - Map of current and historic records of *Z. marina* beds in Whiteness Voe (Z1), including extent of area covered in UAS SSLS surveys in 2023-2024. The indicative historic distribution is based on the mapped extent of *Z. marina* in Hiscock (1989), with survey transect lines mapped in that report shown in blue. The centre point records in black are from the digitised MNCR Whiteness Voe Survey dataset.

3.3.2 Weisdale Voe & the Loch of Hellister

Weisdale Voe is a long narrow voe in West mainland running south to north, to the west of Whiteness Voe. The upper part of the voe is very shallow, with the Burn of Weisdale entering the voe at its head. There is evidence that eelgrass beds in this area used to be extensive pre-1930s, but had reduced to a smaller fragmented band of thin beds "among decaying seaweed" on the western shore by 1978 (Scott and Palmer, 1987). In 2023, the UAV surveys identified potential bands of subtidal vegetation on the western shore, but only a small, sparse bed of *Z. marina* was confirmed via paddleboard survey. The extent of eelgrass beds has declined greatly in Weisdale Voe, with only a small remnant patch remaining since the site was last surveyed nearly 50 years ago.

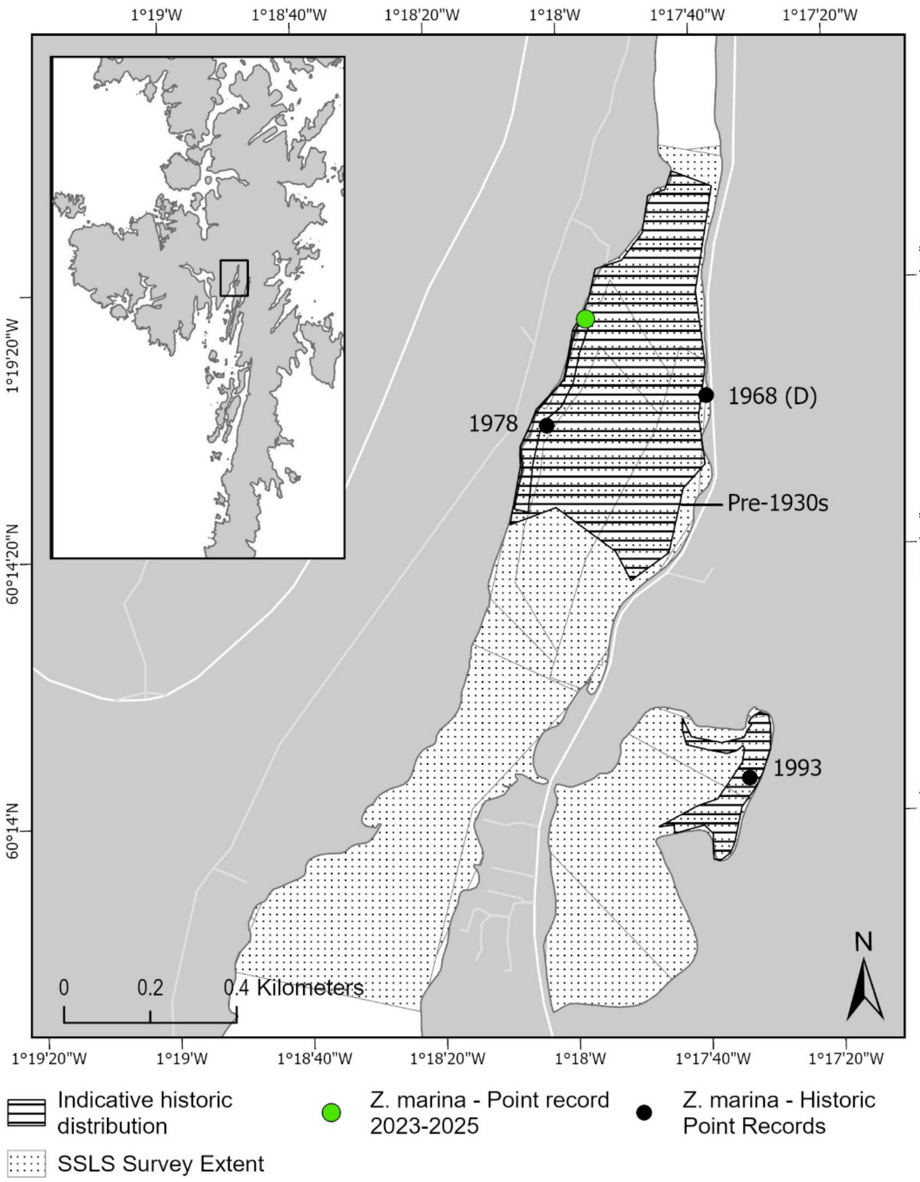

Figure 12 – Map of current and historic records of *Z. marina* in Weisdale Voe (Z2) and the Loch of Hellister (Z3), including extent of area covered in UAS SSLS surveys in 2023-2024. The indicative historic distribution of *Z. marina* in Weisdale is the reported distribution pre-1930s and on the western shore in 1978 (Scott and Palmer, 1987). The indicative historic distribution in the Loch of Hellister is based on the map of biotopes in Fig. 12.2 (Thorpe, 1998).

The Loch of Hellister is a large lagoon approximately 0.8 km in length, connected to Weisdale Voe via four culverts. Thorpe (1998) provide a full description of the Loch of Hellister as part of the MNCR lagoon surveys. There is limited current flow or wave action, although there is tidal exchange between the loch and Weisdale Voe. The 1993 MNCR Shetland lagoons survey recorded *Z. noltii* in the north-east section of the lagoon above 0.5 m, and a dense *Z. marina* bed between 0.5 and 2 m depth in the same area (Figure 11) (Thorpe, 1998). It is likely the identification of *Z. noltii* at this site was a misidentification of *Ruppia* sp., as identified in later genetic testing of specimens in 2007. Shore surveys undertaken as part of this project in 2023 also identified only *Ruppia* sp. as present in the north-east section and along the southern shore, but could not determine depth or density of *Ruppia* sp. due to high volumes of green algae (Giesler, RJ. 2023, *pers. obs.*). No *Z. marina* was observed from shore, or in a paddleboard survey in February 2025, although water clarity was low which prevented confidence in confirming absence. There was no evidence for *Z. marina* beds in the aerial footage from the site, but detection is more challenging against the dark sediment colour (Figure 12).

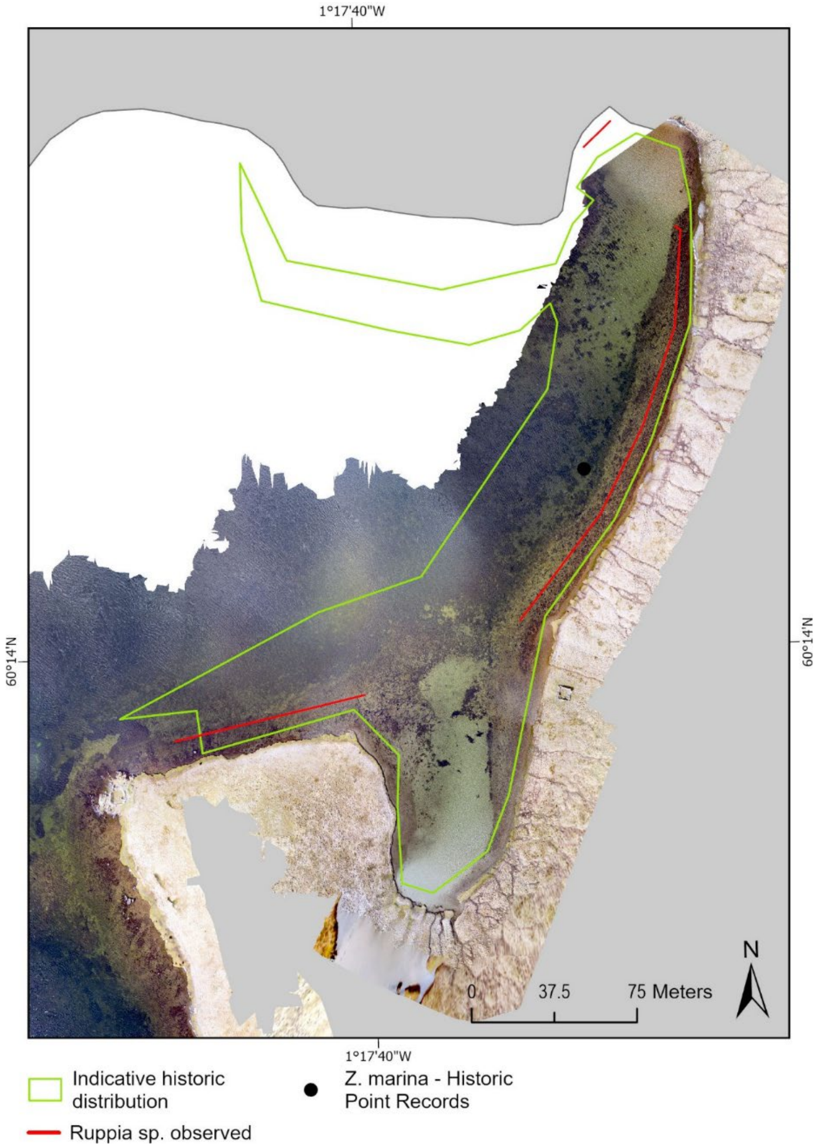

Figure 13 – Orthomosaic photo generated from aerial footage of the north-east corner of the Loch of Hellister from 05/07/2023. The location of *Ruppia* sp. observed from a shore survey on the same date is shown by the red line. Indicative historic distribution based on maps in Thorpe (1998).

3.3.3 Burra Isles

The sheltered South Voe area between West and East Burra is described in Howson (1999). There were two *Z. marina* beds identified in South Voe which persisted at least until the early 1990s (Scott and Palmer, 1987). There are records from the 1986-87 OPRU/MNCR Shetland, Foula and Fair Isle survey which document a dense but very patchy *Zostera* bed at 1 m depth at South of the Holms below the narrow channel which links the islands at Bridge End, and a small bed on muddy sand in the shelter of the Holm of Papil (Figure 13) (Hiscock, 1986). There are two herbarium specimens from this area, one collected from the Holm of Papil site in 1980, and a drift specimen collected from Minn beach in 2007.

UAS surveys in 2023 and 2024 found no evidence for subtidal *Z. marina* beds. It is possible that small sparse beds may have been missed in analysis of aerial photos, but snorkel searches near Papil in 2021 found no evidence for seagrass presence (Shucksmith, R. 2021, *pers. comm.*).

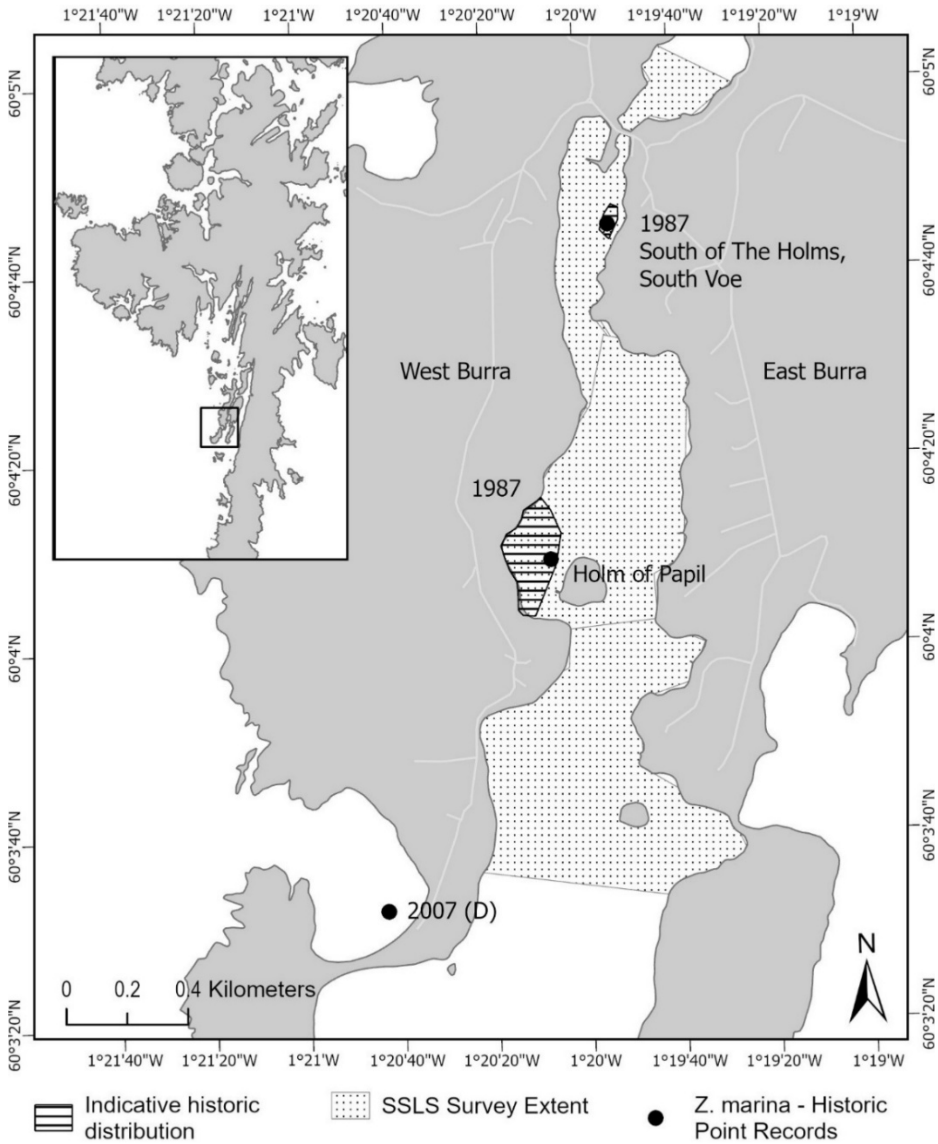

Figure 14 - Map of the Burra isles, including extent of area covered in UAS SSLS surveys in 2023-2024. Historic records of *Z. marina* beds are recorded in the 1986-87 OPRU/MNCR Shetland, Foula and Fair Isle and in Scott and Palmer (1987).

3.3.4 The Vadills & Marlee Loch

The Vadills is a large, complex lagoon system at the head of Brindister Voe, which includes shallow basins and silled lagoons. It is a very sheltered environment, in an area of Shetland with low levels of terrestrial development. The Vadills Lagoon system is a designated SAC (UK0017068) for its Annex 1 coastal lagoon habitat, with seagrass and maerl noted within the site descriptors.

Scott and Palmer (1987) note that "*The 'marlie' used to be very abundant in this sea-loch and was regarded as a nuisance by anglers. About the time of its dramatic decline in Weisdale Voe it all but disappeared from Marlee Loch as well*." Eelgrass beds were recorded in Marlee Loch and at the head of the Vadills in 1983 by W. Scott and in 1985 in the MNCR Shetland Littoral and Sublittoral Survey but were not found in extensive surveys in the Vadills area in 1993 (Howson, 1998; Scott and Palmer, 1987). There are also multiple *Ruppia* sp. records within inner part of the Vadills system.

UAS surveys in 2023 and 2024 found no evidence for subtidal *Z. marina* beds (Figure 17). It is possible that small sparse beds may have been missed in analysis of aerial photos, but extensive beds are likely absent from the area.

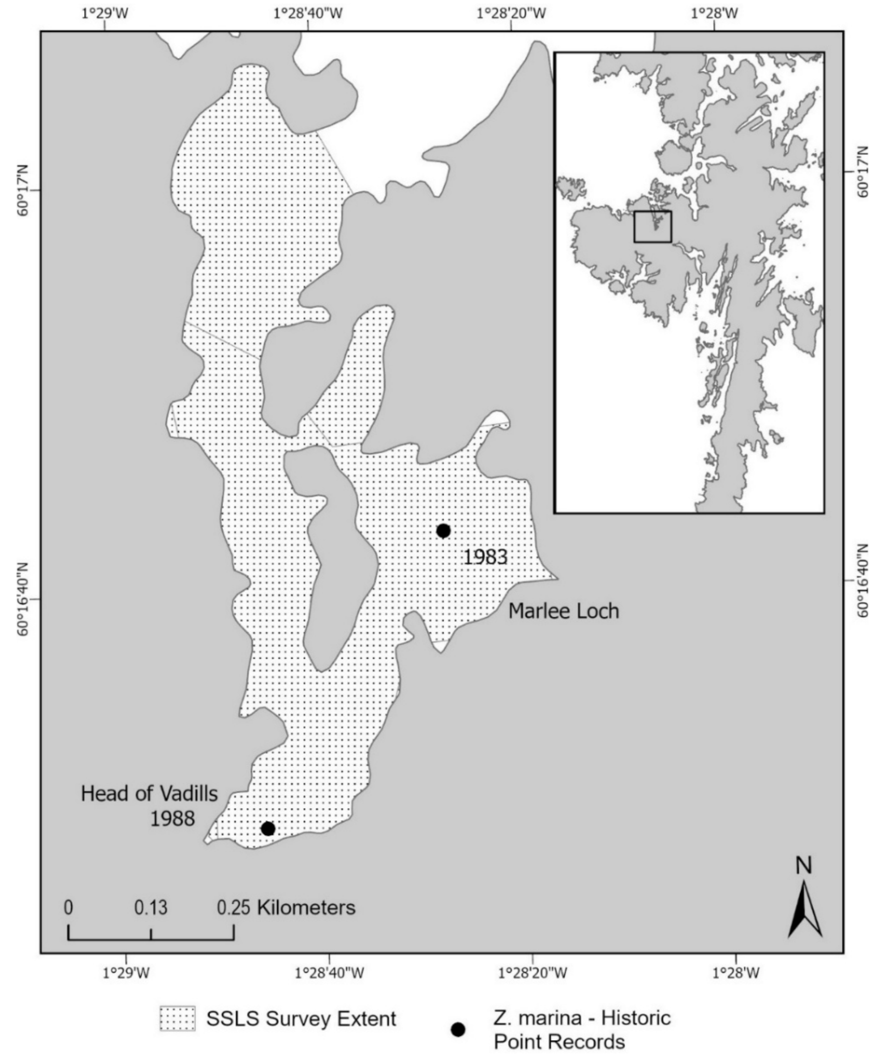

Figure 15 – Map of the Vadills and Marlee Loch in Brindister Voe, including extent of area covered in UAS SSLS surveys in 2023-2024. Historic records of *Z. marina* beds are recorded in MNCR Shetland Littoral and Sublittoral Survey (1988) and Scott and Palmer (1987).

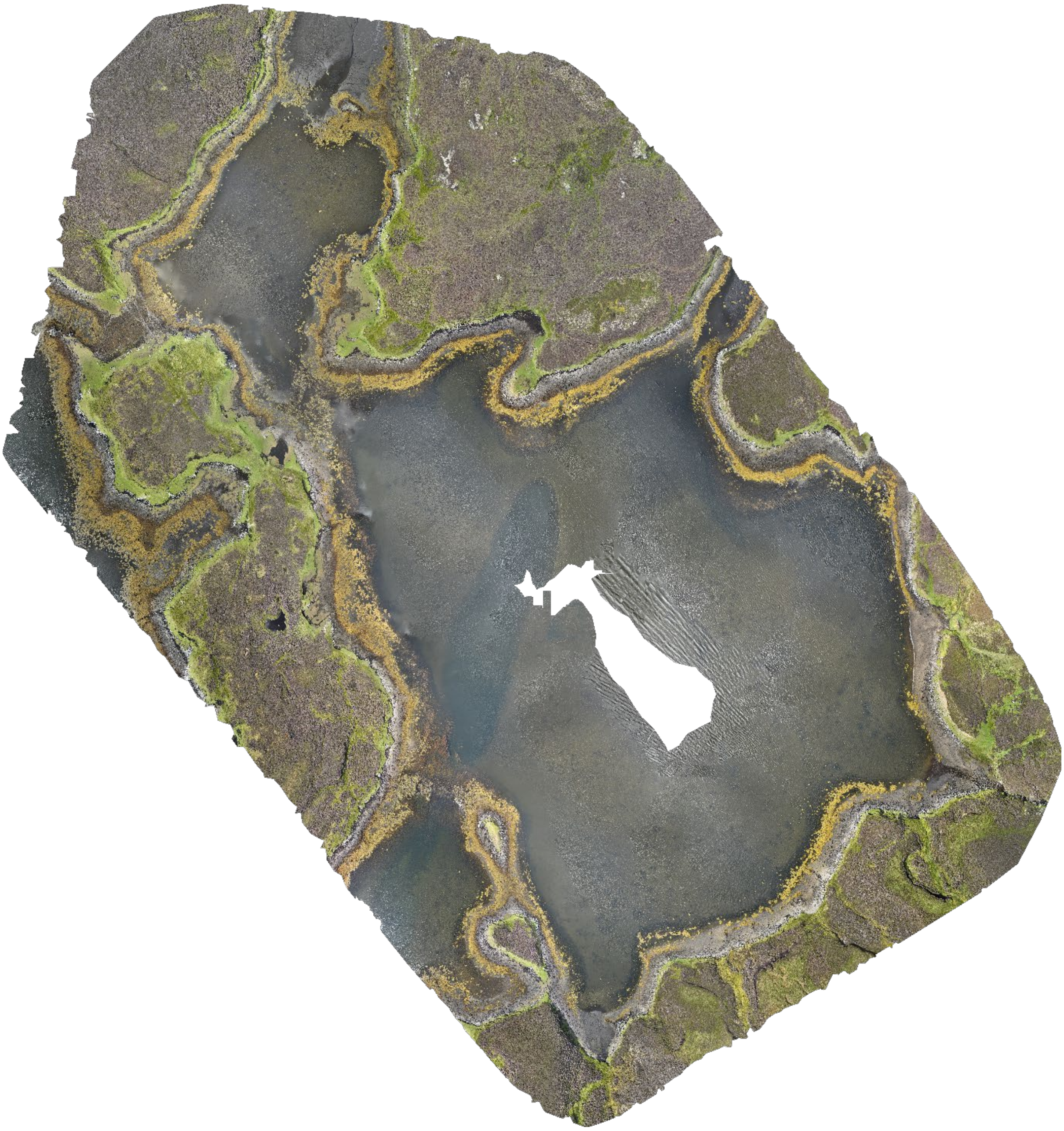

Figure 16 – Orthomosaic image of Marlee Loch in the Vadills SAC, generated from multiple aerial images of the area using a DJI Mavic 3E UAS.

3.3.5 West Mainland – Tresta Voe, Effirth Voe and Semblister

The Firth and Tresta Voe make up the inner basin of Sandsound Voe. There are historic records of *Z. marina* beds in Tresta Voe and the area below Semblister which were recorded as "not seen recently" in Scott and Palmer (1987) (Figure 18). In 1980, "a small quantity" of *Z. marina* on the south side of Effirth Voe was reported by W. Scott (Scott and Palmer, 1987). There are two herbarium specimens from this area, one collected from Effirth Voe in 1980, and a drift specimen collected near the head of Tresta Voe in 1978.

UAS surveys of Tresta Voe in 2024 and Effirth Voe and the area below Semblister in 2025 found no evidence for subtidal *Z. marina* beds. It is possible that small sparse beds may have been missed in analysis of aerial photos, especially those in Effirth Voe and Semblister which took place in winter when *Z. marina* density is low. However, there have been no community reports of *Z. marina* in the wider area despite popularity as a recreational free diving spot. Paddleboard searches of the Semblister area undertaken in July 2025 found no evidence of seagrass beds in the area.

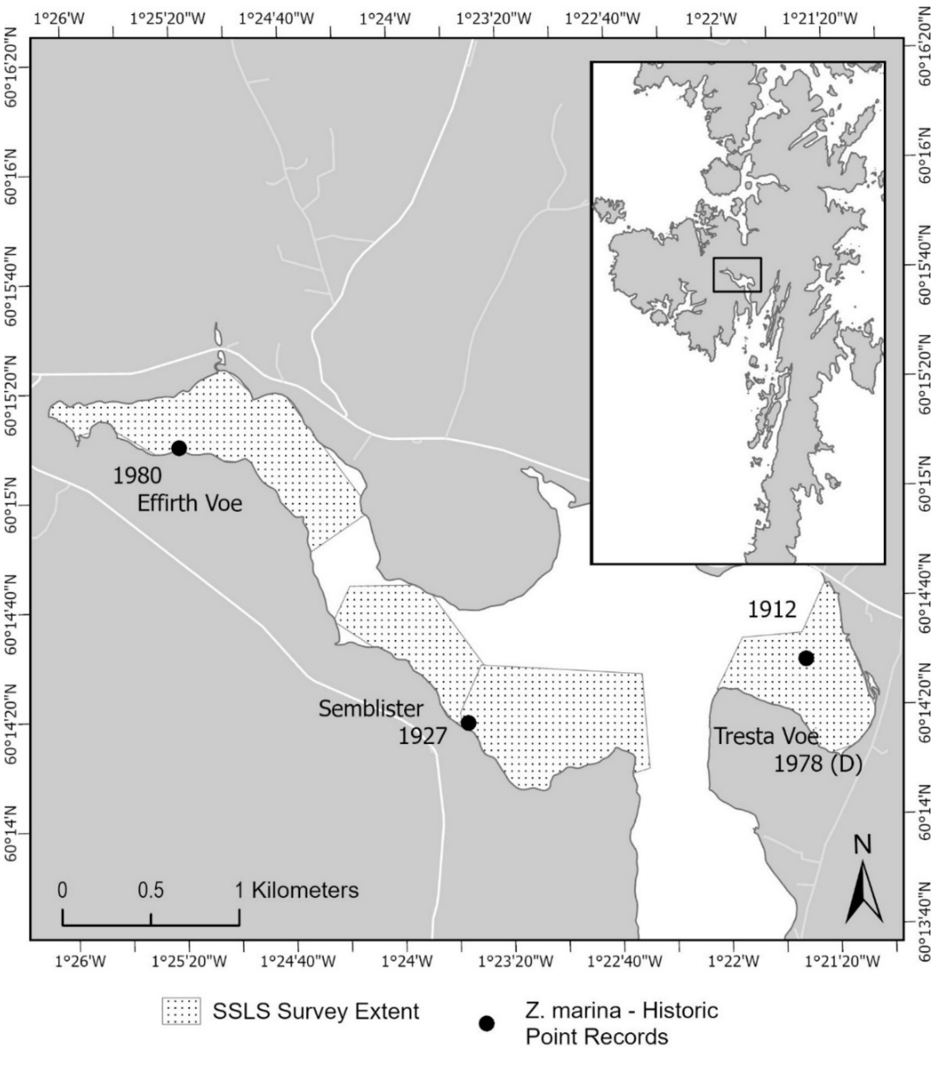

Figure 17 – Map of Tresta Voe and Effirth Voe in west Mainland, including extent of area covered in UAS SSLS surveys in 2023-2024. Three historic records of *Z. marina* beds are recorded in Scott and Palmer (1987).

3.3.6 Saltness, Brae

Located south of Brae in north Mainland, Saltness is a small lagoon connected to Busta Voe. There are records of *Ruppia maritima* from 1986 to 2007 in the southern part of the Voe, where a small stream enters the lagoon. The area was surveyed by Entec (1996) with the site called the Houb of Burravoe, with communities of *Zostera sp*. and *Ruppia sp*. noted from the shallow pond area (Entec, 1996). There have also been community reports of seagrass (species unknown) from this area. However, it is not known if the observed species was *Zostera marina* or *Zostera noltii*. Aerial photographs of the site were not conclusive, as the sediment colour is dark influenced by stream runoff making identification of features challenging (Figure 19).

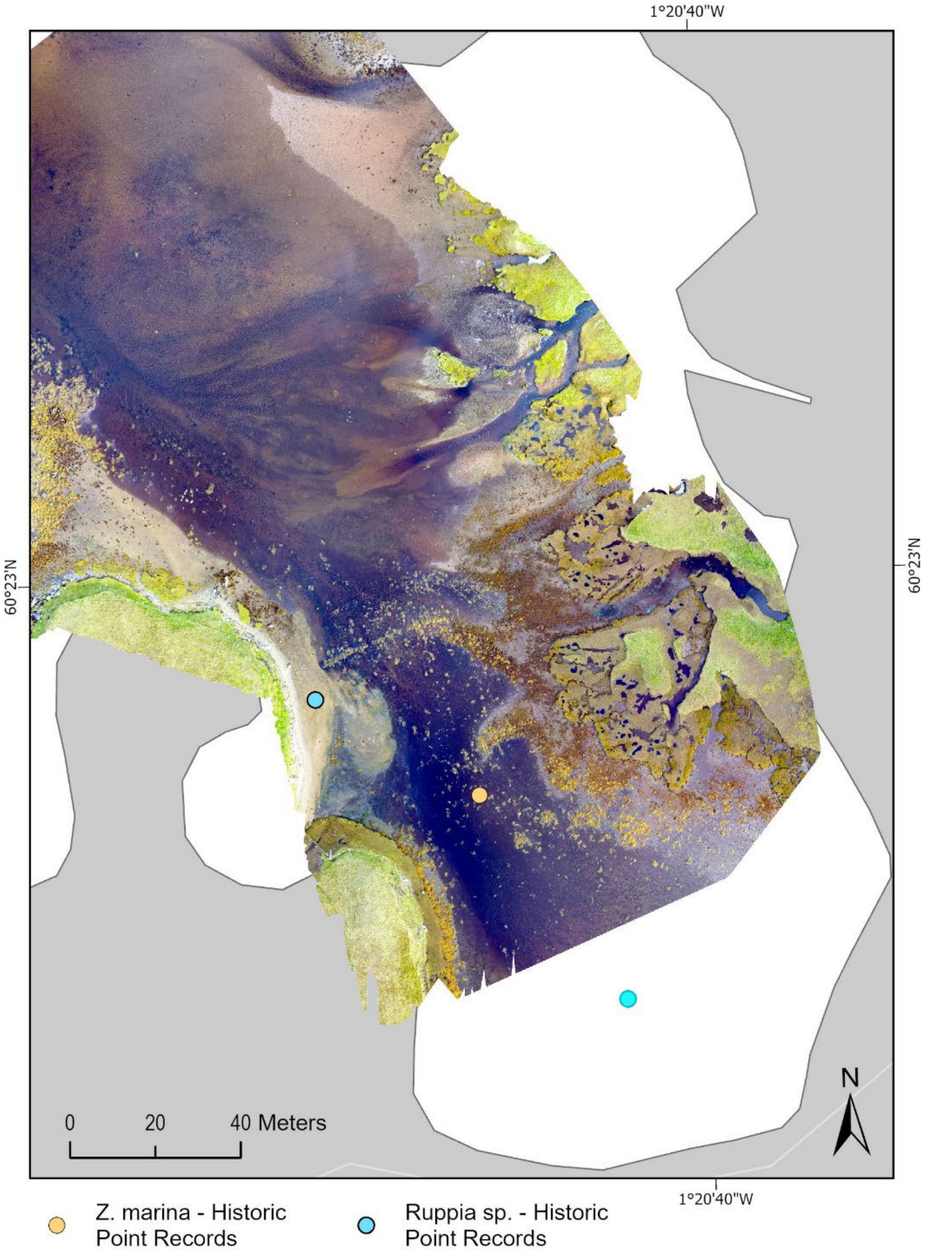

Figure 18 – Aerial orthomosaic image of Saltness lagoon on the east side of Busta Firth near Brae. The location of *Zostera sp.* is provided by Thorpe (1998) but the original record could not be verified.

4 Discussion

4.1 Historic distribution of *Z. marina* in the Shetland Islands

This study identified twelve locations with historic records of subtidal *Z. marina* beds. *Zostera marina* appears to have been locally abundant in the Shetland Islands until the 1930s (Hiscock, 1986; Scott and Palmer, 1987). The current distribution is very restricted, with confirmed sightings of *Z. marina* only found in two voes in west Shetland. There was no evidence from aerial footage to suggest that further extensive eelgrass beds remain in the area, although these absences still require ground truthing via in-water surveys (e.g. snorkel or paddle surveys). It is also possible that new or unreported beds exist that have never been recorded and hence were not shortlisted within the survey area, although there are relatively few sites with appropriate levels of shelter, depth, and sediment type across Shetland. It is therefore considered unlikely that any large beds exist that are unrecorded.

The key sites identified as having extensive historic seagrass beds are in the west of Shetland, in the sheltered, shallow areas at the head of Whiteness, Wesidale, Effirth, Tresta and Brindister Voe and in South Voe between the Burra isles (Scott and Palmer, 1987). The long narrow voes provide shelter from the high wave exposure found on the outer west coast of Shetland. The importance of the west Shetland voes for diverse marine habitats is reflected in the presence of historic native oyster (*Ostrea edulis*) records from similar areas, with South Voe between the Burra Isles classed as the most important oyster fishery area in Shetland in the 1880s (Shelmerdine and Leslie, 2009). *Ostrea edulis* also declined before the early 1900s, and is now rare in Shetland (Shucksmith, 2017). Areas in west Mainland have also been identified as important nursery areas for juvenile commercial fish species (Thomason & Fraser, 2025). While the small areas of remaining seagrass are unlikely to play a significant nursery habitat role at their current extent, seagrass habitat in the UK has been found to support juvenile commercial fish species including pollack, cod, whiting, saith, herring and plaice (Bertelli and Unsworth, 2014; Peters *et al.*, 2015).

In the 1830s to 1890s, seagrass in Shetland was described as "common" (Edmondston, 1845). References to practices of using seagrass as bedding material and requiring paths to be cut for boats indicate that at several sites such as Weisdale Voe and Marlee Loch it was locally abundant (Scott and Palmer, 1987). All records indicate that *Z. marina* has shown a continuous decline in extent since the 1930s, having disappeared from Unst, Tresta Voe and Semblister by the 1980s. The current extent of *Z. marina* in Shetland is approximately 1.62 ha, with bed sizes ranging from just over 25 m^2 to 1,463 m^2 (Table 2). When compared to records from the Outer Hebrides of extensive beds covering 280 to 360 ha, beds in Shetland are very small (Kent *et al.*, 2021; Malthus *et al.*, 2006). Even at historic high abundance levels Shetland's seagrass extent is likely to have been significantly less than in other parts of Scotland, with the largest bed extent on record in Weisdale Voe measuring approximately 24 ha at its pre-1930s coverage (Figure 12) (Scott and Palmer, 1987).[4] This is likely due to the relative lack of suitable shallow, sheltered areas in Shetland waters, with wave driven exposure an important predictor of habitat suitability for eelgrass beds (Bekkby *et al.*, 2008). This is also reflected in the relatively low number of sites with historic records.

[4]Area calculated in ArcGIS Pro based on description of historic coverage in Weisdale Voe in Scott & Palmer (1987).

The only remaining sites with confirmed *Z. marina* beds are the upper part of Whiteness Voe and Weisdale Voe. There has been no recovery of seagrass from losses in the early 1900s, with decline in seagrass extent continuing from the 1980s to the present day. The initial decline in the early 1900s has previously been attributed to seagrass wasting disease (*Labyrinthula zosterae*.) (Scott and Palmer, 1987). Other pressures which may have contributed to this decline include severe winter frosts which are known to have contributed to loss of native oyster reefs (Shelmerdine and Leslie, 2009), and changing land management practices including the introduction of drainage channels which could have altered local environmental conditions. Since that initial loss, other anthropogenic activities, including from terrestrial sources, may have further impacted seagrass beds or prevented recovery. Nutrient enrichment from marine sources such as historic finfish aquaculture sites and terrestrial sources such as wastewater discharge can increase seagrass susceptibility to pathogens, reduce light, and increase epiphyte growth (Ruiz *et al.*, 2001). In Shetland the presence of these pressures has varied between sites and over time, and it is thus challenging to attribute the decline across multiple sites to a single pressure.

4.2 Current status of *Z. marina* in Shetland

The fourteen observed beds in Whiteness Voe meet the OSPAR definition of seagrass bed habitat, with all beds over 25 m^2 in area with greater than 5 % seagrass cover (OSPAR, 2009). The average cover in the two sampled beds was 49 %, and underwater photographs from other beds show comparable densities. Shoot density reduces dramatically in winter months, with beds far sparser and with shorter leaves compared to summer months. This was visible in both the aerial photographs and from in situ observations. Shoots were observed washed up on the shore from as early as mid-September with the onset of autumn storms in Shetland. This is not an unusual phenomenon as illustrated by historical accounts of drifted seagrass in Whiteness Voe (Druce, 1925).

Eelgrass beds have persisted in Whiteness Voe for over 100 years, with the earliest reference to *Zostera* sp. at this location from 1888 (Druce, 1922). Comparison of the extent of seagrass beds shown in Whiteness Voe from surveys in the late 1980s with the current mapped distribution suggest the extent of seagrass has been relatively stable over this period (Hiscock, 1989). It is challenging to quantify exact changes, but the 1989 habitat map suggests there may have been some loss of seagrass in the upper eastern part of the voe, but with expansion of beds at the south end near Otter Holm (Figure 10).

Subtidal eelgrass meadows in Whiteness Voe are likely to have persisted primarily through vegetative spread. Scott and Palmer (1987) report that *Z. marina* flowers are very rarely produced in Shetland but are typically observed in August. Only sparse numbers of flowering shoots were observed in Whiteness Voe in August 2023 and 2024, although more extensive flowering has been seen in April to June 2025 (Giesler RJ, *pers. obs)*. This may indicate low levels of seed production and high variability in flowering occurrence between years in Shetland eelgrass. A study of *Z. marina* reproductive strategies in Canadian populations across different environmental conditions showed that the robustness of seed banks was linked to reproductive shoot density (Vercaemer *et al.*, 2021). In Scotland and other areas of the UK, vegetative propagation is the primary mechanism of spread for subtidal *Z. marina*, with seed production less frequently observed than for intertidal species (Cleator, 1993; Potouroglou *et al.*, 2014). However, seed production may contribute to colonisation of vacant habitat or recovery following disturbance (Cleator, 1993; Potouroglou *et al.*, 2014). Low levels of sexual reproduction of *Z. marina* in Shetland may have contributed to the lack of resilience in seagrass populations following extensive loss in the early 1930s and subsequent lack of recovery (Alotaibi *et al.*, 2019; Hämmerli and Reusch, 2003; Ries *et al.*, 2023). Nevertheless, studies have identified large seagrass beds that have persisted for over 100 years as a single clone or with low levels of genetic diversity (Alotaibi *et al.*, 2019; Boström *et al.*, 2014).

Low light conditions during the winter at high latitudes may create a short growing season and pose a challenge for natural eelgrass recovery. The environmental conditions measured in Whiteness and Weisdale Voe appear to be well within the temperature and salinity tolerance limits for *Z. marina* which are relatively broad. The optimum temperature range for growth and germination is given by Davison & Hughes (1998) as between 10 to 15 °C, although *Z. marina* will tolerate temperatures between 0 and 30 °C. Analysis of *Z. marina* beds in Sweden at sites situated at 58°2N found that light attenuation condition at those locations were suitable for *Z. marina* growth between March and October in shallow sites but optimum temperature for reproduction has been identified as between 15 and 20 °C (Nejrup and Pedersen, 2008). Temperature in Whiteness and Weisdale in the 2024 to 2025 period ranged between 4°C and 17 °C, and salinity between 3 and 34 in Wesidale Voe, and 24 and 34 in Whiteness Voe. *Zostera marina* occurs at salinities from 5 to 35, and while it can tolerate a wide salinity range from 0 to 45, salinities below 5 PSU are thought to impact plant fitness (Nejrup and Pedersen, 2008). It is possible the lower salinity in Weisdale Voe may contribute to the lower condition of seagrass at this site, although the logger was deployed far closer to a small burn than the seagrass bed (Nejrup and Pedersen, 2008; Salo *et al.*, 2014).

Drifted seagrass is known to be a mechanism for spread and colonisation of novel areas. Rafting of flowering shoots is a driver of gene flow in *Z. marina* across the North Sea (Gamble *et al.*, 2021), and the potential mechanism for initial establishment of *Z. marina* in Shetland. The observation of drifted seagrass in Fair Isle where there are no known subtidal habitats supports connectivity between the Shetland Islands and other areas in Scotland. Drifted seagrass is also reported from other areas in Shetland with no recorded beds. Further investigation of the provenance of drifted seagrass specimens through genetic comparison with known populations in Shetland, Orkney and the west coast of Scotland would potentially reveal mechanisms by which seagrass is dispersed across the northern isles. Initial analysis of genetic connectivity of *Z. marina* populations in the UK indicate that west coast populations including those in Shetland and Orkney are genetically connected, with the exception of populations in the Solway Firth (Finger and Lilley, 2023). If restoration was to introduce novel seagrass material from outside of Shetland, *Z. marina* populations from the west coast and Orkney populations are likely to be the best choice of source material (Kent *et al.*, 2021).

4.2.1 Seagrass restoration

Across Shetland, the distribution of subtidal eelgrass habitat has diminished drastically since the early 1900s (Scott and Palmer, 1987). The current restricted distribution of *Z. marina* makes the status of eelgrass beds in Shetland vulnerable. Anthropogenic stressors from other human activity both past and present may affect seagrass distribution and resilience. Seagrass beds are sensitive to disturbance to the rhizome system, including from moorings and anchors, and towed bottom-contact fishing. In Shetland, eelgrass beds are protected by closed areas for scallop dredging introduced by the Shetland Shellfish Management Organisation (SSMO) to protect important local marine habitats in 2018 (Shelmerdine and Mouat, 2019). The *Z. marina* beds in Whiteness and Weisdale Voe are also listed as development restricted areas in Shetland Islands Council policy (Shucksmith, 2017).

Seagrass restoration is becoming an important focal species of ecological restoration research and practice (Pazzaglia *et al.*, 2021). There is evidence that restoring eelgrass habitats also restores the important ecosystem services they provide, including supporting biodiverse assemblages of species and sequestering carbon stocks (Orth *et al.*, 2020). However, accurate data on the historic and current spatial distribution of seagrass is an important precursor to restoration projects. This study identifies several areas in Shetland where seagrass habitat would once have been extensive, and in which seagrass restoration could be trialled. This includes Weisdale Voe, South Voe in Burra, and the Vadills SAC. Further surveys would be required to determine if sediment type and current environmental and anthropogenic pressures make these sites suitable.

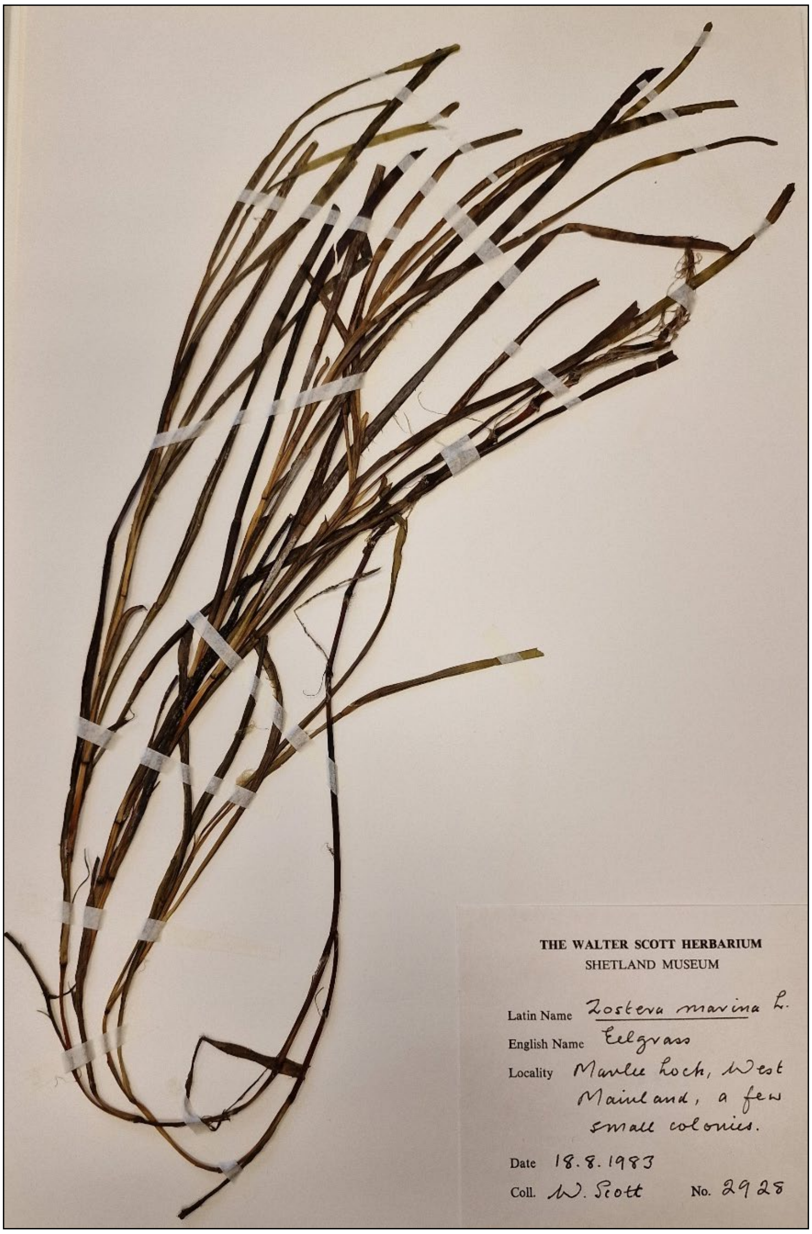

Figure 19 – Herbarium specimen of *Z. marina* from Walter Scott's collection at the Shetland Museum.

4.3 Study Limitations

4.3.1 Using historic records to inform baseline mapping

This study reviewed historic records from databases such as the National Biodiversity Network, NMPi, digitised datasets from MNCR surveys available the government data repository and the DASSH data archive. The digitised point records were matched where possible with the corresponding survey reports and publications. Challenges in relying on digital datasets which collate records across surveys without further context are evident in comparison of the latitude and longitude of point data with location descriptions or detailed survey methodology. In some cases, data has been digitised with a high coordinate uncertainty, but the location description is accurate. Correcting the location of these records requires access to the correct reference map, which was made possible through access to the relevant OS map version and knowledge of local place names. In other cases, the method of digitising survey data could lead to difficulties in interpreting accurate historic locations. As an example, habitat and species records from the 1989 MNCR Whiteness Voe Survey dataset have been digitised with locations given for the central point of the transect (Figure 4). While there is nothing inherently problematic with this approach, the dataset does not contain information on survey approach or transect coordinates and the survey report has not been digitised, although it is publicly accessible via the National Archives (Hiscock, 1989). These inaccuracies are only evident when viewed at the hyper-local scale but may be problematic if presence data is integrated into habitat models or when assessing potential sites for restoration.

Records were also supplemented with data from other historic records, including published reports and herbarium specimens. Non-traditional historic sources were also reviewed including books on Shetland's folklore, culture and language, which provided additional context for the changes in seagrass distribution over time (Vellend *et al.*, 2013). Incorporating historical data sources into the review not only provided historical context for the study but also guided the existing survey design. The extensive collection of Shetland natural history reports, herbarium specimens and records held locally at the Shetland Library and Shetland Museum and Archives was invaluable in this review and demonstrates the value of local collections in identifying baseline habitat distributions for marine restoration.

4.3.2 Utilising UASs to survey subtidal eelgrass habitat

This study successfully used small, entry level UAS to identify subtidal eelgrass beds and map edge boundaries through manual analysis of aerial photographs. Detection of seagrass bed edges is easier in areas with light, sandy sediment as the contrast between seagrass bed edges and surrounding sediment is high (Natural Resources Wales, 2019). Dark sediment and reduced water clarity were challenges at two sites with high freshwater influence (Saltness and Loch of Hellister), where it is possible that small seagrass patches could have been overlooked in analysis of aerial photographs. All beds in Whiteness had clear boundaries between seagrass extent and surrounding sediment, although at some sites beds were interspersed with kelp and algae especially at the shallower edge. There is potential for confusion of seagrass beds with other subtidal habitats including algal beds. Seagrass beds were more distinctive in late summer (August/September) when they were at their most dense with a dark green colour identifiable in aerial photos (Figure 20).

In Weisdale Voe, it was more challenging to distinguish between seagrass and algae growth, and more extensive paddleboard surveys were needed to confirm habitat features. However, as surveys were guided by the location of suspect beds from aerial photographs, this was much less time consuming than an extensive search of the whole upper voe. At a larger scale it might be desirable to automate the process of photograph analysis. Automated image classification methods to aid in classifying bed extent may also increase the ability to detect patchier beds where seagrass is more interspersed with other subtidal vegetation (Duffy *et al.*, 2018). However, repeating UAS surveys at different times of year can also be advantageous, as winter photos when algal growth is at a minimum showed clearer bed edges than in summer months (Figure 4).

Figure 20 – Aerial image of eelgrass bed Z1-I in the centre of Whiteness Voe taken September 2023. The dark green colour of the eelgrass bed is distinguished from kelp habitat, with the abundance of *Chorda filum* in the bed also visible.

In areas such as the Shetland Islands, characterised by highly complex coastlines that can be challenging to access, surveying using traditional methods can be time-intensive and expensive. Furthermore, remote sensing using satellite imagery is challenging when conditions are frequently windy and wavy, as the likelihood of getting suitable images is low (Bekkby *et al.*, 2008). While these windy and changeable conditions that characterise Shetland's weather also restrict when it is possible to conduct UAS survey flights, UAS can be quickly deployed in response to available weather windows.

However, this meant that in this study it was not always possible to plan survey times to match ideal conditions (Nahirnick *et al.*, 2019b). Where possible, surveys were planned around low tides to maximise visibility of subtidal features. UAS offer an adaptive, flexible approach that can quickly survey large areas of remote coastline.

The applicability of this survey methodology to other regions will be influenced by the water visibility and environmental conditions at the location of interest (Nahirnick *et al.*, 2019b). Larger survey drones with flight planning capabilities improve standardisation and positional accuracy of aerial images for photogrammetry, while UASs mounted with multispectral cameras can enable better distinction between seagrass and macroalgae (Elma *et al.*, 2024). However, small, consumer-grade UASs are easily accessible to the public and could offer an effective means to engage communities in locating and monitoring seagrass habitats, especially in remote or island communities. Combining UAS surveys with community ground truthing via snorkel, swim, kayak or paddleboard surveys to investigate features of interest proved an effective means to confirm suspect subtidal features, reducing in situ survey time.

5 Conclusion

This report describes the past and present distribution of seagrass beds in the Shetland Islands. There has been a large decline in subtidal *Z. marina* beds since the 1880s. Much of this decline appears to have occurred in the 1930s at similar times to widespread decline of *Z. marina* across northern Europe, but there has been no recovery and continued loss of seagrass at sites within the last 30 years. The current known distribution of *Z. marina* in Shetland is limited to two voes in west Mainland. This study greatly increases the accuracy of data on seagrass distribution, accurate mapping of bed extent and current distribution allows monitoring of future declines or increases, assessment of blue carbon contribution and captures a snapshot of health.

The findings of this report could guide future restoration activity in Shetland. The areas of Weisdale Voe and between the Burra Isles are likely suitable sites to trial restoration activity, although further assessment of current benthic habitat conditions will be needed. Further ground truthing surveys of sites where there is no evidence of *Z. marina* presence to confirm loss, will aid in confirming the status of *Z. marina* in Shetland.

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Appendix 1. Historic records of seagrass distribution

Table A 1 – Databases searched as part of the review of historic seagrass records in Shetland.

Records	Year	Site	Species & No. of records	Source
1986-87 OPRU/MNCR Shetland, Foula and Fair Isle survey (Species point records)	1986-1987	Z1,6,7	*Z. marina*: 5	Government Data Portal – JNCC - MNCR Surveys
1986-87 OPRU/MNCR Shetland, Foula and Fair Isle survey (Habitat point records)	1986-1987	Z1,6,7	SS.SMp.SSgr.Zmar: 6 IMS.Zmar: 6	Government Data Portal – JNCC - MNCR Surveys
1988 MNCR Shetland littoral and sublittoral survey (Species point records)	1988	Z5	*Z. marina*: 2	Government Data Portal – JNCC - MNCR Surveys
1988 MNCR Shetland littoral and sublittoral survey (Habitat point records)	1988	Z5	SS.SMp.SSgr.Zmar: 1 IMS.Zmar: 1	Government Data Portal – JNCC - MNCR Surveys
1989 MNCR Whiteness Voe survey (Species point records)	1989	Z1	*Z. marina*: 7	Government Data Portal – JNCC - MNCR Surveys
1989 MNCR Whiteness Voe survey (Habitat point records)	1989	Z1	S.SMp.SSgr.Zmar: 5 IMS.Zmar: 4	Government Data Portal – JNCC - MNCR Surveys (NBN showed 4 of these records)
1993 MNCR Shetland lagoons survey (Habitat point records)	1993	Z3	*Z. marina*: 2 Z. noltei: 2	Government Data Portal - MNCR Surveys
1993 MNCR Shetland lagoons survey (Species point records)	1993	Z3	*Z. marina*: 1 Z. noltei: 1	Government Data Portal - MNCR Surveys
1993 SNH Phase I survey of Brindister Voe and the Vadills Marine Conservation Area	1993	Z4,5	*Z. marina*: None *R. maritima*: 4	DASSH Data Search
1994 SNH sublittoral survey of Whiteness Voe (Shetland)	1994	Z1	*Z. marina*: 3	NMPi
1994 SOAFD Whiteness Voe Shetland sublittoral sediment survey (Species point records) (Habitat point records)	1994	Z1	*Z. marina*: None	Government Data Portal - MNCR Surveys Species Records Habitat Records
2020 Seagrass Survey	2020	Z1	*Z. marina*: 1	National Biodiversity Network Gateway
Shetland Biological Records Centre (via Paul Harvey) – Drift Specimen records	2006-2007	Fair Isle, St Ninian's	*Z. marina*: 2	National Biodiversity Network Gateway
Shetland Museum Herbarium	1968-1980	Z1,2,4,6,8,10 + 2 drift	*Z. marina*: 13 specimens *R. maritima*: 7 *R. spiralis*: 6; *R. cirrhosa*: 1	In person search of herbarium collection

National Biodiversity Network Gateway (last reviewed 12/04/2024)				
Royal Botanic Garden Edinburgh Herbarium	1990	Fair Isle	*Z. marina*: 1 drift specimen	RBGE Herbarium Online Catalogue Search

Table A 2 – Literature reviewed for historic records of seagrass in the Shetland Islands, including text from various sources.

Literature	Year	Site	Pages	Details
EDMONDSTON'S FLORA OF SHETLAND –1st Edition 1845	1845	n/a		"*Ruppia maritima*: Near Mossbank; Dales Voe; near Busta" "Zastora marina, "Drew." Sandy sea shores, generally covered unless at very low tides, common."
Alexander Craig-Christie Esq. (1870) IV. Notes of a Botanical Excursion to Shetland in 1868, Transactions of the Botanical Society of Edinburgh, 10:1-4, 165-170, DOI: 10.1080/03746607009468670	1868	Z10		"The author gave an account of the various places he had visited in Shetland, and enumerated the plants he met with. He stated that he has been enabled to add twenty species to the list of plants contained in Edmondston's "Flora of Shetland." The following is the list of plants which were collected between 31st August and 24th September 1868: […] *Zostera marina.* Balta Sound, Unst"
Tudor, J. R. (1883). *The Orkneys and Shetland; their past and present state.* London: Edward Stanford	1888	n/a	p.424	"The following plants are common or pretty frequent in Shetland : […] *Zostera marina*."
Angus, J.S. (1914) A glossary of the Shetland Dialect. Paisley, Alexander Gardner	1914		P. 93	MARLIK, n. a sea-weed which, when dried and cleaned, is used for stuffing mattresses {Zostera marina). MUI, n. a sea-weed of a green colour which cattle eat.
Druce, G. C. (1922). *Flora Zetlandica*. Arbroath: T. Buncle & Co.	1922		p.529	2520. *Zostera marina* L. (F.) Common, E. Fl. Balta Sound, C.C. [Notes by W. Scott(?) Some washed up on the beach at Whiteness, 1955]. Var. angustifolia Hornem. The only form seen, Whiteness; Balta, *Beeby*.
Druce, G. C. (1925). *Additions to the Flora Zetlandica*: Supplement to Report of the Botanical Society and Exchange Club of the British Isles for 1924.	1924		p.625-636	"We had a delightful morning at Whiteness, Stromness Voe and Weiss Voe where we found heaped up on the Voe-shingle quantities of the type *Zostera marina*, which Beeby failed to detect in Zetland and with its var. angustifolia."

				2520 *Zostera marina* L. Whiteness Voe. Beeby only saw the var. angustifolia in Zetland but the *type was abundant here and the waves had piled up a mass of it along the coast.
Jakobsen, J. (1932). Etymological Dictionary of the Norn Language in Shetland. London, David Nutt (A.G. Berry).	1932		p. 542	Marlok, sb., a kind of long, tin seaweed, grass-wrack, Zostera. Edm.: marlak, kind of seaweed (Zostera marina). Also commonly by abbreviation.: marl, marel. Ai. (Fogrigert): marlie. Dried and used as an underlayer for a bed; a marli bed: Wd.;St. – No. marlauk, m., seaweed, grass-wrack, prop. Sea-onion. – As a place-name, name of a small lake connected with the sea (partly a creek, partly a lake), is found in A. "de marli-loch" (near Fogrigert)l in this spot grows the seaweed in question.
			p.576	Mui, sb., 1) *a muddy and sandy stretch of shore,* now esp. as the name of a part of the foreshore, south of Baltasound, U^{m}: de Mui (U^{ba}.). Also 2) the name for a kind of sea-grass, growing on muddy and sandy foreshore, sub-merged at flood-tide. U^{m}. – O.N. mor, m., a plain with sandy or gravelly soil; No. mo, m., partly sandy soil, partly fine, dusy earth: Icel. Mor, Faer. Mogvur, m., peaty soil
Hiscock, K. (1986) Marine biological surveys in Shetland Volume 1 – Summary of Survey Results. Nature Conservancy Council Report No. FSC/OPRU/28/86/Vol.1	1986	Z6		"Shallow muddy sand colonised by *Zostera marina*. Chorda filum also present in large amounts. Zostera provided a substratum for rissoid gastropods and shelter for Gobiusculus flavescens and swarms of musids (Site 64 [Burra – Papil]) The small areas of sea grass *Zostera marina* present in Shetland are the remnants of previously much more widespread beds. The beds currently known may act as sources for recolonisation of other areas and are considered to be of high nature conservation importance.
Scott, W., & Palmer, R. (1987). *The flowering plants and ferns of the Shetland Islands*. Lerwick: The Shetland Times.	1987	All	p.338-339	Reviewed historic records and distribution to 1987.
Howson, C.M. 1988. Marine Nature Conservation Review: survey of Shetland, Foula and Fair Isle, 1987. (Contractor: Field Studies				Not accessed.

Council, Oil Pollution Research Unit, Pembroke.) Nature Conservancy Council, CSD Report, No. 816.			
Hiscock, K. (1989). *Marine biological survey of upper Whiteness Voe, Shetland Islands*. Nature Conservancy Council, CSD Report No 973 (Marine Nature Conservation Review, Report No MNCR/SR/009/89)	1987-1989	Z1	Extensive surveys in Upper Whiteness Voe "The work undertaken included surveys of the extent of seagrass *Zostera marina* and the description and mapping of sublittoral habitats and associated communities."
Cleator, B. (1993) *The status of the genus Zostera in Scottish coastal waters*.SNH Review No.22, Edinburgh, Scottish Natural Heritage			South Voe, West Burra – Md sand below low water – 1980 – Plants are winter green and rarely flower, have declined since 1930 – Source: Scott Whiteness Voe (1989) Scott, MNCR Plants found on a variety of sediments including coarse sand which is unusual for Scotland. Largest Shetland bed. Marlee Loch 1983 Greatly declined. Scott Unst 1887 No Later Record Gott (East coast, central Mainland) *Z. noltii* 1993 Unauthenticated record
Bunker, F.St.P.D., Bunker, A.R., & Perrins, J.M. 1994. Survey of Brindister Voe and the Vadills (Shetland) Marine Consultation Area. (Contractor: Marine Seen, Hundleton, Dyfed.) Lerwick, Scottish Natural Heritage. (SNH Research, Survey and Monitoring report, No. NE/93/210).	1994		Not accessed.
Entec. 1996. Broad scale habitat mapping of intertidal and subtidal coastal areas: Busta Voe and Olna Firth, Shetland. (Contractor: Entec, Wallsend, Tyne and Wear.) Scottish Natural Heritage Research, Survey and Monitoring Report, No. 75	1996		In the southeast of the Houb [of Burravoe] there is a shallow (c. 10cm) tidal pond of reduced salinity. The mud/peat/sand substratum within the pond supported both *Ruppia* and *Zostera* beds.
Howson, CM (1998) Shetland (MNCR Sector 1). In: Marine Conservation Review. Benthic marine ecosytems of Great Britain and the north-east Atlantic, ed. By K. Hiscock, 73-108.	1985-1993	Z1,Z3	The seagrass *Zostera marina* occurred in several small beds around this upper basin, contributing to the high conservation value of the Voe (Hiscock 1989). *Zostera marina* was also found in the area in South Voe Howson 1988) and in the large houb at Hellister on Weisdale Voe (pers. obs.). The houbs at Bridge of Walls and Hellister and the Vadill at the

Peterborough, Joint Nature Conservation Committee (Coasts and Seas of the United Kingdom. MNCR series.)			head of Whiteness Voe also all contain beds of the seagrass *Ruppia maritima* (Hiscock 1989; Howson 1988). The seagrass *Ruppia maritima* was found in the innermost basins but *Zostera marina*, recorded from Marlee Loch ('Marlee' is the Shetland word for seagrass) within the Vadills in 1985 (Hiscock 1986), was not found despite extensive searches in 1993 (Bunker, Bunker & Perrins 1994).
Thorpe, K (1998) Marine Nature Conservation Review Sectors 1 & 2. Lagoons in Shetland and Orkney: Area Summaries. Peterborough, Joint Nature Conservation Committee. (Coasts and Seas of the United Kingdom. MNCR series.)	1998	Z3	In the north-east of the Loch, the shallow areas between sea level and 0.5 m depth were influenced by freshwater input from two streams entering the lagoon. Here muddy sand with scattered cobbles, pebbles and gravel was colonised by sparse stands of seagrass *Zostera noltii*, some serrated wrack Fucus serratus and lugworms Arenicola marina (Znol). Below this, between 0.5 and 2 m depth, close to the streams, muddy sand was colonised by extensive areas of dense seagrass *Zostera marina*, with occasional patches of serrated wrack F. serratus (Zmar). Shore crabs Carcinus maenas were frequent amongst the plants.
	1986	Z4,5	Hiscock (1986) described beds of the seagrass *Zostera marina* with a distinct flora and fauna (including species such as the pipefish Syngnathus acus) from this southern basin (Zmar). However, the eelgrass Zostera beds were not recorded during the 1987 survey (Howson 1988) or those in August 1993 (MNCR survey; Bunker et al. 1994).
	1996	Z11	The southern end of the lagoon was influenced by freshwater input from the stream. The peaty, fine sand here was dominated by the tasselweed *Ruppia maritima* (Rup). Associated species included lugworms Arenicola marina, amphipods, the green alga Enteromorpha sp. and filamentous green algae.

				In the northern part of the lagoon, there was peaty sand dominated by lugworms A. marina (FaMS). There were clumps of unattached and attached plants including the green algae Enteromorpha spp., spiral wrack F. spiralis, knotted wrack Ascophyllum nodosum and tasselweed *R. maritima* (FChoG). Entec (1996) noted seagrass Zostera sp. beds in this area.
Howson, CM (1999) Marine Nature Conservation Review Sector 1. Shetland: Area Summaries. Peterborough, Joint Nature Conservation Committee (Coasts and Seas of the United Kingdom. MNCR series.)	1999	Z6,7	p.136	Burra: Of particular note are two small beds of eelgrass *Zostera marina* mixed with C. *ft/um* in the shelter of South Voe, on soft flocculent mud in the northern end of the voe and on firmer sandy mud behind the island of Papil (Zmar). The opisthobranch *Akera bullata* is common on the mud amongst the *Zostera* whilst rissoids and the bivalves *Parvicardium ovale* and *Musculus marmoratus* are found on the leaves.
		Z1	p.141	Roads fringe most of the coastline in this area with linear settlements along many of these. There has been concern that sewage entering the head of Whiteness Voe from surrounding houses has created eutrophic conditions and adversely affected the beds of eelgrass *Zostera marina* and other biotopes in the voe's northern basin (Bunker, Rostron & Perrin 1995). Eelgrass *Zostera marina* occurs in several small beds around this upper basin, often mixed with C. filum, and the plants supports large numbers of the gastropod Rissoa membranacea and the mussel Musculus costulatus (Zmar). Coarse sand in the Zostera beds contains bivalves M. costulatus, M. bidentata and Venerupis senegalensis, the polychaete Protodorvillea kefersteini and the amphipod.
ERT (Scotland) Ltd. (2006) Site Condition Monitoring: surveys of lagoons in The Vadills Lagoon Special Area of Conservation, July –	2003	Z4,5	p.69	One other feature of interest in The Vadills was the reported occurrence in Marlee Loch of *Zostera marina* in the 1930s. This was not seen during the present survey, either on transect TV03LT2 or during other snorkel swim searches, yet core samples from the vicinity

August 2003. Scottish Natural Heritage Commissioned Report No.209 (ROAME No.F02AA409c)	contained what looked like the remains of seagrass buried in the mud. Survey work in 1993 also reported on the apparent absence of Zostera from Marlee Loch (Bunker et al., 1994).

Table A 3 – Details of the last known record of *Zostera* sp. at each identified site prior to the surveys undertaken as part of this study.

Location	Site	Date of last historic record	Latitude/Longitude (DD - WGS84) *(Derived from description)	Most Recent Source	Notes from source records
Whiteness Voe	Z1	2020		1994 SNH sublittoral survey of Whiteness Voe (Shetland)	Numerous records from MNCR Surveys in 1986,1989 and 1994. Specimens collected in 2020 by staff at UHI Shetland. Several extant beds identified by local swimmers.
Weisdale Voe	Z2	1978	60.241498, -1.300765*	Herbarium record Walter Scott, ZCM Scott & Palmer 1987	Thin beds on the west side of Weisdale Voe, between Houll and Kurkigarth, sandy bottom with decaying seaweed, dredged specimen 1978. "In vast quantity and practically filling the head of Weisdale Voe norht of a line from Houll to Huxter, but suddenly almost disspeared in the 1930s!"
Loch of Hellister	Z3	1993	60.232448, -1.297682	1993 MNCR Shetland lagoons survey - Species point records	Extensive areas of dense *Zostera marina*, occuring in patches from 2 by 2m to wide bands between the Fucus serratus zone and above, and the Chorda filum below. Amongst the Zostera, occasional patches of Fucus serratus were present. Carcinus maenas were also noted amongst the plants.
Marlee Loch	Z4	1983	60.278582, -1.474389*	Scott & Palmer 1987	"A few small colonies, 1983, Scott (ZCM). The 'marlie' used to be very abundant in this sea-loch and was regarded as a nuisance by anglers. About the time of its dramatic decline in Weisdale Voe [1930] it all but disappeared from the Marlee Loch as well; fortunately, it still survives in this sheltered, secluded inlet whose name commemorates the abundant Zostera beds of earlier times."
Vadills - Head	Z5	1988	60.274588, -1.479374	1988 MNCR Shetland littoral and sublittoral survey	Head of Vadills and Marlee Loch (Shetland)
Burra – Papil	Z6	1986	60.069220, -1.335287	1986-87 OPRU/MNCR Shetland, Foula and Fair Isle survey	Muddy sand plain with small bed of Zostera and abundant Chorda.

Burra – South of Holms	Z7	1987	60.079078, -1.331495	1986-87 OPRU/MNCR Shetland, Foula and Fair Isle survey	Zostera bed at 1m BCD. Dense but very patchy, Zostera bed on soft (jelly like) mud.
Effirth Voe	Z8	1980	60.252706, -1.422050*	Scott & Palmer 1987	South side of Effirth Voe, Bixter, in small quantity, 1980, Scott (ZCM)
Semblister	Z9	1927	60.238400, -1.393171*	Scott & Palmer 1987	Thought extinct by Scott (1987). West side of The Firth, below Sembister, 1927, not seen recently]
Tresta Voe	Z10	1912	60.241276, -1.358508*	Scott & Palmer 1987	"Abundant and forming a 'bank' at the head of Tresta Voe, c. 1912, J.L.Jamieson, not seen recently"
Unst – Balta Sound	Z11	1839 to 1887	60.756550, -0.857802*	Scott & Palmer 1987	'Grows in sand around the coast [of Unst]; totally immersed in sea-water; almost always used for bedding' 837, Edmonston (1839, p.111)
Brae - Saltness	Z12	1995	60.38286, -1.345745*	Thorpe 1998	In the northern part of the lagoon, there was peaty sand dominated by lugworms A. marina (FaMS). There were clumps of unattached and attached plants including the green algae Enteromorpha spp., spiral wrack F. spiralis, knotted wrack Ascophyllum nodosum and tasselweed *R. maritima* (FChoG). Entec (1996) noted seagrass Zostera sp. beds in this area.

Appendix 2. List of Surveys

Table A 4 - List of surveys conducted as part of the Searching for Shetland's Lost Seagrass project. The latitude and longitude of the central point of the survey extent is given (WGS 84).

Survey Code	Site	Location	Date	Survey Method	Survey Type	*Zostera marina* bed presence	Survey Area (m2)	Latitude	Longitude
SSLS-1	Z1	Whiteness Voe	19/04/2023	UAS Survey	Search within radius	Present	342433	60.193097	-1.288945
SSLS-2	Z7	Burra - Bridge End	27/04/2023	UAS Survey	Search within radius	No evidence	264788	60.078645	-1.331014
SSLS-3	Z4/Z5	Vadills	19/06/2023	UAS Survey	Search within radius	No evidence	404618	60.279495	-1.477942
SSLS-4	Z1-A	Whiteness Voe	05/07/2023	Snorkel GPS Track	Extent	Present	5681	60.196226	-1.287504
SSLS-5	Z3	Loch of Hellister	05/07/2023	UAS Survey	Search within radius	Present	159997	60.232791	-1.297077
SSLS-6	R	Brae	02/08/2023	UAS Survey	Search within radius	No evidence	191612	60.384981	-1.350385
SSLS-7	Z6	Burra - Papil	29/08/2023	UAS Survey	Search within radius	No evidence	399529	60.070993	-1.331773
SSLS-8	Z1-B/C	Whiteness Voe	30/08/2023	Snorkel GPS Track	Extent	Present	8111	60.194204	-1.284663
SSLS-9	Z1-G/H	Whiteness Voe	06/09/2023	Snorkel GPS Track	Extent	Present	13194	60.188069	-1.288927
SSLS-10	Z1 -D/E/F	Whiteness Voe	13/09/2023	Snorkel GPS Track	Extent	Present	4841	60.190353	-1.287404
SSLS-11	Z1	Whiteness Voe	13/09/2023	UAS Survey	Search within radius	Present	200177	60.193349	-1.288189
SSLS-12	Z12	Brae	04/10/2023	UAS Survey	Search within radius	No evidence	251198	60.384269	-1.350518
SSLS-13	R	North Collafirth	04/10/2023	UAS Survey	Search within radius	No evidence	219375	60.538361	-1.331777
SSLS-13	R	North Collafirth	04/10/2023	UAS Survey	Search within radius	No evidence	173172	60.538986	-1.350005
SSLS-14	Z1-I	Whiteness Voe	12/11/2023	Paddleboard	Search within radius	Present	23914	60.191319	-1.290934
SSLS-15	Z1	Whiteness Voe	05/02/2024	UAS Survey	Search within radius	Present	309298	60.191871	-1.288611
SSLS-16	Z2	Weisdale Voe	26/04/2024	UAS Survey	Search within radius	Present	631190	60.237242	-1.302290
SSLS-16	Z3	Hellister Loch	26/04/2024	UAS Survey	Search within radius	No evidence	256854	60.232451	-1.297193
SSLS-16	Z2	Weisdale Voe	26/04/2024	UAS Survey	Search within radius	Present	444094	60.241350	-1.297848
SSLS-17	Z1-J/K	Whiteness Voe	26/05/2024	Snorkel GPS Track	Extent	Present	11671	60.187505	-1.289706
SSLS-18	Z2	Weisdale Voe	29/05/2024	Paddelboard	Search within radius	Present	92831	60.240747	-1.298673
SSLS-19	Z2	Weisdale Voe	26/06/2024	UAS Survey	Search within radius	No evidence	106781	60.239352	-1.296983
SSLS-20	Z10	Tresta	03/08/2024	UAS Survey	Search within radius	No evidence	431593	60.240366	-1.358339

Survey Code	Site	Location	Date	Survey Method	Survey Type	*Zostera marina* bed presence	Survey Area (m2)	Latitude	Longitude
SSLS-21	Z4/Z5	Vadills	03/08/2024	UAS Survey	Search within radius	No evidence	276736	60.277828	-1.477441
SSLS-22	Z6	Burra Papil	18/09/2024	UAS Survey	Search within radius	No evidence	944499	60.066593	-1.332500
SSLS-23	Z1-L	Whiteness Voe	22/09/2024	Paddleboard	Search within radius	Extent	124349	60.192741	-1.288118
SSLS-24	Z2/Z3	Weisdale Voe & Loch of Hellister	03/10/2024	UAS Survey	Search within radius	Present - Z2-A only	876704	60.237408	-1.300100
SSLS-25	D	Scousburgh	28/11/2024	UAS Survey	Search within radius	No evidence	436119	59.948871	-1.334557
SSLS-25	D	St Ninians	28/11/2024	UAS Survey	Search within radius	No evidence	514174	59.968272	-1.336450
SSLS-26	Z8	Effirth Voe	12/02/2025	UAS Survey	Search within radius	No evidence	713659	60.252865	-1.416936
SSLS-26	Z9	Semblister	12/02/2025	UAS Survey	Search within radius	No evidence	335694	60.242655	-1.398224
SSLS-26	Z9	Semblister	12/02/2025	UAS Survey	Search within radius	No evidence	710165	60.237800	-1.384729