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Angiosperm Monitoring for the EU Water Framework Directive 2013 – 2015: Baseline seagrass surveys of the Montrose Basin, Eden Estuary, Forth Estuary and Loch Ryan.

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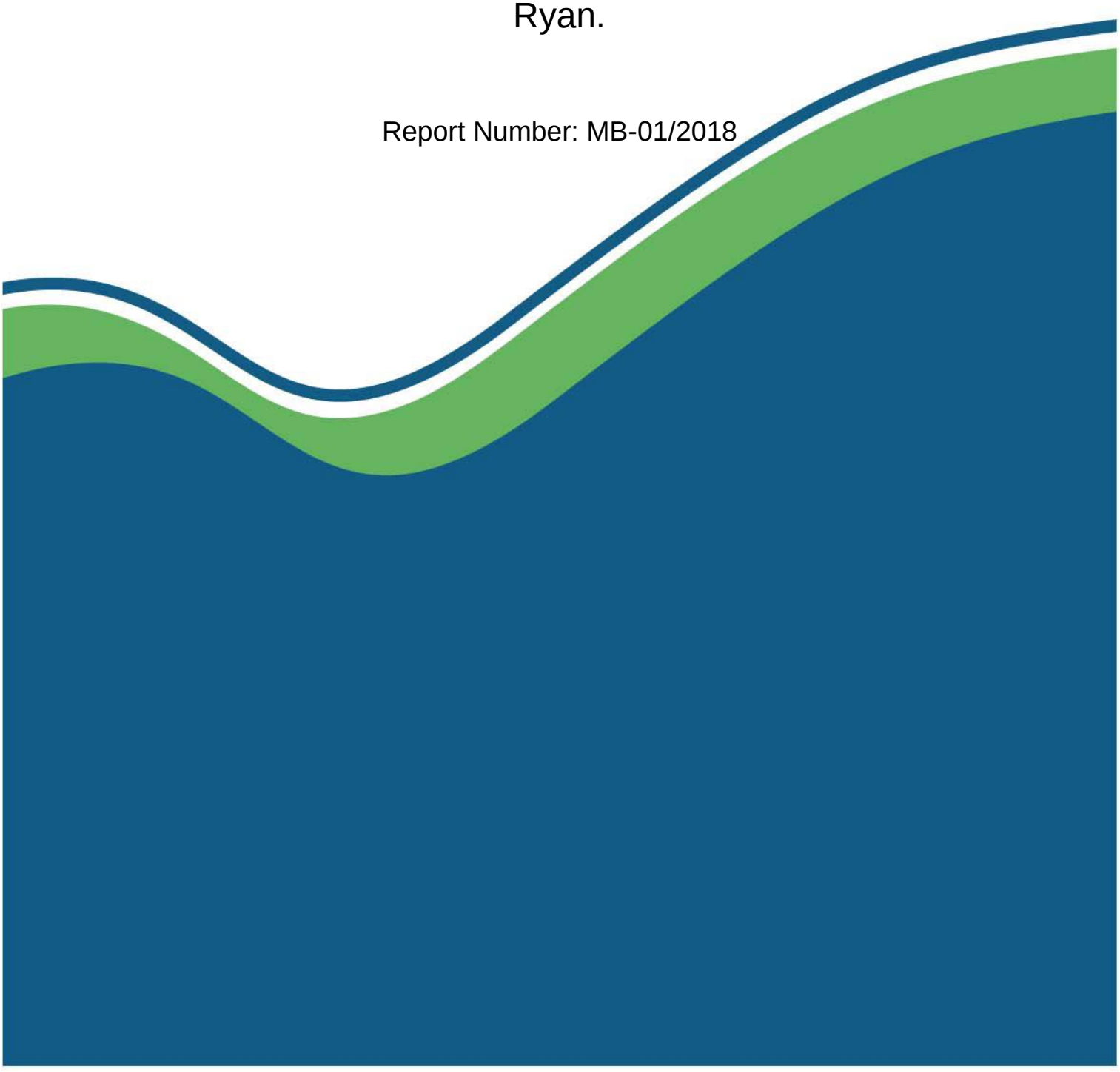

Angiosperm Monitoring for the EU Water Framework Directive 2013 – 2015: Baseline seagrass surveys of the Montrose Basin, Eden Estuary, Forth Estuary and Loch Ryan.

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Abstract

Seagrass are marine flowering plants found in shallow coastal areas around the world. Scotland holds 20% of seagrass beds in north-west Europe. They are important for many reasons including supporting various associated species and it is for this reason Scotland has listed them as a Priority Marine Feature. Seagrass are regarded as indicative of a healthy environment and are particularly susceptible to pollution and nutrient enrichment which make them ideal indicator species for reduced water quality.

To classify the ecological quality of seagrass within a water body, historical baseline data is compared to the current status of the site chosen. A desk study was carried out to find this baseline data but due to past studies not being completed for the purpose of the WFD, they did not contain the necessary parameters needed to run the UKTAG intertidal seagrass tool. They did, however, provide location information which was used to focus sampling effort.

SEPA surveyed 4 sites (Montrose Basin, Eden Estuary, Forth Estuary & Loch Ryan) in order to produce baseline data for future WFD classification. This totaled an area of 2,781,267m^2 (~278 ha). Further surveys are needed to provide current data to classify the status of seagrass within the waterbody and also to provide baseline data for other seagrass beds in Scotland.

Keywords: Angiosperm**,** Zostera, Seagrass, Scotland, Montrose, Eden, Forth, Loch Ryan, SEPA, WFD, Marine, Intertidal

Contents

Figures

Tables

Acronyms

AIH – Available Intertidal Habitat

BSBI – Botanical Society of the British Isles

BQE – Biological Quality Element

CASI – Compact Airborne Spectrographic Imager

EQR – Ecological Quality Ratio

GIS – Geographic Information Systems

GPS – Global Positioning System

LNR – Local Nature Reserve

MAB – Opportunistic Macroalgal Blooming

MCA – Marine Consultation Area

MNCR – Marine Nature Conservation Review

NIR – Near Infrared imagery

PMF – Priority Marine Feature

RGB – Red, Green, blue imagery

RSL – Reduced Species List

SAC – Special Area of Conservation

SEPA – Scottish Environment Protection Agency

SNH - Scottish Natural Heritage

SPA – Special Protection Area

SSSI – Site of Special Scientific Interest

SWT – Scottish Wildlife Trust

WFD –Water Framework Directive

Angiosperm monitoring for the EU Water Framework Directive: baseline seagrass surveys of the Montrose Basin, Eden Estuary, Firth of Forth and Loch Ryan.

1. Purpose of this document

The purpose of this document in the first instance was to examine historical seagrass information for location, extent and percentage cover at various sites around Scotland. This was to be used as baseline data for the classification of seagrass for the Water Framework Directive (WFD). As the data was not collected for WFD purposes it was inherently patchy and lacked the necessary information for the three components of the seagrass tool used to assess ecological quality.

The purpose of the report now is to provide a record of baseline seagrass data for future use at each of the sites surveyed by the Scottish Environment Protection Agency (SEPA). It discusses the importance of seagrass for ecological assessment and aims to summarise data from historical surveys carried out at several sites in relation to seagrass beds. The historic data (Appendix 1-4) was then used to direct and focus the efforts of SEPA survey teams in order to provide the baseline survey information on seagrass.

2. Introduction

The European Union Water Framework Directive (WFD, 2000/60/EC) establishes a framework, which aims to protect transitional and coastal waters, inland surface waters, and groundwater. To reach this aim it requires all water bodies to be assessed to determine ecological quality.

The WFD specifies the biological or chemical quality elements that are to be used to assess the ecological and chemical status of a water body. The five biological quality elements to define the status of transitional or coastal water bodies are – angiosperms (seagrass and saltmarsh), phytoplankton, macroalgae (Reduced Species List (RSL) and Opportunistic Macroalgal Blooming (MAB), benthic invertebrates and fish. The only truly marine angiosperms are seagrasses, which are particularly sensitive to human disturbance and can, therefore, be used for monitoring purposes (Short and Wyllie-Echeverria, 1996). Each quality element has an individual survey protocol and calculation tool to help classify the ecological quality status of each water body.

Ecological status classifications can be composed of four different assessments; the biological quality element, physico-chemical conditions (e.g. dissolved oxygen), specific pollutants and hydromorphology. The classifications then indicate if the quality of the environment is good, or where it may need improvement and what needs to be improved.

2.1 Seagrass

Seagrasses are a group of flowering plants that grow in shallow marine and estuarine habitats throughout the world. The majority of seagrass species are completely marine with only a few species extending into the intertidal zone (Barnes and Hughes, 1999).

In the UK only five species of seagrass are found: three species of *Zostera* (genus *Zosteraceae*) (Davidson *et al*, 1991) and two species of *Ruppia* (genus *Potamogetonaceae*). *Ruppia* spp. are more often regarded as seagrass associates and not part of the traditional seagrass arrangement (Kuo and den Hartog, 2001) but the environmental preferences are

very similar to that of *Zostera* spp. and they may occur together (Foden and Brazier, 2007). For the purposes of the WFD both genera are monitored.

2.2 Ecological Importance

Seagrass communities are highly productive important biological features: they are used as shelter, nurseries, spawning and feeding areas by birds, fish and invertebrates, and provide attachment for other organisms such as epiphytic hydroids and algae (Levinton, 1995). Seagrass beds can provide important nursery grounds for commercially important fish species. Several studies have shown that such species associated with seagrass have a higher biomass compared with those of nearby un-vegetated locations (Hemminga and Duarte, 2001). *Zostera* beds provide an invaluable winter food (Davison and Hughes, 1998) for migrant birds of national and international importance such as Wigeon and Brent Geese. The presence of beds also stabilises the sediment, due to their extensive root network, and increases the deposition of organic material by reducing hydrodynamic forces. This stabilisation protects coastlines from erosion (Phillips, 1974) and the extensive root network aerates the sediment creating a more suitable habitat for benthic invertebrates. It is for these reasons that Scotland has listed seagrass as a Priority Marine Feature (PMF).

Seagrass beds in Europe were considered of higher importance at the beginning of the 20th Century (Hily *et al,* 2003) before a 'wasting disease' struck during the 1930's (den Hartog, 1987 and Giesen 1990), caused by a pathogenic slime mould protist of the genus *Labyrinthula* (Vergeer and den Hartog, 1991*). Zostera marina* plants were particularly affected, with almost 90% loss of populations in Western Europe (Hily *et al,* 2003).

There were reports prior to the 1930's of declines in England (Butcher, 1934) and France (Lami, 1935) but none as catastrophic as those later on. The disease spreads through leaf to leaf contact and is characterised by lesions that develop into dark spots which quickly spread along the length of the leaf causing it to die within a few weeks. After repeated leaf defoliation, the rhizomes become discoloured and die (den Hartog, 1989). Investigations into the disease have led to the theory that it is a secondary decomposer of old leaf material (den Hartog, 1987) linked to already stressed plants (Young, 1937: Tutin, 1938; Rasmussen, 1977) as generally healthy tissue can resist infection (Vergeer and den Hartog, 1994). Numerous attempts to isolate the pathogen from healthy seagrass have failed (Muehlstein *et al,* 1991).

In Europe, 1984, the disease was reported to have reoccurred again but no significant declines were observed (Short *et al*, 1988). Seagrass beds have progressively recovered but have not reached the same extent as previously and more recently smaller infestations have been reported (Brockelmann *et al*, 2012).

Seagrass communities have also declined due to human activities. They are particularly susceptible to eutrophication and turbidity, and activities such as dredging or water heating have an adverse effect on bed extent.

2.3 Distribution in Scotland

Twenty percent of seagrass beds in north-west Europe occur in Scotland (Tyler-Walter *et al*, 2016). These beds are distributed all around the coast with three species of the genus *Zostera* found (*Z. noltii*, *Z. marina* and *Z. angustifolia*) and two species of *Ruppia* (*R. cirrhosa* and *R. maritima*). *Zostera* spp. form two types of communities; a mixture of *Z. noltii* and *Z. angustifolia* are generally located on the east coast whilst *Z. marina* occurs predominantly on the west coast. *Ruppia* spp. are generally found on the west and northern coasts. Figure 1 shows the general distribution of *Zostera* spp. and *Ruppia* spp. around Scotland pre and post 1940 (Cleater, 1993) whilst Table 1 describes the difference in morphology and habitat between species.

Z. angustifolia and *Z. noltii* both occur in the intertidal zone. *Z. noltii* is more tolerant to desiccation and is found higher on shores of mud and sand, whilst *Z. angustifolia* occurs between the mid and low water mark, on muddy sediments or in channels that do not completely dry out at low tide. *Z. marina* is generally regarded as the sublittoral species, predominantly in fully marine environments with a relatively course sediment (Davison & Hughes, 1998).

R. maritima grows on sheltered coastal sediments in brackish water but may also be found in full salinity and near freshwater (Tyler-Walters, 2001). A dwarf variant also occurs on tidal mudflats particularly in north-eastern Scotland. *R. cirrhosa* occurs in similar habitats to *R. maritima* but is tolerant to more saline environments and can grow in deeper water (Preston *et al*, 2002).

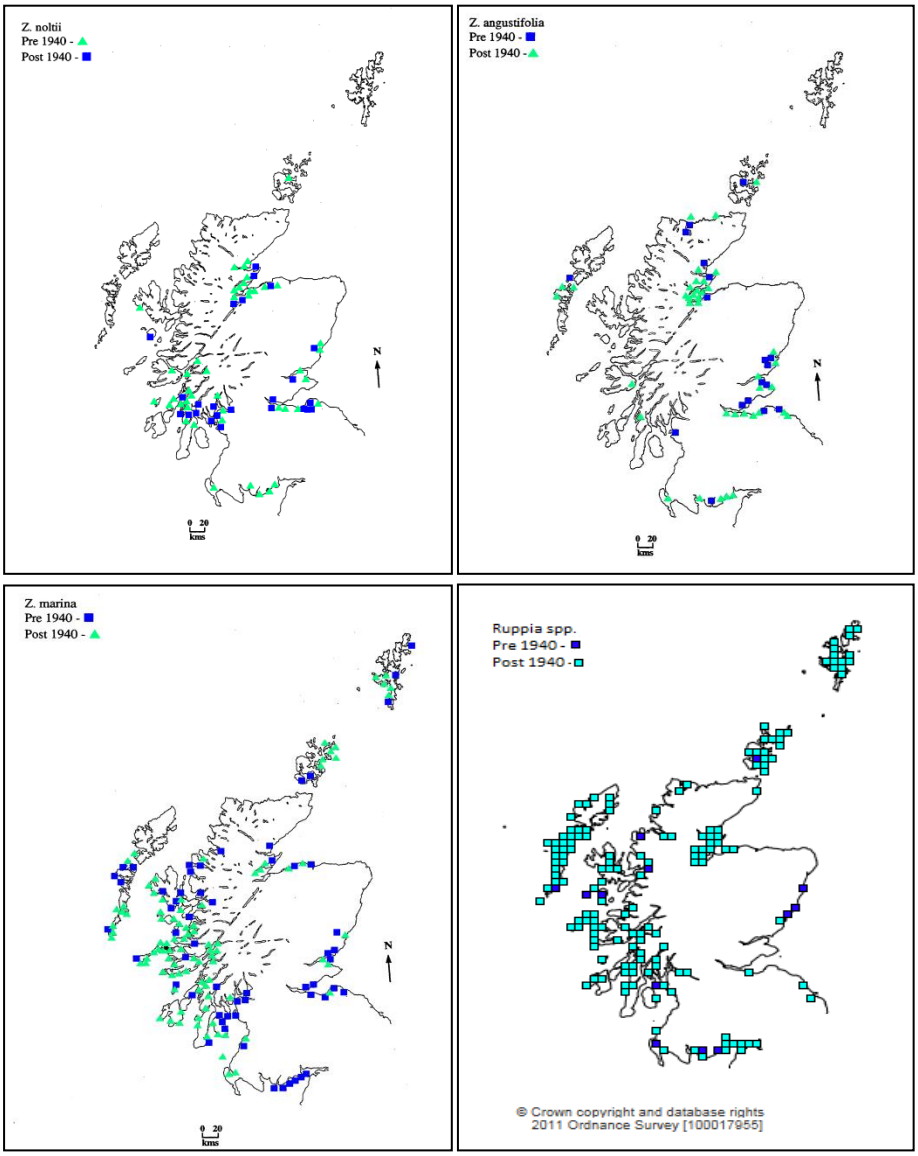

Figure 1: General distribution of seagrass species in Scotland (Zostera spp. distribution from Cleater, 1993; Ruppia spp. distribution from (NBN Gateway: https//data.nbn.org.uk).

Table 1: General descriptions and habitats of UK seagrass species (*Zostera* spp. descriptions taken from the UK Marine SACs Project, 2016; *Ruppia* spp. taken from Streeter *et al*, 2009)

Species	Description	General Habitat
Zostera noltii	Leaves grass green in colour Leaf tips blunt and emarginated (notched), becoming indented in older leaves Leaves alternately arranged and flattened, 6-22cm long, 0.5-1.5cm wide with 3 irregularly spaced veins Leaf sheath short and the base clasps the stem but is not fused into a tube. Flowering shoots un-branched or with only a few branches at base. Seeds, 1.5-2mm long (excluding style), white and smooth Rhizome 0.5-2mm thick with 1-4 roots per node Rhizomes with fibre bundles in the innermost layers of the outer cortex.	Intertidal, on higher shore in mud and sand. Rarely found below the low water mark.
Zostera angustifolia	Light, yellow-green leaves Leaf tips are initially rounded but become emarginated (notched) as the plant matures. Leaves alternately arranged and flattened, 15-30cm long, around 1.5-3cm wide, with 3-5 veins Leaf sheath near the base fused into a tube around the stem Flowering shoots branched, 10-30cm long, 1mm width Seeds 2.5-3mm long (excluding style) ribbed and brown. Rhizomes 1-2mm thick with slightly swollen nodes. Fibre bundles occur in the outer layer of the cortex.	Intertidal, mid to low tide mark in muddy sediments and/or channels
Zostera marina	Leaves dark green with leathery texture Leaf tips narrow, rounded and may have a sharp point Leaves are alternately arranged and flattened, max 1m but typically 20-50cm long, 4-10mm wide, with 5-11 parallel veins which may be regularly spaced Leaf sheath at the base fused into a tube around the stem Flowering shoots branched, maximum length 60cm Seeds up to 3.5mm long (excluding style), ribbed and brown. Rhizome fibre bundles are present in the outer cortex.	Subtidal, muddy-sand sediments.
***Ruppia* spp.**	*R. maritima* - bright green submerged leaves, 0.4 – 0.9mm wide - stems very slender, much branched, to 30cm - flower peduncles <2.5mm, straight or curved - fruits 2 - 2.8mm *R. cirrhosa* - similar to *R. maritima* but leaves wider 0.2 – 1.4mm wide - peduncles spiralled, much longer >4mm - fruits larger 2.7 – 3.4mm	*R. maritima* grows in a variety of shallow water of brackish lagoons, creeks, drainage dykes. *R. cirrhosa* grows in similar conditions to *R. maritima* but prefers more brackish conditions and more tolerant of deeper water.

There used to be much confusion and discussion over the taxonomic status of *Z. angustifolia* (Cleater, 1993) and even today, the distinction is unclear. It is thought that *Z. marina* is a highly variable species found in both subtidal and intertidal habitats. In the intertidal area it exhibits a smaller morphology with narrow and shorter leaves: this description matches the current description of *Z. angustifolia*, which is now considered by many to be an intertidal sub-species of *Z. marina* (Hily *et al*, 2003). In the UK the distinction is still made between the two on the basis of morphology and habitat type (Davison and Hughes, 1998).

2.4 WFD Seagrass Classification Tool

The tool devised to monitor seagrass is composed of three individual parameters, each of which is compared to baseline data or data from the previous assessment. These parameters are:

- Taxonomic composition – number of observed species compared to number of previously recorded species.
- Shoot density / % cover loss – estimated percent cover expressed as percent cover loss/gain.
- Spatial bed extent –percentage loss or gain of the total area of seagrass beds.

Taxonomic composition is based on the stability of species richness: the number of species found compared to the previous number found. *Zostera* spp. are considered to species level and recorded as *Z. noltii, Z. angustifolia* or *Z. marina.* Although as discussed previously Z *angustifolia* is regarded by some as an intertidal version of *Z. marina,* it is treated as a separate taxon for WFD purposes. Due to the difficulty in taxonomic identification of *R. cirrhosa* and *R. maritima*, only the genus is identified (WFD-UKTAG, 2014). Therefore, a maximum of four taxa may be found in a Scottish water body.

Shoot density is expressed as percent cover of seagrass compared to the previous percent cover. Under good conditions the density of a bed should remain the same or increase, and a deterioration of water body quality may cause a reduction in density.

Spatial bed extent is defined by the total area of seagrass beds within the water body with the current bed extent compared to the previous extent. As more spatial data is collected a rolling mean will be calculated, which will reduce potential 'noise' caused by a high degree of natural inter-annual variability. Until then both single year and combined (up to five years) data will be used.

Each individual parameter is calculated separately and then combined and averaged, with equal weighting. This gives a final Ecological Quality Ratio (EQR) status score for that Biological Quality Element per water body. Table 2 gives a simplified overview of the EQR status and each metric.

Table 2: Overview of EQR status and each metric of the WFD Seagrass tool

High	No loss of seagrass species, < 10% loss of extent or density
Good	Loss of 25 – 33% of species, > 10% loss of extent and density
Moderate	Loss of 33 – 66% of species > 30% loss of extent and density
Poor	Loss of 66 -75% of species, >50% loss of extent and density
Bad	Loss of all species, >70% loss of extent and density

2.5 SEPA Method

SEPA has been trialling seagrass surveys since 2012 in conjunction with the MAB surveys. Sites that have been visited are the Montrose Basin, the Eden Estuary, the Forth Estuary and Loch Ryan (Figure 2).

These particular sites were chosen because they have multiple pressures on the water body and are monitored for other chemical or biological aspects. Additional monitoring for seagrass gives a more holistic view to understand the ecosystem as a whole.

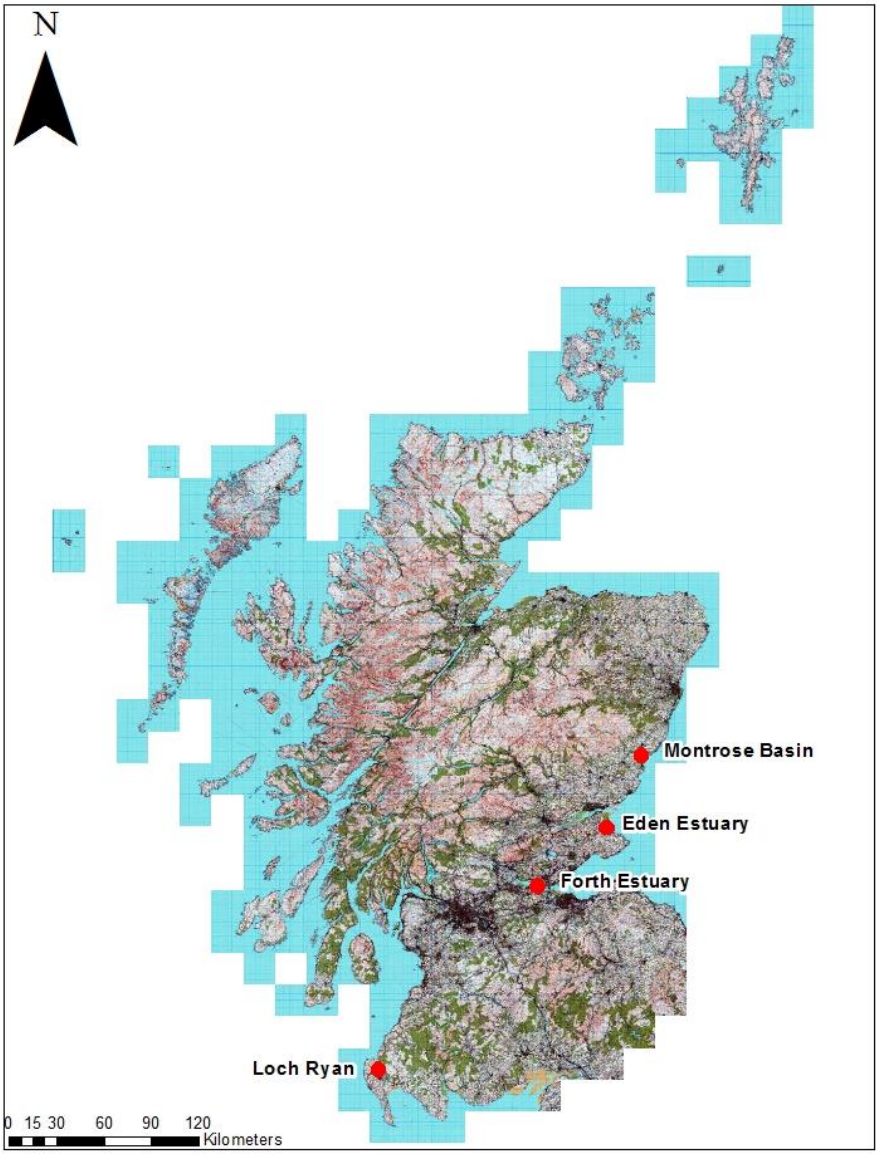

Figure 2: Sites surveyed for Seagrass by SEPA during 2013-2015

Sampling is carried out during the summer months (June – September), at peak seagrass growth. The area covered is between mean high water and mean low water on a spring tide. Extent of seagrass cover is estimated from GIS maps generated from data collected using Trimble GPS GeoXH units, capable of mapping to accuracies of 10cm. Randomly placed 0.25m^2 quadrats are used to assess percent cover of seagrass and taxonomic composition of the area. Assessment is carried out over the entire intertidal area of the water body where seagrass has the potential to grow.

3. Montrose Basin

3.1 General overview

The Montrose Basin is the estuary of the South Esk River, located on the east coast of Scotland between Aberdeen and Dundee, covering an area of approximately 7,500,000m^2. It is a shallow, sheltered, almost circular tidal basin set behind the town of Montrose and connected to the sea by a narrow channel in the south-east corner. The South Esk River flows into the basin at the south-western corner and a smaller tributary, the Tayock Burn, drains into the basin at the north-eastern corner. Historically the river flowed into an area known as the Lurgies, which was reclaimed but never properly dried out resulting in an area of wet grassland. The shoreline of the Montrose Basin has shown little natural change, with the greatest changes occurring due to land reclamation: most notably on the western and eastern shores, re-routing the railway line, and in the south-east corner by Rossie Island.

At low tide numerous channels completely drain the basin leaving extensive areas of mudflats (approximately 6,587,300m^2 of available intertidal habitat, not including the channels) with extremely strong tidal flows, reaching up to 3.5ms^{-1} on a spring tide (Angus Council, 2004). The basin traps sediment transported down from the river South Esk and sediment carried in on a strong flood tide, causing it to gradually silt. The sediment varies in its coarseness over the basin but is characterised as estuarine mud. A study by Atkins *et al* (1992) discovered that a band of the finest sediments ran from near the north-east corner of the basin to the south-west corner. It was also found that the salinity of the Montrose Basin is strongly marine influenced due to the volume of water entering the estuary on a flood tide being greater than the freshwater input.

The mudflats are highly productive supporting a variety of flora and fauna, some of which have national and international importance. The mudflats are composed of a mosaic of communities including *Zostera* spp, macroalgae (for example *Cladophora* spp, *Enteromorpha* spp and fucoids) and mussel beds. The west and south-east of the basin contain saltmarsh habitat: this area exhibits a succession of communities accounting for approximately half of all saltmarsh areas within the Dundee and Angus area (Angus Council, 2004).

The estuarine sediments are dominated by oligochaete and polychaete worms, alongside the mud shrimp, *Corophium volutator* and the mud snail, *Hydrobia ulvae*, together with several bivalves (*Cerastoderma edule* and *Macoma balthica*) (Akins *et al*, 1992). Due to the salinity regime being highly marine influenced, a greater number of typically marine benthic invertebrates are also found.

3.1 Use

Use of the Montrose Basin is mixed, with a variety of recreational activities, mainly due to its designation of Local Nature Reserve (LNR). The town of Montrose dominates the eastern shore with the rest of the surrounding area being rural with large areas of agricultural land. The majority of low-lying land is used for grazing with some smaller areas used for arable farming, which have a tendency to flood.

The Scottish Wildlife Trust (SWT) visitors centre is located on the southern bank of the Montrose Basin and provides facilities for walking and viewing local wildlife. The Montrose Sailing Club is located in the south-eastern corner with a number of small moorings where sailing, windsurfing and canoeing occur, but are restricted to the South Esk channel. The basin is also a popular angling site for salmon and sea trout (Buck, 1993). Other activities include bait-digging and wildfowling, although there are a limited number of permits per season to shoot.

Montrose Harbour is located in the channel connecting the basin to the sea and is the main area of human influence. Traditionally the basin has been exploited commercially for salmon and sea trout, and at one time was Scotland's second largest exporter of salmon. Net fishing still continues within season though not to the extent it once was. During the 19th and early 20th Centuries mussel cultivation gave it the largest mussel beds in the Kingdom of Fife (MBHS, 2004); this has ceased commercially and the harvest is now only for recreational fishing bait. Today the busy harbour caters for oil-related and commercial shipping, including the exports of timber, grain and paper.

3.1 Conservation Status

The Montrose Basin is an example of a relatively undisturbed and undeveloped estuary, holding several statutory designations due to the variety of habitats supporting wildfowl and waders. Since 1974 the basin has been a Site of Special Scientific Interest (SSSI) and in 1981 it became a LNR with specific bye-laws set in place to protect the birds and the environment. Table 3 shows all the designations of Montrose Basin and the reason for the designation.

It has high species diversity within the intertidal zone compared to other sites and is a site of international importance, supporting wintering populations of pink-footed goose, greylag goose and common redshank. Consequently it was designated a Special Protection Area (SPA) under the European Commission Birds Directive, in 1995 and became a Ramsar site under the Convention on Wetlands of international importance. Large populations of birds of national importance (Shelduck, Wigeon and Eider) also use the estuary, with intertidal *Zostera* beds supporting approximately 3000 wintering Wigeon.

Table 3: Summary of the designations of Montrose Basin

Designation	Reason for designation
Special Protection Area (SPA)	Good example of an estuary relatively undisturbed and undeveloped. Regularly supports at least 20,000 waterfowl including those of international importance - Greylag Goose (*Anser anser*), Knot (*Calidris canutus*), Pink-footed Goose (*Anser brachyrhynchus*), Redshank (*Tringa totanus*)
Ramsar Site	A Wetland of International Importance by supporting 20,000 waterfowl including internationally important species.
Site of Special Scientific Interest (SSSI)	Supports breeding wildfowl and wintering waders. Contains habitats of importance - intertidal mud flats, saltmarsh, marsh, saline lagoons.
Local Nature Reserve (LNR)	Reed swamps, plant communities, invertebrates, wildfowl and waders
Scottish Wildlife Trust (SWT) Nature Reserve	Nature conservation value

3.1 SEPA seagrass data: 2008 – 2013

Due to the variety of habitats, the Montrose Basin has been subject to several scientific studies including MAB (SEPA conducted 2006 – 2013), saltmarsh (most recently the joint SEPA-SNH Saltmarsh Inventory, 2009 – 2012 (Haynes, 2016)) and seagrass. *Zostera* spp. have been recorded in the Montrose Basin since 1848 (pers.com Jim McIntosh, BSBI), although *Z. angustifolia* has been subsumed into *Z. marina* in the Botanical Society of the British Isles (BSBI) distributional database with there being some doubt in the identification of several records. Several seagrass studies monitored *Zostera* spp. presence and percent cover (as summarised in Appendix 1), though few have mapped density and extent. Therefore, this data cannot be used as baseline data to determine the water body status for WFD classification but it can be used to help design the initial survey plan for collecting data in future years.

In 2008, 2009 and 2010 SEPA staff conducted surveys in the Montrose Basin as part of the WFD assessment for MAB. No data was specifically collected as part of the WFD Seagrass assessment; at a minimum the presence/absence of seagrass species was recorded, and in some instances the percent cover (density) or species of seagrass was also recorded (Figure 3). No spatial information on the extent of the seagrass beds was recorded/collected. The spatial data displayed for seagrass in 2010 was created based on the spatial data collected for MAB assessment and is not true a representation of seagrass distribution; therefore should not be used as baseline data for the WFD seagrass assessment.

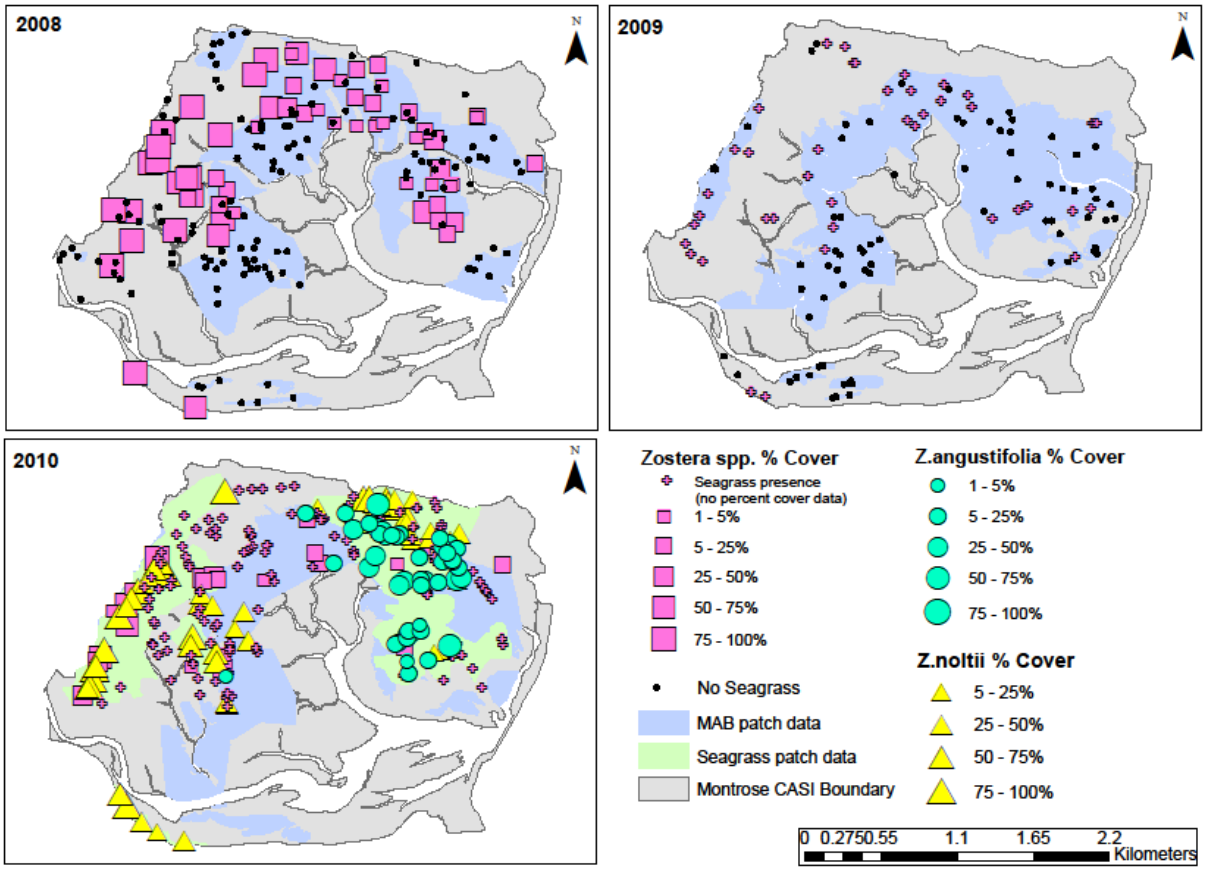

Figure 3: Seagrass species distribution and extent across the Montrose Basin, 2008-2010

In 2011, SEPA staff conducted a trial seagrass sampling survey in connection with on-going MAB sampling. The sample stations used for MAB surveys were selected at random using aerial photography (to determine patch area and size) and data from previous years surveys. It was decided that as part of the trial, two transects would be sampled specifically for seagrass, and if seagrass was found to be present at MAB sample stations the percent cover would be recorded.

Figure 4 shows the sample stations where seagrass species were found in 2011 and the percent cover. The figure shows that seagrass density is greatest along the northern and western areas of the basin, sparse distribution in the east and only two occurrences to the south of the main channel. Unfortunately not all sample stations were identified to species level with 33 stations recorded as *Zostera* spp; nine of which were along the dedicated transect line. Of the remaining 20 stations, thirteen were identified as *Z. noltii*, three as *Z. angustifolia*, and the remaining a mix of both species.

True colour Red Green Blue (RGB), Near Infra-Red (NIR) and CASI aerial imagery were also collected as part of the MAB classification before the survey was carried out. This allowed a more focused effort on sample areas and allowed ground-truthing of any ambiguous areas on the imagery. This also removed the need to walk round all MAB and seagrass areas during the survey as the patch sizes and areas were taken from the imagery; smaller areas of interest were still walked round for ground truthing purposes but not to the same extent as in previous years. The MAB patches that were used for classification were used as a starting point for mapping the spatial extent of the 2011 seagrass beds. As in 2010 the patches created were based on the spatial data collected for MAB assessment and were not a true representation of seagrass distribution.

Following on from the 2011 SEPA survey, 2013 was the first year that a full seagrass survey was conducted and spatial data was collected specifically for the distribution of seagrass (Figure 5). It was carried out in conjunction with a MAB survey and is to be used as the baseline data for future seagrass surveys and WFD classification.

Historical data in Appendix 1 was used to design the survey and direct field staff to areas where seagrass had been located previously. Although limited data was available on the extent of seagrass beds it gave an indication of spatial cover in certain areas.

Looking between the years it can be seen that seagrass is found growing in the same general locations (see Figures 4 & 5). A small bed of *Z*. *noltii* can be found on the south side of the channel and is the dominant species along the west side of the basin. *Z. angustifolia* occurs mainly to the north-east of the basin but can also be found growing with *Z. noltii* towards the north-west corner.

The total area of seagrass coverage within the Montrose Basin during 2013 was 1,747,000m^2 with an average density of 41.8%. Using the 2011 trial data as the baseline, WFD classification was calculated to give an indicative final classification of Good with an EQR of 0.766. For future years the 2013 data should be used as the baseline data as it is the only year that has been specifically surveyed for the seagrass tool.

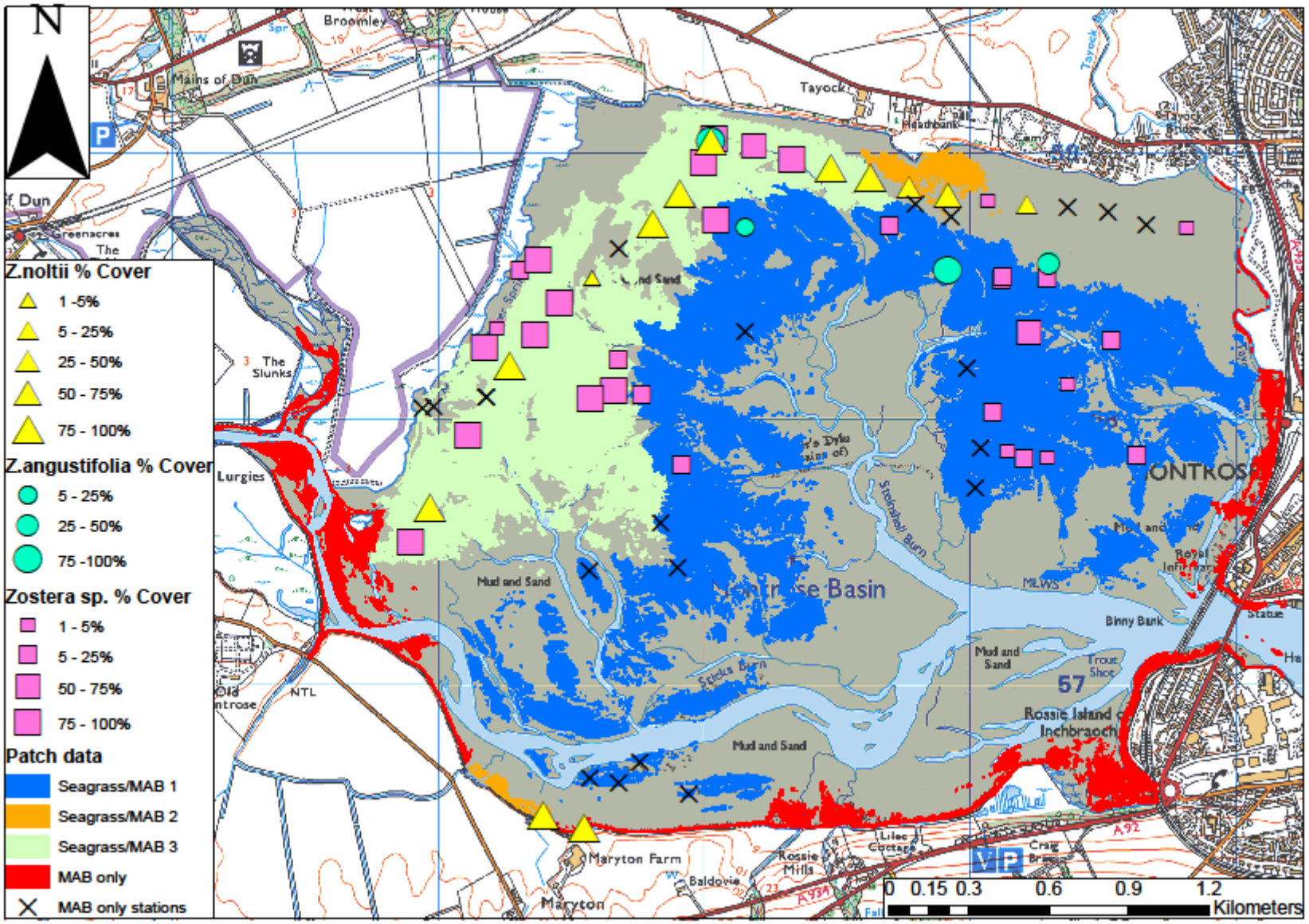

Figure 4: Seagrass species distribution and extent across the Montrose Basin in 2011

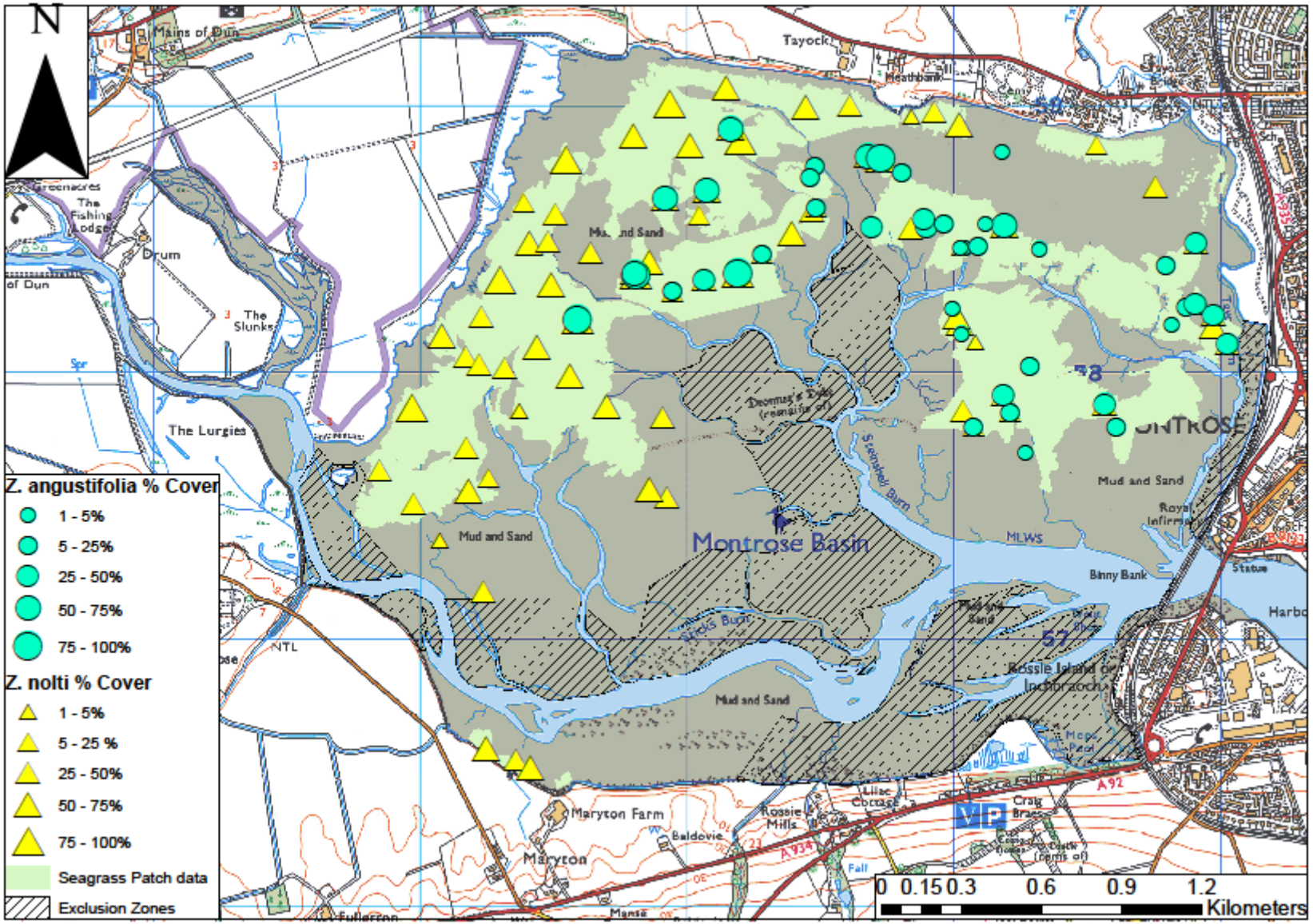

Figure 5: Seagrass species distribution and extent across the Montrose Basin in 2013

4. The Eden Estuary

1.1 General Overview

The Eden Estuary (Figure 6) is a relatively small estuary, around 5,350,000m^2, located north of St. Andrews on the east coast of Scotland, between the much larger Firth of Tay and Firth of Forth estuaries. The estuary is fed by the River Eden, draining approximately 400km^2 of predominantly low lying land, 76% of which is of prime agricultural land (JNCC, 2008) making potential eutrophication one of the most significant pressures on the Eden Estuary.

For the purpose of this report the upper estuary refers to the narrow channel upstream of Guardbridge, whilst the inner estuary is the area upstream of the narrowing between Coble Shore and Coble House Point. The outer estuary is the largest part of the estuary, downstream of Coble shore to the estuary's mouth.

The entrance of the Eden estuary is protected by a large spit dune system at West Sands. The mouth is exposed to strong wave and tidal action whilst the inner part of the estuary is mostly sheltered due to its formation. The estuary itself consists of extensive mudflats and saltmarsh with areas of swamp, marsh and wet grassland.

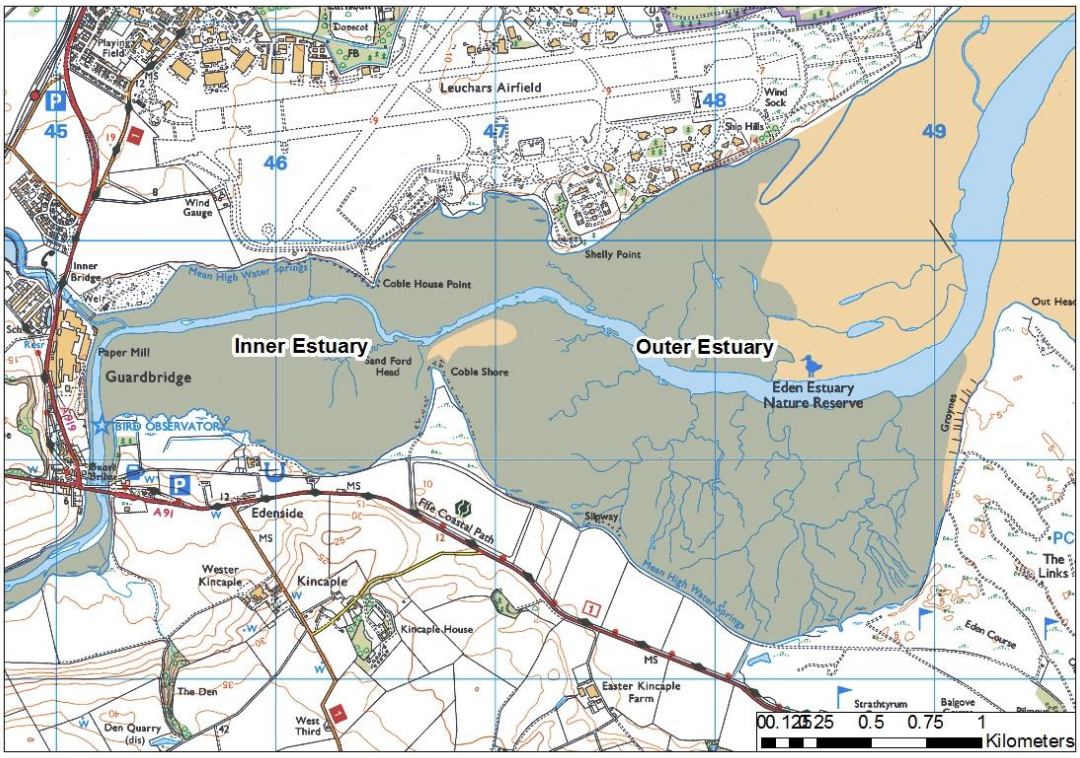

Figure 6: The Eden Estuary

Freshwater water influence is relatively low and at high tide the water is well mixed with a salinity of approximately 28‰ (Johnston *et al*, 1979). At low tide most of the mudflats are exposed with a single narrow channel, often very shallow in some places, running from the upper estuary to the sea. The mudflats consist of a variety of sediments ranging from coarse sand to very soft mud in some of the inner areas.

Mudflats on the northern bank of the inner estuary support dense algal mats of *Enteromorpha* spp. with *Ulva* sp. and *Porphyra* sp. also present. Sediments in this area are dominated by oligochaetes, *Corophium volutator* and *Hediste diversicolor*, (Bates et al, 2004).

The dominant infauna of mudflats in the outer estuary are similar to that of the inner estuary but *C. volutator* is found in lower numbers whilst there are greater numbers of the cockle, *Cerastoderma edule*. Mussel beds occur in patches on north and south banks of the channel and *Fucus vesiculosus* is found where suitable substratum is present. During the summer much of the outer estuary is covered by green algal mats. Caudwell and Jones (1994) carried out a baseline study on these green algal mats, finding the maximum density of algal cover east of Coble Shore to be approximately 60%. They also compared 1994 data to earlier photographs, concluding that the mats were not a new occurrence and did not appear to be significantly more extensive.

The upper shore, either side of Shelly Point, is differentiated from the majority of the mudflats by a localised high abundance of the bivalve, *Mya arenaria* alongside other bivalves. Sediments near the mouth of the estuary tend to be firmer, with high numbers of amphipods and greatly reduced numbers of oligochaetes and *H. diversicolor* (Bates et al, 2004).

Zostera spp. are also found throughout the estuary, with *Z. noltii* mainly found on mudflats in the inner estuary whilst *Z. angustifolia* and *Z. marina* is located in the outer estuary and in channels (Fife District Council, 1998).

1.2 Use

The Eden Estuary is used for a variety of purposes, though mostly recreational activities such as walking, bird watching, horse riding and wildfowling, which is controlled by a permit system. On the south shore there are areas of saltmarsh that are used for grazing by horses.

The land surrounding the estuary has several uses such as farming, forestry, golf, Leuchars British Army Station, formally RAF Leuchars and the Guardbridge papermill. The station occupies the majority of the northern bank from which jet planes flew across the whole site when it was RAF Leuchars. This occurred for many years and had no apparent adverse effect on the wildlife (JNCC, 2011). A major source of pollution to the estuary was the Guardbridge papermill: in 1992 a £2.5 million treatment plant was constructed to improve the quality of the effluent discharged. In 2008, it ceased to operate and the site is now owned by St. Andrews University, which hopes to revitalise the area by establishing a Green Energy Centre and Knowledge Exchange Centre to generate and distribute energy.

Small-scale mussel harvesting used to occur in the estuary but due to sewage discharges they were classified as unfit for human consumption in 1992 under the EC Shellfish Hygiene Directive (EEC, 1991). A new sewage treatment works was commissioned in 1995 to provide full biological treatment in order to improve the effluent discharged (Clelland, 1997).

1.3 Conservation Status

Despite its small size, the Eden Estuary is of significant importance for nature conservation (Table 4). It contains a variety of habitats, becoming a SSSI in 1971. The site supports internationally and nationally important populations of waders and waterfowl and those of regional significance such as Wigeon, Teal, and Dunlin.

In 1978 the Eden Estuary became the third LNR in Scotland, due to the need to manage the numerous activities in the estuary.

The SSSI forms part of the Firth of Tay and Eden Estuary SPA, together covering a geomorphologically complex area of estuarine and coastal habitats. It is classed as a wetland of international importance, regularly supporting thousands of wintering waterfowl such as Greylag Goose, Pink-footed Goose and Redshank. The site also supports 2.5% of the Great

British breeding population of Western Marsh Harrier. Together the two estuaries are also designated a SAC and a Ramsar site of international importance.

Table 4: Summary of the designations of the Eden Estuary (SNH – 2006, 2011) (JNCC - 2006, 2008, 2011)

Designation	Reason for designation
Special Protection Area (SPA)	Regularly supports 48,000 internationally important waterfowl over winter and supports several breeding populations of Western Marsh Harrier (*Circus aeruginosus*), Little Tern (*Sterna albifrons*) and Bar-tailed Godwit (*Limosa lapponica*).
Special Area of Conservation (SAC)	Variety of habitats – saltmarsh communities, sparse beds of eelgrass *(Zostera angustifolia* & *Zostera noltii*), mussel beds and extensive mudflats. Important breeding ground for the Common seal (*Phoca vitulina*)
Ramsar Site	A site of complex estuarine and coastal habitats in East Scotland. Invertebrate rich intertidal mudflats. Site supports 27,000 internationally important wintering waterfowl and important populations of several other species such as the Ringed Plover (*Charadrius hiaticula*)
Site of Special Scientific Interest (SSSI)	Extensive mudflats with a rich invertebrate fauna, mussel beds and seagrass (*Zostera angustifolia* & *Z. noltii*). Areas of saltmarsh, sand dunes and locally extensive areas of brackish and freshwater swamp. . Site supports nationally important wintering populations of waders and the internationally important Shelduck (*Tadorna tadorna*) and Red-breasted merganser (*Mergus serrator*). It is also of regional significance for several other species of waterfowl and waders.
Local Nature Reserve (LNR)	Diverse habitats of mudflats, sandbanks and saltmarsh. Supports thousands of wintering migratory birds.

1.4 SEPA Seagrass data: 2008 – 2015

The Eden Estuary has been the focus of a number of environmental studies (see Appendix 2) although none specifically focused solely on seagrass.

Between 2008 – 2011 SEPA staff conducted surveys in the Eden Estuary as part of the WFD assessment for MAB. MAB was the main focus of the surveys and the presence of seagrass was only noted at a few locations: the actual occurrence of seagrass in the Eden estuary in previous years is thought to be higher. In some instances density (as percent cover) or species of seagrass was also recorded (Figure 7).

The first year a full seagrass survey was conducted was 2013, in conjunction with a MAB survey, and spatial data collected specifically for the distribution of seagrass beds. Figure 8 shows the location of seagrass species and the percent coverage of patches found. The average percent cover of these patches ranged between 3 – 51%. As with the survey carried out by SNH in 2006, *Z. noltii* was found to be dominant in the Inner Estuary whilst *Z. angustifolia* was more prevalent in the Outer Estuary. Seagrass cover over the whole estuary was 172,200m^2 with an average percent cover of 28.21%.

During August 2015, another full seagrass survey was conducted in conjunction with a MAB survey (Figure 9). The survey was carried out by three teams over four days, whilst in 2013 the survey was completed in three days, therefore, the appeared increase in seagrass coverage may partly be down to a more intensive survey carried out in 2015. Seagrass was present over an area of 558,800m^2 with an average percent cover of 29%.

A trial classification was run from the results of the 2015 seagrass survey. The Eden Estuary is of High status (1.00 EQR). SEPA's confidence in the results is: 99% confident that the Eden Estuary is high and 0.9% confident that the estuary is Good status. Due to the 2015 survey being more intensive a third survey would need to be completed to ensure this status is correct and not the result of the appeared increase in seagrass coverage.

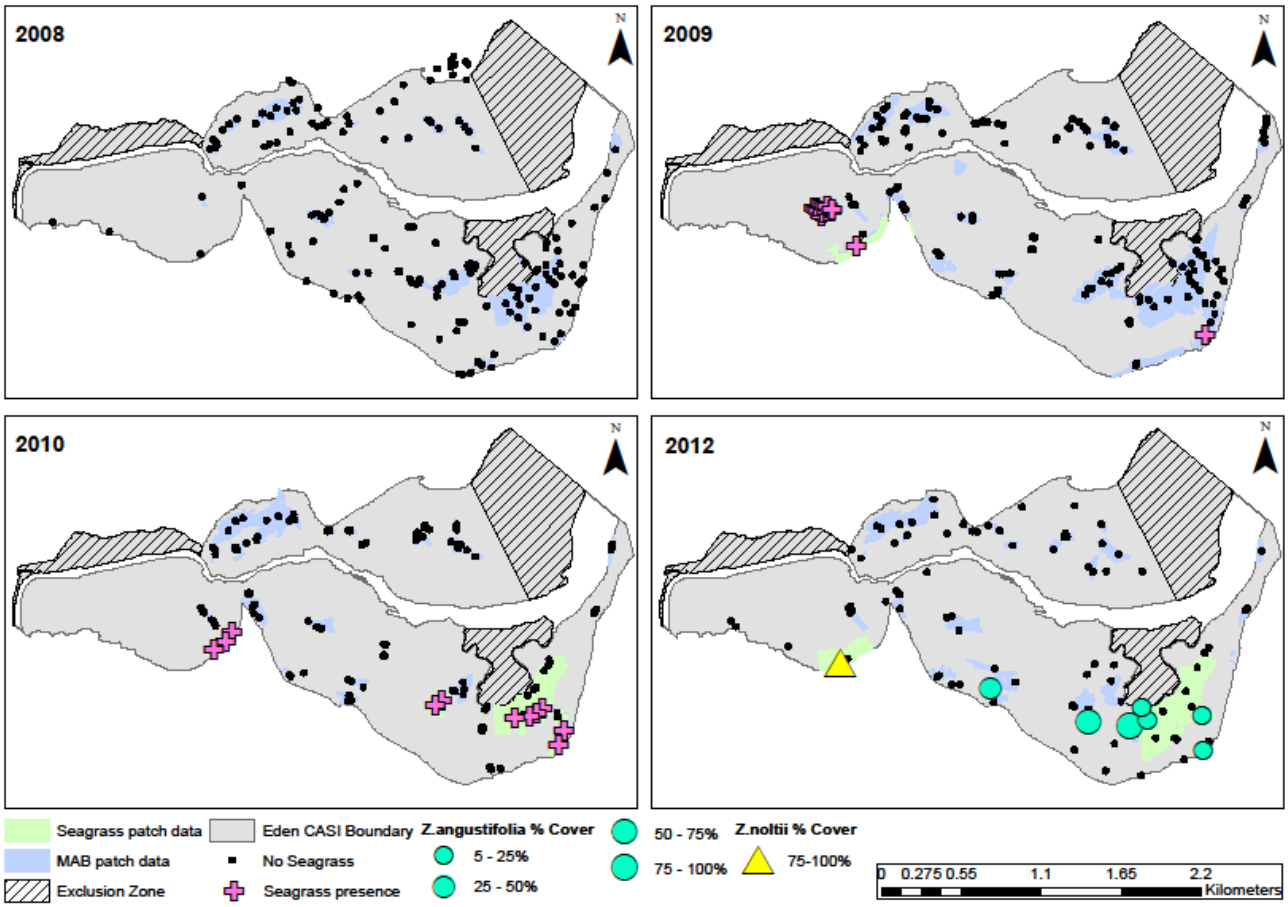

Figure 7: Presence/Absence of seagrass species in the Eden Estuary between 2008 – 2012 (Percent cover data shown where possible)

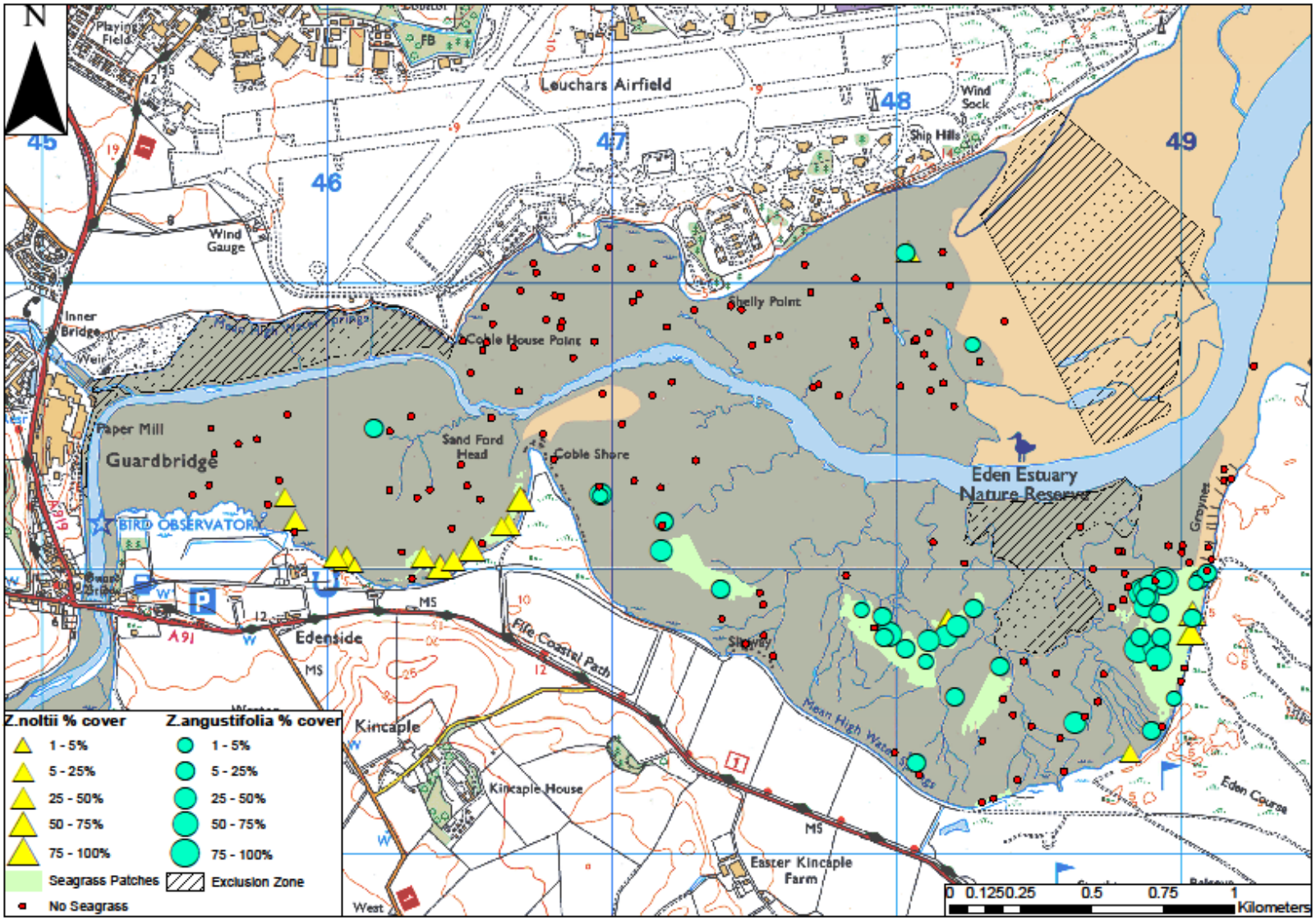

Figure 8: SEPA seagrass data collected in 2013

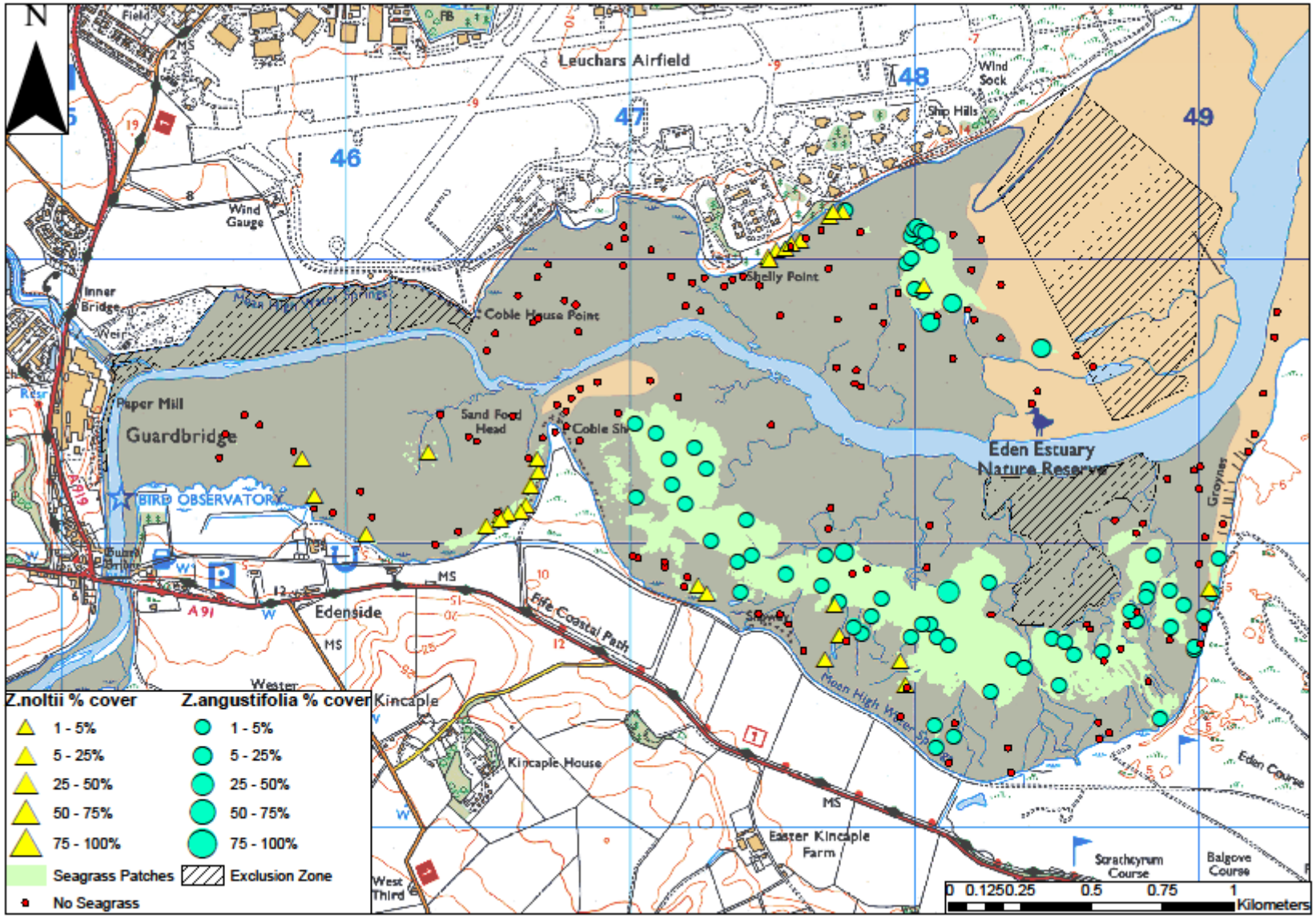

Figure 9: SEPA seagrass data collected in 2015

5. Forth Estuary

5.1 General Overview

The Firth of Forth is a large estuary located on the east coast of Central Scotland, extending eastwards from the River Forth near Stirling to its outer limit between Dunbar and Fife Ness. It consists of the Forth Estuary and the Outer Firth, where the Forth Rail Bridge is the divide between the two.

For the purpose of this report when referring to the Firth of Forth, we are referring to both the Forth Estuary and the Outer Firth.

The complex estuary contains a variety of intertidal habitats and is of major importance for supporting migratory and wintering populations of waterbirds. The extensive mudflats of the Forth Estuary support *Zostera* spp. and a rich community of invertebrate fauna. There are also some small areas of saltmarsh. In the Outer Firth the estuary widens and the shoreline becomes more diverse with numerous sandy bays, sand dunes, rocky outcrops, mussel beds and artificial sea walls.

5.2 Use

The Firth of Forth is one of the most populated and industrialised areas in Scotland. There are many towns which line the shore, including Edinburgh, which all deliver urban effluent into the Firth causing a decline in water quality. In the past the upper estuary between Stirling and Alloa suffered from chronic anoxia due to organic water, whilst the middle estuary was affected by industrial waste (McLusky, 2015). Improvements to treatment facilities over the last few decades have led to an increase in water quality.

There are several bridges which carry traffic across the Forth; the Forth Rail Bridge, Forth Road Bridge, Kincardine Bridge, Clackmannanshire Bridge and the new Queensferry Crossing.

The Forth is one of the most important shipping areas in Scotland, with ports at Burntisland, Grangemouth, Kirkcaldy, Leith, Methil and a naval dockyard at Rosyth, which includes a ship building/repair yard.

Fishing in the Outer Firth used to be a large part of the economy, with immense oyster beds and herring fishery, which were destroyed in the Victorian times by over fishing and increasingly polluted waters. The remaining fisheries were wiped out in the 20th century by developments in trawling for haddock and cod. Today, inshore fishing is heavily dependent on shellfish, largely consisting of langoustine, scallops, crabs and lobster (WWF Scotland, 2006).

Coal mining was also a major industry on the shores of the Forth, with large mines near Alloa, Kirkcaldy and Longannet. Large bings or waste heaps created from the mining were deposited on the shore, which slowly eroded leading to coastal erosion problems.

Historically, the Forth Estuary area between the Kincardine and Forth Bridges lost a significant proportion (50%) of intertidal area as a result of land reclamation for agriculture, chemical works and docks (McLusky, 2015). The construction of ash lagoons for Cockenzie and Longannet Power Stations, which closed in 2013 and March 2016 respectively, added to this. Much of the shoreline in this area has undergone construction of seawalls and barriers to aid in this reclamation.

The Firth of Forth is also important for numerous recreational activities, namely sailing and other water sports, whilst the beaches and coastal paths are popular for walking.

5.3 Conservation Status

The Firth of Forth is a site of great nature conservation interest due to the combination of estuarine and coastal habitats. It is a SPA under the European Wild Birds Directive due to supporting wintering, post-breeding and migratory bird populations, which are of European and international importance. The site is also underpinned by a SSSI, which is important for the variety of coastal habitats in the area, such as mudflats, sand dunes, saltmarsh, reedbeds, grasslands, saline lagoons and rocky shorelines. The shoreline of the Outer Firth is rockier than the Forth Estuary, with features such as fossil deposits and volcanic rocks of geological and geomorphological interest.

There are several islands (Inchmickery, Isle of May, Fidra, The Lamb, Craigleith, Bass Rock and Long Craig) in the Firth of Forth, which together form the Forth Islands SPA; regularly supporting 90,000 seabirds including those of national and European importance. Several of the islands also form the Forth Islands SSSI – Fidra, The Lamb and Craigleith - forming the second largest seabird colony in the region. These volcanic formed basalt islands are home to a range of seabirds but most notably populations of Puffin and Cormorant, numbers of which have declined in recent years.

Additionally, the Firth of Forth is a RAMSAR site for wetlands of international importance.

5.4 SEPA Survey 2014

Due to its size and the proximity of the Firth of Forth to Edinburgh, there have been numerous studies carried out on a variety of subjects. Records of *Zostera* spp. in the Forth go back to 1863 but spatial data could not be found. Studies within the last decade have been carried out by Masters students of Heriot-Watt University. The historical data collected by the 2011 and 2013 Heriot-Watt University Masters projects in Appendix 4 (Zoutenbier, 2011; Box, 2013) were used as a guide for the design of the survey plan but lacked the necessary components of the seagrass tool in order to use it as baseline data. It did though, allow for the examination of change in extent. In addition, another Masters student (Finlay, 2014) independently surveyed seagrass in the Firth of Forth but it is not known what month the survey was completed.

The Firth of Forth covers several water bodies. It is for this reason SEPA chose to focus on the Forth Estuary, upstream of the bridges, rather than the Outer Firth. Figure 10 shows the sites surveyed by SEPA in 2014 and the division of the estuary by water body. Each water body is classified separately for the WFD classification tools.

Sites which Zoutenbier (2011) had identified seagrass at were used as 2014 SEPA survey sites. As the sites at Carriden and Brucehaven had the most background information it was decided that these would be priority sampling sites during the survey.

Over a two day survey period during August 2014, SEPA staff visited six sites. Of these six sites, five were intensively mapped and species data density and composition were collected. The sixth site was found to be too big to be fully surveyed within half a tidal window and the decision was made at the time to concentrate on the seagrass beds found to collect robust data.

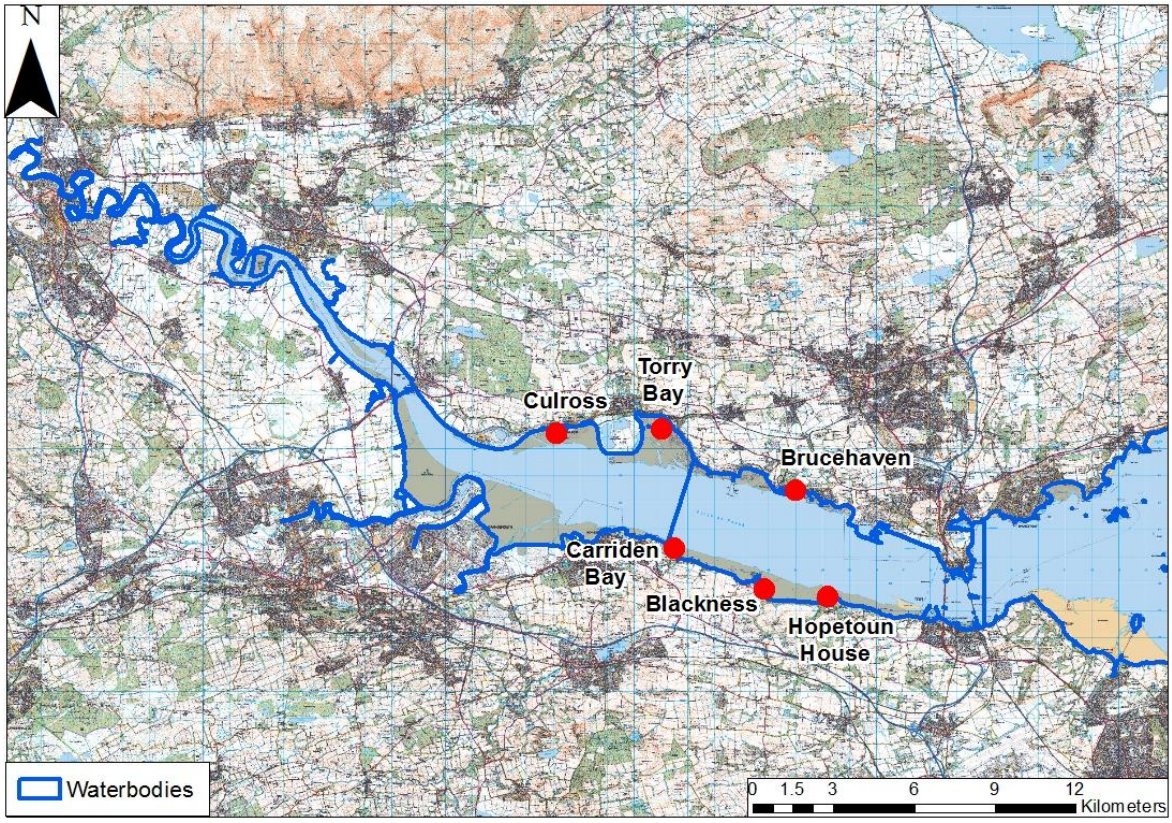

Figure 10: The Forth Estuary showing sites surveyed within each different waterbody

Figure 11, shows the information collected by SEPA staff at Carriden bay. Sample stations containing seagrass, ranged in density as percent cover, between 41% and 99%. *Z. noltii* was found in all these stations, with one also containing *Z. angustifolia*.

Figure 12, shows the changes in the seagrass beds mapped between 2011 and 2014. Zoutenbier (2011) only mapped one of the beds, but the one to the east was present during 2011 (pers.com. Dr Alastair Lyndon, Heriot Watt University). There is very little difference in the beds between 2013 and 2014 which would suggest that these beds are relatively stable and there may only be slight fluctuations around the edges. Between 2011 and 2014, there is no change in the main location of the seagrass bed to the west of the bay; potentially the three seagrass beds merged into one larger bed during the season.

Figure 13 shows the seagrass bed extent found at Brucehaven by SEPA staff and the percent cover of seagrass species found at each sample station. Only *Z. noltii* was found at this site. The area of the bed was 17,370m^2, with the percent cover of seagrass at the sample stations ranging between 26% and 80%. Due to time constraints SEPA were not able to explore the area to the east, which Finlay mapped (Appendix 3), giving an extra area of 5,230m^2. The area had not previously been described as a location for seagrass and therefore was not considered an area to be explored.

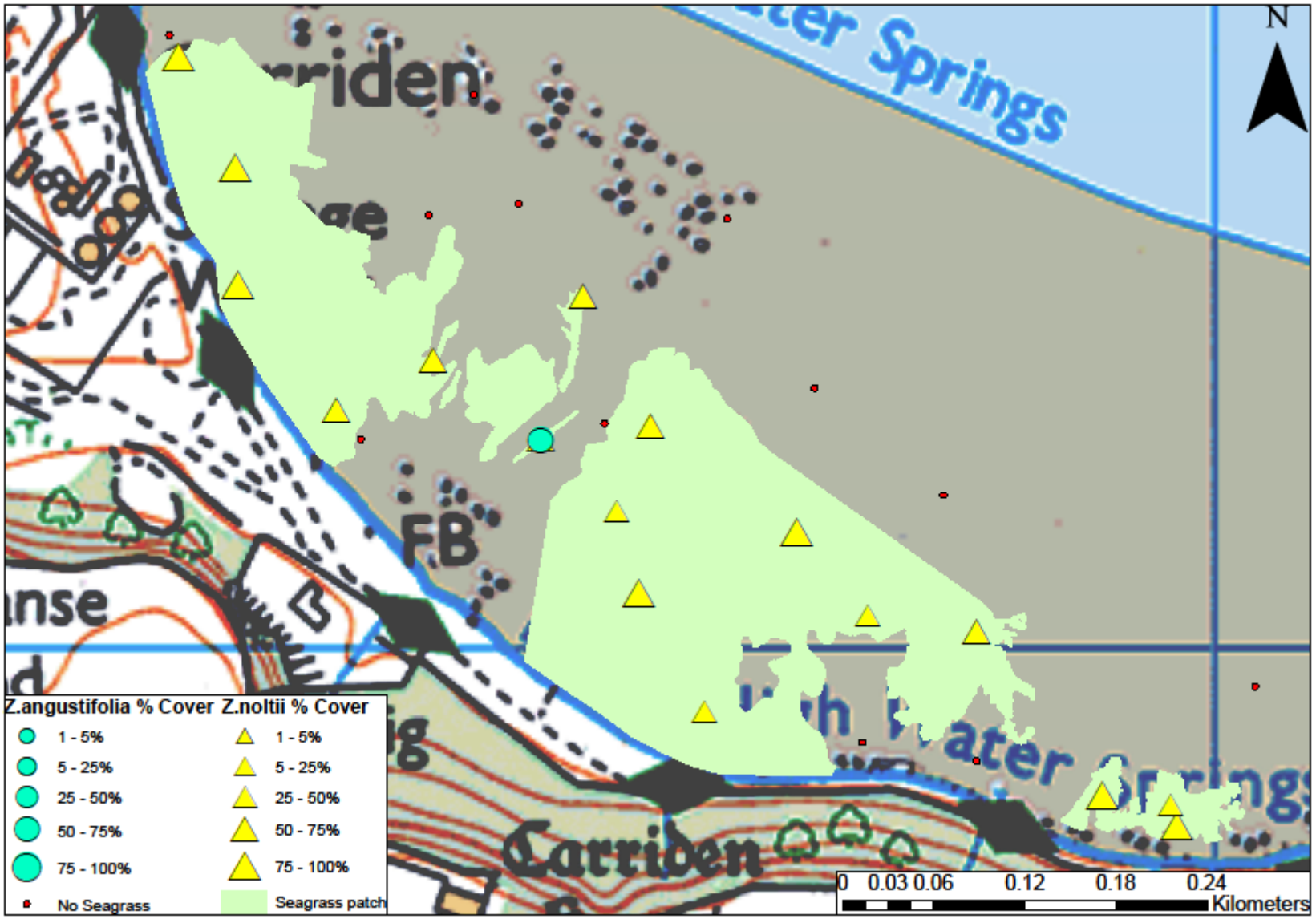

Figure 11: Seagrass percent cover and patch data at Carriden Bay, 2014

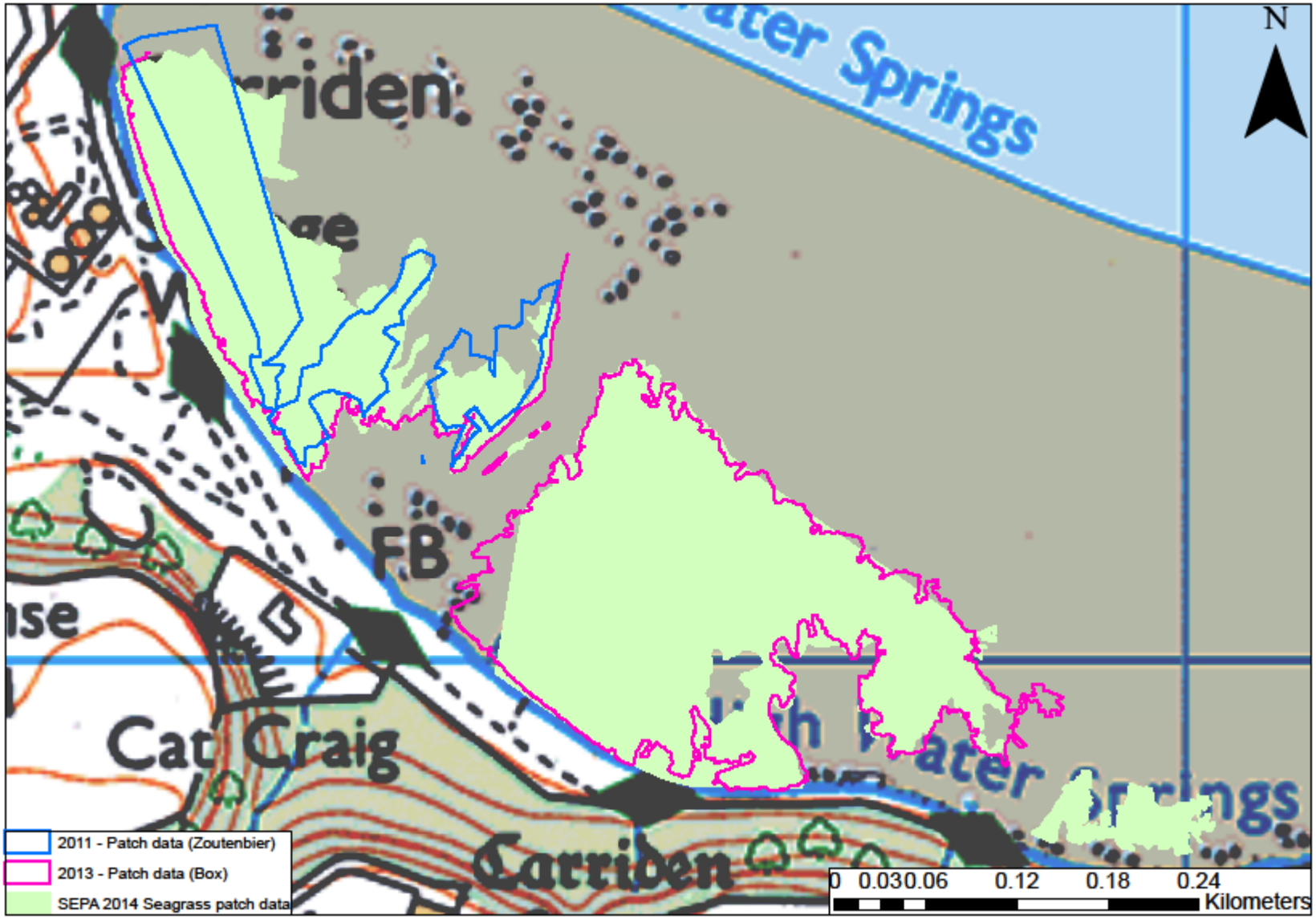

Figure 12: Change in seagrass bed extent at Carriden Bay between 2011 and 2014

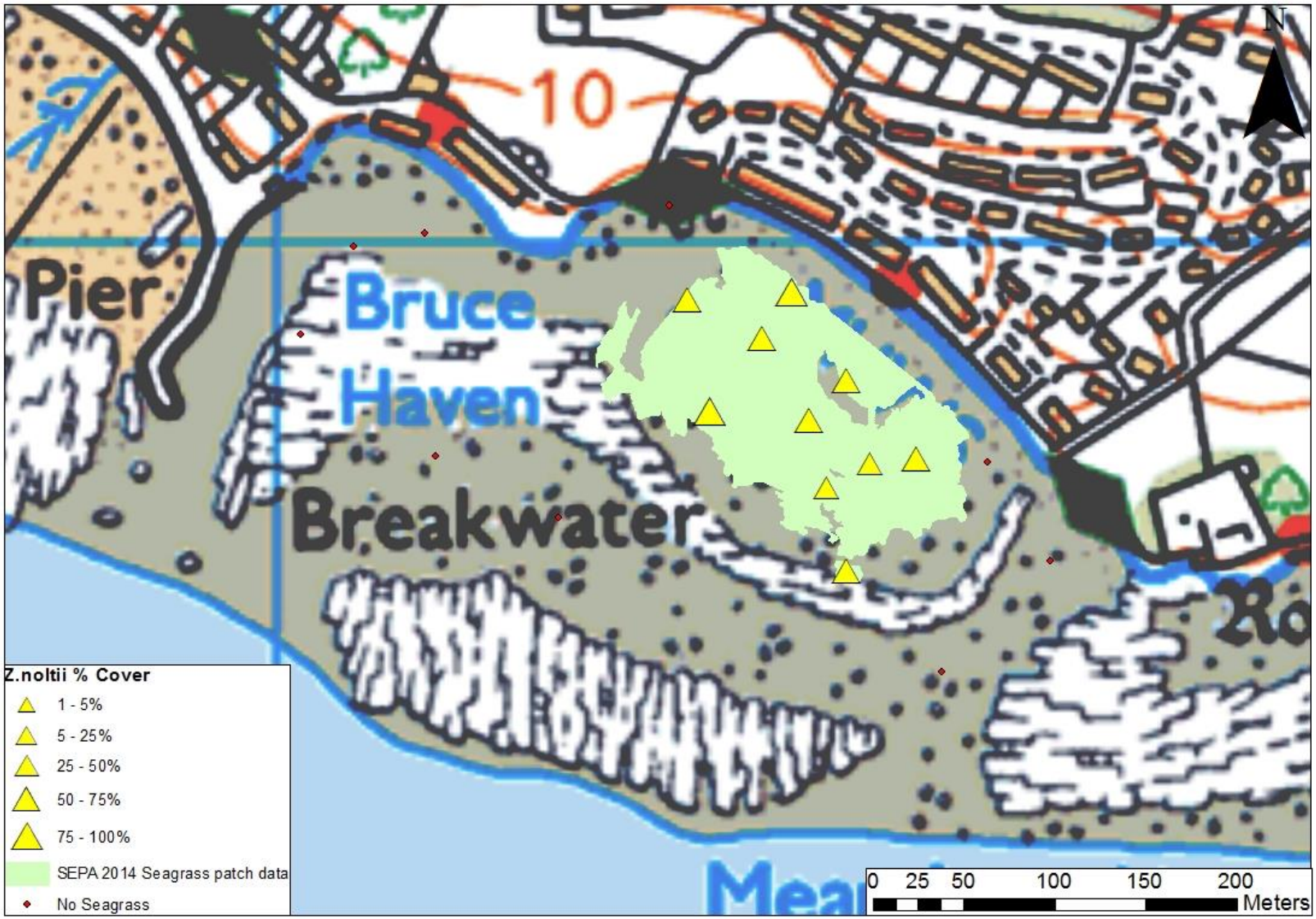

Figure 13: Seagrass percent cover and bed extent as surveyed by SEPA at Brucehaven during 2014

The information collected by SEPA staff in 2014 at Blackness is shown in Figure 14. *Z. noltii* was the only seagrass species found, with sample station percent covers ranging between 19% and 68.5%. One sample station not included within the seagrass beds was found to contain a very small sparse patch of seagrass, estimated at 2.5% coverage within a 0.25m^2 quadrat.

The area of the shore between Blackness Castle and Hopetoun House was split into two; with the first sampling area at Blackness and working east towards Hopetoun House (Figure 15) and the second at Nethermill Bridge and continued west towards Blackness (Figure 16). Due to time constraints it was decided that all points to the east of Abercorn point would not be sampled and efforts should be directed west from Abercorn Point towards Blackness. Over the two areas station percent covers ranged from 0.5% up to 92.5%

Figure 17 shows the information collected at Culross by SEPA. Finlay's (2014) survey covered a greater area and estimated the seagrass extent to be 20,278m^2 (Appendix 3). Due to the sticky/deep nature of the sediment, not all of the site could be covered by SEPA within the allocated tidal window. The only species found at this site was *Z. noltii* and seagrass percent cover was quite high with stations ranging between 33.5% and 72.5%

Again, due to time constraints the area towards the northwest of Torry Bay was the only section that was fully surveyed for seagrass during the tidal window (Figure 18). Several small distinct seagrass beds were mapped and the only seagrass species found to be present in this area was *Z. noltii*. Finlay (2014) surveyed the full area of Torry Bay estimating that the seagrass covered 218,478m^2 (Appendix 3) This includes the 215,371m^2 from Torry Bay and an extra 3,107m^2 from what Finlay named as Ironmill Bay. Ironmill Bay is situated further round the coast to the east, which SEPA was unable to access at the time due to the proximity to the MOD territory. SEPA, therefore, included Finlay's data at Ironmill Bay as an extension of the Torry Bay site.

In summary, Table 5 shows the extent of seagrass beds in the Forth Estuary as surveyed by Finlay (2014) and SEPA during 2014. The average percent cover of *Zostera* spp. was collected and analysed by SEPA.

Finlay (2014) determined that the total *Zostera* spp. coverage in the Forth Estuary was approximately 594,000m^2. If we minus the areas that the SEPA survey did not cover – Torry Bay which was not surveyed in full, then the extent cover is 375,472 m^2. This is very close to that area surveyed by SEPA. Unfortunately Finlay (2014) did not collect density data (as percent cover), which means areas that SEPA did not survey cannot be used as baseline data for the WFD Seagrass tool. In addition, Finlay (2014) recorded *Z. angustifolia* more often than the SEPA survey, despite covering some of the same areas. These discrepancies in identification must be confirmed if the survey were to be reproduced.

Table 5: Summary of seagrass bed details as surveyed by Finlay (2014) and SEPA (August 2014).

Water body	Site	Finlay (2014)	SEPA (2014)	
		Area (m^2)	Area (m^2)	Average % cover
Lower Forth Estuary	Carriden	73,375	81,383	67.65
	Blackness	256,308	29,066	45.06
	Blackness Castle		216,680	47.5
	Hopetoun House		4,765	64.5
	Brucehaven	25,511	17,370	63.1
Middle Forth Estuary	Culross	20,278	2,639	53.63
	Torry Bay	218,478	18,764	53
Total Area (m^2)		**593,950**	**370,667**	

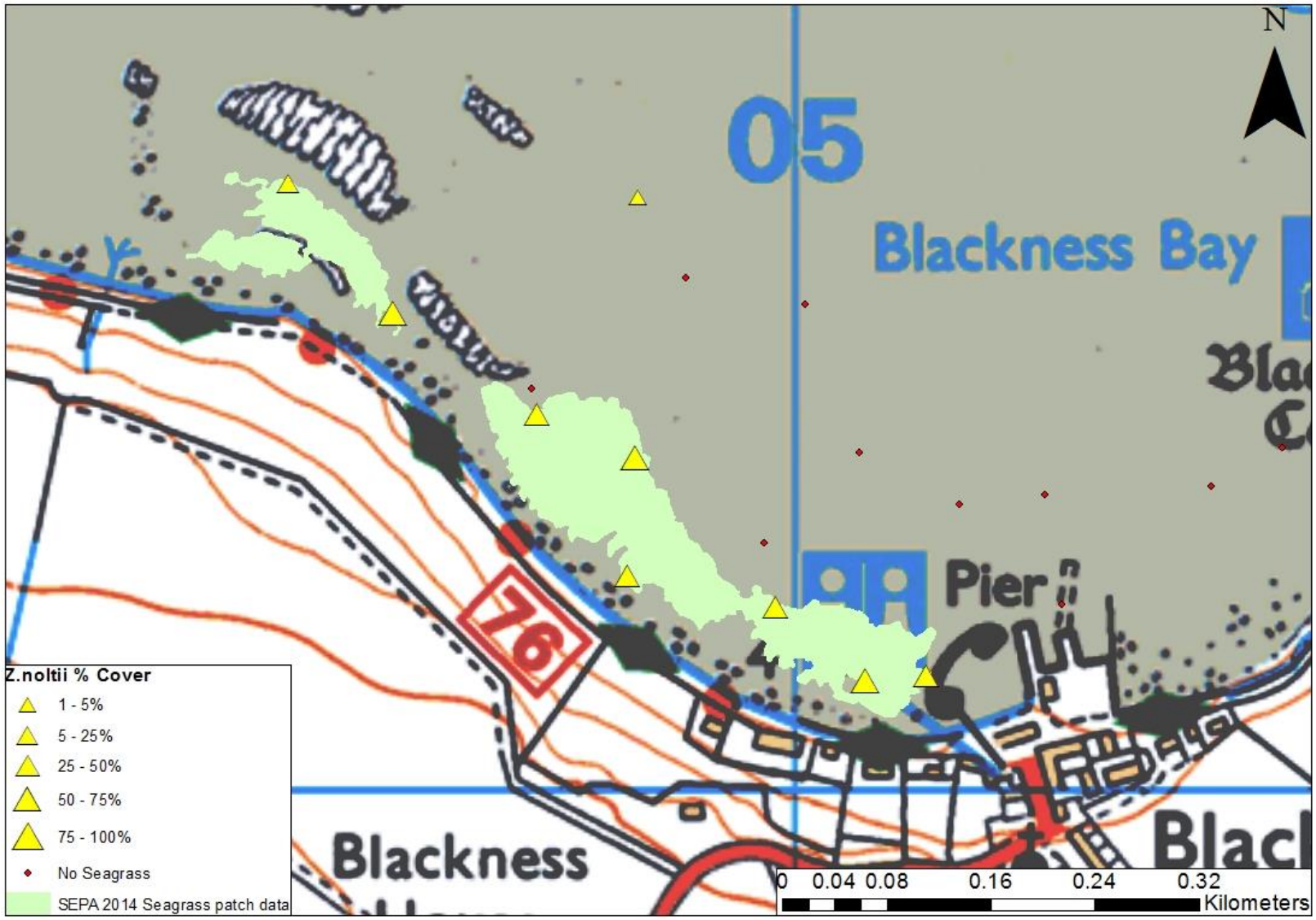

Figure 14: Seagrass percent cover and bed extent as surveyed by SEPA at Blackness during 2014

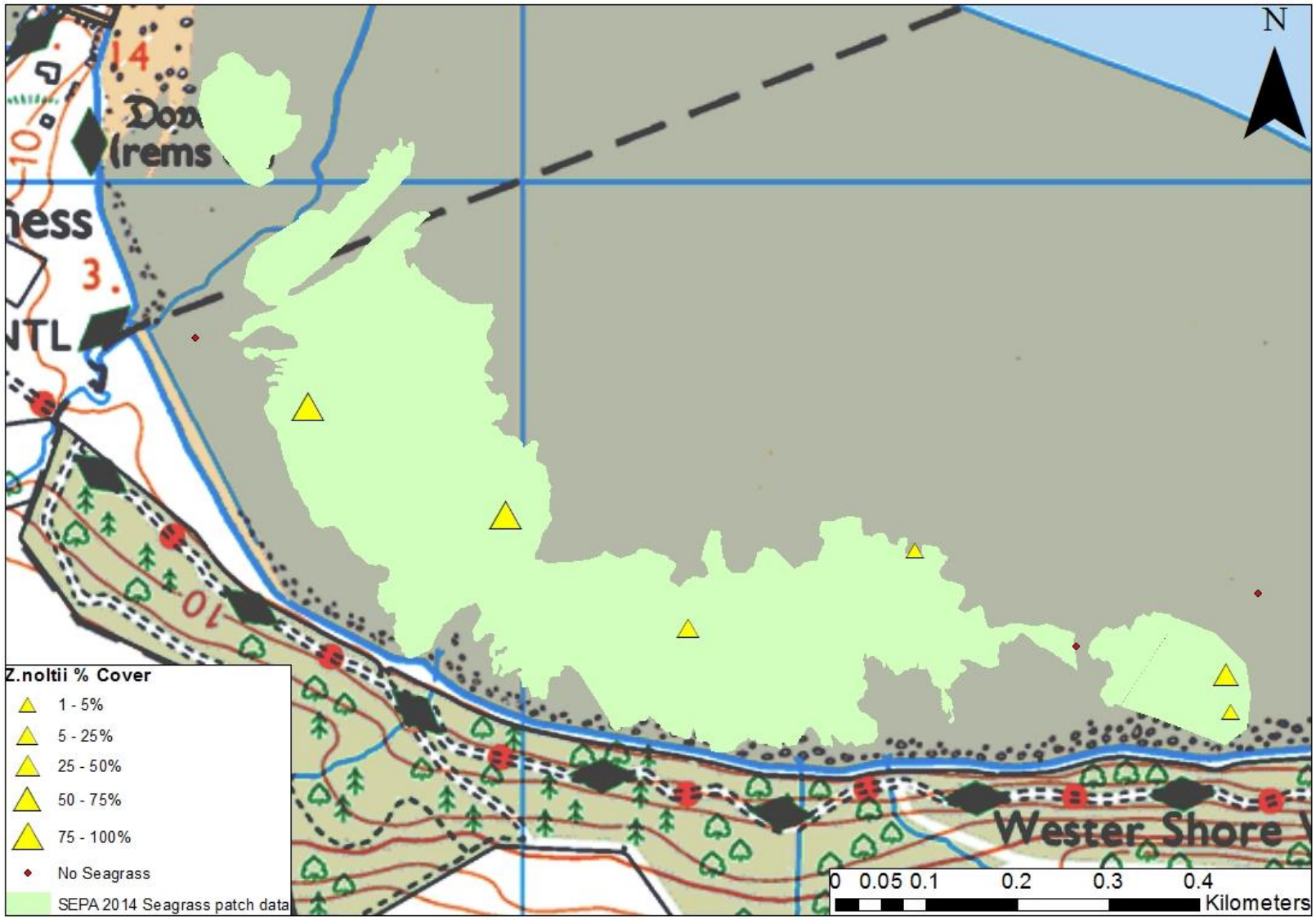

Figure 15: Seagrass percent cover and bed extent at Hopetoun to Blackness as surveyed by SEPA during 2014

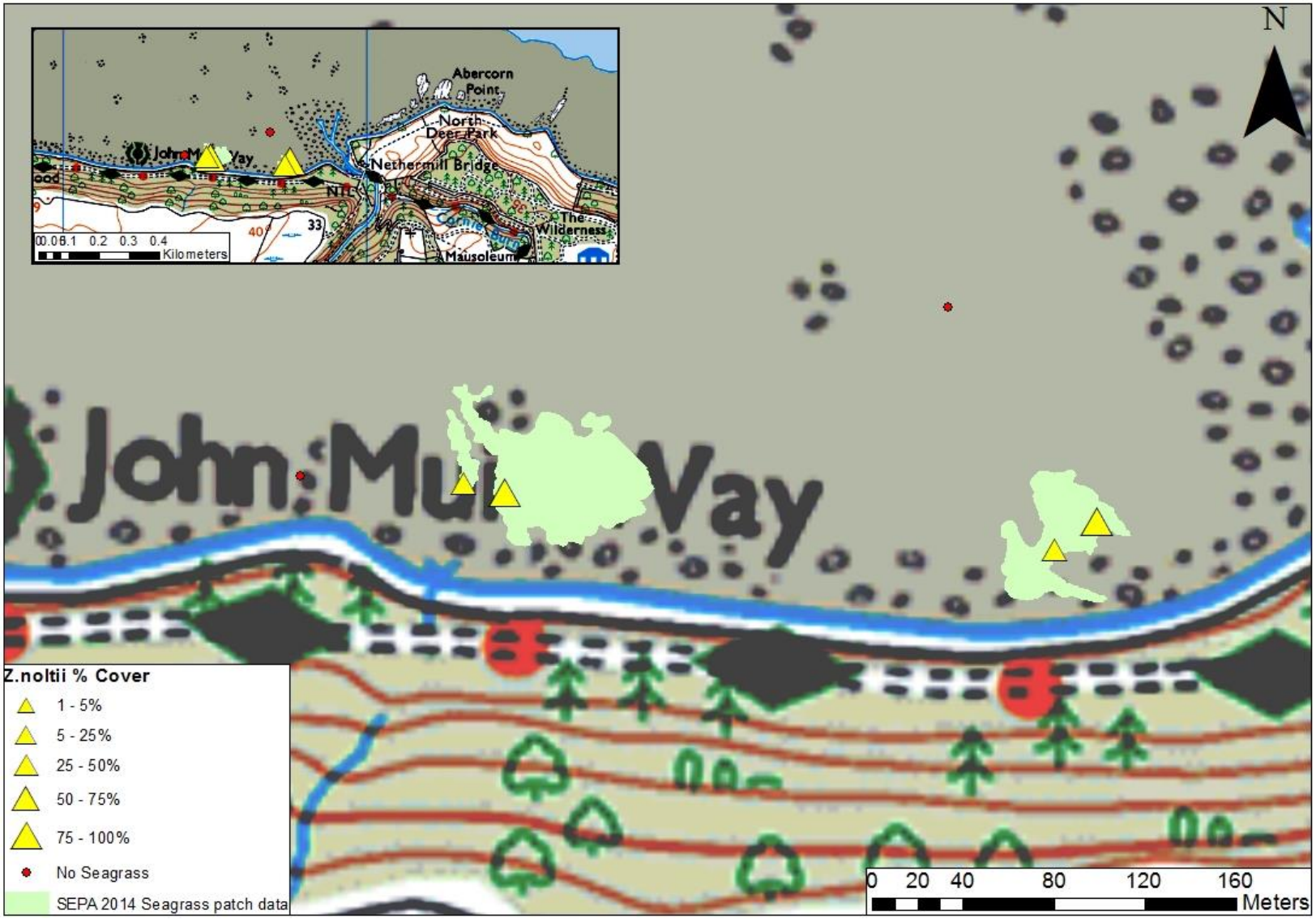

Figure 16: Seagrass percent cover and bed extent as surveyed by SEPA at Hopetoun during 2014

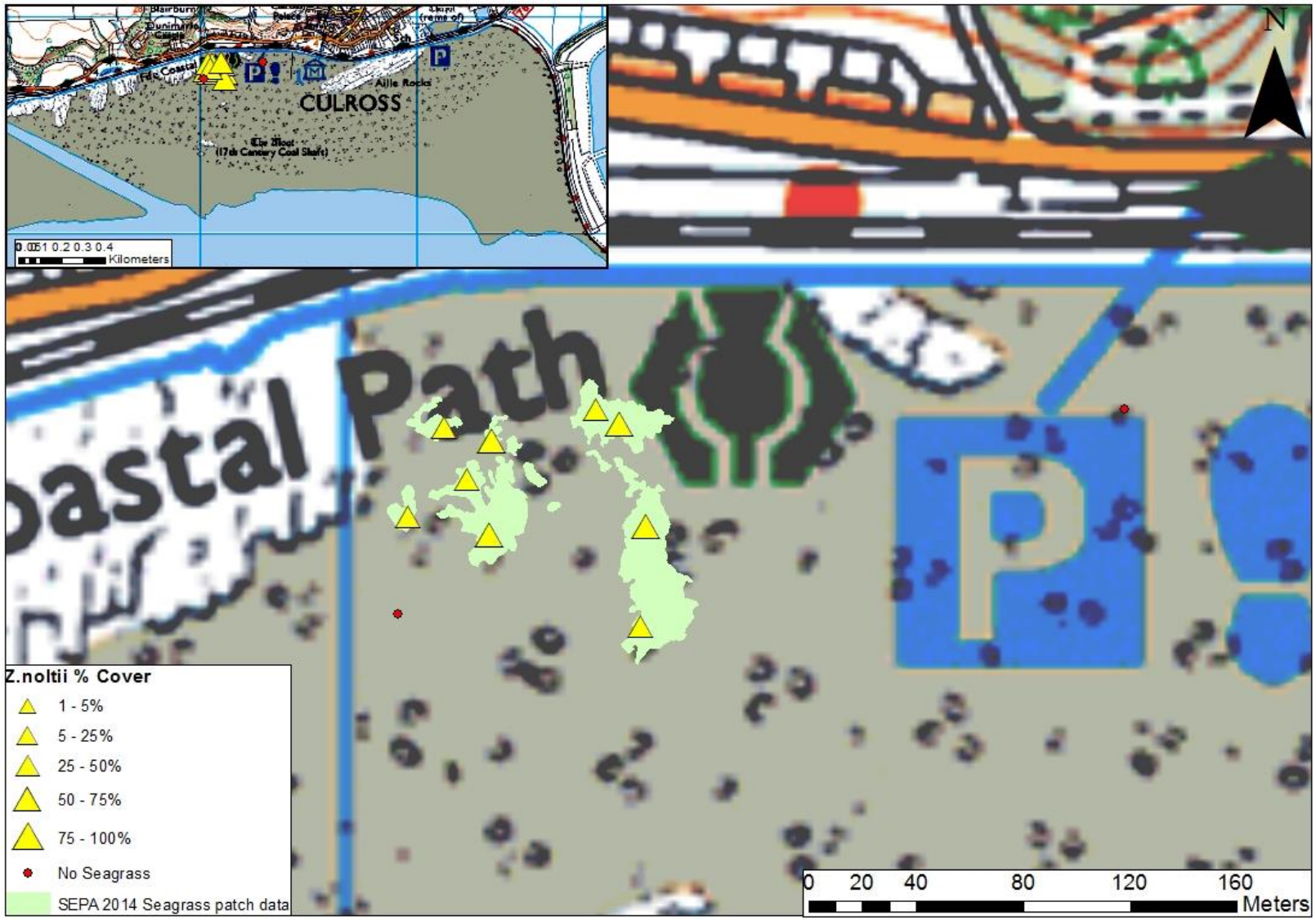

Figure 17: Seagrass percent cover and bed extent as surveyed by SEPA at Culross during 2014

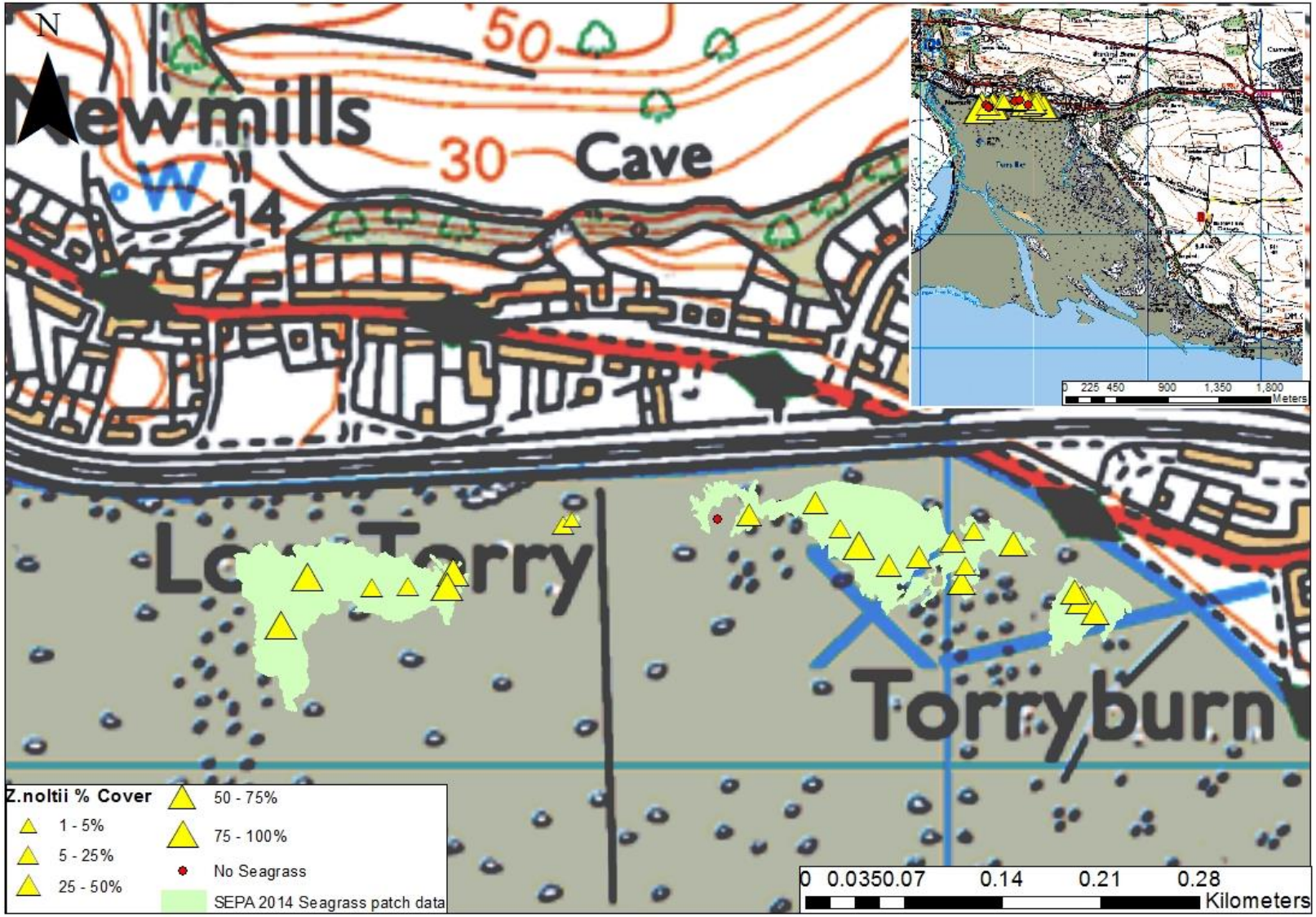

Figure 18: Seagrass percent cover and bed extent as surveyed by SEPA at Torry Bay during 2014

6. Loch Ryan

6.1 General overview

Loch Ryan is the most southerly located Scottish sea loch, found on the west coast of Scotland at the southern entrance to the Firth of Clyde. The loch is fairly uniform being shallow and 13.4km long. Based on bathymetry, it can be split into two basins separated by a shingle sand spit. The southern basin at the head of the loch has a depth less than 5m above chart datum whilst the outer part ranges from approximately 8-20m at the mouth (UKHO, 2012). A dredged channel 5m deep also runs down the southern basin to the port of Stranraer to allow ferry access.

The loch is completely marine and is unique for its large bed of native oysters (*Ostrea edulis*) and species rich intertidal communities. There is little fresh water influence which comes from the Water of App, near Finnarts Bay and several burns. In the southern basin the temperature fluctuates considerably, particularly in the summer months (Dumfries and Galloway Council, 1999).

The entrance to the loch faces north and is therefore exposed to winds and waves from that direction. Although its orientation is such that it is sheltered from the prevailing south-westerly winds, the steep rocky cliffs found at the entrance to the Loch create a funnelling effect. In addition, the southern basin is sheltered from wave action but may be affected by winds due to the low lying nature of the surrounding land (Crosby, 1989). The sediments of Loch Ryan vary considerably in relation to wave exposure. There is little sub-tidal bedrock and in adverse conditions, due to the shallow depth and muddy sediments, water turbidity increases significantly.

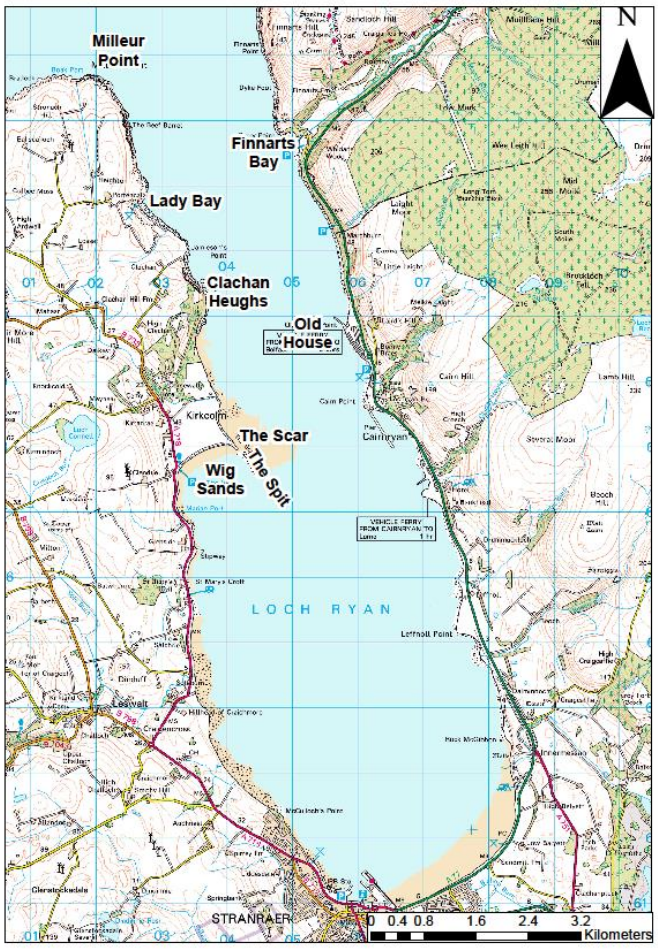

Figure 19: Loch Ryan

The shores of Loch Ryan are predominantly sedimentary apart from at the entrance to the loch, which is bounded by steep rocky cliffs grading down to a short boulder and bedrock slope (Crosby, 1989). This horizontal rock, which extends down to Old House Point on the eastern side and Clachan Heughs on the western side, is animal dominated and relatively species poor (Dipper & Beaver, 1999). Finnarts Bay and Lady Bay on opposite sides of the loch are two sandy bays within this rocky region (Figure 19).

Towards the centre of the loch the shore is composed of mixed sediment, which continues as a sand bank known as 'The Scar'. The bay inside the Spit, known as 'Wig Sands' comprises mostly fine sand with some patches of stones and cobbles. The eastern side of the Scar is composed

of cobbles, mussel shells and coarse muddy sand. It provides a habitat for a diverse range of intertidal algae and filter feeders.

Shores of the southern basin tend to be relatively flat sandy mud with patches of pebbles and boulders. The subtidal consists of soft mud and muddy sand with beds of the native oyster (*Ostrea edulis)* being prevalent.

The beach at the head of the loch is composed of fine sand, which becomes muddier towards low water. The sediment is inhabited by numerous polychaetes and bivalves, specifically clams (*Mya arenaria*) and cockles (*Cerastoderma edule*) whilst there are extensive patches of *Z. noltii* higher on the shore (Howson, 1989; Dipper & Beaver, 1999). There are also several patches of stones and mussel shells (Howson, 1989) that create a less mobile substrate for *Fucus spiralis* and other algae to attach to.

6.2 Use

Use of Loch Ryan is mixed, with some leisure activities, but is mainly commercial interest, with an oyster fishery and ferries from Cairnryan.

Loch Ryan is of commercial importance for the harvesting of native oysters (*Ostrea edulis)* and Razor Shells (*Ensis spp*.). The rights to the oyster fishery have been held by the Wallace family of Cairnryan since the 18th century. They were commercially fished until 1954, but poor spatfall and overfishing allowed only an intermittent fishery to survive. The fishery underwent improvement to re-establish the beds and continues to be Scotland's only regularly exploited commercial oyster fishery (Conner and Little, 1998). Since 1986 there has been a ban in the loch on mobile fishing gear to further protect the oyster beds (Dipper & Beaver, 1999). Although there is still some concern over increased numbers of oysters being washed ashore and siltation of fine sediments due to the 'fast ferry' jet propulsion operations (Dumfries and Galloway Council, 2012).

Salmon netting used to be carried out during April to September but issues arose (wave movements and stronger undertows) due to the introduction of fast ferries making these sites inoperable (Dumfries and Galloway Council, 2012). Wave movement made boat launching difficult and washed the sand away leaving rocks and bedrock, further exacerbating the problem (Dumfries and Galloway Council, 1999).

Sea angling also occurs at numerous sites in the loch throughout the year but the wash from the ferries makes it difficult (Dumfries and Galloway Council, 1999) with signs being put up warning those using the coastline of the ferry wash dangers.

Two major stakeholders in Loch Ryan are Stena Line and P&O, who between them operate three fast catamaran ferries and five conventional ferries to Northern Ireland. There have been a number of issues, which have arisen from their operation causing Stena Line and P&O to make changes to their operating procedures to address these incidents (Dumfries and Galloway Council, 1999). In the past the ferries used piers at both Stranraer and Cairnryan but the development of a second port at Cairnryan stopped the ferry traffic into the southern basin since November 2011. This relocation reduces the dredging in the southern basin and the impacts of sediment movement associated with the jet propulsion, therefore, reducing pressure on the habitats, particularly the oyster beds. (Solway Firth Partnership, 2014).

Several Sewage Treatment Works used to discharge into Loch Ryan from nearby towns - Stranraer, Kirkcolm, Cairnryan and Leswalt, but in 2011 work began on Scottish Water's "Loch Ryan Wastewater Treatment Project". To improve waste water discharges Scottish Water aimed to construct a new Waste Water Treatment Works (WWTW) at Smithy Hill, north-west of Stranraer. They also aimed to construct a new long outfall pipe near Portpatrick to transfer

final effluent to the Irish Sea and construct a new pumping station at Port Rodie, Stranraer. In December 2013, the WWTW began to discharge effluent from Stranraer, Kirkcolm and Leswalt to the north channel of the Irish Sea. Whilst Cairnryan village now shares a new smaller treatment works with the Stena Line ferry port at Cairnryan due to the addition of a new ferry port. The creamery at the head of Loch Ryan also used an outfall pipe in the southern basin which was updated by the installation of an aeration tower in order to reduce organic loading and balance pH. Today there are only some storm and emergency overflows from pumping stations and the small sewage works at Cairnryan which still discharge into the loch.

6.3 Conservation Status

Loch Ryan is one of the largest and shallowest sea lochs in Scotland, inhabited by a unique collection of species, which bears more resemblance to areas of southern Britain than to other Scottish sea lochs.

Loch Ryan currently has no statutory conservation designations but is a designated Shellfish Waters and Shellfish Harvesting Area (2006/113/EC and 91/492/EEC respectively).

In 1990, with emerging coastal development pressures and following completion of the Marine Nature Conservation Review Survey (MNCR) (Howson, 1989) the Loch was designated a non-statutory Marine Consultation Area (Dumfries and Galloway Council, 1999). The MNCR began in 1987 by the Nature Conservancy Council and was taken over until its completion in 1998 by the Joint Nature Conservation Committee (JNCC). Its aim was to provide comprehensive baseline information on marine habitats and species.

The loch also has great ornithological importance, the MNCR survey in 1989 (Howson, 1989) identified fourteen intertidal and nine subtidal habitats, which are particularly important as feeding grounds for wetland bird species: most notably the seagrass and extensive *Ostrea edulis* beds. These habitats support species which are classed as nationally important, including Canadian pale-bellied Brent geese, Scaup and Common eider. In addition the rocky shores around the mouth of the Loch, from Milleur Point to Corsewall Point, are a SSSI recognised for their geological importance.

6.4 SEPA seagrass data: 2010 – 2013

Loch Ryan has been the focus of few studies: there is little information regarding historical records for *Zostera* species and even less for those found within the intertidal area. Records discovered only give general areas of presence, no quantitative data could be found.

In 2010, SEPA staff conducted a survey of seagrass presence in Loch Ryan and found it to be present at two locations in the loch (Figure 20). Little information was gathered on percent cover and species composition; only presence/absence of seagrass was noted and some spatial information on the seagrass beds collected.

The first area that was surveyed was at the south end of the loch, near Stranraer. Only three stations with no seagrass were noted and the edge of a seagrass bed was mapped using a hand-held GPS. The second location, towards the northwest of the loch called Wig Sands, was more intensively surveyed. There were 38 presence/absence point stations collected but unfortunately only 21 of these contained percent cover information. No species composition information was recorded but some edges of seagrass beds were mapped. This information was used to design the sampling area for the 2013 seagrass survey.

In 2013, a full seagrass survey was conducted and information was collected on all parameters for WFD assessment to be used as baseline data. The proposed survey sample sites were

spread across the entire area in both locations, well beyond the extents surveyed in 2010, to ensure that information was collected on all seagrass beds in both areas.

Seagrass beds mapped at Wig Sands (Figure 21) covered 21,100m^2 with an average percent cover between 30-40%. In the Stranraer area (Figure 22) the seagrass covered 83,700m^2 with an average percent cover between 12-56%. *Z. noltii* was the only seagrass species found in the loch.

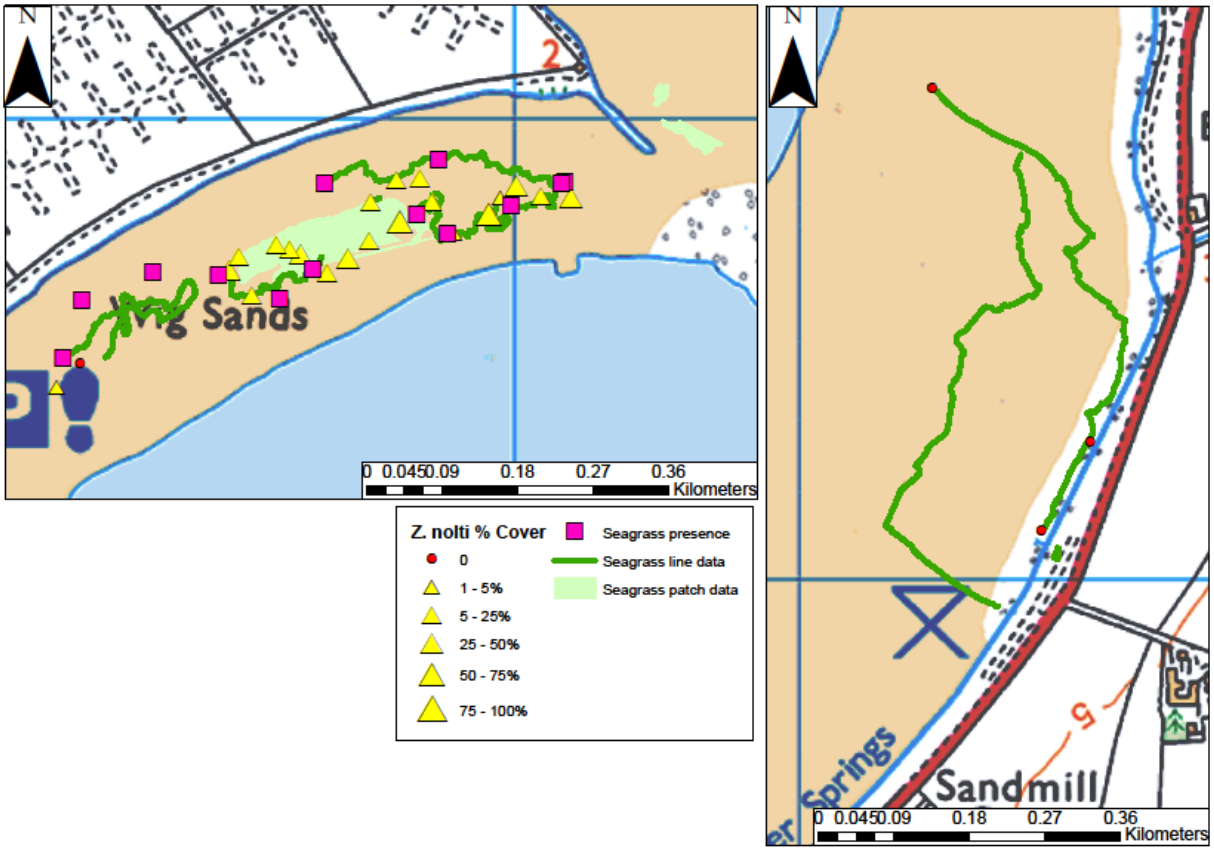

Figure 20: Seagrass data collected in 2010 at "Wig Sands" (top) and at "Stranraer" (right)

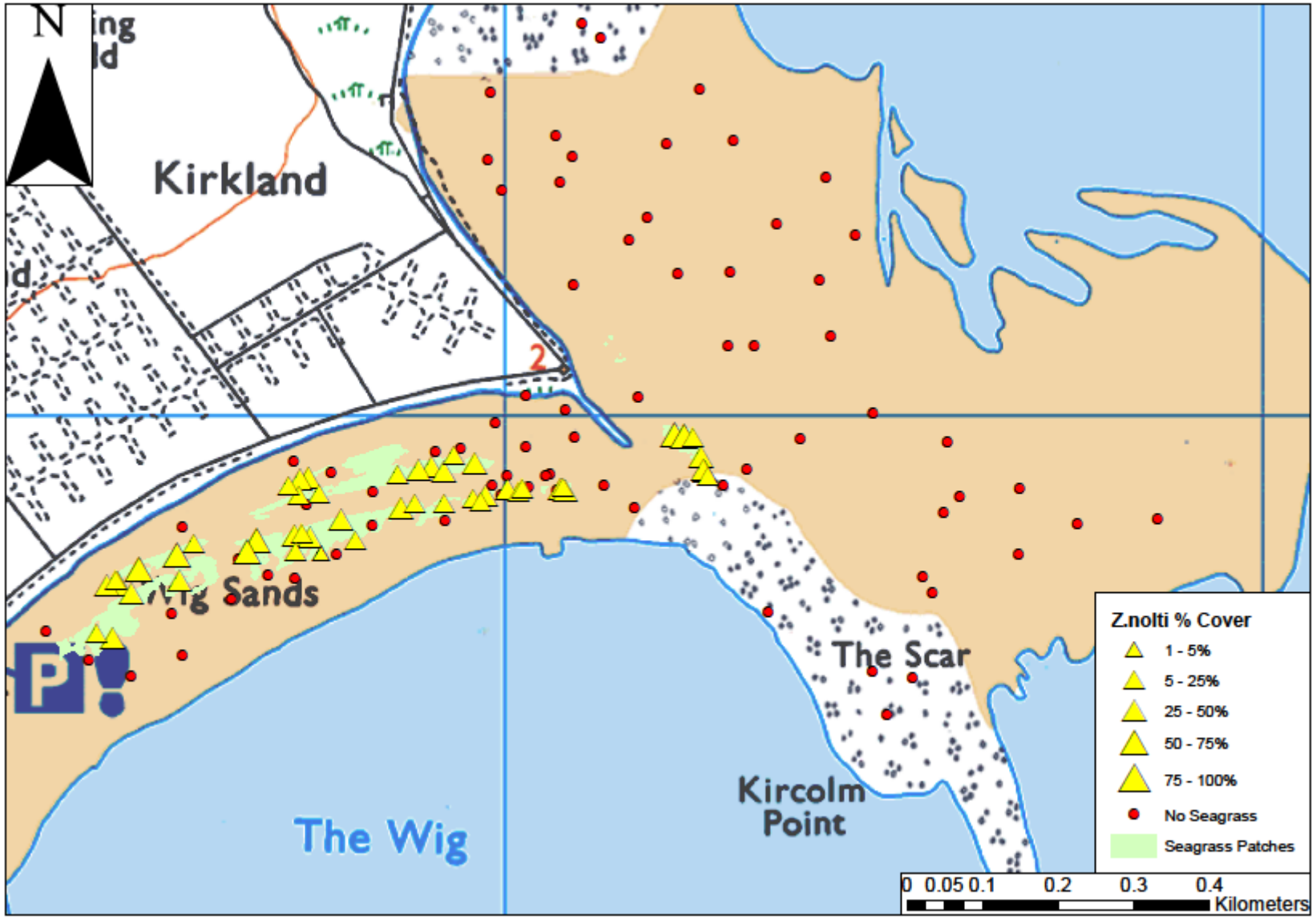

Figure 21: *Z. nolti* data collected in 2013 at "Wig Sands"

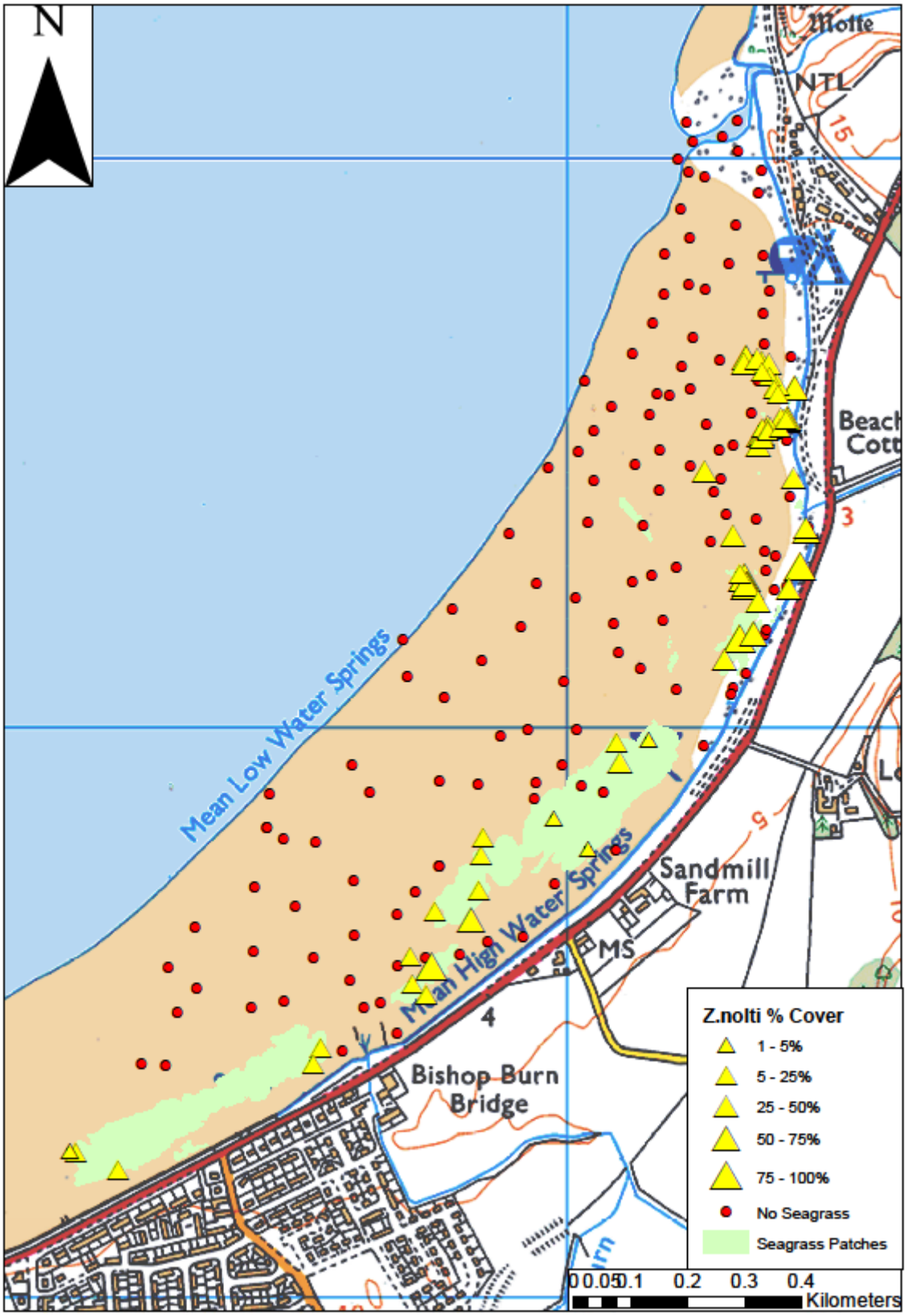

Figure 22: *Z. nolti* data collected in 2013 at Stranraer

7. Conclusion

Hiscock *et al* (2004) stated that seagrass beds were especially well developed in Scotland compared to other parts of Britain and Ireland with "…development most likely due to the presence of extensive suitable habitats and possibly uncontaminated waters". However, in general there is little information regarding the extent of intertidal seagrass beds around Scotland especially on the West coast. This lack of information may be due to the location of some beds occurring in remote places.

Cleater (1993) described two types of *Zostera* communities – intertidal and subtidal. The most widespread being that of intertidal mixed *Z. noltii* and *Z. angustifolia* on the East coast and in estuaries. This is typical of what was found by SEPA surveys in the Montrose Basin and Eden Estuary with the addition of extensive cover of opportunistic algal growth. Excessive cover of opportunistic algae can outcompete seagrass, compromising its health and inhibiting or eliminating it completely (Dennison *et al,* 1993).

Sites in the Forth Estuary were overall smaller and, therefore, supported much smaller patches of seagrass compared to the rest of Scotland but the average percent cover of seagrass was higher than at the other sites. This higher percent cover may be due to the much lower amount of opportunistic algae present, which was only observed in small areas at the top of shores or near freshwater input.

In Loch Ryan seagrass occurred with minor amounts of algae but the substrate may not have been as suitable for promoting growth as some of the other sites surveyed. In places, old mussel beds inhibited growth, whilst in others no seagrass was present on a shell/gravel/sand substrate.

Table 6 shows the extent of seagrass coverage and the average percent cover of patches in each water body surveyed. The Forth Estuary is spread over multiple water bodies due to its size and variation in morphology. This is the baseline survey data SEPA will use to run WFD classification in future years.

Table 6: Summary of seagrass extent and average percent cover at the sites surveyed by SEPA

Water Body	Year Surveyed	Area (m^2)	Average % cover
Montrose Basin	2013	1,747,000	41.80
Eden Estuary	2015	558,800	29.00
Lower Forth Estuary	2014	349,264	57.56
Middle Forth Estuary	2014	21,403	53.32
Loch Ryan	2013	104,800	33.31

Any real changes to seagrass brought about by human disturbance may take at least 5-10 years (Duarte & Kirkman, 2001) to appear. Therefore, long term monitoring is essential to provide robust data for classifying ecological status as per WFD guidelines. Natural variation in the seagrass beds is mitigated by classifying the data based on a five-year rolling mean, which also allows the identification of underlying trends as well as minimising natural variability.

Going forward, repeat surveys should be completed in the near future to provide further annual data in order for the WFD seagrass tool to be run and ecological status classified.

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APPENDIX 1

Historical seagrass surveys in the Montrose Basin

In 1982, McLusky and Roddie (1983) carried out a baseline survey for the Nature Conservancy Council. Seventy five stations were sampled along transects that were 500m apart. All three *Zostera* spp. were found to be present in the Basin, although *Z. noltii* was only found at one site, very close to the end of the South Esk River. Plant species and percent cover where recorded in a 2m x 2m quadrat using the Domin Scale (Table 7). Figure 23 shows the cover of *Z. marina* and *Z. angustifolia* using this scale. The yellow triangle indicates the only location that *Z. noltii* was found.

Table 7: The relationship of the Domin Scale with percent cover and frequency (Bannister, 1966)

Domin Number	Range of Cover Values (%)	Range of Frequencies	Combined Range	Mean
+ (isolated, cover small)	0	0-2	0-2	1
1 (very scarce, cover small)	0-4	1-5	1-9	5
2 (scarce, cover small)	0-4	5-10	5-14	10
3 (scattered, cover small)	0-4	10-30	10-34	22
4 (abundant, cover c. 5%)	5-10	5-100	10-110	60
5 (abundance, cover c. 20%)	10-25	10-100	20-120	70
6 (cover 25-33%)	25-33	25-100	50-133	91
7 (cover 33-50%	33-50	33-100	66-150	108
8 (cover 50-75%)	50-75	50-100	100-175	137
9 (cover 75-95%)	75-95	75-100	150-195	172
10 (cover 95-100%)	95-100	95-100	190-200	195

Two distinct areas of plant communities were found. Most seagrass was found along the western and northern shores alongside *Salicornia* sp. and *Cladophora* sp. *Z. marina* dominated the northern shore of the Basin, whilst *Z. angustifolia* was predominantly found on the western side. The rest of the basin was characterised by *Enteromorpha* spp. and fucoids. McLusky and Roddie (1983) concluded that the Montrose Basin was a productive estuary, rich in fauna but seemed to be in a '…transitory state with regard to organic enrichment….' suggested to be caused by domestic sewage and agricultural run-off. However, if an area is well flushed this can lead to a higher biomass of animals. They recommended that several sites should be chosen to be sampled annually and a Basin-wide survey carried out every ten years.

The University of Dundee's Environmental Advisory Unit carried out a baseline survey designed to satisfy the requirements of the Scottish Wildlife Trust (SWT) Management Plan (1991) to increase the knowledge and understanding of the ecology of the Montrose Basin (Atkins *et al*, 1992). The SWT Management plan had identified the mudflats as a primary resource habitat but no active management was possible as the ecology of the basin was not well known at that time (SWT, 1991). The survey repeated and extended the 1982 survey by McLusky and Roddie (1983) with the sampling strategy and most locations being identical in order to compare data collected.

As the concern for organic enrichment had been raised by McLusky and Roddie (1983), Akins *et al* (1992) also carried out a bacteriological study, sampling 20 sites near the harbour and main channel. It was noted that although sewage contamination was detectable at high tide, due to the visual observation of a sewage plume moving upstream from the interceptor sewer

and into the basin, the level of contamination was low and well within the limits set by the European Economic Community.

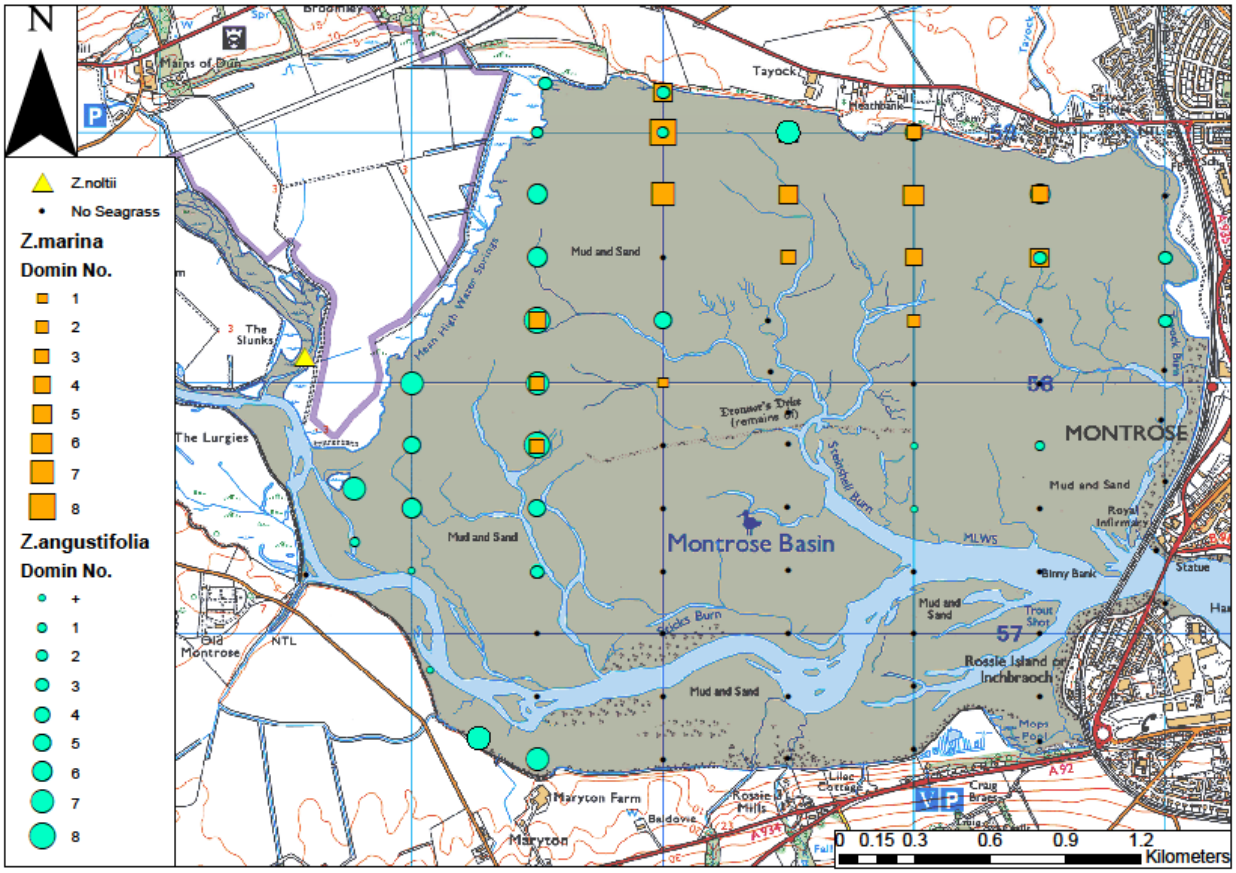

Figure 23: Coverage of *Z. marina*, *Z. angustifolia* and *Z. nolti* in the Montrose Basin during 1982 (McLusky & Roddie, 1983)

Atkins *et al* (1992) recorded two species of *Zostera* – *Z. noltii* and *Z. angustifolia* (Figure 24) but both were identified differently to that of McLusky and Roddie (1983). They determined that *Z. noltii* was the smaller dark green species whilst *Z. angustifolia* was the larger more yellow species. *Z. marina,* the largest species, was recorded in 1982 but not in the 1991 survey or subsequent surveys thereafter. This suggests a possible misidentification in the earlier 1982 survey where *Z. angustifolia* was actually *Z. noltii* and *Z. marina* was *Z. angustifolia.* This was further substantiated by the two main species distributions being broadly similar in both the 1982 and the 1991 surveys, as shown in Figures 23 and 24 respectively.

Akins *et al* (1992) typically found *Zostera* spp. in areas of coarse sediment, low fines, low organic carbon content and relatively low interstitial salinity. They concluded that between 1982 and 1991 there was a substantial reduction in percent cover (62% decline) and area where it was present. *Zostera* spp. were recorded at 38 stations in 1982 compared to only 19 of those stations in 1991 but was still found to be dominant in the north of the Basin where the salinity was less, although the extent was not as great as in 1982 towards the river channel or eastwards.

In contrast there was found to be a 30% increase in cover and area of opportunistic green algae (*Enteromorpha* spp. and *Cladophora* spp.), which may explain the reduction in *Zostera* cover. The presence of such opportunistic algae may be a contributing factor to the decreased extent of *Zostera* species. Another reason maybe a decline in deteriorating environmental

conditions as *Zostera* is particularly sensitive to pollution. Figure 25 shows a pictorial representation of coverage in the Montrose basin in 1991.The light green coloured area indicates seagrass and light green algae cover (290,000m^2). Dark green indicates dense green algae cover of *Enteromorpha* spp. and/or *Cladophora* spp. (2,640,000 m^2). The pink areas are fucoid cover and mussel beds (170,000 m^2). It was recommended that a series of annual surveys should be carried out in early September: 12 sites across the basin were selected, the results of which would be comparable to the 1991 survey.

The annual monitoring was carried out between 1994 and 1997 by Caudwell and Jones, University of Dundee's Environmental Advisory Unit, and complemented the early baseline survey conducted by Atkins *et al* (1992). At each of the 12 sites the percent cover of four 1m^2 quadrates were recorded and the mean displayed as a Domin number. Unfortunately, due to a combination of the patchy nature of *Zostera* spp. and the low number of sample sites, many seagrass areas did not fall within the stations (of the 12 sites only 3 were recorded as having seagrass present). Although comments were made on the presence of *Zostera* spp. out-with the quadrats, the location and area covered was not recorded as the aim of the survey was not to map seagrass beds.

Between 1994 and 1997, it was noted that there was an extensive thick bed of *Z. noltii* present in the south-western corner of the Basin, near the Lurgies (Caudwell & Jones, 1995, 1996, 1997, 1998): although since 1982 it was only represented in a sample station quadrat in 1995. Sparse plants of *Z. angustifolia* were recorded at the same station in 1995. It was also noted to be present around this station in small patches during 1997 but was not represented within the quadrat (Caudwell & Jones, 1996, 1998).

Over the entire nine year period, *Zostera* spp. were recorded at only four of the 12 sites, which highlights the patchy nature of seagrass beds often found in Scotland.

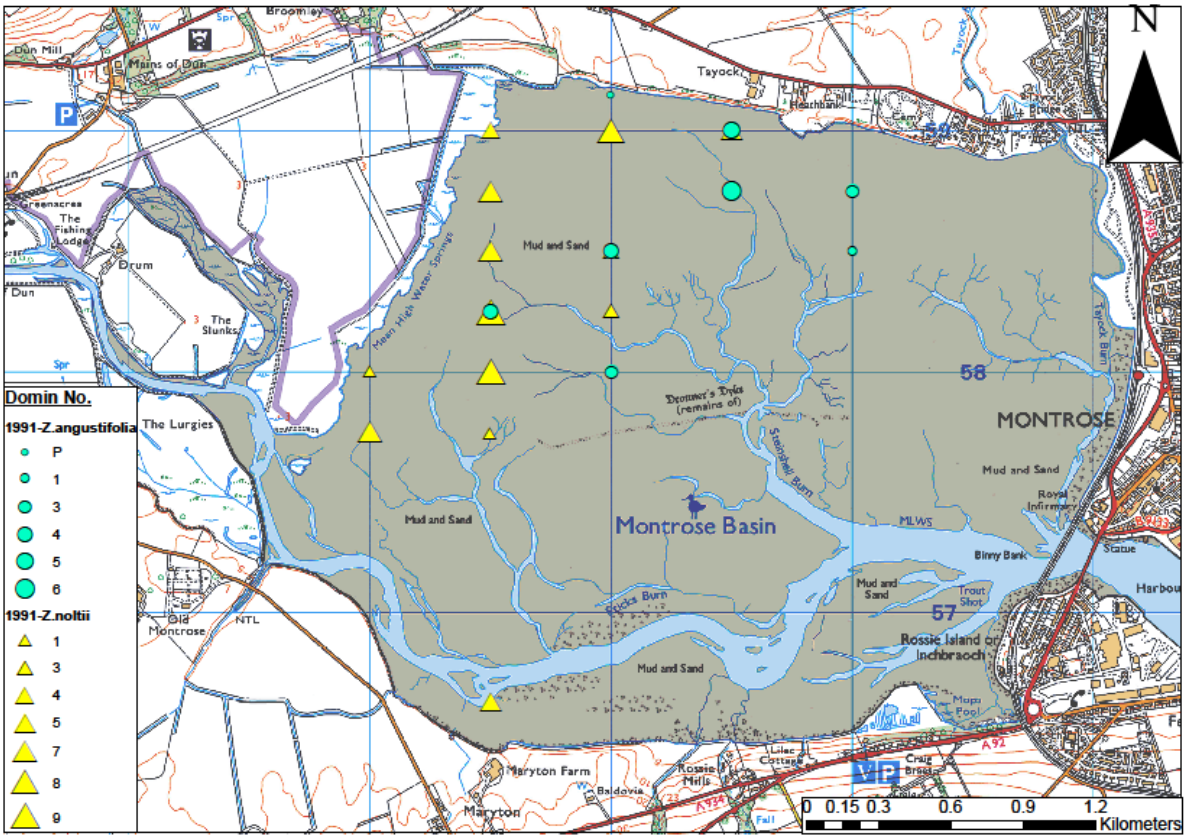

Figure 24: Coverage of Zostera species in 1991 in the Montrose Basin (Atkins *et al*, 1992)

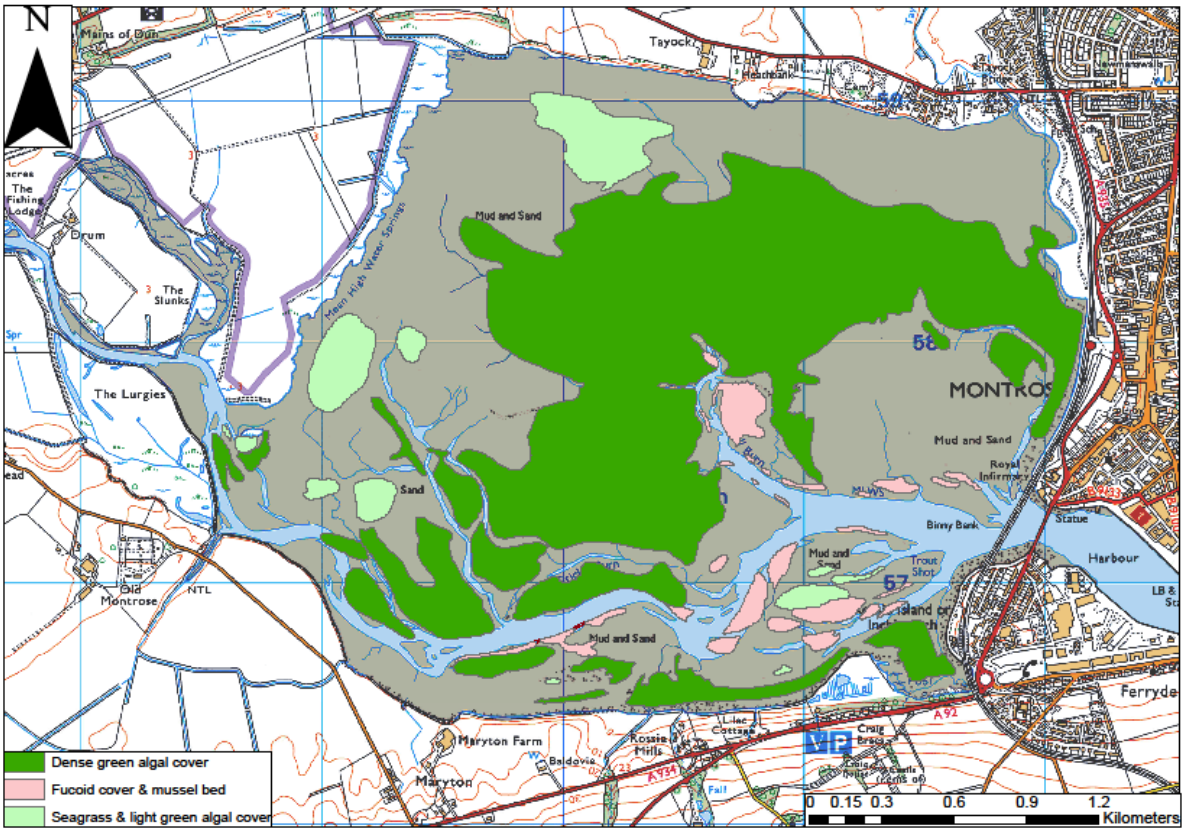

Figure 25: Coverage of Montrose Basin georeferenced from the 1991 aerial photographic survey (taken from Akins *et al*, 1992.)

In 1998, Cook completed a dissertation at the University of Aberdeen for the degree of Master of Science in Ecology. The aim was to map *Zostera* spp. coverage and area whilst determining the species reproductive strategy and whether or not hybridisation occurred between species.

Cook (1998) found that *Zostera* spp. were present in a vast area of the basin as shown in Figure 26. *Z. angustifolia* dominated the northern shore but was sparsely distributed, preferring wetter areas such as channels. *Z. noltii* was found on drier sediments in the western area, was not as extensive in coverage but showed greater density where it did occur. The maximum density of *Z. noltii* in a quadrat was 100% compared to 50% of *Z. angustifolia.*

The area covered by *Zostera* spp. was also mapped. This was done by GPS, where the carrier walked round the seagrass beds. The patchy nature of *Zostera* posed problems in defining its extent and in this study the edges of the bed were defined as:

- *Z. angustifolia*: one plant per m^2 were included as part of a bed.
- *Z. noltii*: where a patch was $1m^2$ and less than 10m away from the main bed were included.

This created three main seagrass beds which were split into beds 1 and 2, in the north of the basin, covering an area of $1,000,000m^2$, and bed 3 in the west, covering $860,000m^2$. Unfortunately the area between the two large patches was not mapped but it was noted that although there were patches of *Z. noltii* present it was not to the same extent found in the mapped regions. In addition, personal communication with the SWT Ranger at the time suggested the area was very muddy and not as suitable as other parts of the basin for growth of *Zostera* spp. The southern shore of the basin was also not surveyed as the SWT site manager suggested *Zostera* spp. where not present in this area (pers.com B. Cook, 2014)

Finally, in 1999 a saltmarsh survey was conducted for Scottish Natural Heritage (SNH), which noted that *Zostera* communities within the basin were well developed: *Z. noltii* formed dense stands in the west and south of the basin, and *Z. angustifolia* was found in the north. It was also commented that *Z. marina* had been recorded here in the past but Hogarth (1996) stated that it may have been a misidentification error as it usually occurs below mean low water levels and has not been recorded recently.

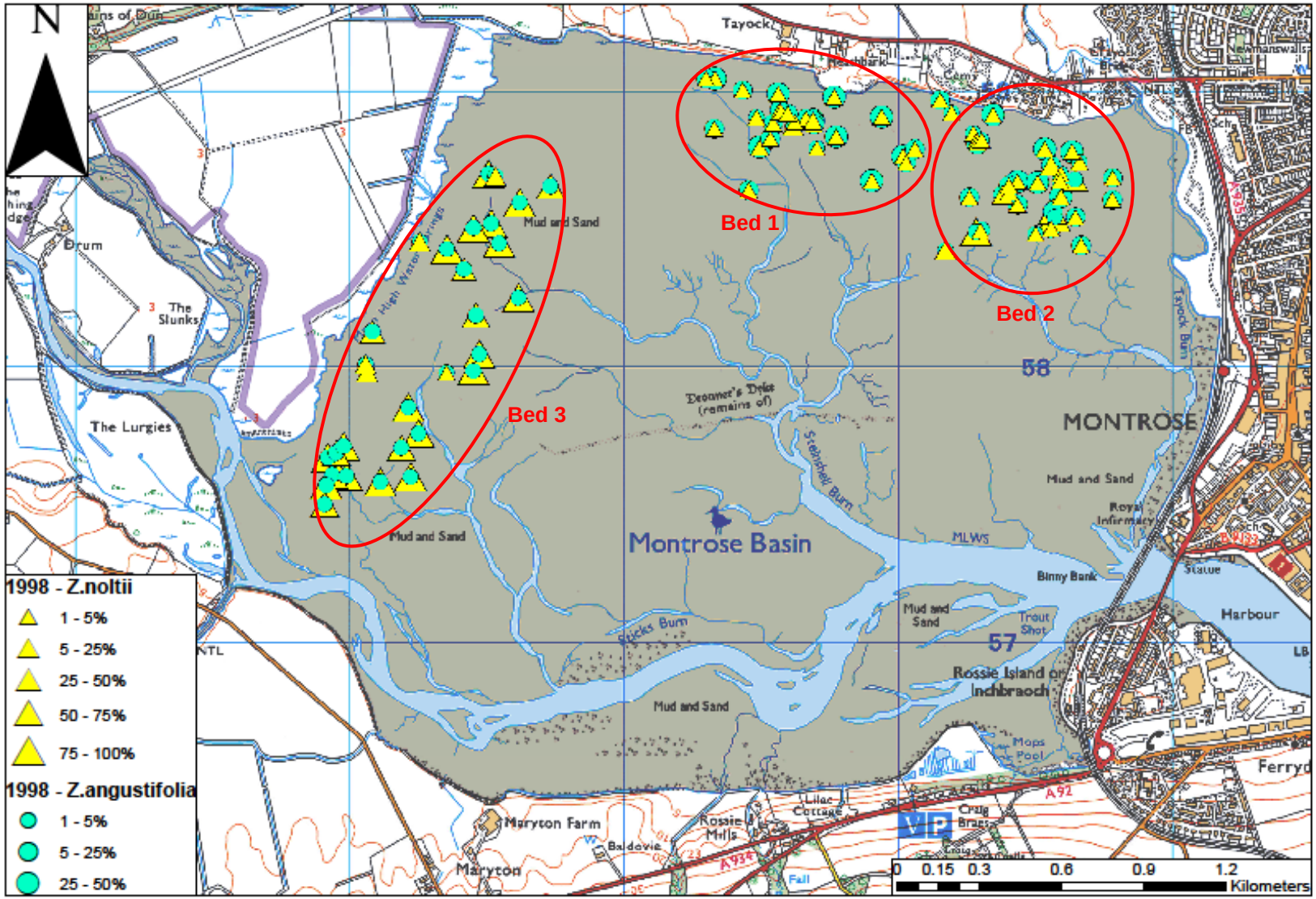

Figure 26: *Z. noltii* and *Z. angustifolia* location and percent cover across the Montrose Basin in 1998 (Cook, 1998)

APPENDIX 2

Historical seagrass surveys in the Eden Estuary

In 2004, SNH commissioned a report on the 'Broad Scale mapping of Habitats in the Firth of Tay and Eden Estuary' (Bates *et al*, 2004). This study comprehensively biotope-mapped the intertidal and subtidal habitats within the SAC using satellite imagery and acoustic mapping techniques.

During this survey only one small bed of *Zostera spp*., at 15-20% coverage, was observed east of St. Martins Point, although the extent of it was not recorded. They noted that several beds of *Zostera spp.* where known to be present in the estuary, with *Z. noltii* being located on mudflats to the north side of the estuary whilst *Z. angustifolia* and *Z. marina* where found in shallow drainage channels on the south side (Bates *et al,* 2004). This distribution had been mapped previously by the North East Fife District Council but unfortunately this data could not be located for this current report.

As part of SNH's commitment to Site Condition Monitoring of SSSI's, assessments of notified features of interest at designated sites are made on a rolling program. Surveys were carried out on *Zostera spp.* at Tayport to Tentsmuir SSSI and Eden Estuary SSSI: these provided presence-absence data along several defined transects. The survey was designed to be simple and repeatable, building on the results of Bates *et al* biotope mapping in 2004 and those carried out by the Fife Ranger Service for the North East Fife District Council in 1981-85, 1992 and 1994.

Five transects (Figure 27), based on previously recorded locations of *Zostera* beds, were established and marked at the top of the shore with a fixed re-locatable point. Sampling points were located every five metres along the transects and *Zostera spp.* recorded. The angle of some transects were as such, in order to provide a more comprehensive survey, instead of traversing from the top of the shore to the bottom, they were angled through the most dense area of *Zostera*.

A rowing boat was also used to survey the channel by slowly working along both sides of the channel and recording *Zostera spp*. locations by GPS. Unfortunately turbid water conditions caused difficulty in viewing the sea bed, and consequently no *Zostera spp*. were found.

The results of the survey indicated significant changes to the distribution of *Zostera spp*. in the Eden Estuary since the surveys carried out by Bates *et al* (2004) and the Fife Ranger Service. *Z. noltii* was mainly confined to the inner estuary whilst *Z. angustifolia* had a patchy distribution in the outer estuary. Areas of *Z. noltii* had increased from previous surveys particularly on the south shore of the inner bay, whilst *Z. angustifolia* had declined most notably around the middle of the estuary.

On the north shore (Transect A) of the inner estuary *Z. noltii* formed a narrow band at the top of the shore which from observations has never expanded into the mid-shore (SNH, 2006). It was observed that an extensive bed of *Z. noltii* was present in front of the papermill breakwater wall but this fell outside of the transect (SNH, 2006)

The noticeable increase of *Z. noltii* on the south shore (Transects B & C) of the inner estuary has only occurred in the decade preceding the 2006 report as it was not present in the 1992 survey. At Transect B a dense bed of *Z. noltii* was present which was described in the 1992 survey as only consisting of sparse plants of *Z. angustifolia*. In the previous surveys at

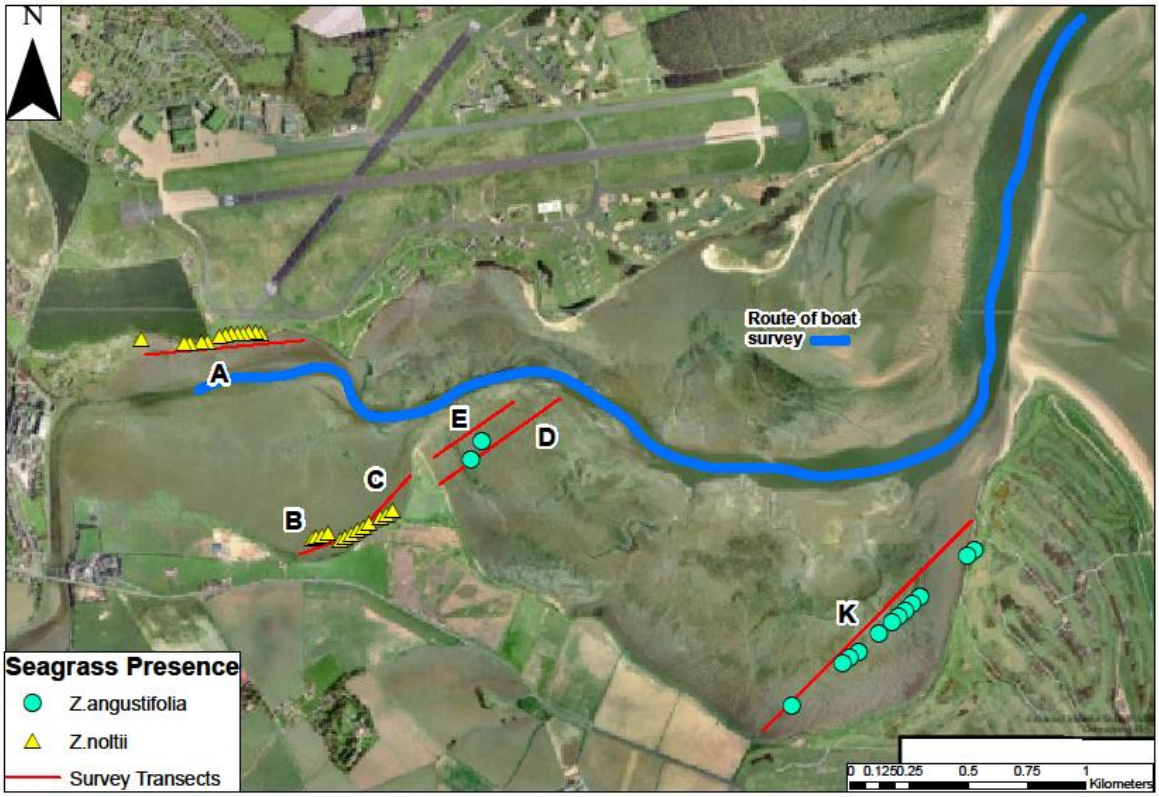

Figure 27: Approximate location of transects and route of boat survey in the Eden Estuary with presence of seagrass species (from SNH, 2006)

Transect C a sparse bed of *Z. angustifolia* was found next to a narrow band of Z. noltii. The SNH, 2006 survey observed the same band of *Z. noltii* but no evidence of *Z. angustifolia*.

In the outer estuary *Z. angustifolia* was found to have a patchy distribution with a more dense and extensive cover in the wetter areas, such as channels, where the macroalgal blooming species were also heavily present. On transects D and E, the dense *Z. angustifolia* bed which was previously recorded had almost disappeared entirely. No *Z. marina* was found in the Eden Estuary, although the original management plan by North East Fife District Council (NEFDC, 1987) named it as "Common Eelgrass" and states it was found in shallow drainage channels which is not its usual habitat.

In August 2009, Chocholek (2013) carried out a case study in the Eden Estuary on 'The impacts of climate change on estuarine ecosystems'. Part of this study looked at species adaptation/acclimatisation, aiming to identify morphological changes to the seagrass, *Z. noltii*. Consequently the distribution of *Z. noltii* in the Eden Estuary was mapped (Figure 28), with this then being compared to a study by Johnston *et al* (1979) who previously studied the distribution and movements of shorebirds within the Estuary. Unfortunately access to the original study by Johnston *et al* (1979) could not be obtained for this report.

The total extent of the *Z. noltii* in 2009 covered an area of approximately 18,500m^2 whereas the total extent of all *Zostera spp.* in 1977 was 113,600m^2. Johnson *et al* (1979) found that *Z. marina* (possibly *Z. angustifolia*) had limited presence on the south-eastern shore (Kincaple Flats), whilst those shores on the northern side between Shelley Point and Coble House Point were dominated by fucoids.

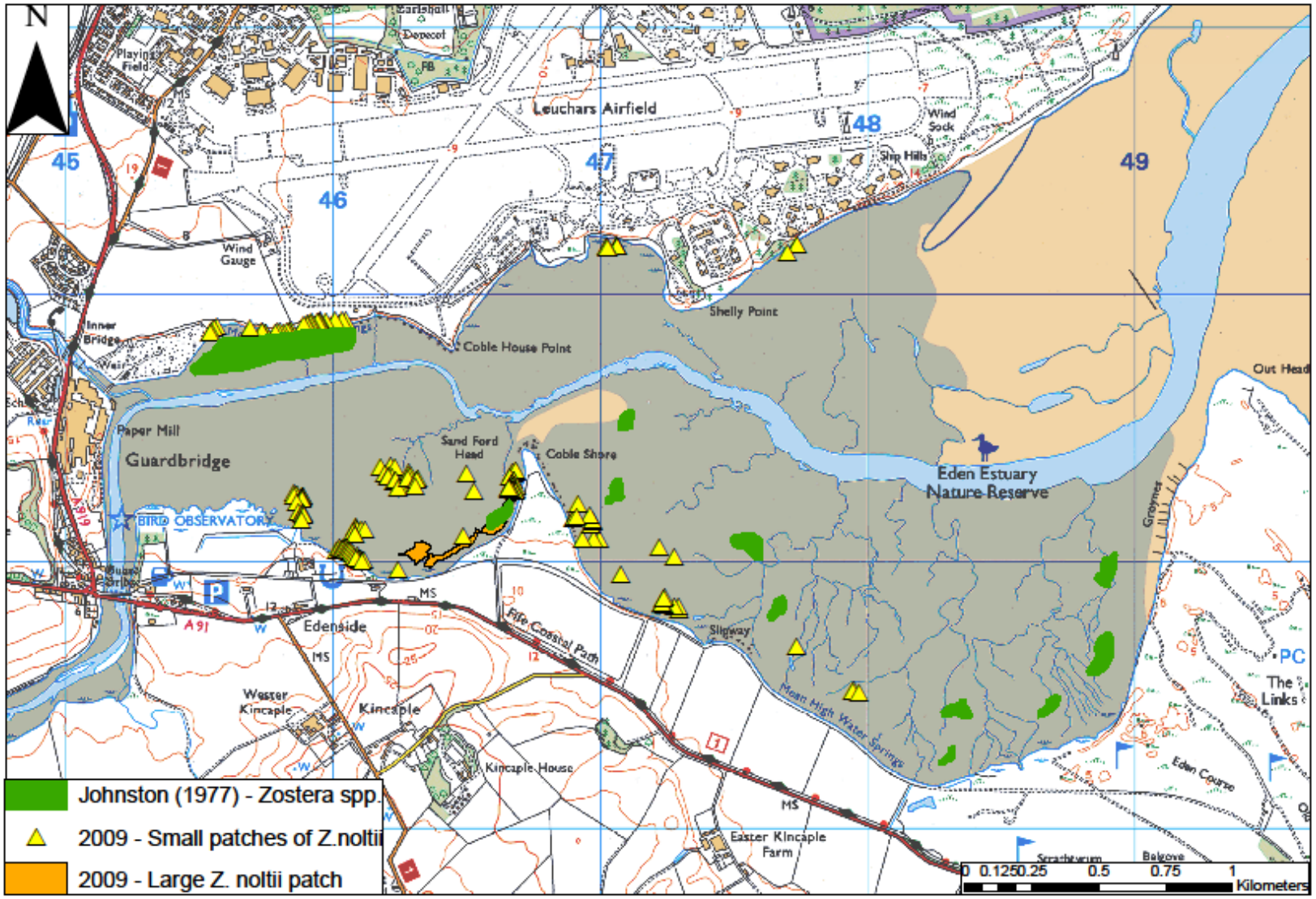

Figure 28: Historical extents of seagrass beds (data from pers.com. Chocholek, 2013)

APPENDIX 3

Historical seagrass surveys in the Forth Estuary

Significant populations of *Zostera* spp. have been recorded on the southern shore of the Firth of Forth (Cleater, 1993). Cleater (1993) found historical records of *Zostera* spp. at Torry Bay, from as early as 1987, but as early as 1863 at Leith in the Outer Firth, although *Zostera* spp. are no longer present at this particular site

In 2003, SNH commissioned a report on the "Firth of Forth National Vegetation Classification Survey 2003" (Morris, 2005). Its aim was to undertake a survey down to the mean low water spring tide mark covering all plant communities in the Firth of Forth SSSI, in order to produce a vegetation map of the area. Although there are no maps or area coverage in the summary report, they do comment on the sites where *Zostera* spp. were present/absent (Table 8).

Table 8: Sites and seagrass notes from the Firth of Forth National Vegetation Classification Survey 2003 (Morris 2005)

Site	Notes
Ironmill Bay to Rosyth	None
Torry Bay	Extensive *Zostera* communities (*Z. noltii* & *Z. angustifolia*)
Carriden to Blackness	Large areas of *Zostera* but could not be confirmed due to access problems
Blackness Bay	*Zostera* beds were noted but could not be verified due to access problems

Due to the rise in interest in seagrass there have been several projects carried out between 2004-2014 by Masters students at Heriot-Watt University, Edinburgh.

In 2004, D.E. White submitted a thesis for a Masters project entitled "A mapping study of the seagrass *Zostera* in the Forth Estuary using GPS and aerial photography and an assessment of their potential to accumulate trace metals". Unfortunately this thesis could not be acquired but is referred to in a subsequent thesis by Zoutenbier (2011).

In 2011, Reinier Zoutenbier submitted a thesis for a Masters project entitled "*Mapping the Distribution of Seagrass in the Firth of Forth, Assessing the Sediment Composition on a Micro Habitat Scale and Analysing the Impact of Climate Change on Seagrass Distribution*". He identified six potential site locations of seagrass beds in the Forth Estuary (Figure 29) from past records as being sites where *Zostera* spp were located or were thought likely to support *Zostera* spp. Three more locations were identified in the Outer Firth but were not of interest for this current report.

The shores at these sites were visited to establish the presence of *Zostera* spp. The species composition was not discussed in detail within Reinier's report; although excerpts stated that "*Zostera noltii* was found at all sites" in the Forth Estuary, and "the mixed *Zostera* bed at Carriden Bay", the latter leading the reader to assume that several species of seagrass were found at this site. The seagrass bed visited at Culross had previously been reported to consist of only *Z. angustifolia* (White, 2004) but when surveyed by Zoutenbier, *Z. noltii* was the only species present.

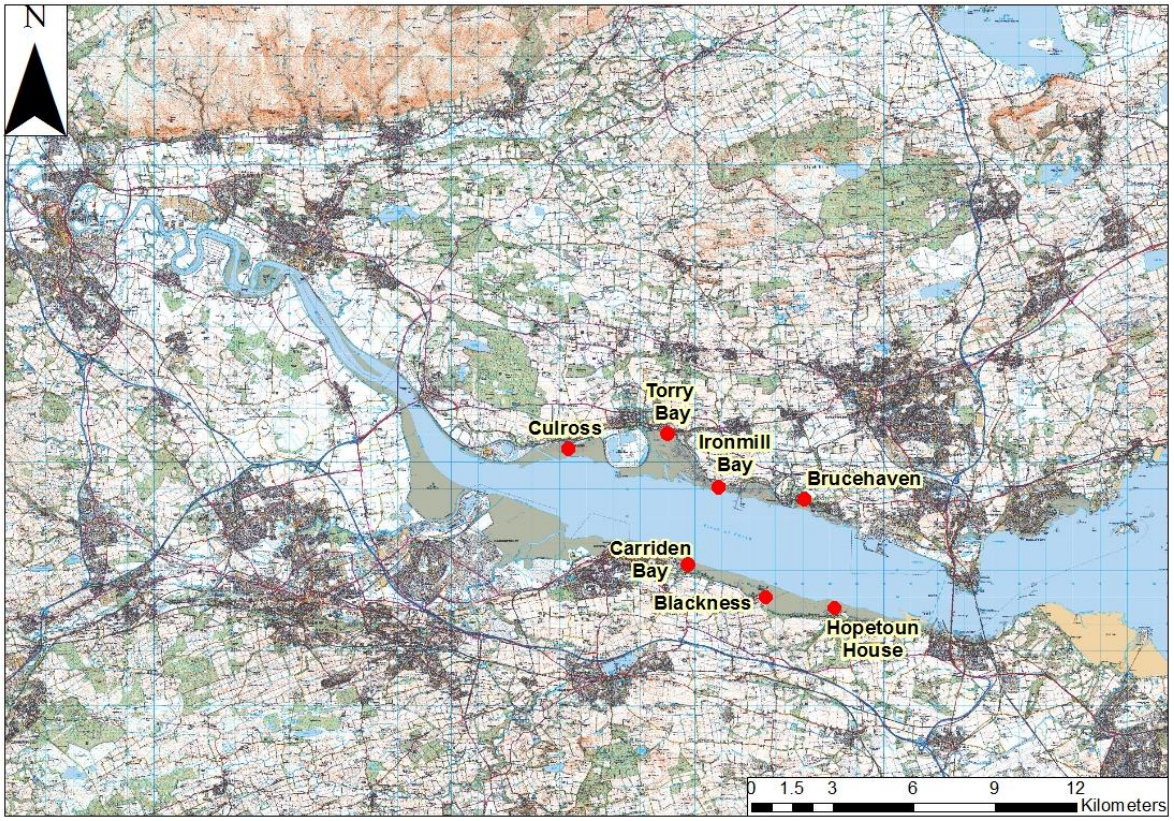

Figure 29: Potential seagrass site locations identified in the Forth Estuary by R. Zoutenbier in 2011. (The shore between Blackness to Hopetoun House is identified as one site)

Several sites were then selected to be intensively surveyed by collecting spatial data and density estimations of the seagrass beds observed - Carriden Bay and Brucehaven (Figure 30). It must be noted that these figures have been re-projected from the original report as no original spatial data was available. The seagrass patch of approximately 25,000m^2, found at Brucehaven is of interest as in 2003 during the "Firth of Forth National Vegetation Classification Survey 2003" (Morris, 2005) it was not found. For the remaining sites in the Forth Estuary no detailed information was reported, only two figures of maps showing a rough outline of the area walked to determine *Zostera* spp. distribution.

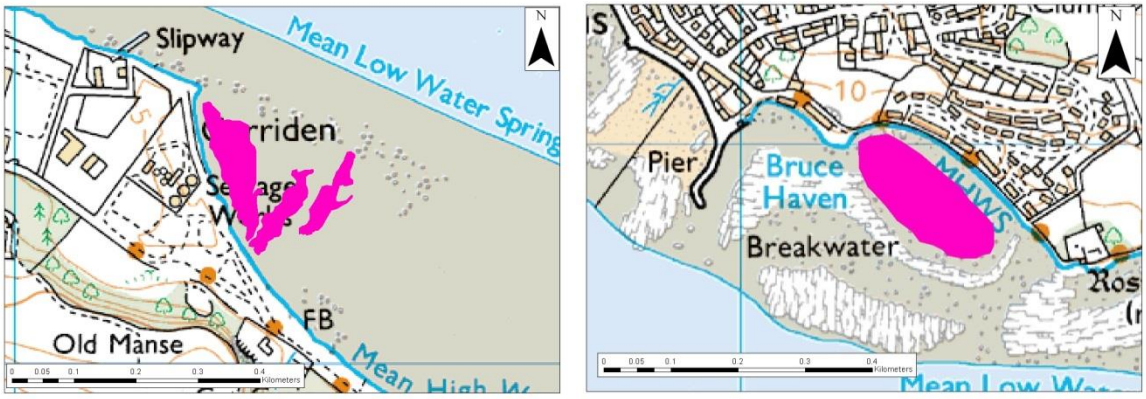

Figure 30: Seagrass bed and density data 2011 (Top Left – Carriden, Top Right – Brucehaven)

In 2013, another Heriot-Watt Masters student, Tetrienne Box, submitted a project entitled "*Mapping Intertidal Seagrass in Forth and Eden and Create an Environmental Envelope to Aid Monitoring Efforts and Assess Sea Level Rise Impacts*". It aimed to produce an environmental envelope suitable for predicting where intertidal *Zostera* species could be found.

Locations within the Forth Estuary were chosen based on historical records and Zoutenbier's (2011) report –Culross, Brucehaven and Carriden Bay. Tyninghame and Dalgety Bay were also chosen but these are located in the Outer Firth. Complete walk-round GPS data was collected for intertidal *Zostera* spp. using hand held GPS devices. For each seagrass bed, the species and an approximate of cover were recorded where possible. Species presence and change in extent at Carriden Bay were compared to the data collected by Zoutenbier (Figure 31). Box (2013) found that although the extent in the western patch was similar to that mapped by Zoutenbier, there was a 46% increase in seagrass extent. This was due to another patch, eastwards of the first, not mapped in 2011 but was known to be present (pers.com. Dr Alastair Lyndon, Heriot-Watt University, 2018).

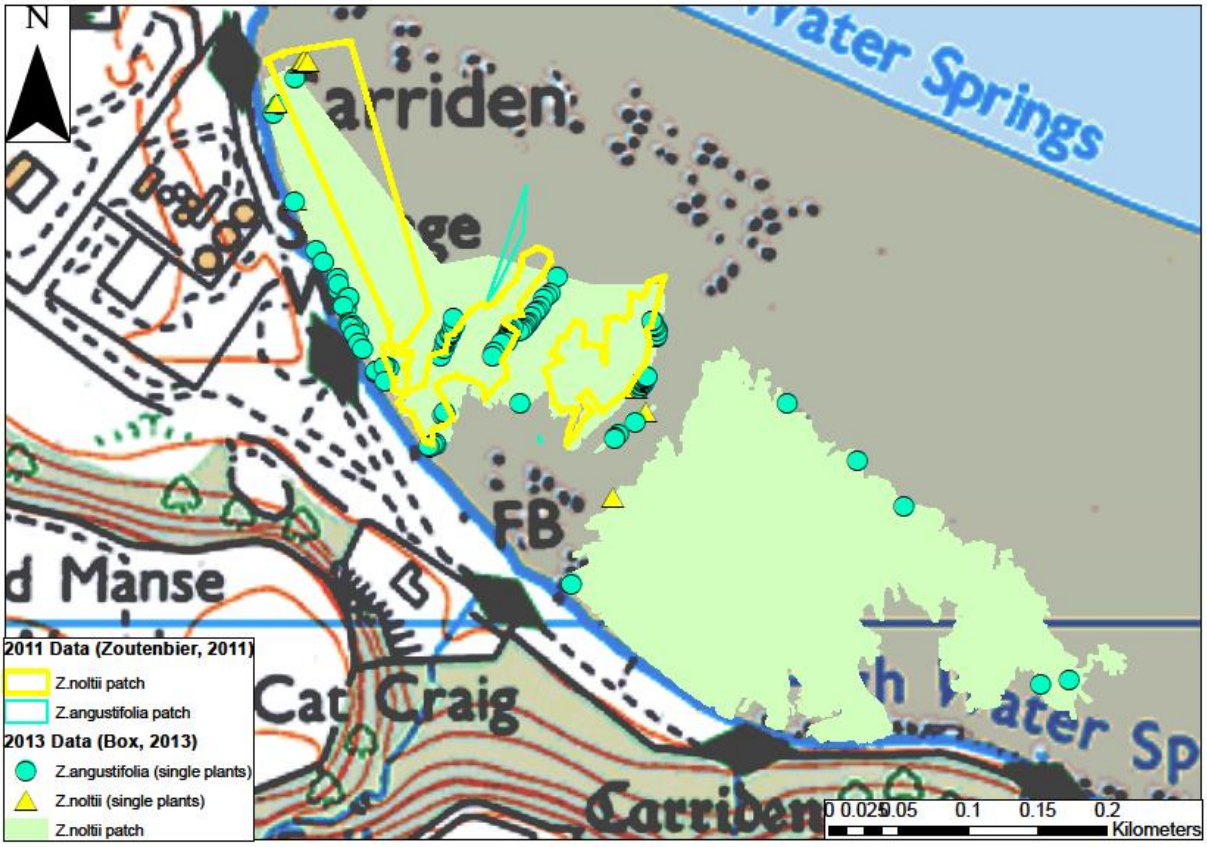

Figure 31: Comparison of Zoutenbier's (2011) and Box's (2013) seagrass extent data at Carriden

Overall, Box (2013) found that there was 94,862m^2 of *Z. noltii* and 32,636m^2 of *Z. angustifolia* at the five sites visited with *Zostera* presence in the Forth Estuary and the Outer Firth. This figure should not be used as the definitive extent of seagrass in the Firth of Forth as not all sites known to have seagrass present were visited as part of this project.

In 2014, another Heriot Watt Masters student, Samantha Finlay, submitted a thesis for a Masters project entitled "*Mapping seagrass distribution in the Firth of Forth"* aiming to provide a spatial extent baseline of seagrass for use in monitoring under the WFD.

Finlay (2014) carried out surveys during the same year as the SEPA survey, mapping the extent of seagrass between May and August 2014 revisiting those sites in the Forth Estuary which Zoutenbier (2011) and Box (2013) visited (Figure 32). An additional shore at Kincardine Bridge was included but no seagrass was present. Particular focus was given to Carriden Bay as this site had been mapped previously by Zoutenbier (2011) and Box (2013).

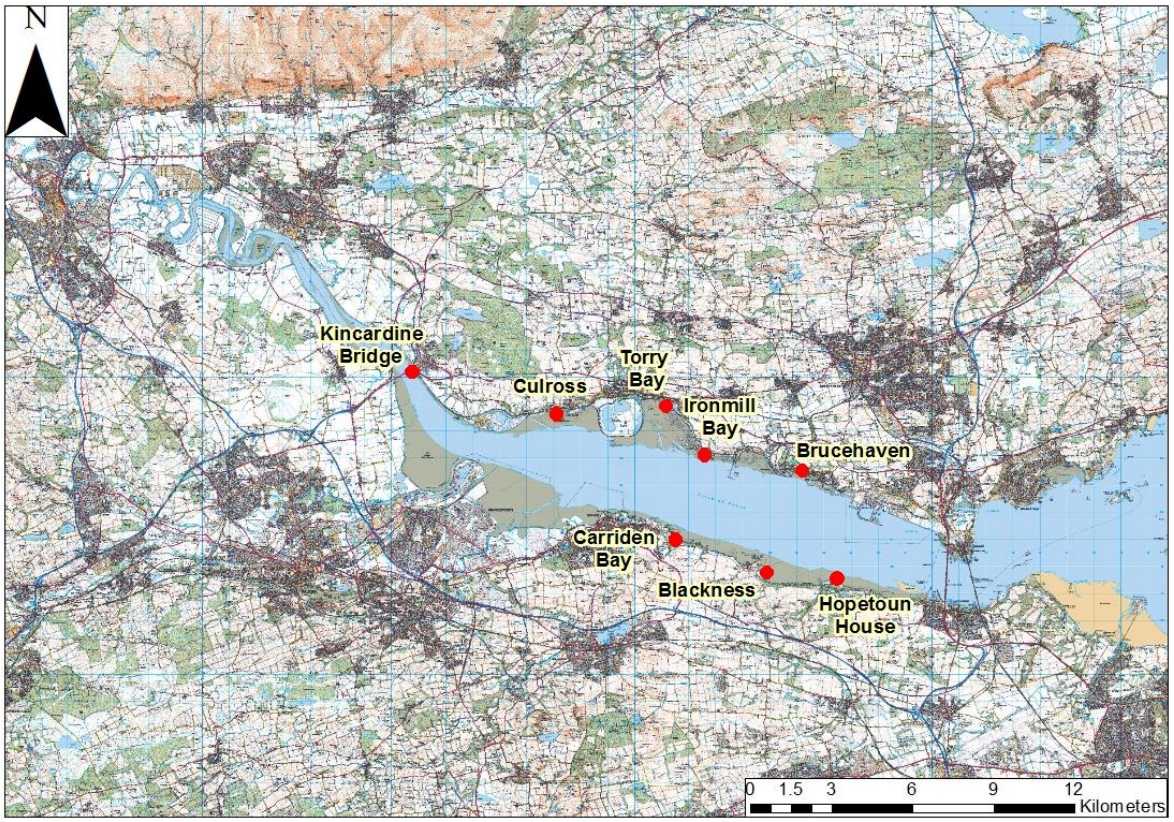

Figure 32: Location of seagrass sites as surveyed by Finlay (2014)

Figures 33 to 49 show the locations and extent of seagrass beds mapped with comparison of the data SEPA collected.

Figure 33 shows the comparison in the extent data collected by Finlay (2014) and SEPA at Carriden Bay. Finlay determined there was 73,375m^2, approximately 8000m^2 less than what SEPA had mapped. In the west of the bay, Finlay had mapped three separate patches whereas SEPA mapped a single large patch, potentially suggesting they merged into one. It is not known specifically what month, between May and August, Finlay (2014) collected the data at this site so differences in extent may be due to natural variation in growth of seagrass species during the season.

At Brucehaven, figure 34 shows the extent of seagrass mapped by Finlay in 2014, there are slight differences to the extent of the patch towards the west of the site compared with SEPA data but it still very similar which is likely due to the rocky area limiting further expansion of the bed to the south of the shore.

Figure 35 shows the comparison of data collected at Blackness Bay by Finlay (2014) and SEPA. Finlay (2014) who also mapped a small patch at the west of the site, which was not present when SEPA surveyed the area.

Finlay (2014) surveyed the same area between Blackness Castle and Hopetoun House (Figures 36 & 37). The seagrass beds surveyed by both parties are very similar. Due to time constraints when mapping SEPA decided that all points to the east of Abercorn point would not be sampled and efforts should be directed west from Abercorn Point towards Blackness.

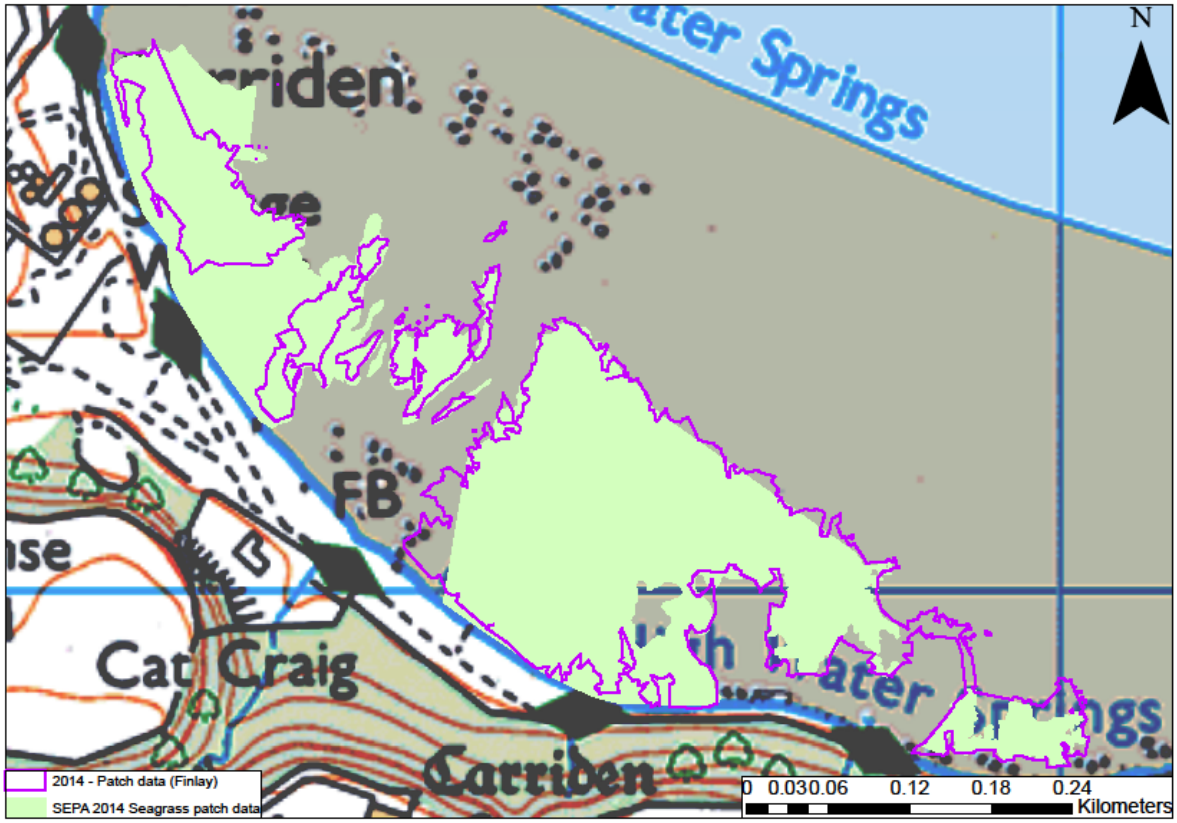

Figure 33: Seagrass bed extent at Carriden Bay during 2014 as surveyed by Finlay (2014) and SEPA

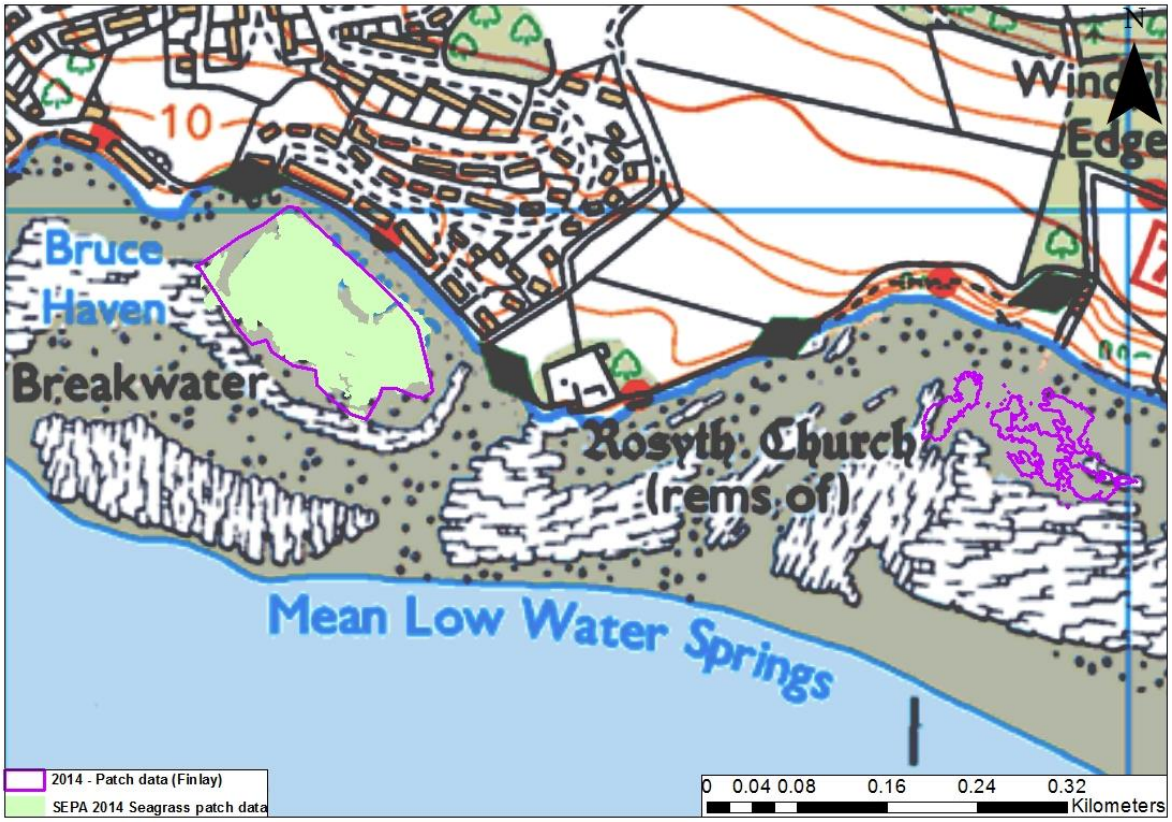

Figure 34: Seagrass bed extent during 2014 at Brucehaven as surveyed by Finlay (2014) and SEPA

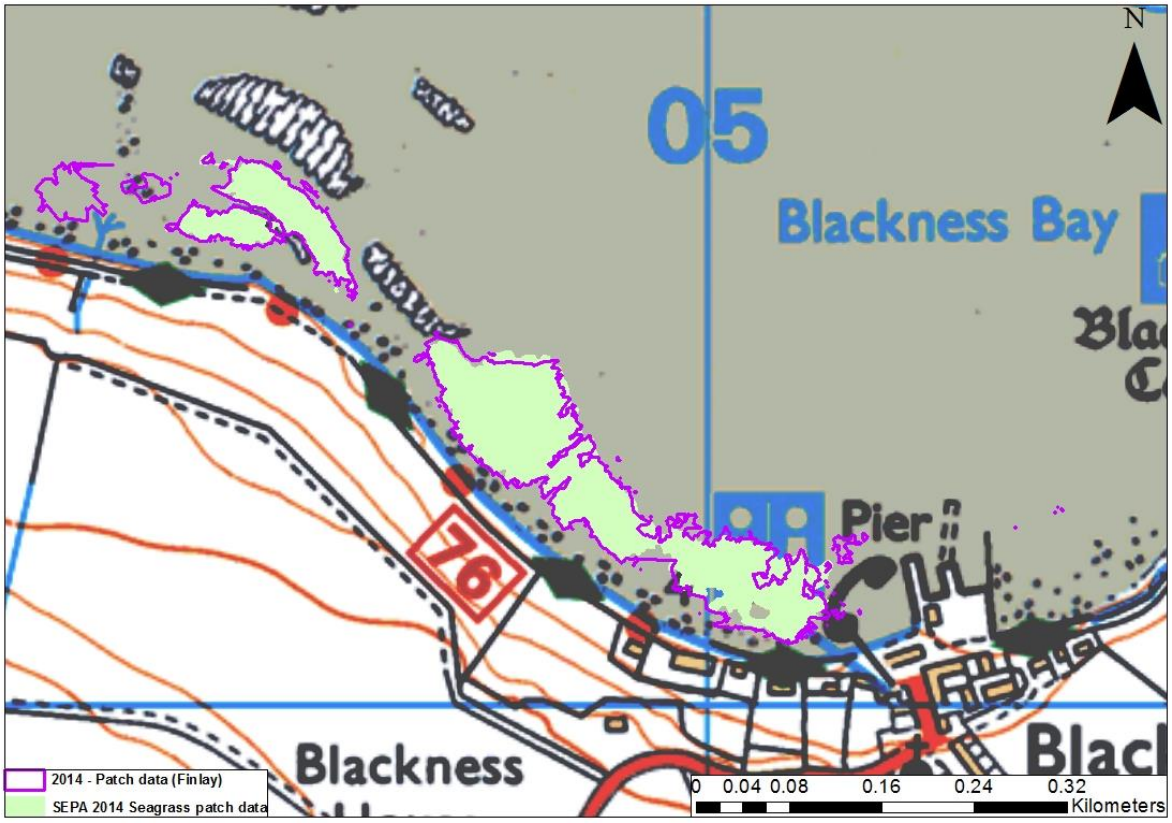

Figure 35: Seagrass bed extent during 2014 at Blackness Bay as surveyed by Finlay (2014) and SEPA

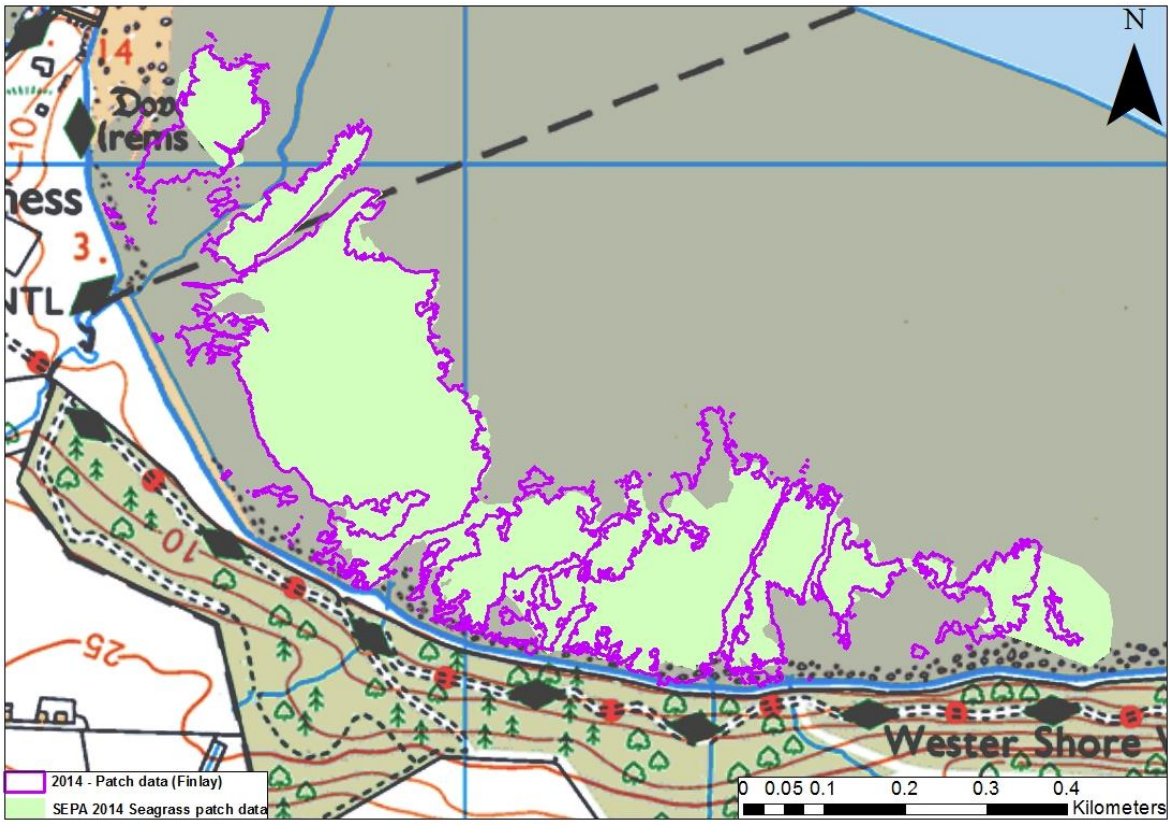

Figure 36: Seagrass bed extent during 2014 at Blackness (eastside) surveyed by Finlay (2014) and SEPA

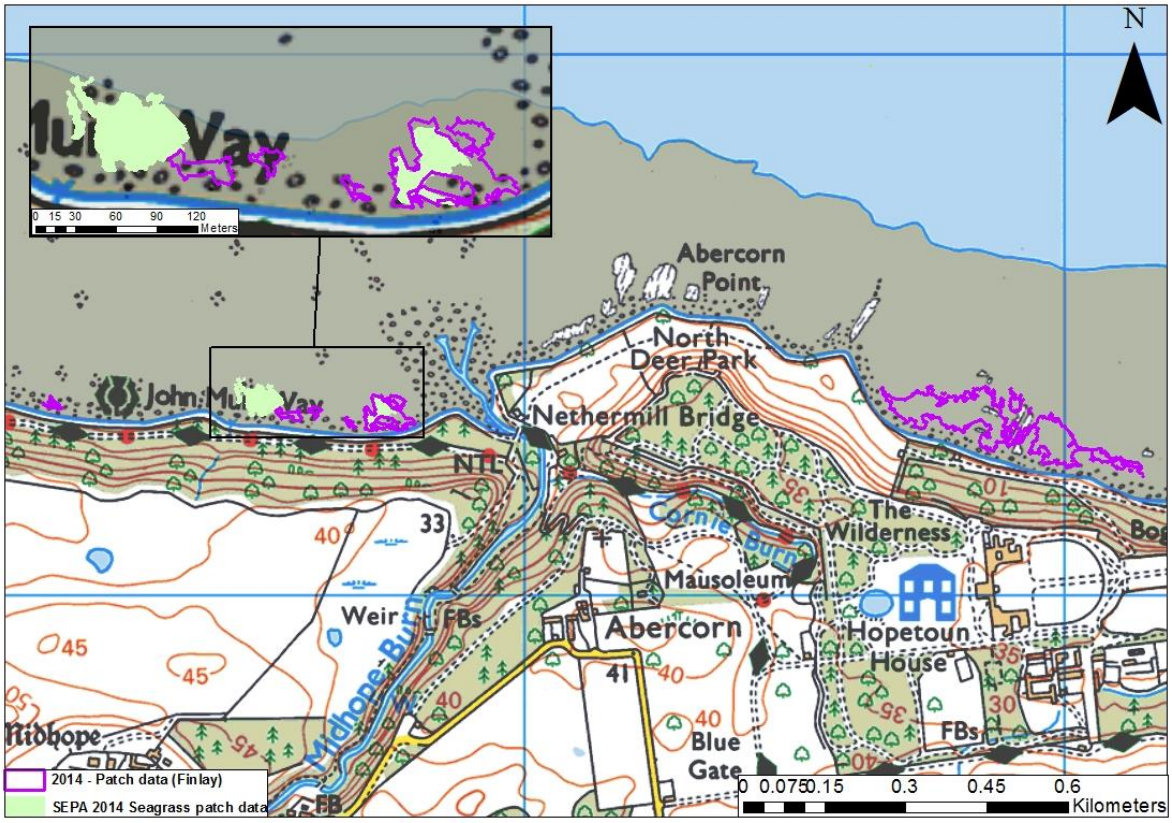

Figure 37: Seagrass bed extent during 2014 at Hopetoun House as surveyed by Finlay (2014) and SEPA

Figure 38 shows the information collected at Culross by Finlay's (2014) survey and a comparison by SEPA. Finlay (2014) covered more ground and estimated the seagrass extent to be 20,278m^2. Due to time restraints, SEPA were unable to cover the same area.

Finlay (2014) surveyed the full area of Torry Bay (Figure 39) estimating that the seagrass covered 215,371m^2. SEPA were unable to cover the whole of Torry Bay within the allotted time period of half a tidal window.

Figure 40 shows the area surveyed by Finlay (2014) named as Ironmill Bay and separated from Torry Bay by a stone wall. Ironmill Bay is actually situated further along east along the coast which SEPA was unable to access at the time due to the proximity to the MOD territory.

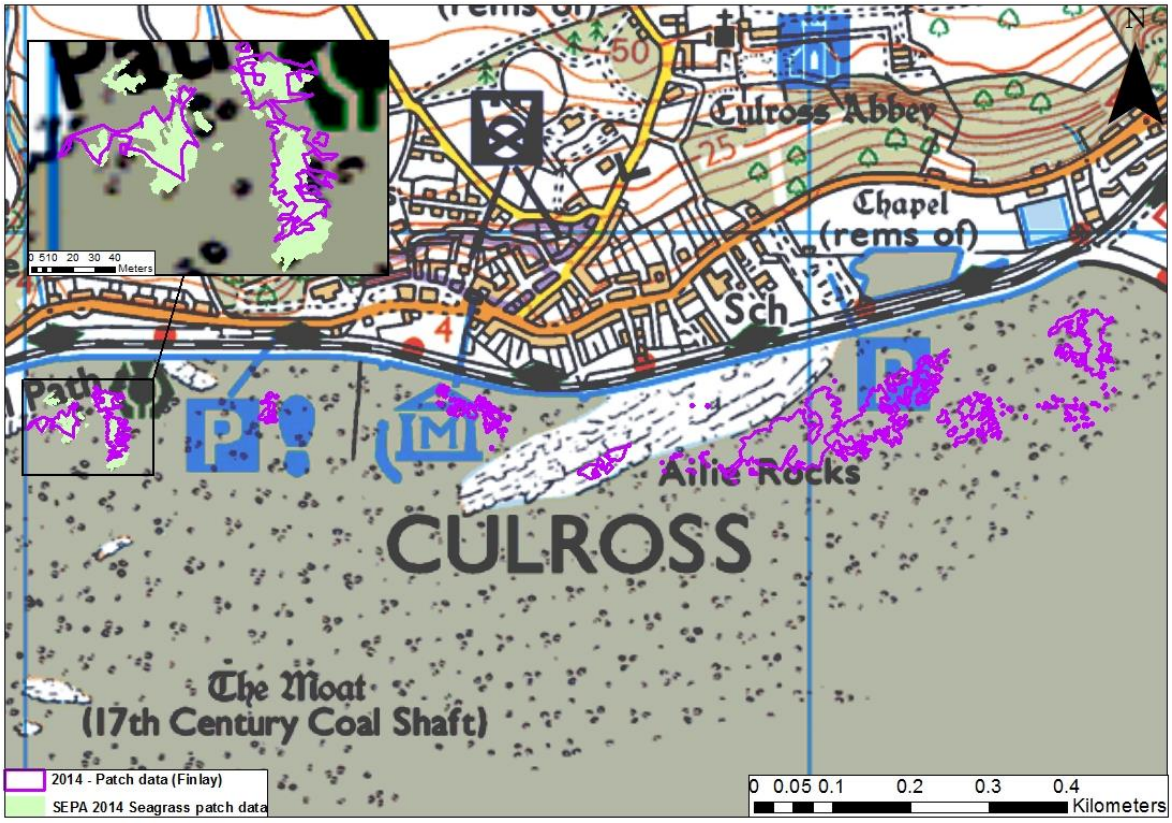

Figure 38: Seagrass bed extent during 2014 at Culross as surveyed by Finlay (2014) and SEPA

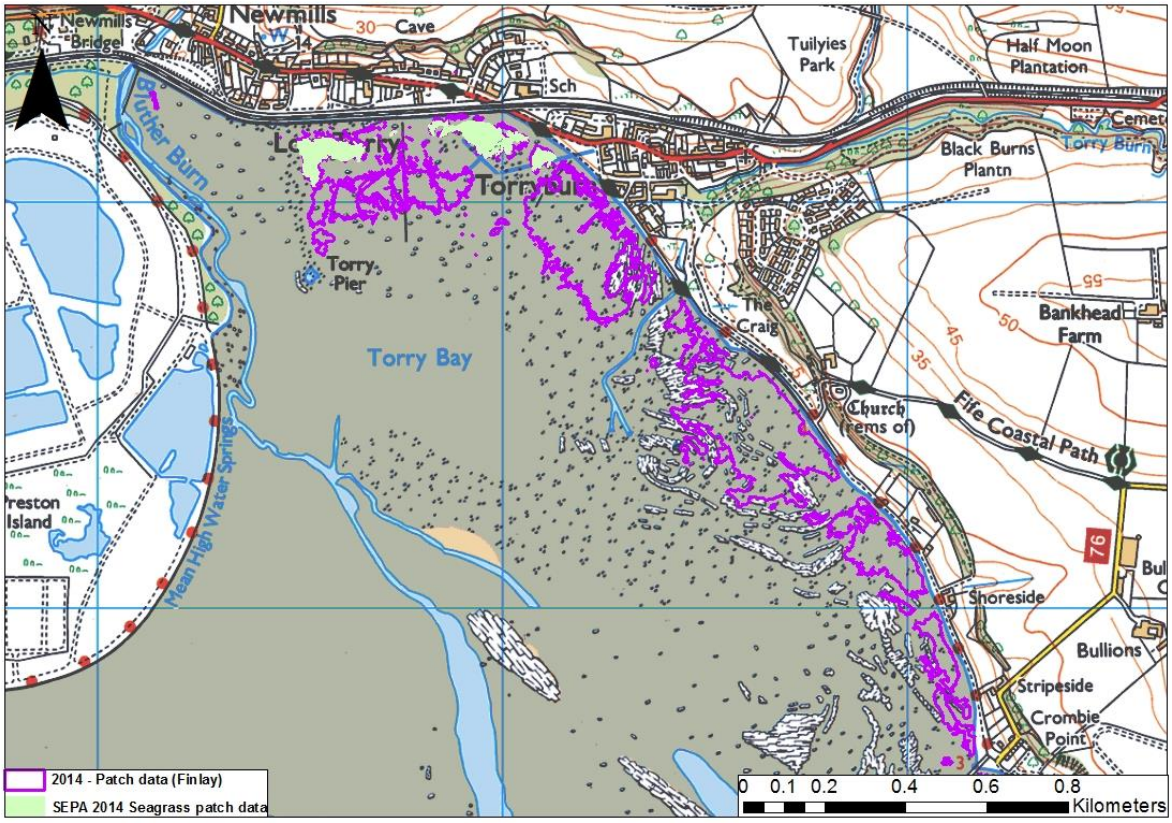

Figure 39: Seagrass bed extent during 2014 at Torry Bay as surveyed by Finlay (2014) and SEPA

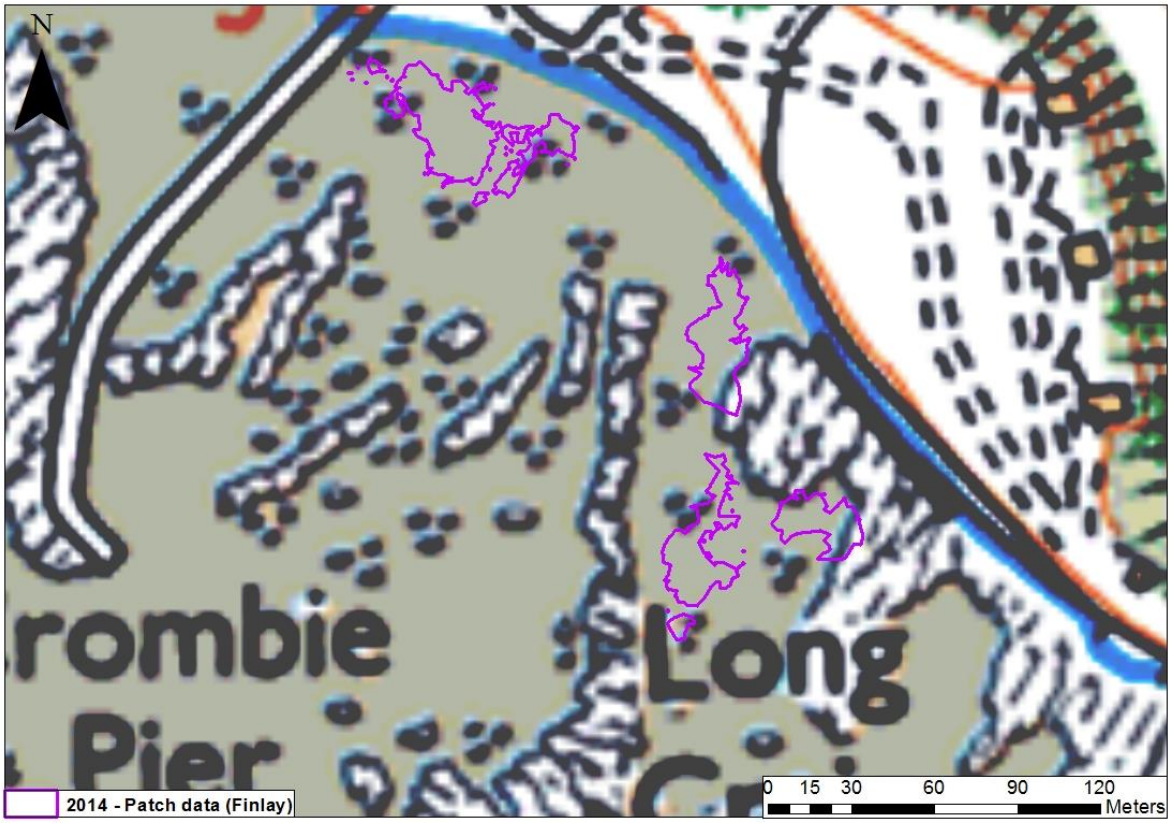

Figure 40: Seagrass bed extent during 2014 at Ironmill Bay as surveyed by Finlay (2014)

Finlay discovered that total *Zostera* spp. coverage in the Forth Estuary was approximately 700,000m^2, with the largest beds being found at Torry Bay and Blackness. *Z. noltii* was found at all sites and *Z. angustifolia* present at all sites except Torry Bay, Ironmill Bay and Brucehaven.

In addition, Finlay (2014) compared, where possible, species present and the extent of seagrass surveyed in 2014 to that found in historic records. Table 9 summarises the records of extent as this report is interested in changes in spatial data. Where figures do not match those in Finlay (2014), areas were calculated from the original shapefiles received by the authors.

Table 9: Historical Zostera records for the shores of the Firth of Forth

	Year Surveyed and extent (m^2)			
	White (2004)	Zoutenbier (2011)	Box (2013)	Finlay (2014)
Culross	28,000	-	-	20,278
Torry Bay	380,000	-	-	215,371
Ironmill Bay	-	-	-	3,107
Brucehaven - west bed	-	25,000	21,359	20,280
Brucehaven - east bed	-	-	3,626	5,231
Carriden - Bed 1	-	18,420	29,443	15,730
Carriden - Bed 2	-		50,707	57,645
Blackness	389,000	-	-	256,308
Total Extent (m^2)	**797,000**	**43,420**	**105,135**	**593,950**

APPENDIX 4

Historical seagrass surveys in Loch Ryan

In 1982 the Clyde River Purification Board (now SEPA) were commissioned to carry out annual surveys of the beach and seabed at the head of Loch Ryan around the Galloway Creamery outfall until 1999. Although the survey concentrated on the sediments and infauna, the presence of *Zostera* spp. were noted. A bed was found on the upper and middle shore towards the eastern end of the beach (CRPB, 1982). Later surveys described *Zostera* spp. to have a patchy distribution throughout the intertidal zone.

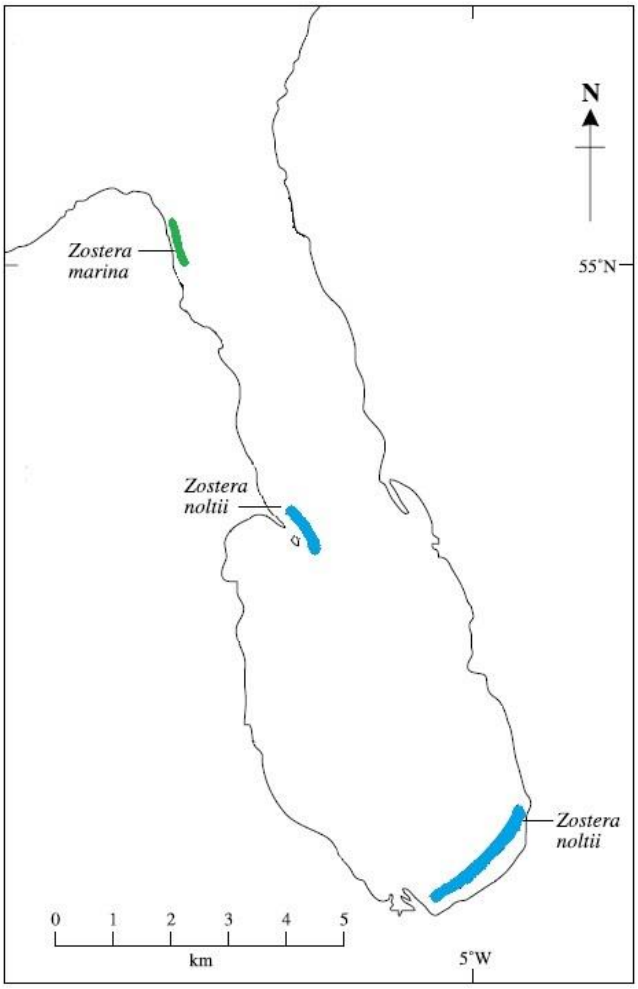

Figure 41: Distribution of habitats in Loch Ryan as found by Howson (1989) – taken and altered from Connor & Little (1998)

In 1989, Howson (1989) carried out intertidal and subtidal surveys of Loch Ryan as part of the 'Surveys of Scottish Sealochs' for the MNCR. A narrow band of *Z. marina* was discovered near the entrance to the Loch at a depth of 3.5-5m (Figure 41). A band of *Z. noltii* was located on the Spit; where it was restricted to a narrow band between cobbles and pebbles. In addition, a larger area of *Z. noltii* was reported at the head of the Loch.

Dipper & Beaver (1999) completed an area summary of the Sealochs in the Clyde Sea, stating that "the Spit" supported a bed of *Z. angustifolia* which was not mentioned in the earlier report by Howson (1989).

Unfortunately no other historical data could be found.