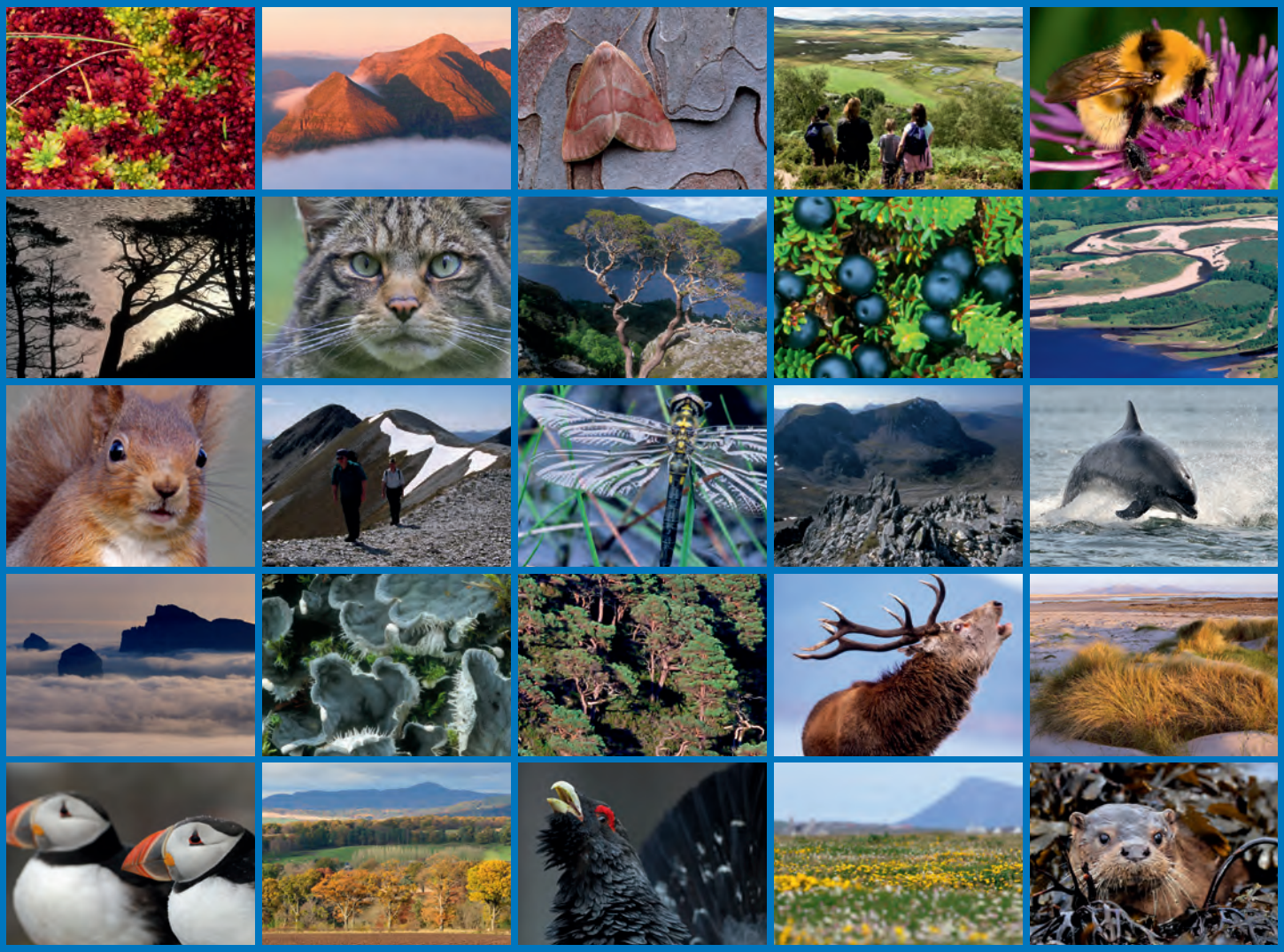
Scottish Natural Heritage
Commissioned Report No. 702

Loch Fleet eelgrass study 2012 – the extent and abundance of eelgrass in the Loch Fleet SSSI in 2012



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COMMISSIONED REPORT

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Loch Fleet eelgrass study 2012 – the extent and abundance of eelgrass in the Loch Fleet SSSI in 2012

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COMMISSIONED REPORT

Summary

Loch Fleet eelgrass study 2012 – the extent and abundance of eelgrass in the Loch Fleet SSSI in 2012

Commissioned Report No. 702
Project no: 13609
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Background

Loch Fleet Site of Special Scientific Interest (SSSI) is a shallow, bar-built estuary with a tidal basin extending to approximately 630 ha in total. It is located in east Sutherland between Embo and Golspie on the east coast of Scotland.

During a survey in Loch Fleet in 2000 two species of eelgrass; the narrow-leafed (*Zostera angustifolia*) and the dwarf eelgrass (*Z. noltei*), were identified and the extents of the two eelgrass communities within Loch Fleet were mapped.

In 2012 Seastar Survey Ltd was contracted by Scottish Natural Heritage to investigate a perceived decline in overall eelgrass abundance on the intertidal sandflats within Loch Fleet SSSI by completing a desk study and a field survey. This document reports on the extent and abundance of eelgrass beds within Loch Fleet in September 2012. It also discusses possible reasons for the decline in eelgrass abundance.

Main findings

- The eelgrass survey in September 2012 confirmed the presence of both *Z. angustifolia* and *Z. noltei* in the Loch Fleet SSSI.
- These species currently form three different types of eelgrass communities in the estuary; 1) *Z. angustifolia* beds; 2) mixed *Z. angustifolia* and *Z. noltei* beds; and 3) *Z. noltei* beds.
- One *Z. noltei* bed, five mixed *Z. angustifolia* and *Z. noltei* beds and nine *Z. angustifolia* beds were identified in 2012.
- The eelgrass mapped in 2012 covered an area of 23.7 hectares in total.
- Current evidence suggests that the extents of the eelgrass beds in Loch Fleet have decreased between 2000 and 2012. Overall the decline in eelgrass extent between 2000 and 2012 has been estimated to be approximately 85 % (155.7 hectares in 2002 compared to 23.7 hectares in 2013; N.B. caution needed as the estimate is acquired from comparisons between 2000 hand-drawn maps and 2012 digital maps).
- Compared to 2000 all the beds are reduced in size with the largest declines found along the Mound causeway, along the western/southern coastline and at Creag Bheag with reductions of 100 %, 97.5 % and 97 % respectively. The smallest decline is found in the bay between Balblair Wood and Ferry Wood with a decline of 70 % overall (N.B. caution needed as estimates are acquired from comparisons between 2000 hand-drawn maps and 2012 digital maps).

- One eelgrass bed, the *Z. angustifolia* bed along the Mound causeway, recorded in 2000 was not recorded in 2012.
- There have been changes in positions and reductions in sizes of several eelgrass beds in Loch Fleet (e.g. along Creag Bheag, along the southern coastline and in the bay between Balblair Wood and Ferry Wood).
- Establishing a current environmental baseline at Loch Fleet together with regular monitoring of the eelgrass beds and the baseline data would be beneficial to fully establishing the factors controlling the apparent decline of eelgrass in the Loch Fleet estuary but also allow the natural cycle of the eelgrass present to be determined.

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1. INTRODUCTION

1.1 Project background

Seastar Survey Ltd was contracted by Scottish Natural Heritage to investigate the perceived decline in eelgrass abundance on the intertidal sandflats at Loch Fleet (Figures 1.1 and 1.2), which has been designated as a Site of Special Scientific Interest (SSSI) as well as being part of the Dornoch Firth and Loch Fleet Special Protection Area (SPA), Ramsar site and a National Nature Reserve (NNR). These designations are in place in part as a result of eelgrass being an important food source for overwintering wildfowl.

Eelgrass is a type of seagrass, which are flowering plants (Phylum Angiospermophyta) adapted to estuarine and marine environments (Green and Short, 2003). Of about 60 species worldwide, only five seagrass species (*Zostera marina*, *Z. noltei*, Z. *angustifolia Cymodocea nodosa* and *Posidonia oceanica*) are native of European waters, with the former three being different species of eelgrass (flat leaves; Borum *et al.*, 2004). For the remainder of this report reference will be made to eelgrass wherever possible, but if not indicated in the original reports (e.g. journals or commissioned reports), the term seagrass will have been used as there was no further detail given.

Seagrass communities are considered to be important biological habitats as the presence of these communities have a number of positive effects on the immediate and surrounding environment, including sediment stabilisation, increased deposition of organic material, encourage nutrient recycling, export detrital material to nearby habitats and provide habitat heterogeneity for a variety of associated fauna and flora (Cleator, 1993).

Several studies have reported a decline in seagrass communities worldwide (e.g. Orth *et al*., 2006; Waycott *et al*., 2009; Short *et al*., 2011) but it has also been reported that there is an apparent decline in the abundance of some Scottish eelgrass communities (Cleator, 1993). A number of factors have been identified as threats to these habitats including disease, pollution, coastal development and certain types of fishing activity (Cleator, 1993).

This document will report on the current eelgrass distribution and abundance in Loch Fleet and discuss these results in relation to previous eelgrass extent surveys in the estuary. Potential factors affecting the current distribution and health of these eelgrass beds will also be discussed.

1.1.1 Loch Fleet

Loch Fleet is a shallow, bar-built estuary with a tidal basin extending to approximately 630 ha in total (SNH, 2006a). It is located in east Sutherland between Embo and Golspie on the east coast of Scotland (Figures 1.1 and 1.2).

The loch is bordered on one side by the Mound causeway, a road crossing built in the early nineteenth century which cut short the flow of the tide. The river Fleet flows through sluice gates in the causeway and into the loch (SNH, 2006a).

The southern boundary of the loch is characterised by relatively low-lying farmland whilst the northern coastal fringe is dominated by pine woodlands. The seaward boundary is characterised by sand dunes and lichen-rich dune heath is present.

In the north-eastern bay between Ferry Wood and Balblair Wood (see Figure 1.3) there are two spits, one from the southern and one from the northern shore. These spits are characterised by gravel and cobbles over sand and splits the bay in one inner and one outer

section of the bay. Of note is that these spits are not apparent on all maps but require consideration when mapping the eelgrass within the SSSI.

1.1.2 Previous eelgrass studies at Loch Fleet

Prior to 2000 there appears to be no survey effort to determine the distribution of eelgrass within Loch Fleet SSSI. However, in recent years two eelgrass related studies have been completed at Loch Fleet; one in 2000 and one in 2006 (SNH, 2000; SNH, 2006b). The study in 2000 mapped the extent and abundance of the eelgrass beds across the estuary, however, the report remains unpublished with the only available data being the resulting eelgrass extent maps (SNH, 2000).

The main objective of the study in 2006 was to initiate monitoring of the marine features within the Loch Fleet and Mound Alderwoods SSSIs (SNH, 2006b). Four monitoring transect lines were established and some basic data were collected (e.g. invertebrate community data) but in terms of informing the current eelgrass distribution study there is little comparable data.

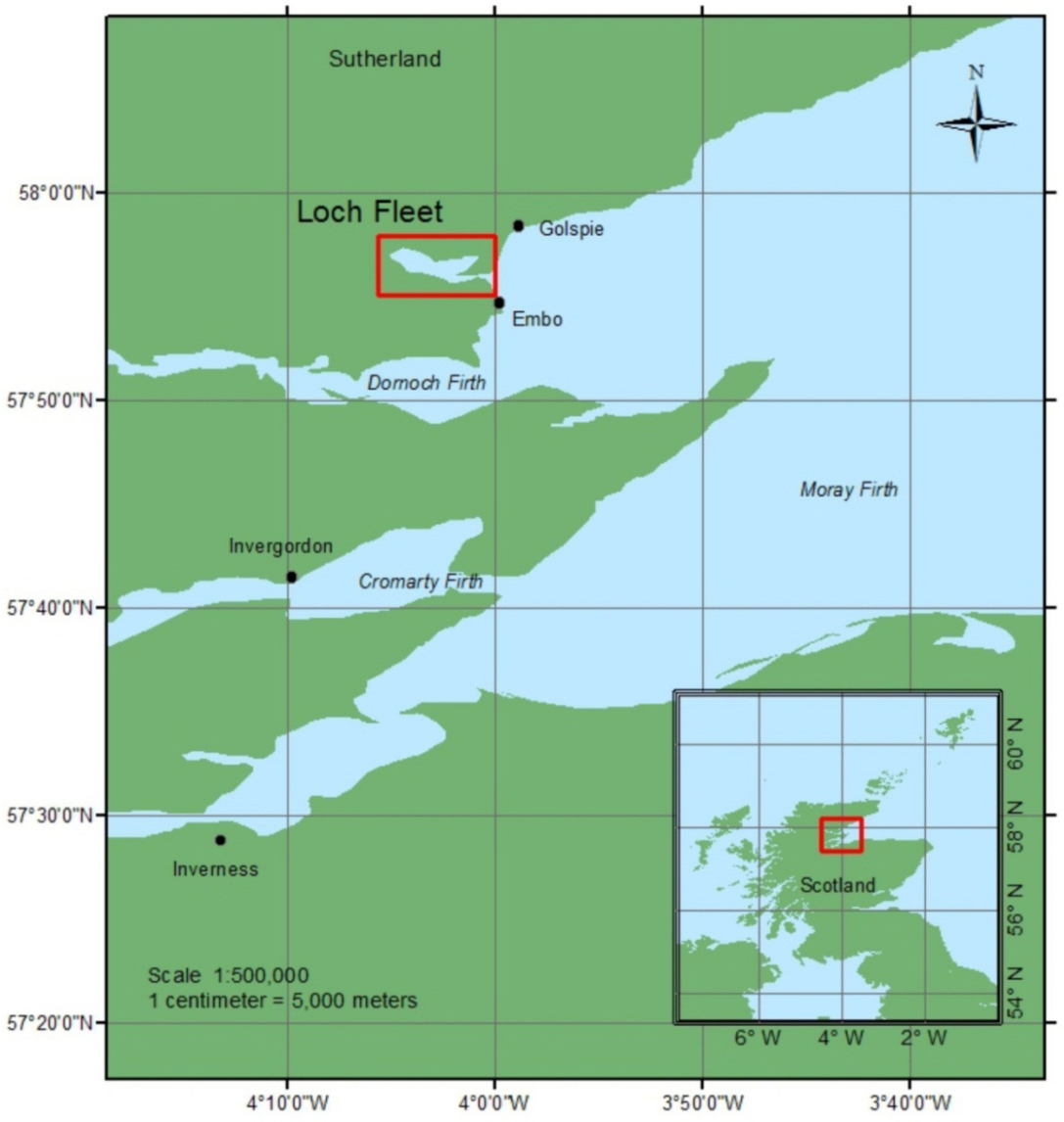

Figure 1.1. Loch Fleet (red rectangle) in relation to the rest of Scotland.

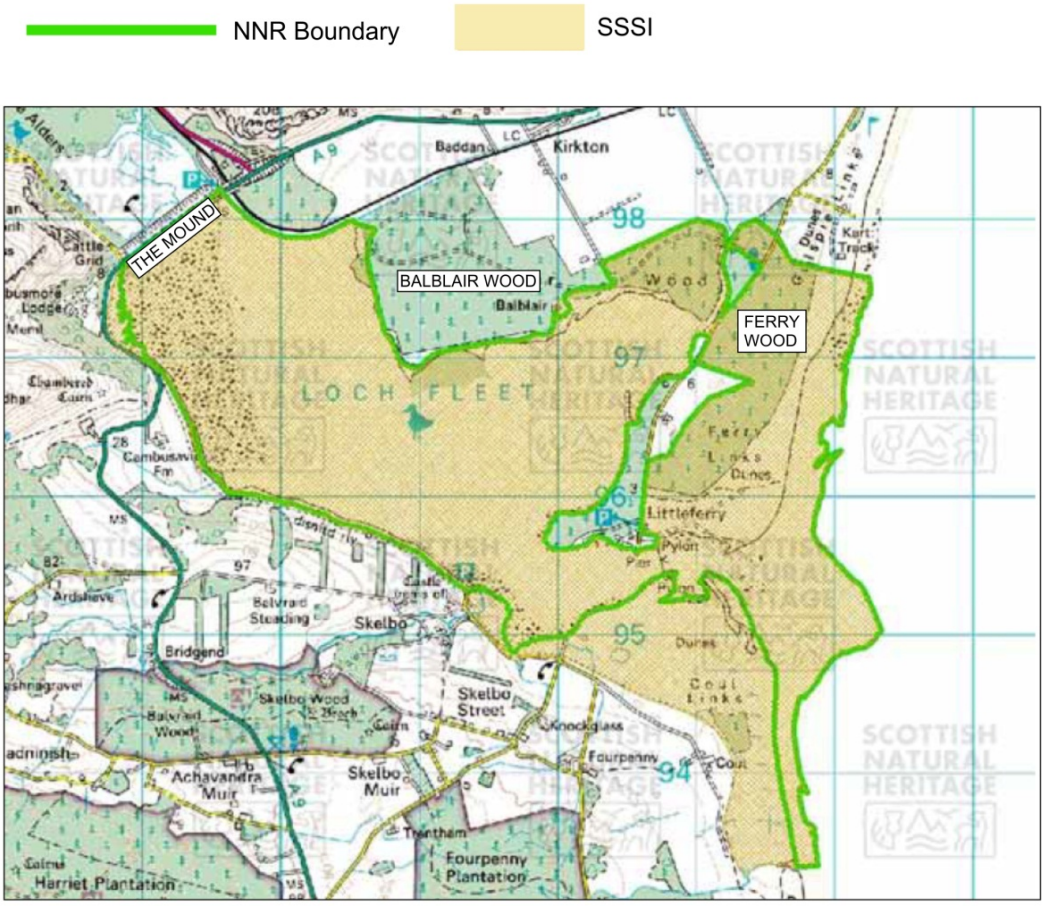

Figure 1.2. Loch Fleet estuary – National Nature Reserve and SSSI (from SNH, 2006a).

Figure 1.3. Loch Fleet estuary – satellite image (from Google).

2. THE LOCH FLEET ENVIRONMENT

2.1 The geological environment

The bedrock underneath Loch Fleet consists of Old Red Sandstone, a sedimentary rock, formed in the Devonian period (417 and 354 million years ago; Barne *et al*., 1996; SNH, 2006a). Shingle ridges have been deposited on top of the sandstone and these ridges extend from the Mound Rock at the western boundary of the tidal basin (at the causeway) to the current coastline, and north from Littleferry to Golspie. Blown sand and alluvial deposits of the dunes are now apparent along the fringes of the basin.

As the ice retreated at the end of the last Ice Age Loch Fleet became a tidal delta (SNH, 2006a). Loch Fleet was then a wide-open bay, embracing a sea loch reaching inland as far as Rogart. Currents sweeping southward gradually dragged shingle across the entrance to the loch, reducing the mouth to a narrow channel through which the tidal current races in and out (SNH, 2006a).

Currently, the tidal basin is characterised by extensive mud- and sandflats backed by saltmarsh and sand dunes with transitions to dune heath and alder (*Alnus glutinosa*) woodland (SNH, 2006b). At high water the basin is full, but at low tide extensive intertidal mud and sand flats are exposed with the River Fleet cutting a channel through the sediments. Mapping has shown that the sediments in the tidal basin rarely move, with islands and channels staying in the same position (SNH, 2006a). This suggests that there is little annual change in the quantity of sediment within the basin from year to year (SNH, 2006a).

There are few records available describing the particle size distribution of the sediment within the loch. However, a study (SNH, 2000) with sampling stations at Ferry Wood and in Loch Fleet (near the causeway) showed the sediment to be characterised by sand (≥95 %) with a small mud fraction (≤5 %).

2.2 The physical environment

There is little available data on the physical environment in Loch Fleet but according to Barne *et al*. (1996) Loch Fleet is a macrotidal estuary with a spring tidal range in excess of 4 m. However, according to the Nautical Almanac (Reeds, 2012) the maximum tidal range (at spring tides) at Portmahomack and Golspie is 3.4 m. The actual tidal range at Loch Fleet is therefore most likely 3.4 m as well and Loch Fleet may therefore not be a macrotidal estuary but further detailed information will be required to assess this fully. There appears to be no information relating to current speeds in the loch.

Of additional interest is that the loch used to extend 6 km inland towards Rogart but the Mound causeway, nearly 1 km in length, truncated the Loch (completed in 1818). The causeway acts as a tidal barrier, stopping the sea some 2.5 km short of its natural tidal limit (SNH, 2006a).

2.3 The biological environment

There are only two recent studies (in 2000 and 2006) involving eelgrass at Loch Fleet. The study in 2000 (SNH, 2000) mapped the extent and abundance of the eelgrass beds across the estuary (see extent maps in Figures 2.1 and 2.2 below). The survey in 2006 also recorded eelgrass (*Zostera* marina) but the study did not result in any distribution or extent maps (SNH, 2006b). However, other related biological data were recorded and are summarised as follows:

The extensive mud- and sandflats support a rich marine invertebrate fauna (e.g. razor shells, cockles and many species of marine worms) and “beds of *Zostera* and *Enteromorpha*” (SNH, 2006a, b). There are also large mussel beds on the north side of the river channel. These provide rich feeding grounds for waders and wildfowl throughout the year but are especially important during the winter months when they provide undisturbed feeding for migratory birds (SNH, 2006a). The tidal waters support a range of fish species which in turn provide a food source for other wildlife. The beds of eelgrass are an important intertidal and shallow subtidal habitat. The extensive root systems of the eelgrass help stabilise the shore and seabed, and the beds shelter a range of juvenile fish and provide a source of food for several wildfowl species in winter (SNH, 2006a).

2.3.1 Loch Fleet eelgrass

Three eelgrass species have been recorded at Loch Fleet; *Zostera noltei, Z. angustifolia* and *Z. marina* (SNH, 2000; SNH, 2006b). However, whilst *Z. marina* and *Z. noltei* are recognised species across Europe *Z. angustifolia* is not (see e.g. Evans, 1988; Davison and Hughes, 1998; Borum *et al.,* 2004; MarLin, 2012). Outside the UK most authors consider *Zostera angustifolia* to be a phenotypic variant of *Zostera marina* and named *Zostera marina var. angustifolia* (MarLin, 2012). This issue requires resolution and the taxonomic status is currently under consideration (see EEA, 2007) but for the benefit of this study all three species are recognised and described (see below).

The identification of the three species is reportedly straightforward as long as the material is from optimal habitats (Evans, 1988). However, in environments such as exposed mudflats or sites subject to large tidal ranges the identification is more challenging. A plant crib to aid identification has been produced by Evans (1988) and added as an Appendix (Appendix 1) in this report. Of particular note is that regardless of the identification of the plants it is the habitat that is considered to be of most importance and protected (e.g. Habitats Directive, Berne Convention, OSPAR, 2006; CITES, 2012; JNCC, 2012; MarLin, 2012).

2.3.1.1 The dwarf eelgrass (*Zostera noltei)*

Zostera noltei has been known under various spellings including *Z. noltii, Z. noltei* and *Z. (Zosterella) noltei* but the most recent accepted spelling is *Zostera (Zosterella) noltei* (see World Register of Marine Species, WoRMS Editorial Board, 2013). This taxon will for simplicity be referred to as *Zostera noltei* for the remainder of this document.

Z. noltei is distributed from the southern coasts of Norway to the Mediterranean Sea, the Black Sea, the Canary Islands (Borum *et al*., 2004). In the UK, recent records are clustered in the Thames Estuary area, Moray and Cromarty Firths, and in Argyll (Davison and Hughes, 1998).

The dwarf eelgrass forms dense beds in the muddy sand of intertidal areas, where *Zostera marina* is sparse due to its lower tolerance to desiccation (Borum *et al*., 2004). *Z. noltei* occurs high up the shore on well drained areas which may be completely dry for a period during each tidal cycle (Cleator, 1993). *Z. noltei* also occurs subtidally but often seems to be absent where the water cover is permanent.

The dwarf eelgrass undergoes a marked die-back in the winter months and may suffer complete loss of foliage. It reportedly regenerates both by seed set and rhizomal growth but the latter is deemed to be more important, particularly in the Moray Firth where seed production is reportedly unimportant (Rae, 1979; Cleator, 1993).

Z. noltei has small leaf bundles with 2 to 5 narrow leaves attached to a horizontal rhizome (Borum *et al*., 2004). Each rhizome holds many shoots on short branches separated by

rhizome segments. The leaves are 0.5-1 mm wide and 5 to 25 cm long (Evans, 1988). The rhizomes are 0.5 to 2 mm thick and the rhizome segments are from 5 to 35 mm long (Borum *et al*., 2004). The most recently formed internodes are light green while older segments turn yellow or brown. The seeds are 1½-2 mm long. The seeds are probably spread by ducks and geese feeding on the intertidal beds (Borum *et al*., 2004). The optimum conditions for seed germination are reportedly 10°C and 10 - 20 Practical Salinity Units (PSU), although the survival of seedlings is enhanced in reduced salinity at 10°C and 1 PSU (Cleator, 1993).

In 2000 *Z. noltei* had a limited distribution in Loch Fleet and plants were found primarily in the northern section of the loch (see Figure 2.1). There is an overlap in the distribution of *Z. noltei* with *Z. angustifolia* in this bed, therefore forming a mixed community. Little other information is currently available about the dwarf eelgrass in Loch Fleet.

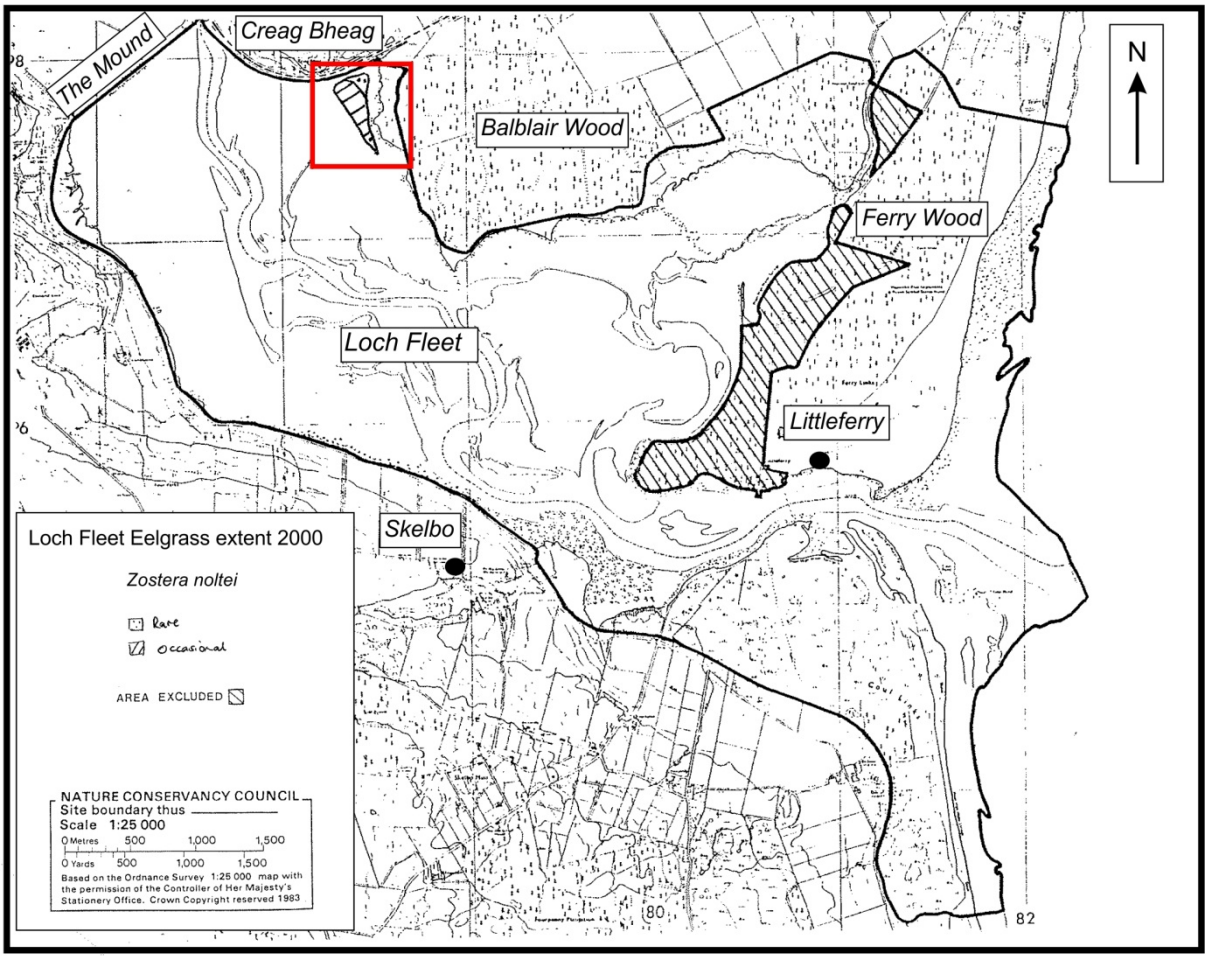

Figure 2.1. Zostera noltei extent in 2000 (marked by red square; line – occasional; dots – rare; from SNH, 2000).

2.3.1.2 The common eelgrass (*Zostera marina)*

Zostera marina was recorded at Loch Fleet during a survey in 2006 (SNH, 2006b). This taxon is the largest of the three British eelgrasses and typically occurs in the shallow sublittoral down to about 4 m depth, in fully marine conditions and on relatively coarse sediments (Davison and Hughes, 1998). The species is still patchily distributed around most of the British coastline, with concentrations of recent records in south-west England and the west coast of Scotland.

The shoots of *Z. marina* have 3 to 7 leaves (Davison and Hughes, 1998). Leaf width varies between 2 mm for young plants and up to 10 mm for large individuals. The leaves are usually 30 to 60 cm long but may be up to 1.5 m in beds on soft sediments at intermediate depths. The roots are thin (0.2-1 mm), covered by fine root hairs and may be up to 20 cm long. The rhizome segments are 2-6 mm thick, the length of each segment varies from 5 to 40 mm and the colour changes from white-green in newly formed segments to dark brown in old segments.

The male and female flowers of *Z. marina* are small, greenish and partly hidden in pockets within the leaf sheaths. Male and female flowers are found on the same individual and may produce several thousand seeds per square meter. Flowering can be observed from early spring to fall. The seeds are 2-4 mm long and, when fully developed, the flowering shoots detach and float away from the bed. The seeds either drop to the sediment within the bed or are dispersed along with the floating shoots (rafting). Seeds are probably also spread by ducks and geese feeding on eelgrass stands (Davison and Hughes, 1998).

2.3.1.3 The narrow-leaved eelgrass (*Zostera angustifolia)*

As a result of the uncertainty in the taxonomic status of *Zostera angustifolia* the baseline knowledge about this taxon is somewhat unclear. For example, *Z. angustifolia* has been described as both an intertidal (found from mid- to low-tide mark; Davison and Hughes, 1998; Zoutenbier *et al*., 2011) and subtidal plant (mainly by being a phenotypic variant of *Z. marina;* MarLin, 2012). The distribution is therefore also uncertain but currently *Z. angustifolia* has been recorded in British Isles, Denmark and Sweden. In Britain, *Z. angustifolia* has a more easterly distribution than *Z. marina,* with concentrations in the Solent, Thames Estuary, and Moray and Cromarty Firths (Davison and Hughes, 1998).

The narrow-leaved eelgrass is usually found in poorly-draining muddy, water-logged sediments (e.g. hollows that retain standing water) and it is susceptible to desiccation (Cleator, 1993). It is typically found in conditions of variable salinity, often in estuaries and the plants do not appear to be adversely affected by short immersion in fresh water (Cleator, 1993; Davison and Hughes, 1998).

Z. angustifolia can adopt an annual strategy with marked die-back during the winter with complete loss of foliage (Cleator, 1993). In the Moray Firth *Z. angustifolia* has been shown to regenerate in spring and flower by May. The *Z. angustifolia* plants show a higher reliance on seedlings for regeneration compared to the other two species (Cleator, 1993).

The distribution of *Z. angustifolia* within Loch Fleet SSSI has not been assessed for over 10 years but the extents of the beds in 2000 were established and these are given in Figure 2.2. The narrow-leaved eelgrass was widespread in Loch Fleet in 2000 with densities typically between occasional (1-5 %) to frequent (5-9 %; assuming the abundance scale used in Figure 2.2 was DAFOR), although smaller sections along the southern fringe of the tidal basin and in parts of the northern bay had higher densities of ≥20 %. As mentioned above, there is a mixed community of *Z. noltei* and *Z. angustifolia* along the Creag Bheag shore.

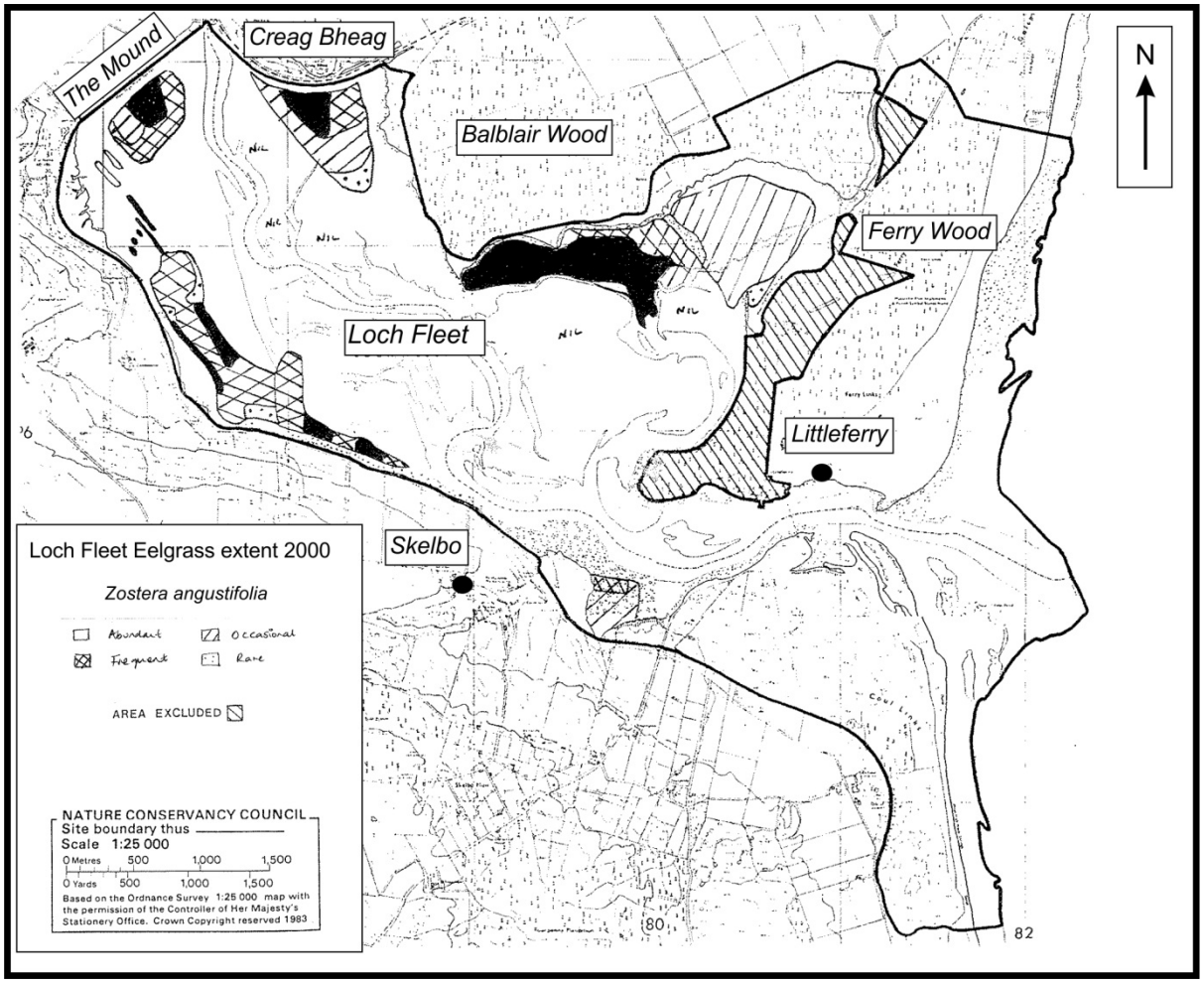

Figure 2.2. Zostera angustifolia extent in 2000 (black – abundant; hash – frequent; line – occasional; dots – rare; from SNH, 2000).

2.3.2 Invertebrates

As described above, Loch Fleet is a small, shallow loch with predominantly sedimentary shores. The invertebrate fauna found in the estuary have reportedly been dominated by oligochaete and polychaete worms, amphipods and bivalves (Wells and Boyle, 1975; Barne *et al*., 1996; SNH, 2006a; SNH, 2006b). The varied substrata and habitats present have resulted in high species richness, therefore potentially making it a candidate for national marine biological importance (Bishop and Holme, 1980).

In a recent study (SNH, 2006b) the infauna in Loch Fleet was shown to predominantly consist of *Tubificoides pseudogaster, Tubificoides benedii, Fabricia sabella, Pygospio elegans, Macoma balthica, Cerastoderma edule* and insect larvae. Other fauna found in the samples are given in Table 2.1.

Table 2.1. Examples of species recorded in Loch Fleet in a recent study (SNH, 2006b).

MCS (Marine Conservation Society) Code	**Species**
G001	Nemertea indet.
G050	*Lineus* sp.
P0145	*Phyllodoce mucosa*
P0672	*Scoloplos armiger*
P0776	*Pygospio elegans*
P0907	*Capitella capitata*
P0919	*Mediomastus fragilis*
P0931	*Arenicola marina*
P1283	*Fabricia sabella*
P1420	*Paranais litoralis*
P1490	*Tubificoides benedii*
P1498	*Tubificoides pseudogaster* agg.
S0458	*Bathyporeia sarsi*
S1385	*Crangon crangon*
W1961	*Cerastoderma edule*
W2029	*Macoma balthica*
	Insect larvae

During the 2006 study a total of five different biotopes were recorded from Loch Fleet. Two mixed substrata littoral rock biotopes were recorded from a site near Ferry Wood, located to the north of the Loch entrance, **LR.LLR.Fpel** and **LR.LLR.Fspi**, together with the seagrass biotope **LS.LMp.SSgr**. The muddy sand biotope **LS.LSa.MuSa.CerPo** was recorded from two transects in the tidal basin, while a similar muddy sand biotope without the presence of *Cerastoderma edule* **LS.LSa.MuSa** was recorded from the entrance to Loch Fleet. All of the biotopes recorded from Loch Fleet are known to occur in locations of variable salinity (Connor *et al*., 2004).

2.3.3 Macroalgae

There appears to be little available data on the macroalgal communities within Loch Fleet. However, one study (SNH, 2006b) reported the presence of *Enteromorpha* spp., *Pelvetia canaliculata, Fucus spiralis, F. vesiculosus, F. ceranoides* and *Ascophyllum nodosum.* There is no quantitative data on the macroalgal species present.

2.4 Important bird populations in Loch Fleet

Throughout the year there are various bird assemblages at Loch Fleet and over 100 different bird species have been recorded within the National Nature Reserve (see SNH, 2006a). The intertidal flats are an important feeding and roosting ground for waders and wildfowl, with the highest numbers during the spring and autumn migrations although some species stay throughout the winter and others breed in the vicinity (SNH, 2006a). Shelduck, wigeon, teal, curlew and redshank are all often seen on the tidal flats.

During the winter months the greylag goose, wigeon, teal, bar-tailed godwit and dunlin form part of the bird assemblage. These species migrate from their northern breeding grounds either to spend the winter in the relative shelter of the Dornoch Firth and Loch Fleet or to pass through on route to wintering areas further south (SNH, 2006a).

Loch Fleet is particularly important for greylag geese in the autumn, as in winter the birds spread further out into the Dornoch Firth (SNH, 2006a). Ospreys regularly nest on the Reserve. Ospreys are one of the success stories amongst Scottish birds, having disappeared from Scotland in the early 1900s but returning regularly to breed in the1950s. The Dornoch Firth and Loch Fleet SPA is a foraging area for approximately 10% of the UK breeding population of this species.

Some bird species have declined at Loch Fleet for reasons that are not fully understood (SNH, 2006a). The wintering population of long-tailed duck has declined since Loch Fleet became an SSSI in 1975 to the extent that this species is now unusual here. Similarly the site once supported nationally important numbers of non-breeding eider duck, but numbers are now much lower than used to be the case (SNH, 2006a). Little terns used to breed in the Reserve but no longer do so, although they can occasionally be seen feeding at the mouth of Loch Fleet.

3. METHODOLOGY

The field work was completed between 14th and 21st September 2012 around the spring tide which fell on 18th September 2012. The survey team mobilised from Southampton on 14th September 2012 and drove to Golspie in Sutherland.

On 15th September the team carried out a site familiarisation exercise to ensure a safe working environment but also to gain a good understanding of the constraints of the survey area. The field survey work commenced in earnest in the afternoon of 15th September 2012 as soon as the water started to ebb.

3.1 Site description

To ensure a sufficient field survey period and clearly identify different part of the site, Loch Fleet was divided into six different survey areas (A – F), with individual eelgrass beds named Seagrass Bed (SB) A – F and sub-areas (patches within each survey area) numbered sequentially (e.g. SB_B_01, SB_B_02 etc.).

The survey areas were delineated based on the eelgrass extents (Figure 3.1) recorded in the 2000 survey (SNH, 2000). The target species for survey area A was *Zostera noltei* whilst the target species for survey areas B – F was *Zostera angustifolia*; all based on the 2000 survey results (see Figures 2.1 and 2.2; SNH, 2000). There appeared to be an overlap of the two species at A and B, therefore forming a mixed eelgrass community in a small section of the loch.

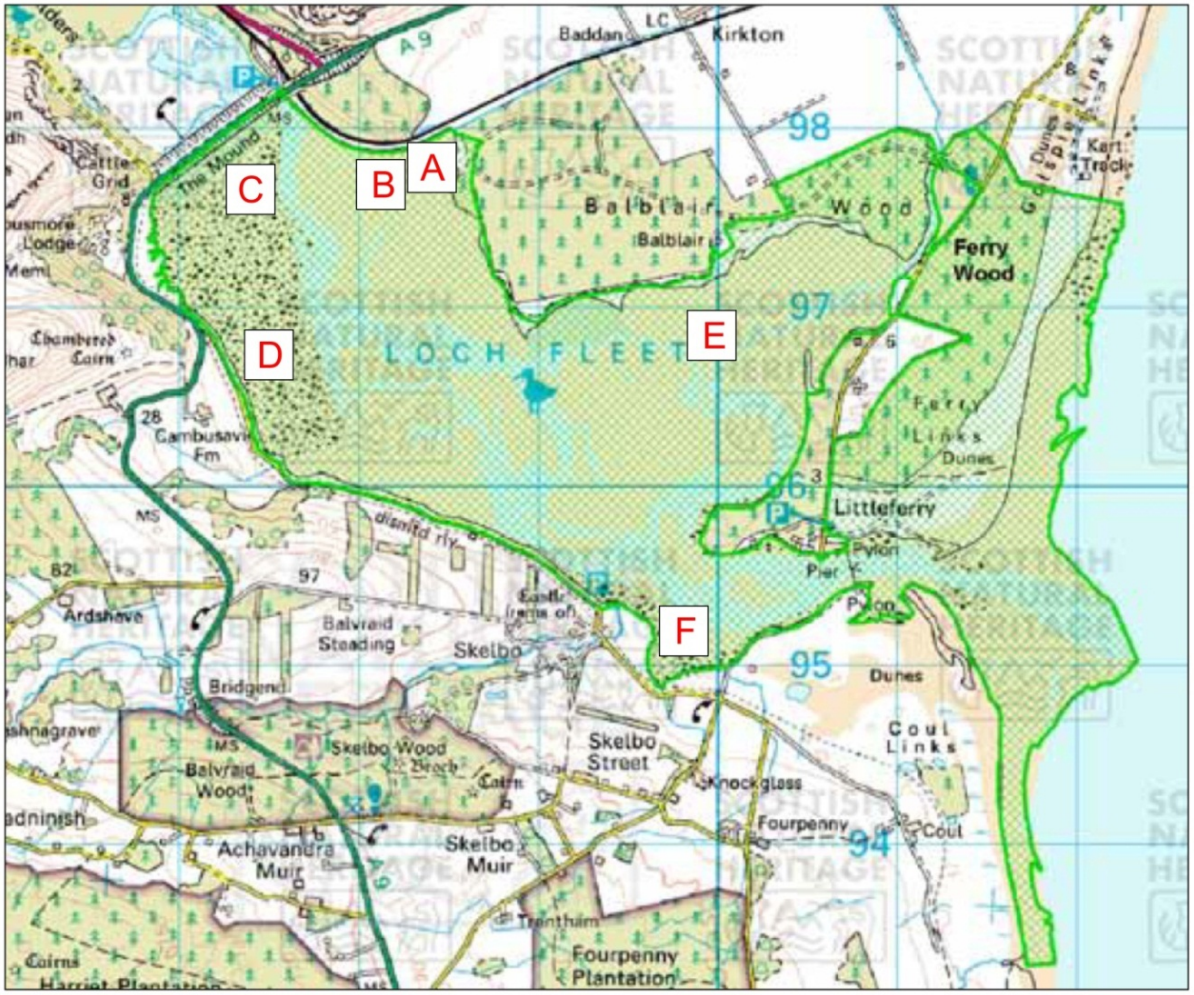

Figure 3.1. Loch Fleet estuary with survey areas A – F (original image from SNH, 2006a).

3.2 Field work methodology

To ensure a good understanding of the entire site, survey locations and the extents of the eelgrass beds prior to any detailed survey work (i.e. quadrat sampling) being completed the field work was carried out in two main phases:

- *Phase 1: map the extent of the eelgrass beds*
- *Phase 2: conduct quadrat surveys to assess eelgrass coverage and health*

3.2.1 Phase 1 – mapping of the extent of the eelgrass beds

Phase 1 was carried out between 15th and 21st September 2012. From the base in Golspie a team of two surveyors drove or cycled to site and walked around the eelgrass beds in Loch Fleet to map the extents of the beds using hand-held DGPS units (Garmin GPSMAP 276C and Garmin 72H).

The Garmin GPSMAP 276C unit was used to allow continuous track recordings to be made around the maximum extent of the various eelgrass beds. The positions were recorded

every time the surveyor changed direction (heading) but also approximately every 10 seconds. The surveyor walked slowly along the boundaries to ensure a good positional coverage.

The Garmin 72H unit was used to take manual fixes at a number of extremities of the eelgrass beds to allow subsequent mapping in GIS or other software packages. The manual fixes also served as back-up and Quality Control in case the other unit failed or resulted in unreliable data.

Phase 1 was originally planned to be completed over the first two days of the field work period. However, as a result of the large size of the estuary, the considerable distances between each of the individual eelgrass patches, the large size of some of the eelgrass patches, the variation and patchiness in the distribution of the eelgrass patches and the substantial amount of ground that had to be covered by the survey team, the mapping of each patch was carried out immediately prior to the abundance assessments in each survey area (i.e. Seagrass Beds A-F).

3.2.1.1 Survey methodology

Based on the data gathered in 2000, each survey area was systematically surveyed by walking across the entire sand/mudflat of each survey area (as given in Figure 3.1). The two surveyors walked next to each other at a distance of approximately 10 - 15 m. The starting point for each patch was along the shore with one surveyor walking along the shore line and the other 10-15 m further out. The entire area was then covered to ensure the entire patch was surveyed and assessed for any evidence of eelgrass.

When an eelgrass bed was encountered a marker would be placed in the mud. The two surveyors would then start surveying the extent by following and marking the furthest extent all along the furthest extremities of the bed. When satisfied the entire bed was identified the two GPS systems were used to obtain positional data along the outer boundary of the bed.

An additional survey assessing any variation in eelgrass cover and density was completed across each bed. If the eelgrass bed was found to exhibit variation in eelgrass cover and density across the patch, the boundary of any denser or less dense patches were marked and finally the positions were recorded using the two GPS systems.

3.2.2 Phase 2 - quadrat surveys to assess eelgrass cover and health

In phase 2 the cover and health of the eelgrass were assessed in each survey area (A - F; see Figure 3.1). In terms of survey effort the study site was split into four main sectors with survey areas A and B surveyed together, survey areas C and D surveyed together, and survey areas E and F surveyed separately.

The survey methodology in these four areas was originally planned as six transects with five quadrat locations along each transect. However, the small scale of some of the individual patches (named “sub-areas”) within each survey area meant that 100 m transects were not achievable. The transect lengths were therefore reduced to 50 m with varying number of quadrats along each transect but with the overall aim of acquiring 30 quadrat samples in each survey area (i.e. Seagrass Bed A-F).

The equipment used for the quadrat surveys included:

- a 50 m long rope marked every 5 m;
- a 0.25 m^2 quadrat;

- a 1 m long ruler;
- hand-held GPS unit;
- Recording forms – based on the MNCR recording forms for intertidal survey work;
- Notebook

The quadrat sampling involved:

1) Selecting a suitable area to lay the transect rope (ensuring eelgrass cover along the entire transect as far as possible);
2) Record Start of Line and End of Line positions (to allow revisits and future monitoring (in WGS84);
3) Randomly generate distances along the transect for quadrat survey work (quadrat size: 0.25m^2);
4) At each randomly selected position the quadrat was placed along the guide rope and the GPS position was recorded (in WGS84);
5) Five photographs (one of the entire quadrat and one of each of the four quarters) were taken to acquire permanent records of the location and the habitat;
6) The habitat was then described and notes were made as to the fauna and flora present as well as a simple classification of the sediment within the quadrat as far as possible;
7) In each quadrat (0.25 m^2) the eelgrass was identified and the percentage cover was estimated;
8) The number of shoots in a quarter of the quadrat (0.0625 m^2) were counted (shoot density);
9) The frond lengths of five of the shoots present in the 0.0625 m^2 quarter were measured;
10) Other assessments included *in-situ* identification of algal and faunal taxa.

3.3 Data analysis and mapping

Immediately after the completion of the field survey work the GPS data were analysed, the identification of the eelgrass samples were confirmed and finally all the data were incorporated into the GIS and mapped, to allow further interpretation of the habitats present.

Of note is that the eelgrass cover and density results in this study are based on the SACFOR scale (Connor *et al*., 2004). For eelgrass cover the range is as follows: <1% - Rare (R); 1-5% - Occasional (O); 5-9% - Frequent (F); 10-19% - Common (C); 20-39% - Abundant (A); 40-79% - Super-abundant (S).

The eelgrass density values are based on the shoot density results as follows: >1/10000 m^2 - Rare (R); 1-9/1000 m^2 - Occasional (O); 1-9/100 m^2 - Frequent (F); 1-9/10 m^2 - Common (C); 1-9/m^2 - Abundant (A); 1-9/0.1 m^2 - Super-abundant (S).

3.3.1 The acquired GPS track and manual fix data

The GPS data acquired from the GPSMAP 276C unit were uploaded into the Garmin MapSource software for assessment and processing. The field logs together with the software allow for delineation of the extents of the various eelgrass beds within Loch Fleet. Finally the eelgrass extent data were exported from MapSource and incorporated into ArcGIS (v.10).
The manual GPS fix data were also uploaded into the GIS and the two sets of data were compared in a Quality Control exercise to ensure an accurate assessment of the extents of the Loch Fleet eelgrass beds.

3.3.2 Quadrat Survey

The quadrat survey data comprised eelgrass cover, shoot density, frond length measurements as well as notes taken regarding the habitat in and around the quadrats. The positions of the quadrats have been incorporated into the GIS and maps have been produced to illustrate these locations.

The eelgrass samples collected in the field were analysed and the plants identified to the lowest possible taxonomic level.

Finally, the results of the species identification and the field data were summarised using bar charts. The field logs are given in the appendices (Appendix 02-05) to allow future assessments and comparisons.

3.4 Eelgrass (*Zostera*) identification

There are well-documented difficulties and uncertainties in the taxonomic status of *Zostera* taxa with several publications on the classification of *Z. marina* and *Z. angustifolia* (e.g. Evans, 1988; Davison and Hughes, 1998; Borum *et al.,* 2004; EEA, 2007; MarLin, 2012). However, there also seem to be considerable similarities between *Z. angustifolia* and *Z. noltei* making identification challenging, particularly when the plants are young or derive from habitats with limiting or imperfect environmental conditions (e.g. Evans, 1988; Cleator, 1993) causing stress to the plants (e.g. exposed mudflats or areas subject to strong current flow).

The features described to determine the identification of *Zostera* spp. are based mainly on adult plants (see e.g. Evans, 1988; Cleator, 1993). In addition, there is a lack of published detailed data in relation to certain biological facts of *Zostera* spp., including growth rates, onset of die-back and habitat requirements, particularly for plants found at the limits of the biological range in places like Scotland or in habitats causing some level of stress. It therefore appears as if DNA analysis is one of the few remaining options available to finally determine the taxonomic status of all three species. For the benefits of this report and based on WoRMS (WoRMS Editorial Board, 2013) *Z. angustifolia* has been assumed to be a separate species (until the taxonomic status has been fully established).

3.4.1 Identification of eelgrass species at Loch Fleet

Based on the *Zostera* spp. descriptions (e.g. Evans, 1988, Cleator, 1993), the large plants found in Loch Fleet were identified as *Z. angustifolia* as the typical size range of these plants was 10-40 cm (frond length), the blade width was between 1-2 mm, the yellow colouration was apparent (a characteristic suggested by Evans, 1988) and these plants were found in water-logged environments (typical for this taxon).

The identification of the small plants was less clear and apparent, particularly in the field. The size of the plants (5-10 cm) suggested that these plants were *Z. noltei* but considering the high latitude (near the northern limit of the known natural range of *Z. noltei*), uncertainties of growth rates (particularly at high latitudes) and the lack of *Z. noltei* in previous studies, it was possible that these plants were small, new shoots belonging to *Z. angustifolia*.

The main distinguishing features between *Z. noltei* and *Z. angustifolia* are (for more detail see above, Appendix 1 and Evans, 1988):

1) Length of sterile leaves;
2) Width of leaves;
3) Rhizome thickness;
4) Flowering stems;

5) Sheaths;
6) Seed colour, size and shape.

Habitat preferences varies (e.g. *Z. noltei* being found in both well-draining and subtidal habitats) although the general consensus seems to be that *Z. noltei* is typically found on well-draining mud- and sandflats whilst *Z. angustifolia* is typically found in water-logged sediments (e.g. Davison and Hughes, 1998).

The small size, the damage (e.g. broken tips) and the lack of flowering stems made the majority of the distinguishing factors unreliable resulting in uncertain *in-situ* identification. The fact that all the eelgrass beds were found in water-logged areas suggested the presence of *Z. angustifolia* only. However, detailed analysis of the small plants in the laboratory established the presence of *Z. noltei*, primarily as plants with seeds were collected during the survey. The differences in the flowering stems and the seeds are two of the main characteristic features separating the species. Of note is that plants with seeds were rare in September 2012 and positive identification of all the eelgrass beds using this method was therefore not possible. However, the size (e.g. leaf length and width, rhizome thickness) and colour of the plants suggest that the small plants are all *Z. noltei*. The conclusion is therefore that the eelgrass beds in Loch Fleet consist of three types; 1) *Z. angustifolia* beds; 2) mixed *Z. angustifolia* and *Z. noltei* beds; and 3) *Z. noltei* beds.

3.5 Survey considerations

Several factors were taken into consideration during the survey, mainly concerning the time available to undertake sampling, access to the sampling areas and the nature of the soft sediment restricting access to some of the outer reaches of the sampling areas, particularly survey area E (see Figure 3.1).

3.5.1 Low water and daylight hours

The areas of interest for this study were only exposed around low water. The tidal character of Loch Fleet resulted in a maximum workable period of approximately 6 hours. However, on most of the days in September the Spring tide low water minimum was around midday. This meant that the surveys had to take place at first light until the flooding tide restricted any survey work around noon. On the first four days additional survey work was possible in the afternoon until darkness made it unsafe and impossible as the quality of the data would have been poor. This working time period was further reduced by the number of daylight hours during the month of September in Scotland.

3.5.2 Access to some sampling locations

The intertidal sampling was completed by foot and access was gained easily to most of the eelgrass beds in Loch Fleet SSSI but in survey areas A and B access by road was restricted. There are two main woodland paths leading down to the bay and the survey team could potentially have walked to gain access. However, walking the 2-3 km with the PPE and survey equipment required would have been challenging and tiring. The use of mountain bikes was therefore considered essential to enable to survey team to gain access, bring all the equipment as well as save energy and time to get to the site.

4. RESULTS

4.1 Mapping of the extents of the eelgrass beds

Eelgrass beds were identified in all but two of the survey areas in Loch Fleet (see Figure 3.1 for reference). Eelgrass beds were found in B, D, E and F (Table 4.1 and Figure 4.1 and Appendix 02) with sizes given in hectares. However, no eelgrass was observed in A and C.

There are two species of eelgrass (*Z. angustifolia* and *Z. noltei*) present in the Loch Fleet estuary (see section 3.4 for details on the identification process) forming three types of eelgrass bed; 1) *Z. angustifolia* beds; 2) mixed *Z. angustifolia* and *Z. noltei* beds; 3) *Z. noltei* beds (see summary in Table 4.1). Each survey area (i.e. Seagrass Bed A-F) will be described separately below with details of the species present and any large and small patches of eelgrass within each area.

Table 4.1. Summary of the eelgrass beds in Loch Fleet estuary ('patch' refers to a small, often dense patch, of eelgrass within the larger bed; area refers to eelgrass bed size in hectares (Ha); ZA = Z. angustifolia and ZN = Z. noltei).

Survey Area	Sub-Area	Patch	Area (Ha)	Eelgrass	Cover	SACFOR
SB_A	-		-	None	None	
SB_B	SB_B_01		0.118	ZA, ZN	5-10%	F
	SB_B_02		0.089	ZA	1-2%	O
	SB_B_03		0.615	ZA	5%	F
	SB_B_04		0.005	ZA	<1%	R
SB_C	-		-	None	None	
SB_D	SB_D_01		0.275	ZA	0-5%	O
	SB_D_01	D1	0.006	ZA	20-30%	A
	SB_D_01	D2	0.006	ZA	5-10%	F
	SB_D_02		0.712	ZA, ZN	0-5%	O
	SB_D_02	D1	0.087	ZA, ZN	5-10%	F
SB_D	SB_D_02	D2	0.037	ZA, ZN	5-10%	F
	SB_D_02	D3	0.041	ZA, ZN	5-10%	F
	SB_D_03		0.020	ZA	1-2%	O
	SB_D_04		0.094	ZA	<1%	R
SB_E	SB_E_01		0.025	ZA	0-5%	O
	SB_E_02		3.159	ZA, ZN	0-5%	O
	SB_E_02	D1	1.308	ZA, ZN	5-10%	F
	SB_E_02	D2	0.033	ZA, ZN	5-10%	F
	SB_E_03		0.164	ZA	0-5%	O
	SB_E_04		0.129	ZA	0-5%	O
	SB_E_05		10.551	ZA	10%	C
	SB_E_05	D1	4.642	ZA	70-80%	S
	SB_E_06		0.736	ZA	10%	C
	SB_E_06	D1	0.148	ZA	50-60%	S
	SB_E_07		6.758	ZA, ZN	0-5%	O
	SB_E_07	D1	0.48	ZA, ZN	5-10%	F
SB_F	SB_F_01		0.407	ZN	0-10%	F
	SB_F_01	D1	0.099	ZN	10-40%	A

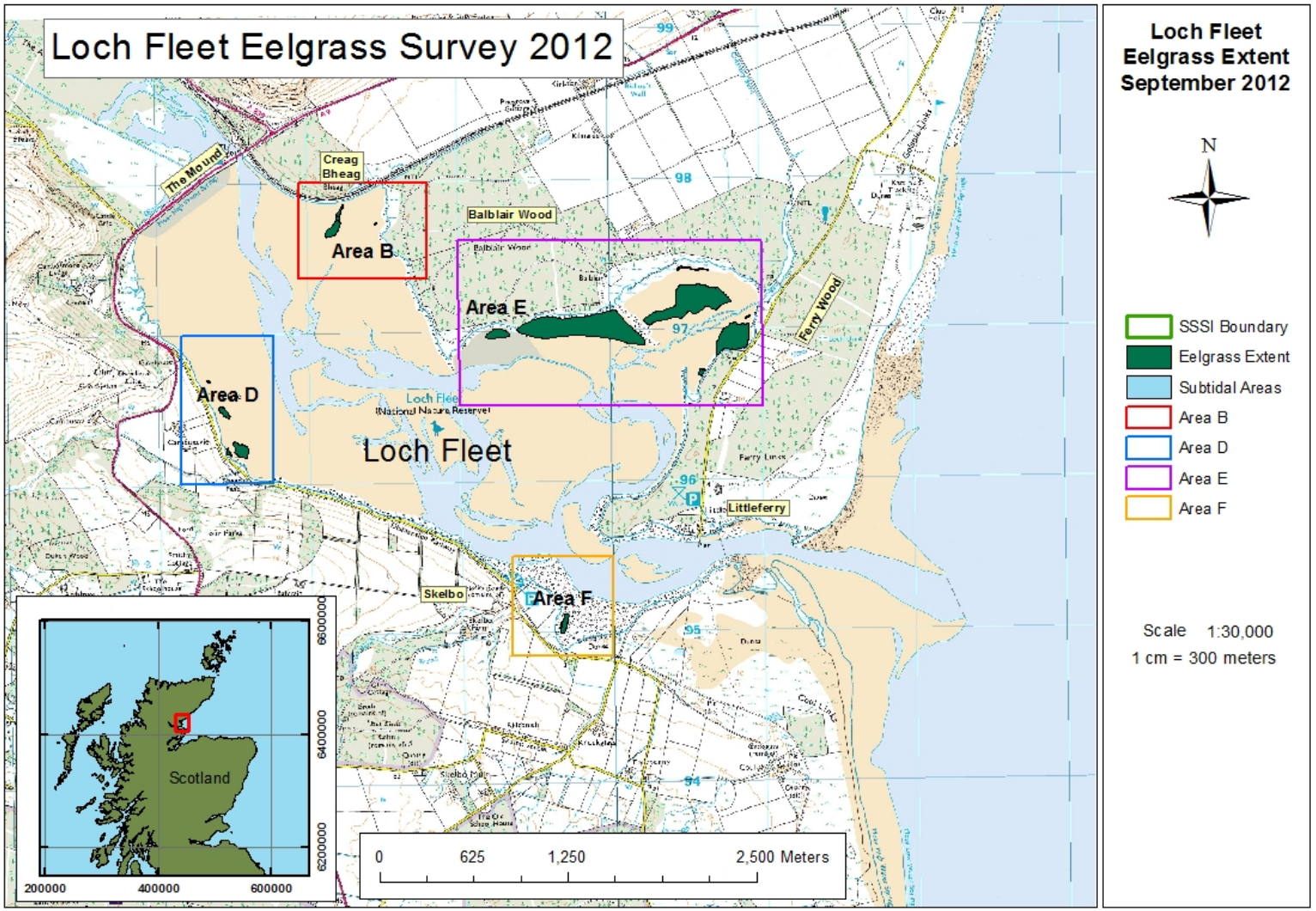

Figure 4.1. The extent of the eelgrass beds (in green) within the Loch Fleet estuary in 2012.

4.1.1 Survey area A

The entire bay in survey area A was surveyed and assessed for the presence of *Z. noltei* but not a single plant was observed. However, three *Z. angustifolia* plants were recorded in this area (described further in B, Sub-Area 4 below). The sediment in A was characterised by muddy sand with casts of *A. marina* (see habitat summary in Table 4.2). Close to shore (≤15 m) the sediment had a higher mud content compared to the areas away from shore, which overall was hard under foot. The depth of the soft sediment close to shore was approximately 3-5 cm whilst the areas away from the shoreline were only 1-2 cm in thickness.

There were patches of dried out seabed, a habitat suitable for *Z. noltei,* and a number of patches with standing water with some blanket weed, a habitat potentially suitable for *Z. angustifolia*, but there was no evidence of this species in this survey area.

Table 4.2. Summary of Loch Fleet survey area A.

Survey Area	A
Target species	*Zostera noltei*
Sediment description	Muddy sand, with areas drying fully at low tide and patches of standing water
Eelgrass bed description	Not present
Other fauna present	*Arenicola marina*, blanket weed, empty bivalve shells (e.g. *Cerastoderma edule, Macoma balthica*)

4.1.2 Survey area B

The search in survey area B started along the shoreline and was then completed in 10-15 m intervals repeated away from the shoreline. The search stretched all the way to the mid-estuary channel next to the bridge (west), the bay next to Sub-Area E and as far as the main channel to the south. The habitat was characterised by muddy sand with *A. marina* (Figure 4.2). Empty bivalve shells (e.g. *Cerastoderma* edule) were common and blanket weed was also present, particularly in the areas of standing water in the dips and channels (where it was abundant) along the sandflat.

Figure 4.2. Characteristic sandflat environment in survey area B.

There were two eelgrass beds in survey area B (Figure 4.3), one small (SB_B_SA4) and one large (see summary in Table 4.3). In general the plants were found in standing water forming channels and dips across the sandflat (there were no plants in areas drying out at low water). *A. marina* and blanket weed were common across the entire survey area. The blanket weed was found in the same habitat as the eelgrass (i.e. in standing water) appearing to compete for space with the eelgrass.

The large eelgrass bed was approximately 250 m by 50 m in size but the eelgrass varied in cover and type of plant across the bed. It was therefore separated into three Sub-Areas (SB_B_SA1, SB_B_SA2 and SB_B_SA3) to reflect the differences in the habitats present.

The eelgrass bed in Sub-Area 1 consisted of both *Z. angustifolia* and *Z. noltei*. The eelgrass cover overall was approximately 5-10% (F – C) but small patches within the Sub-Area had a higher cover (up to 40 % - A). It was not possible to establish separate extents of the two species as there was a complete mixture across the site.

Sub-Area 2 was a sparse eelgrass bed with approximately 1-2% (O) of eelgrass overall. There were only *Z. angustifolia* plants present. There were numerous areas of standing water, which suggests other factors limit the extent of the eelgrass plants in this area. The rhizome network may still be present within the sediment which would allow a fast recovery.

The eelgrass bed in Sub-Area 3 has a cover of around 5-10 % (F - C) but with *Z. angustifolia* plants only. Some patches had a higher density of plants, reaching approximately 40% cover (A), but these areas were discrete in size and tended to be scattered across the area.

Sub-Area 4 consisted of a small patch (15 m × 5 m) immediately east of a sand/gravel bank situated centrally in this part of the bay (not marked on any of the available maps). A total of three *Z. angustifolia* plants were found (R). The plants were found in standing water, in the path of the freshwater flow from the stream in the north-western corner of the bay.

Table 4.3. Summary of the eelgrass beds in Loch Fleet survey area B.

Survey Area	B
Target species	*Zostera angustifolia*
Sediment description	Muddy sand, with areas drying fully at low tide and patches of standing water in sandflat depressions as well as channels running from the freshwater streams
Eelgrass bed description	*Zostera angustifolia* and *Z. noltei* beds present, divided into four beds (or Sub-Areas) as follows: **SB_B_SA1:** Eelgrass bed with 5-10% (F – C) cover overall of both *Z. angustifolia* and *Z. noltei* **SB_B_SA2:** Eelgrass bed with 1-2% (O) cover overall-*Z. angustifolia* only **SB_B_SA3:** Eelgrass bed with 5 (-10) % cover (F) overall - *Z. angustifolia* only **SB_B_SA4:** A total of three *Z. angustifolia* plants were found in SA4 (R)
Other fauna present	*Arenicola marina*, blanket weed, empty bivalve shells (e.g. *Cerastoderma edule, Macoma balthica*)

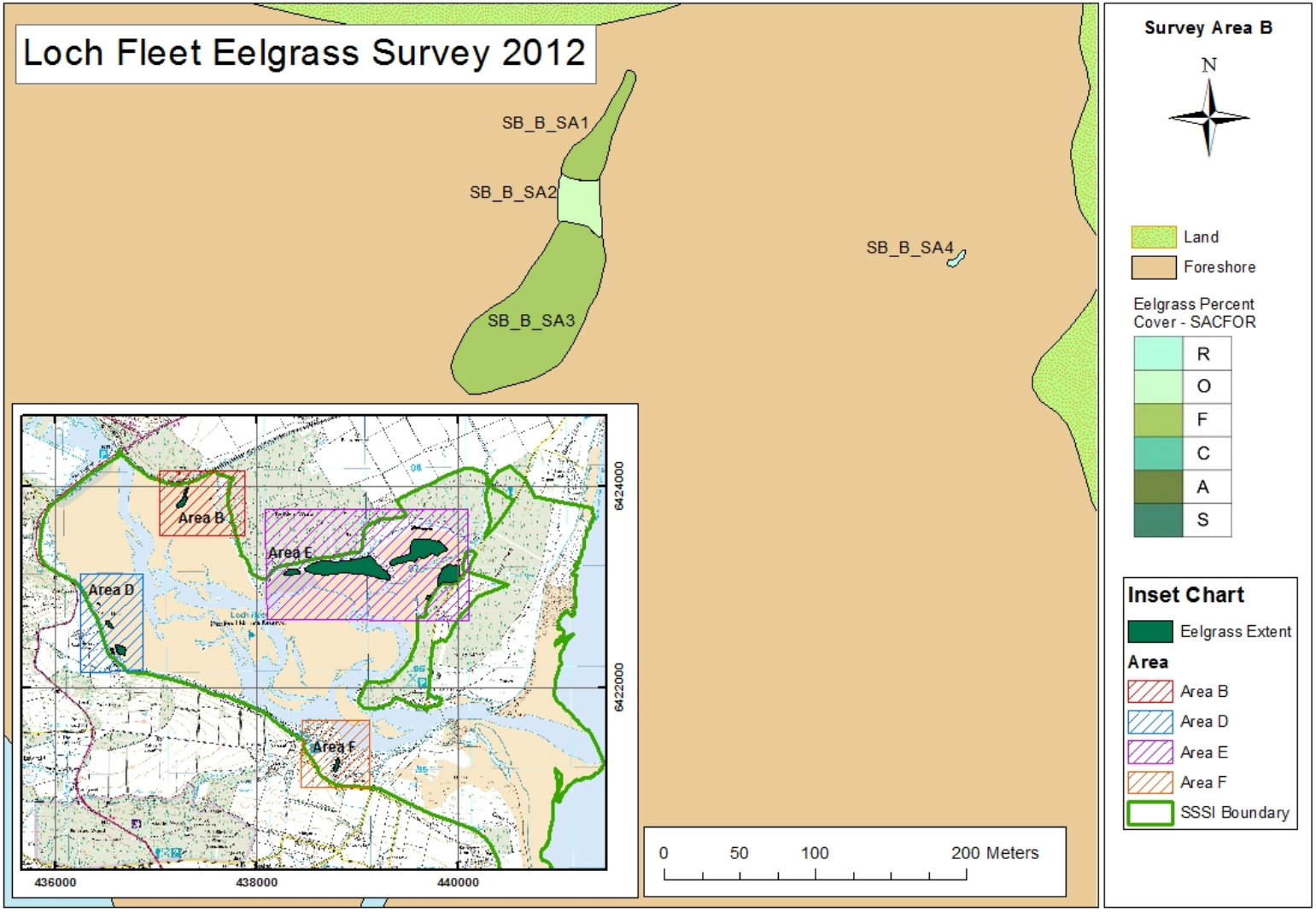

Figure 4.3. The extent of the eelgrass beds in survey area B (eelgrass percentage cover using SACFOR) in the Loch Fleet estuary in 2012.

4.1.3 Survey area C

Survey area C was situated along and beyond the Mound causeway but despite an extensive search there was no eelgrass recorded in survey area C (Table 4.4) in 2012. Parallel and immediately along the causeway was an area stretching out 50-80 m from the shoreline where the sediment was characterised by deep, soft mud (sandy mud) approximately 10 cm thick. The anoxic layer was close to the sediment surface (0.2-0.5 cm) and there was a thick layer of blanket weed on the surface across large parts of the site. Clumps of Fucoid algae were present on any small boulders or cobbles at the surface of the sediment, particularly close in to shore (see Figure 4.4). There was also a shallow water channel running parallel with the causeway approximately halfway across the area, in which the mud was less thick and the sediment was slightly harder under foot.

Beyond the 50-80 m band the sediment changed in characteristics to a muddy sand environment. The sediment was hard under foot with only a thin layer (1-2 cm) of soft sediment in places. A rippled environment was also evident in places, presumably a result of the fast flow of water as the water retrieves during the ebbing period. Blanket weed was still present but less abundant (F to O).

Table 4.4. Summary of Loch Fleet survey area C.

Survey Area	C
Target species	*Zostera angustifolia*
Sediment description	Sandy mud (within 50-80 m of the causeway), consisting of thick, soft mud, and muddy sand (beyond the mud-dominated sediment)
Eelgrass bed description	Not present
Other fauna present	*Arenicola marina*, blanket weed (abundant), empty bivalve shells (e.g. *Cerastoderma edule*), Fucoid algae

Figure 4.4. Photos from survey area C in the Loch Fleet estuary.

4.1.4 Survey area D

Survey area D encompassed an extensive sandflat (muddy sand) area along the south-western section of the Loch Fleet estuary (see Figure 3.1). The field survey team completed a detailed survey across the entire site, walking 10-15 m apart from the southern boundary of the loch to the mid-estuary channel, across from the Mound causeway to the end of the sandflat in the east.

Survey area D was characterised by muddy sand and *A. marina* but there were subtle variations across this area (Figure 4.5). The sediment became coarser towards the east where sand became more dominant and sand ripples were appearing along the eastern boundary. There were several shallow channels and dips across the site (Figure 4.5). Some originated from the freshwater stream whilst others were associated with channels created by the ebbing tide.

While *A. marina* was characteristic of the area, fucoid algae were present along the upper intertidal fringe (found predominantly on the boulders, small boulders and cobbles). Blanket weed with a cover of occasional (1-5 %) to frequent (5-9 %) was present across the site.

There were four individual eelgrass beds identified in survey area D which have been summarised in Table 4.5 with the locations of the eelgrass Sub-Areas given in Figure 4.6. All these beds were found in standing water in dips and channels on the sandflat. Note, however, that eelgrass was not found in all the dips and channels at the site (Figure 4.5).

Figure 4.5. Photos from survey area D in the Loch Fleet estuary.

Table 4.5. Summary of the eelgrass beds in Loch Fleet survey area D.

Survey Area	D
Target species	*Zostera angustifolia*
Sediment description	Muddy sand
Eelgrass bed description	*Z. angustifolia* and *Z. noltei* present, divided into four Sub-Areas (beds) as follows: **SB_D_SA1** Sparse eelgrass bed (0-5 %) overall with two dense patches. *Z. angustifolia* only. **SB_D_SA2** Sparse eelgrass bed (0-5 %) overall but with three dense patches within it, all three included in the quadrat sampling. Both *Z. angustifolia* and *Z. noltei*. **SB_D_SA3** A very sparse eelgrass bed (0-2 %). A few *Z. angustifolia* plants only. **SB_D_SA4** A very sparse eelgrass bed (0-1 %) at the shoreline fringe. *Z. angustifolia* plants only.
Other fauna present	*Arenicola marina*, blanket weed, *Ulva* spp., empty bivalve shells (e.g. *Cerastoderma edule, Macoma balthica*). Fucoid algae were present along the coastal fringe.

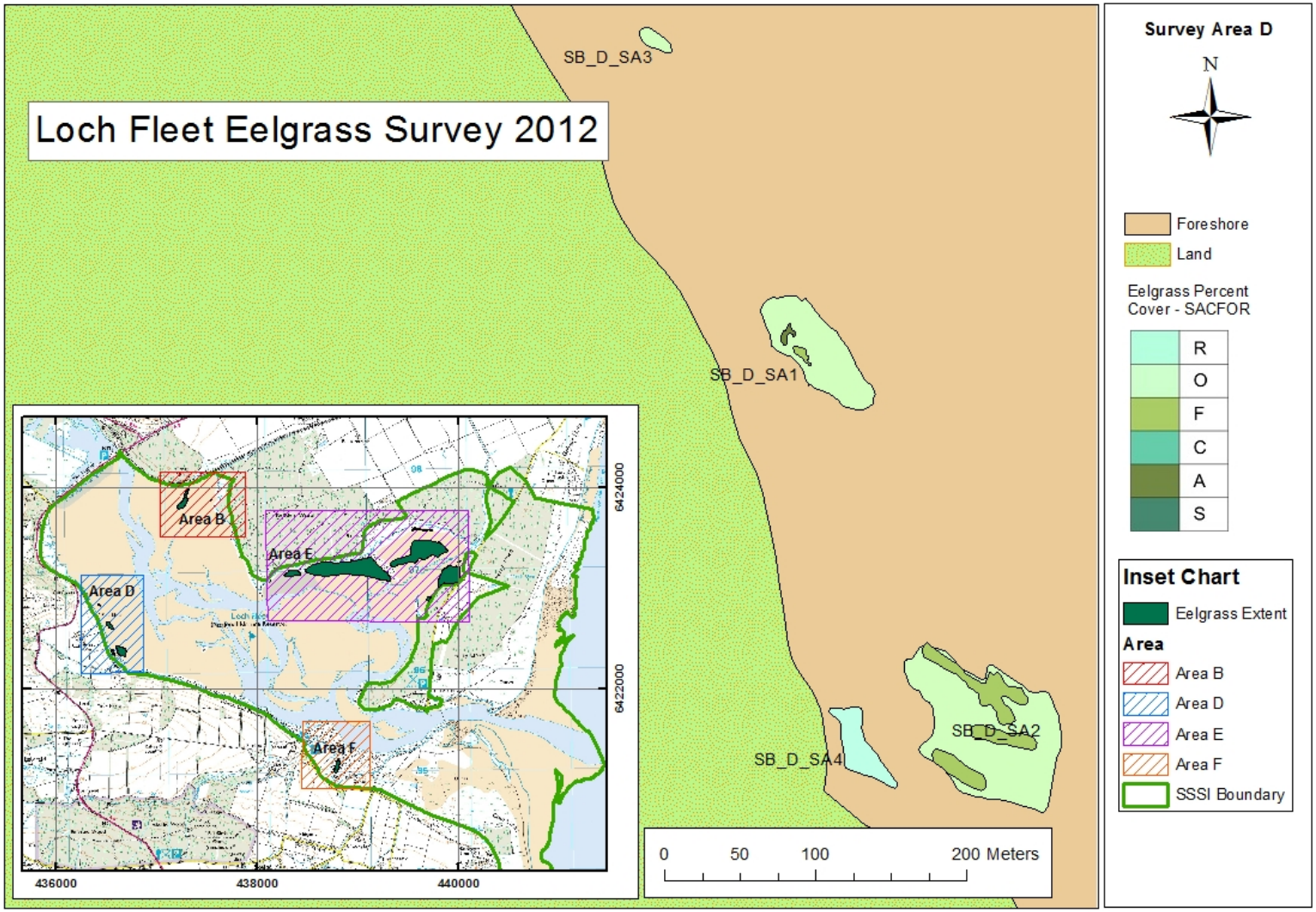

Figure 4.6. The extent of the eelgrass beds (eelgrass percentage cover using SACFOR) in survey area D in the Loch Fleet estuary in 2012.

The eelgrass Sub-Area SB_D_SA1 was approximately 100 m by 40 m in size and it was characterised by a sparse eelgrass bed with a cover in the range 0-5% (O) overall but there were two dense patches located centrally and along the southern fringe (see Figure 4.5) of the bed. The dense patches comprised *Z. angustifolia* plants only with the coverage in SA1 being 20-30% (A - western patch labelled SB_D_SA1_D1 in the Figure 4.6) and the other with a cover of 5-10% (C - eastern patch labelled SB_D_SA1_D2 in Figure 4.6).

Sub-Area SB_D_SA2 was the largest Sub-Area in survey area D being approximately 120 m by 85 m in size. This bed had a sparse eelgrass bed with an overall cover of 0-5% (O). However, there were three relatively large dense eelgrass patches within it (D1, D2 and D3 – see the GIS for further detail). All three patches were selected for more detailed study with transects laid for quadrat sampling (see below). The eelgrass densities in all three patches were 5-10% (F - C) but in places the cover reached 60 % (S). Of note was the presence of both *Z. angustifolia* and *Z. noltei*, which was particularly evident in the dense patches but seen across the Sub-Area as a whole. The identity of *Z. noltei* was established in the laboratory as the samples collected contained plants with seeds.

The eelgrass bed in Sub-Area 3 consisted of *Z. angustifolia* plants only within an area stretching 10 m by 25 m. It was a sparse bed with an overall cover of approximately 0-2% (O) with only a few plants across the entire area.

The forth Sub-Area (SB_D_SA4) was situated along the coastal fringe and fairly centrally in survey area D (see Figure 4.6). This bed was a very sparse eelgrass bed (0-1 %) of only a few *Z. angustifolia* plants. The bed was approximately 2 m outside the saltmarsh fringe and approximately 20 m from the road running along the southern fringe of the loch.

4.1.5 Survey area E

Survey area E was the largest survey area in the Loch Fleet eelgrass study 2012 covering an area approximately 2.2 km by 1.2 km. It was surrounded by pine woods (Ferry Wood to the east and Balblair Wood to the west) on both sides of the embayment (Figure 4.7). There were several small and a few large channels running across the site with the main channel (centrally in the loch) being too deep to cross by foot (see Figure 1.3).

Figure 4.7. Photos from survey area E in the Loch Fleet estuary.

The field survey started at the northern most boundary of the bay using the same survey technique as described above (i.e. survey team walking 10-15 m apart covering the entire sand- and mudflat inside the main channel). The encountered eelgrass beds were then mapped and described (see Table 4.6 and Figure 4.8).

Table 4.6. Summary of the eelgrass beds in Loch Fleet survey area E.

Survey Area	E
Target species	*Zostera angustifolia*
Sediment description	Muddy sand and sandy mud
Eelgrass bed description	*Z. angustifolia* and *Z. noltei* beds present, divided into seven Sub-Areas (beds) as follows: **SB_E_SA1** Small, sparse eelgrass bed with 0-5% (O) cover. *Z. angustifolia* plants only. **SB_E_SA2** Large, sparse bed overall (0-5 %, O) but with a large dense (5-10% cover, F - C) patch. Both *Z. angustifolia* and *Z. noltei* present. **SB_E_SA3** Eelgrass plants at the saltmarsh fringe. *Z. angustifolia* plants only, found in small patches in the tiny (c. 1 m^2) saltmarsh inlets. Cover 0-5% (O). **SB_E_SA4** Sparse eelgrass patch near the eastern spit. Cover of 0-5% (O) of both species but with a small (2 m^2) patch of *Z. noltei* with a higher cover (5-10%, F - C) in the southern corner of the patch. **SB_E_SA5** Large eelgrass bed in muddy sediments, half of the bed (southern extent) at a high cover of up to 80% with remaining cover being around 10% (C). *Z. angustifolia* plants only. **SB_E_SA6** Large eelgrass bed in muddy sediments, half of the bed (southern extent) at a high cover of up to 60% with remaining cover being around 5-10% (F – C). *Z. angustifolia* plants only. **SB_E_SA7** A large, sparse eelgrass bed (0-5% cover, O) across the central, inner part of the bay. A denser patch at the southern edge (5-10% cover, F - C). Both *Z. angustifolia* and *Z. noltei* present.
Other fauna present	*Arenicola marina*, blanket weed, *Ulva* spp., empty bivalve shells (e.g. *Cerastoderma edule*). Fucoid algae were present along the coastal fringe and on the spits.
Note	All the eelgrass beds were found in areas of standing water and often together with blanket weed. In areas SA5 and SA6 the competition for space with blanket weed appeared particularly notable – found together across the two sites.

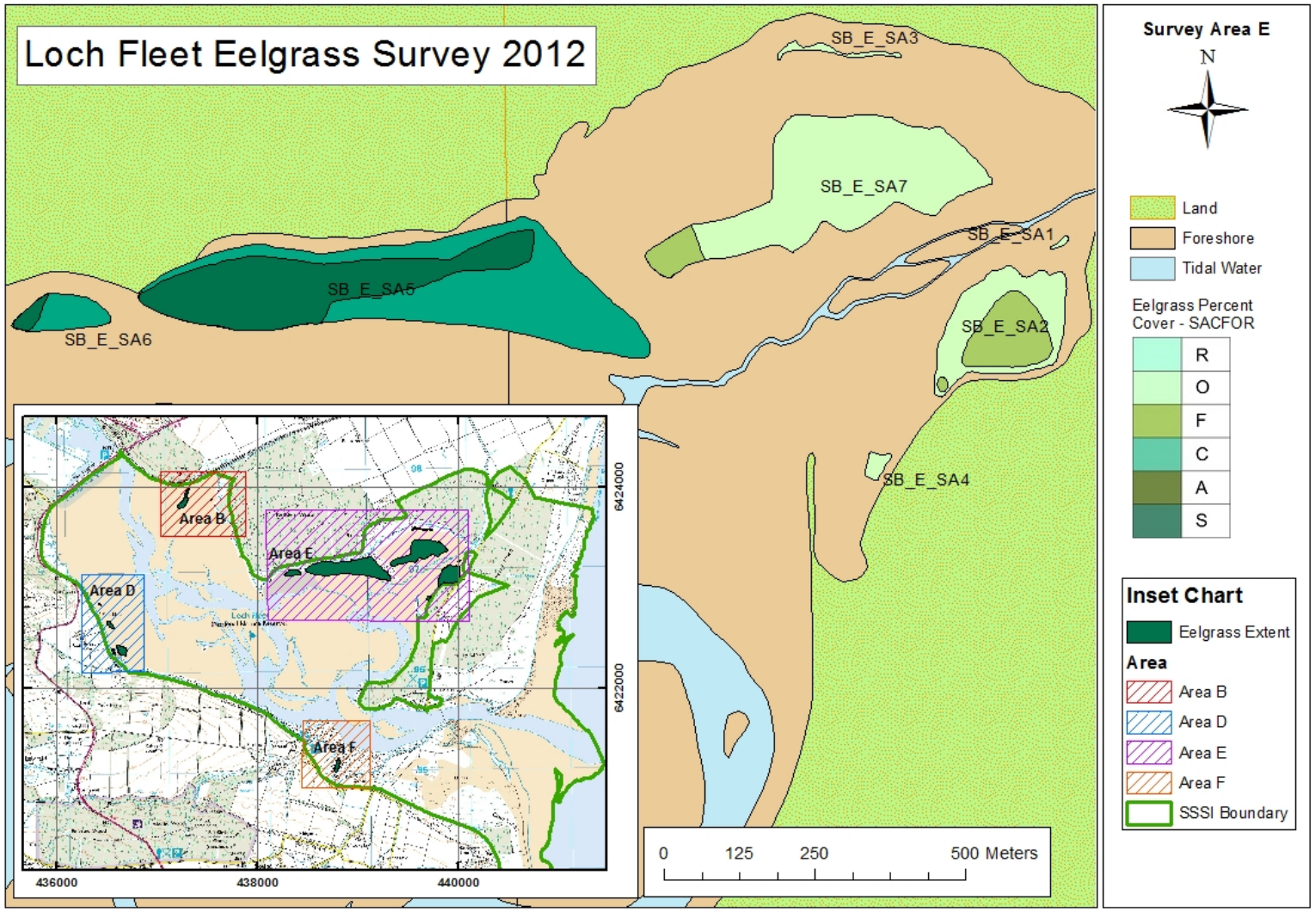

Figure 4.8. The extent of the eelgrass beds in survey area E in the Loch Fleet estuary in 2012 (eelgrass percentage cover using SACFOR).

The Sub-Area 1 (SB_E_SA1) eelgrass bed was a relatively small (35 m long and 12 m wide) patch near the eastern fringe (Figure 4.8). It was a sparse eelgrass bed with 0-5% (O) cover. Apart from *Z. angustifolia* it was also characterised by *A. marina* and blanket weed. The bed was found in an area of standing water (a dip in the sandflat) as were all other beds in this survey area and beyond.

The eelgrass bed in Sub-Area 2 (SB_E_SA2) was a large (300 m long and 180 m wide at the widest point) but sparse bed (overall cover of 0-5%). There was also a large (150 m by 130 m) relatively denser (5-10% cover) patch in the middle of SA2 with eelgrass cover up to c. 60 % (S). Both *Z. angustifolia* and *Z. noltei* plants were present but the latter were particularly evident in the dense patch.

The eelgrass bed found at SB_E_SA3 consisted of *Z. angustifolia* plants found in the tiny inlets (c. 1 m^2) at the saltmarsh fringe. The plants were typically found in small patches within the fringe but these did not extend out into the bay itself. It was not a continuous cover across the entire area but the plants occurred regularly (O) across this saltmarsh area which was 200 m long. The maximum width of the Sub-Area was around 15 m but typically the plants were found in patches only a few metres across (see Figure 4.8). The eelgrass cover ranged within 0-5% (O).

The eelgrass bed in Sub-Area 4 was a sparse eelgrass patch near the eastern spit with both *Z. angustifolia* and *Z. noltei* (Figure 4.8). The eelgrass cover ranged between 0-5% (O) but there was a small (2 m^2) patch of *Z. noltei* with a higher cover of c. 5-10% (F – C). The patch was approximately 50 m long and 40 m wide.

The eelgrass bed (*Z. angustifolia*) in Sub-Area 5 (SB_E_SA5) was large, being approximately 850 m long and 190 m wide. The sediment was characterised by thick, soft mud (c. 15 cm thick) with blanket weed being abundant across the entire area. Half of the eelgrass bed was relatively dense with a high cover at the southern extent reaching a maximum cover of up to 80% (S; see Figure 4.8). The remaining part of the bed was sparser with a cover around 10% (C). Plants were found all along the upper reaches of the intertidal zone. At the edge of the area there was a very clear boundary outside of which there were no plants at all. This boundary was 40 m away from a deep channel running immediately beyond the bed. Other fauna and flora present here included *A. marina*, fucoid algae and a high abundance of empty bivalve shells.

Sub-Area 6 (SB_E_SA6) was very similar in characteristics to Sub-Area 5. It was a medium-sized *Z. angustifolia* eelgrass bed (160 m long and 60 m wide). The soft, thick mud (c. 15 cm) was covered and characterised by blanket weed but the eelgrass plants appeared healthy. Half of the bed (southern extent) had a high cover of up to 60% whilst the cover in the remaining part of the bed was around 5-10%.

The last eelgrass bed in survey area SB E was Sub-Area 7 (SB_E_SA7). This bed was a large (590 m long and 230 m wide at the widest point), sparse eelgrass bed stretching across the central part of the bay (Figure 4.8). The eelgrass cover ranged between 0-5% (O) overall (there were patches with no eelgrass) but there was a denser patch at the southern edge (5-10% cover, F - C), an area immediately north of the spit. There were *Z. angustifolia* and *Z. noltei* present in this patch whilst *Z. angustifolia* plants appear to be the only species present in the remainder of the bed.

Like all the other eelgrass beds, Sub-Area 7 eelgrass plants were found in standing water. There were several dips and channels across this eelgrass bed but of note was the lack of eelgrass plants in some of these dips and channels despite the fact that the habitat appears

suitable. Blanket weed was present across the entire Sub-Area, a factor potentially linked to the lack of eelgrass as these plants might compete for space in the areas of standing water (pers. obs.).

4.1.6 Survey area F

Access to survey area F was gained across the saltmarsh towards survey area D as the fences along the road were high and there were several 'private' signs preventing access.

The bay had mixed sediment characteristics across the site. Coarse sediments (gravels and cobbles) were found along the fringes of the bay. Sandy mud sediments with clumps of fucoid algae (on rocks) as well as a mussel bed were found centrally in the bay. Muddy sand characteristic of the other sandflats in Loch Fleet were found between these other two habitats but eelgrass was only found in one place in the bay.

The eelgrass bed was located in the south-western corner of the bay (Figure 4.9). Only *Zostera noltei* plants were present at the time of sampling. The sediment was characterised by muddy sand and hard under foot conditions (summary in Table 4.7). The bed was interspersed by a high abundance of fucoid algal clumps, particularly on the rocky (cobbles and small boulders) outcrops.

The eelgrass bed was approximately 130 m long and 40 m at the widest point. Coverage varied across the area but with an overall it range between 0-10% (F – C). There was also a denser patch running north to- south along the eastern fringe of the bed (size approximately 100 m long by 10 m wide; see Figure 4.9) where the eelgrass cover reached up to 40 % (S).

Table 4.7. *Summary of the eelgrass bed in Loch Fleet survey area F.*

Survey Area	F
Target species	*Zostera angustifolia*
Sediment description	Muddy sand
Eelgrass bed description	*Z. noltei* plants present in one Sub-Area (bed): **SB_F_SA1** Eelgrass bed with a cover of 0-10 % (F – C), *Z. noltei* plants only.
Other fauna present	*Arenicola marina*, blanket weed, *Ulva* spp., abundant with empty *Mytilus edulis* shells (e.g.). Fucoid algae were present across the site on boulders and cobbles and along the fringe of the bay.

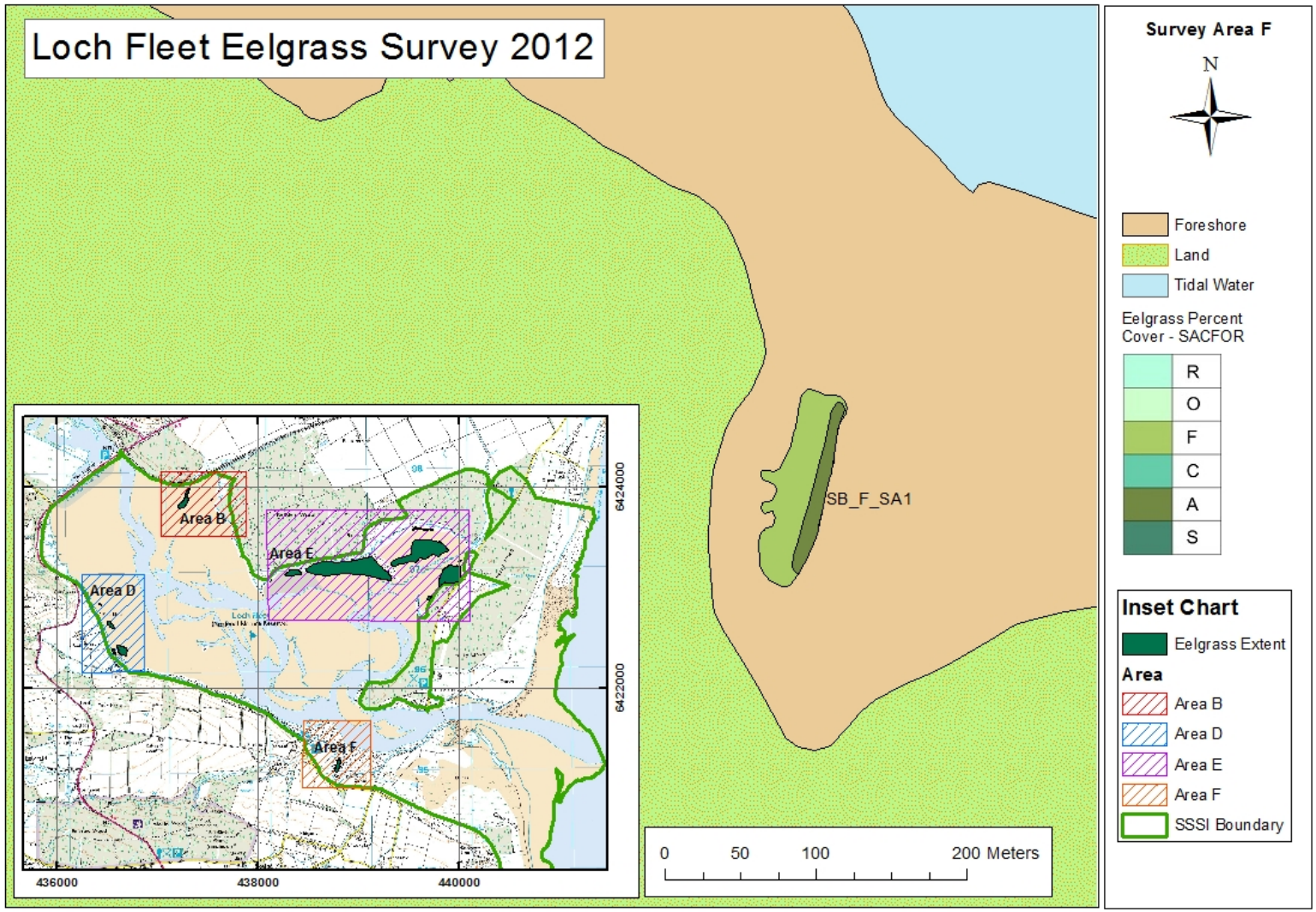

Figure 4.9. The extent of the eelgrass beds in survey area F in the Loch Fleet estuary in 2012 (eelgrass percentage cover using SACFOR).

4.2 Quantitative quadrat sampling

The quadrat surveys were completed along transects in survey areas B, D, E and F (see Figure 3.1). The results from the surveys are given below with the positions of the transect start of line and end of line in Appendix 3, the positions of each quadrat in Appendix 4 and the quadrat survey data in Appendix 5.

4.2.1 Survey area B

There were two main eelgrass communities in survey area B (SA1 and SA3) suitable for quadrat survey work (SA2 was sparse and not suitable for quantitative data collection). However, SA1 was relatively small and only sufficiently large for one quadrat transect. The SA3 eelgrass bed was patchy and again only one area was deemed suitable for quadrat data collection due to the patchy distribution of eelgrass (Figure 4.10).

With the aim of acquiring data from 30 quadrats in each survey area 15 quadrats were randomly laid along each transect line (see Figures 4.10 and 4.12). The results are given in Table 4.8 and Figure 4.11 with more detail in Appendix 5.

The mean eelgrass cover (Figure 4.11) in the two areas was similar (16% and 10%) whilst the shoot density was much higher in SA1 (58%) compared to SA3 (10%). This is believed to be a result of the large number of *Z. noltei* shoots in SA1 (small and numerous across the site) whilst SA3 was devoid of any *Z. noltei* plants (A and B versus C and D in Figure 4.12). The large standard deviation also reflects the variation in shoot density across SA1 compared to SA3. The relative difference in mean frond length (8 cm vs. 17 cm) is believed to be a further reflection of the difference in *Z. angustifolia* and *Z. noltei* present in the two areas as *Z. noltei* plants were found to be a lot shorter than the *Z. angustifolia* plants.

The two eelgrass species were mixed across SA1 and it was not possible to sample only one species using a transect survey methodology. Individual quadrats could potentially be laid and sampled but it would be randomly across each bed and locations would be selected subjectively rather than being randomly selected as was the case in the current study.

Table 4.8. Summary of quantitative data in survey area B Sub-Areas 1 and 3 (mean ±1 S.D.).

Survey Area B	**SA1**	**SA3**
Eelgrass Cover (%)	**15.9** (±12.1)	**10.0** (±11.4)
Shoot Density (ind./0.0625 m^2)	**57.9** (±37.7)	**9.9** (±8.6)
Frond Length (cm)	**8.4** (±1.4)	**17.3** (±4.7)

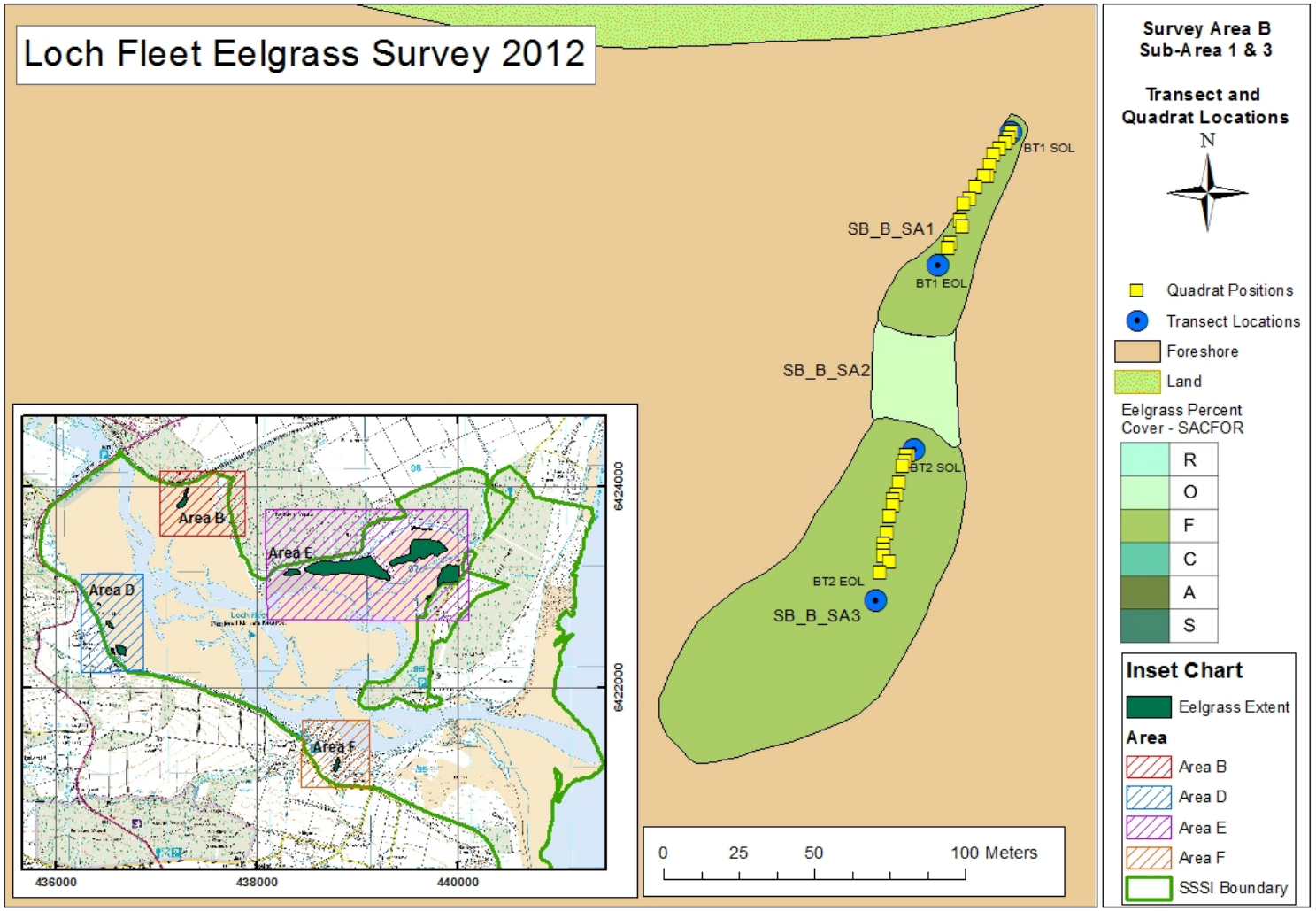

Figure 4.10. The positions of the quadrats in survey area B (yellow squares - quadrat sample location; blue circles – start and end of transect lines).

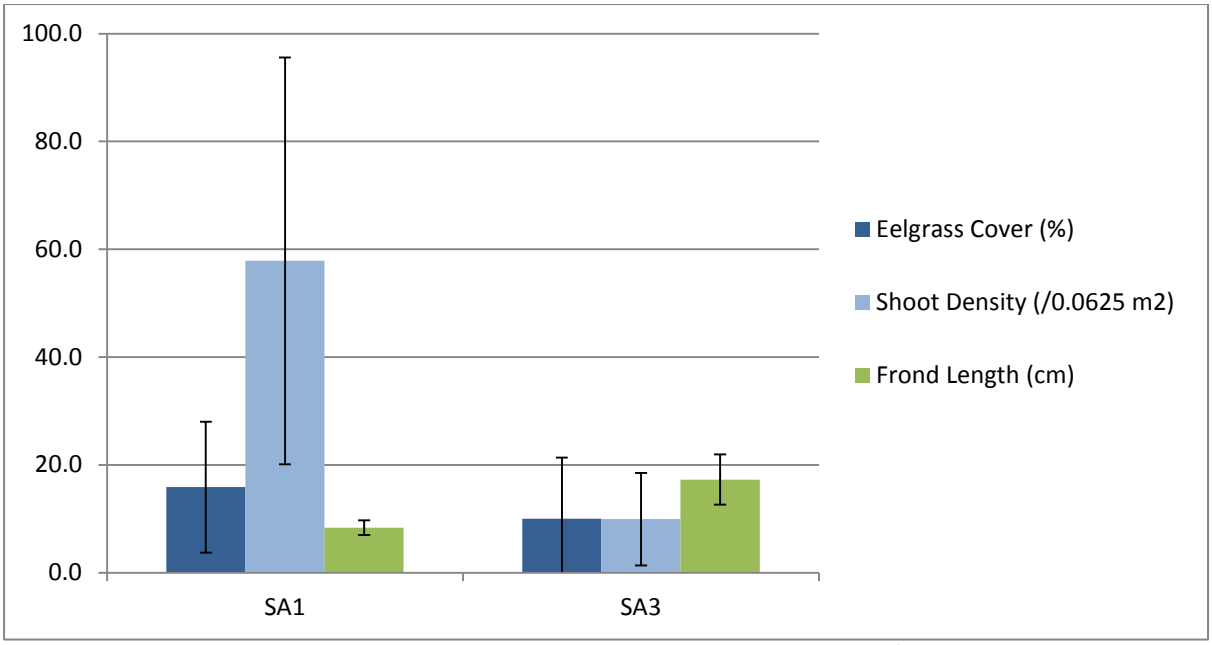

Figure 4.11. Mean eelgrass cover (%), shoot density (ind/0.0625 m^2) and frond length (cm) along two transects (SA1 and SA3) in survey area B (Error Bars ± 1 S.D.).

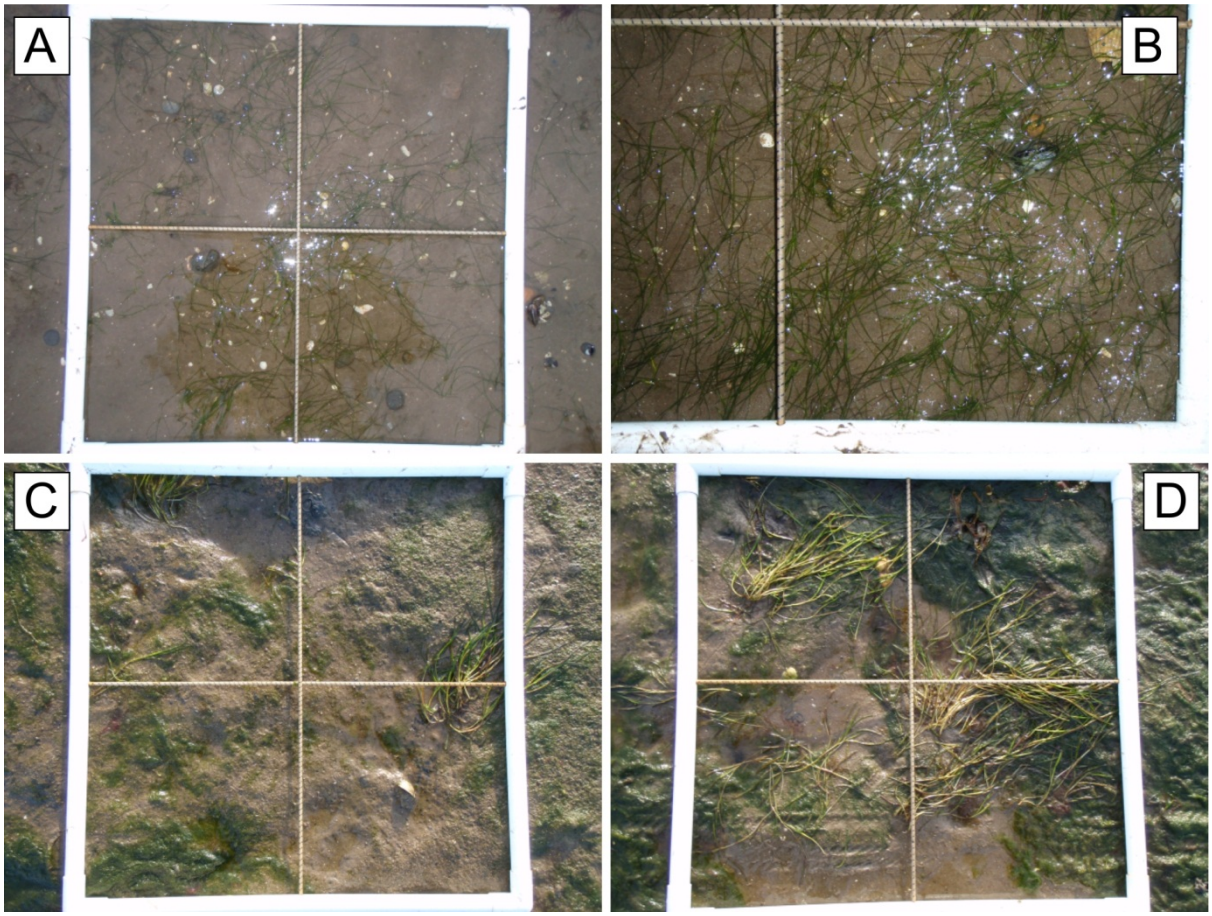

Figure 4.12. Examples of photographs of quadrats within survey area B (A SA1_Q06- ; B – SA1_Q14; C – SA3_Q15; D – SA3_Q07).

4.2.2 Survey area D

There were three Sub-Areas (SA1, SA2 and SA3) in survey area D with eelgrass suitable for quadrat survey work (Figure 4.13). All three areas had both *Z. angustifolia* and *Z. noltei* plants. Observations suggest some differences in eelgrass cover, shoot densities and frond lengths at the three different transects (Table 4.9 and Figures 4.14 and 4.15 as well as Appendix 5). Eelgrass cover and shoot density was highest in SA3 compared to the other two Sub-Areas while frond length was the shortest. Sub-Area 2 had the lowest eelgrass cover and shoot density but the longest mean frond length. These results suggest the highest number of *Z. angustifolia* and lowest number of *Z. noltei* plants in SA1 with the opposite being the case in SA3 (see Table 4.9 and Figures 4.14 and 4.15).

Table 4.9. Summary of quantitative data in survey area D Sub-Areas 1, 2 and 3 (mean ±1 S.D.).

Survey Area D	**All**	**SA1**	**SA2**	**SA3**
Eelgrass cover (%)	**16.7** (±14.8)	**7.8** (±12.5)	**14.4** (±6.2)	**27.9** (±16.6)
Shoot density (ind./0.0625 m^2)	**31.5** (±44.9)	**7.4** (±11.1)	**23.3** (±8.8)	**63.9** (±66.5)
Mean frond length (cm)	**10.5** (±3.3)	**13.5** (±3.4)	**10.8** (±2.3)	**8.8** (±3.2)

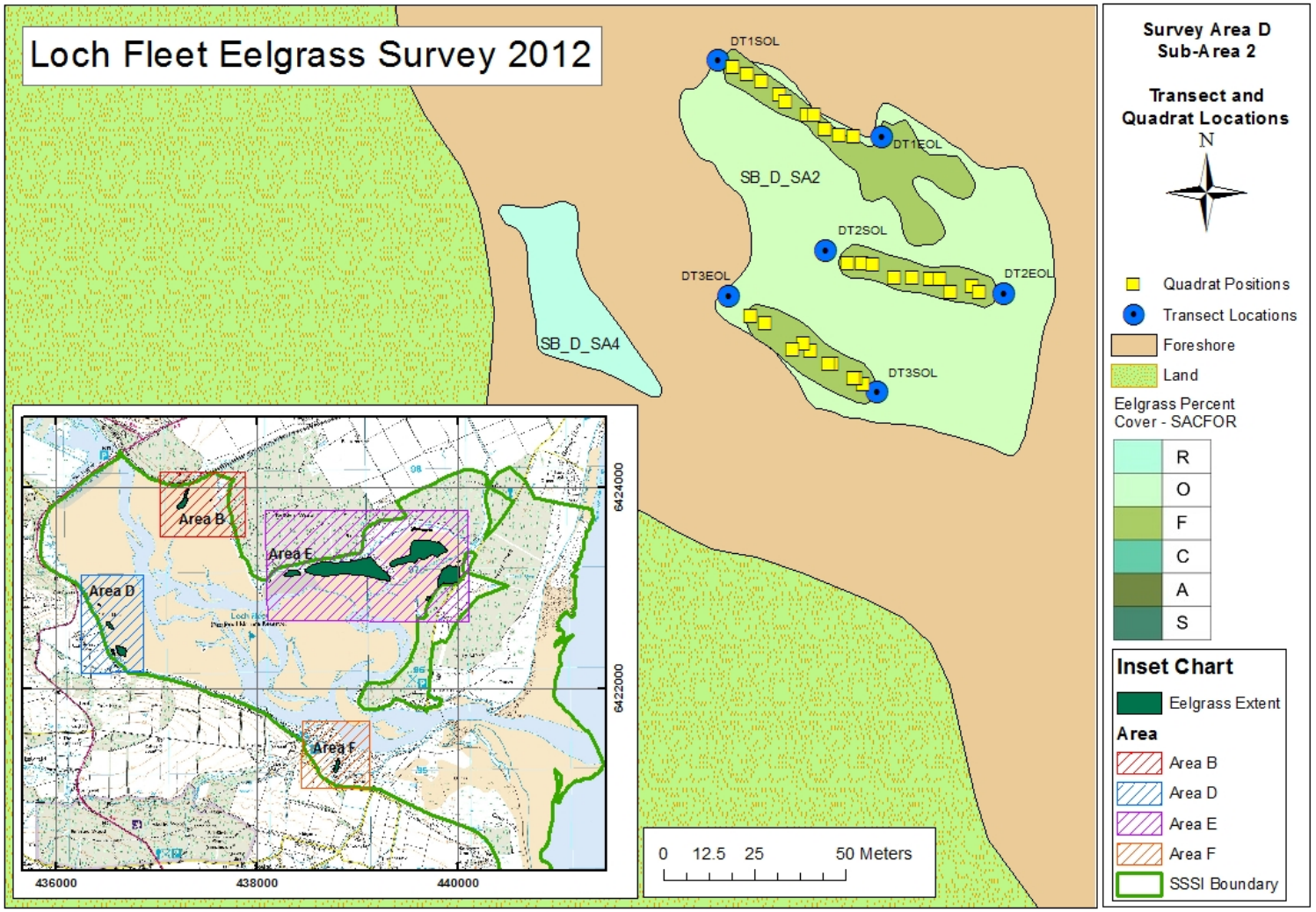

Figure 4.13. The positions of the quadrats in survey area D (yellow squares - quadrat sample location; blue circles – start and end of transect lines).

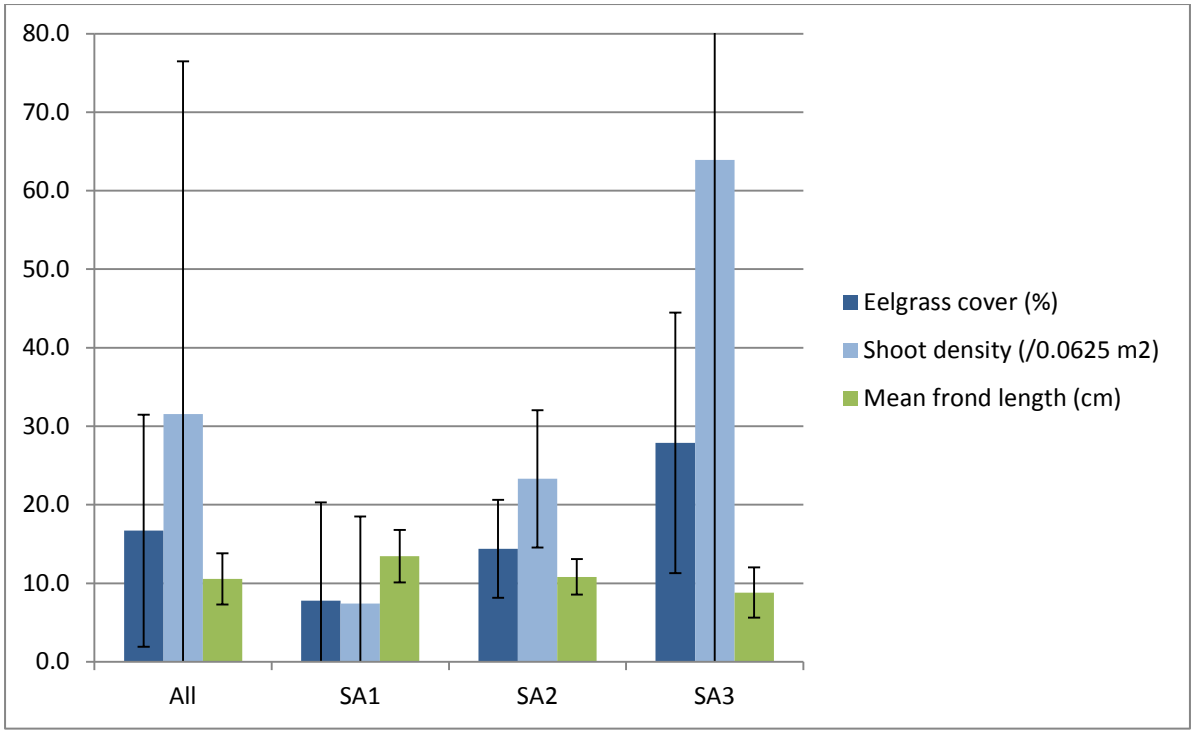

Figure 4.14. Mean eelgrass cover (%), shoot density (ind/0.0625 m^2) and frond length (cm) along the three transects (SA1, SA2 and SA3) in survey area D (Error Bars ± 1 S.D.; note values in Table 4.9 for additional information).

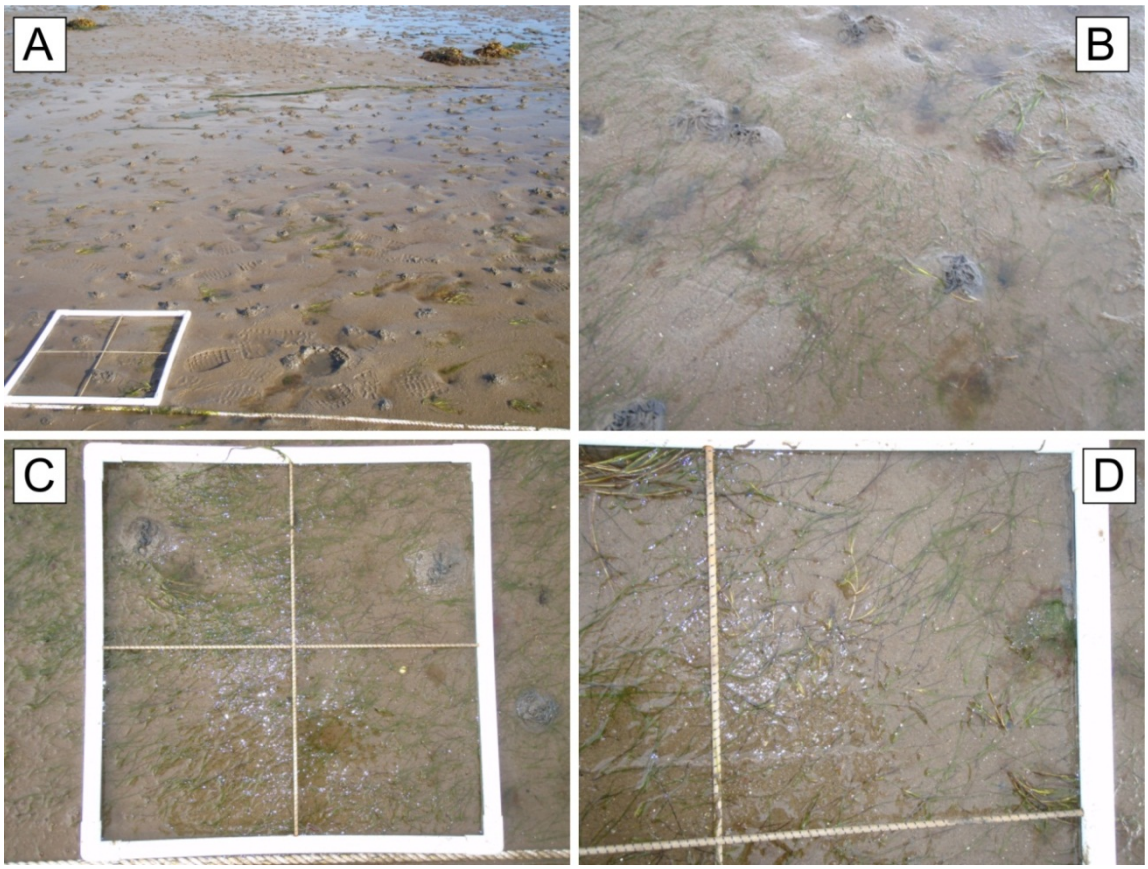

Figure 4.15. Examples of photographs of quadrats within survey area D (A – SA2_T1; B – SA2_T2; C – SA2_T3_Q07; D – SA2_T3_Q06).

4.2.3 Survey area E

Two Sub-Areas were surveyed within survey area E; SA2 and SA5, with two transects in SA5 and one in SA2 (Figures 4.16 and 4.17). Whilst both *Z. angustifolia* and *Z. noltei* were present in SA2, only *Z. angustifolia* was identified in SA5 (Figure 4.18).

In terms of selecting locations for the quadrat transects there was only one obvious section within SA2 suitable for quadrat survey work whilst large sections of SA5 could have been investigated.

Summaries of the quadrat data are given in Table 4.10 and Figure 4.19 with all of the data given in Appendix 5. The mean eelgrass cover was similar across the two Sub-Areas (SA5 and SA2) at approximately 35% (Table 4.10 and Figure 4.19). Shoot density, however, was much higher in SA2 compared to SA5. This is believed to be linked to the presence of *Z. noltei* in SA2 (numerous small plants present in this location) but the lack of *Z. noltei* in SA5.

The frond lengths were also different between the two Sub-Areas with longer frond lengths in SA5 (21 cm) compared to SA2 (13 cm), which is believed to be linked to the presence of large numbers of *Z. noltei* plants at SA2 (see Figure 4.18). The large standard deviation in SA2 suggests high variability in the lengths of the fronds which is most likely linked to the presence of large *Z. angustifolia* plants and small *Z. noltei* plants.

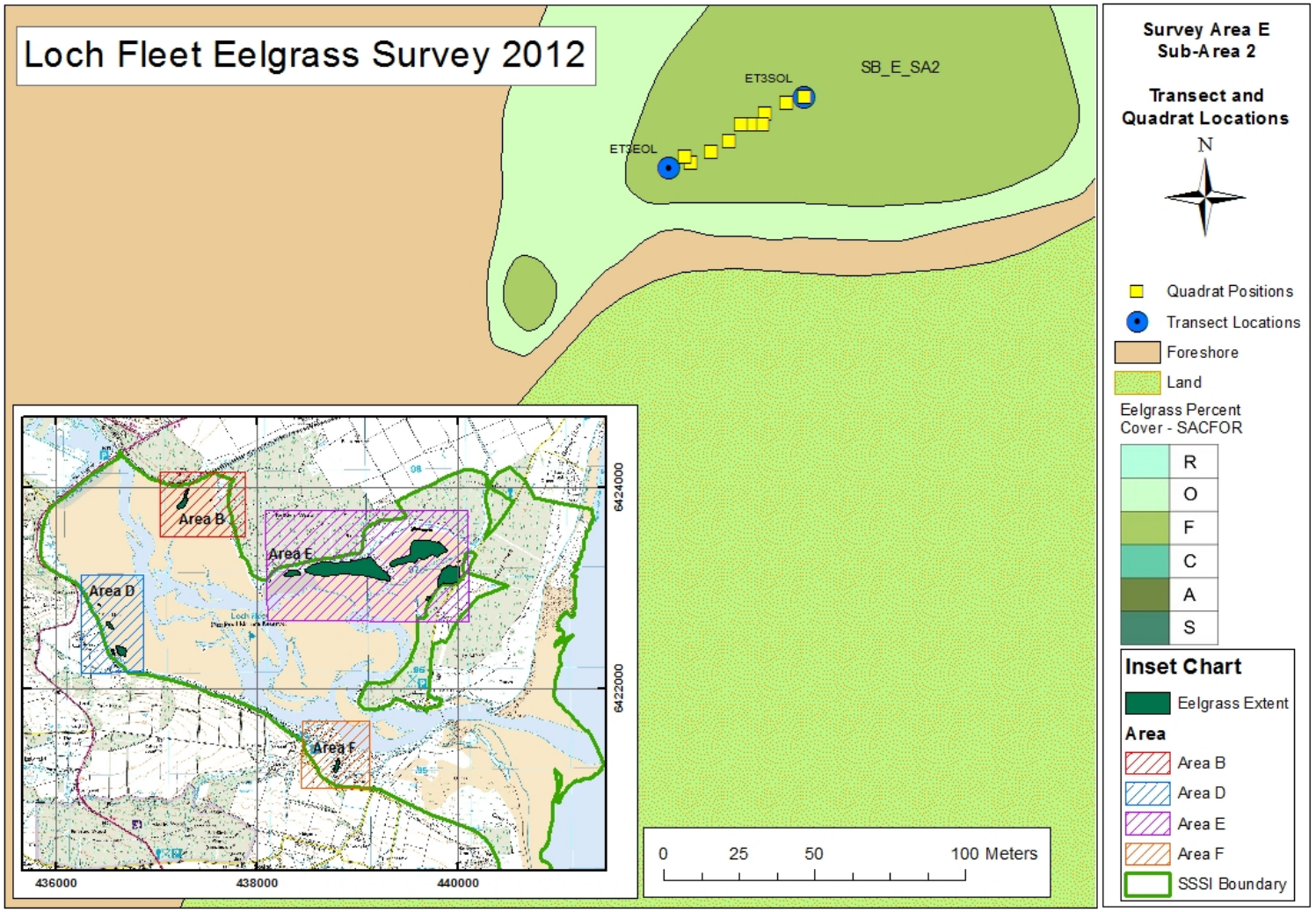

Figure 4.16. The positions of the quadrats in survey area E (Sub-Area 2; yellow squares - quadrat sample location; blue circles – start and end of transect lines).

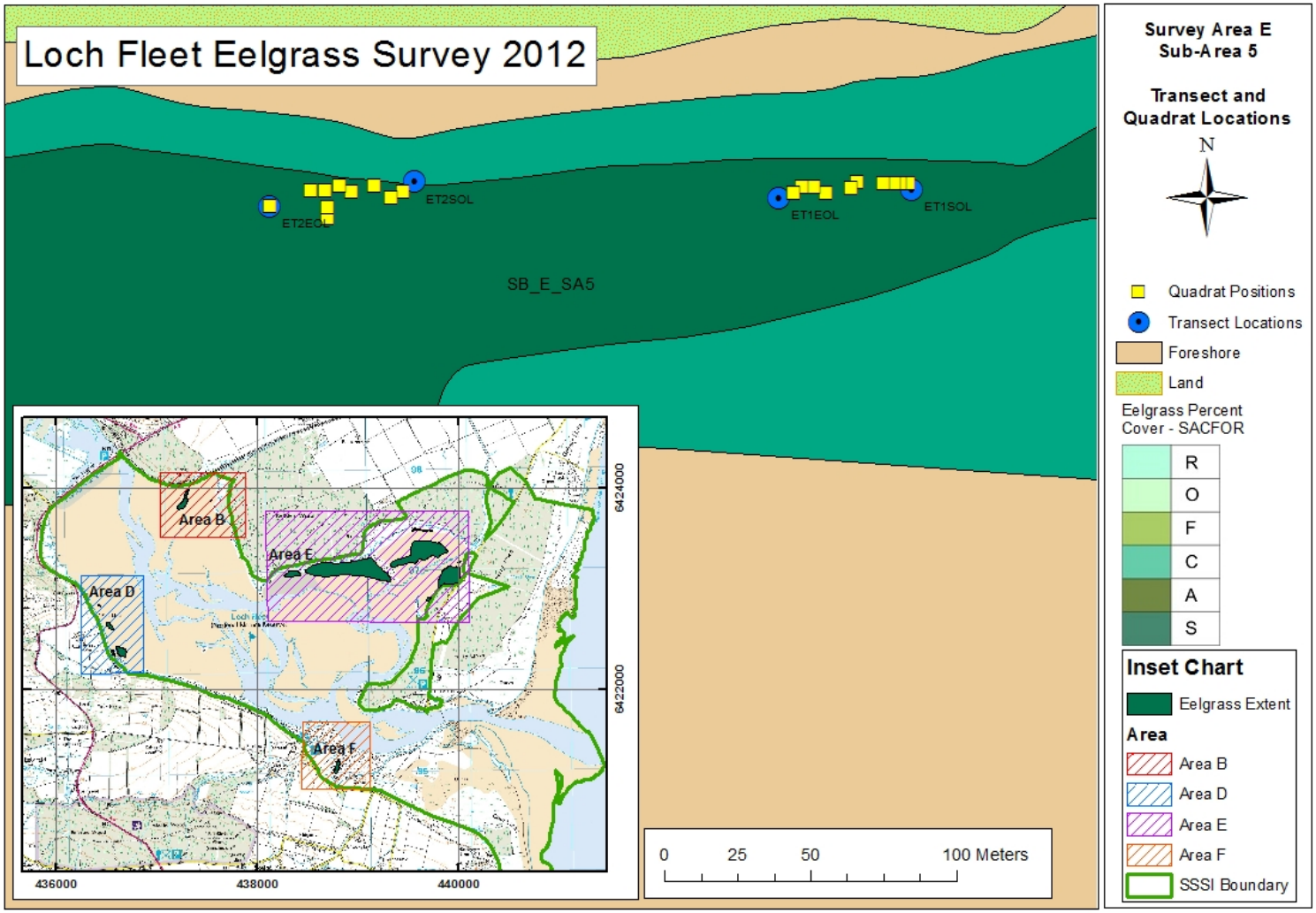

Figure 4.17. The positions of the quadrats in survey area E (Sub-Area 5; yellow squares - quadrat sample location; blue circles – start and end of transect lines).

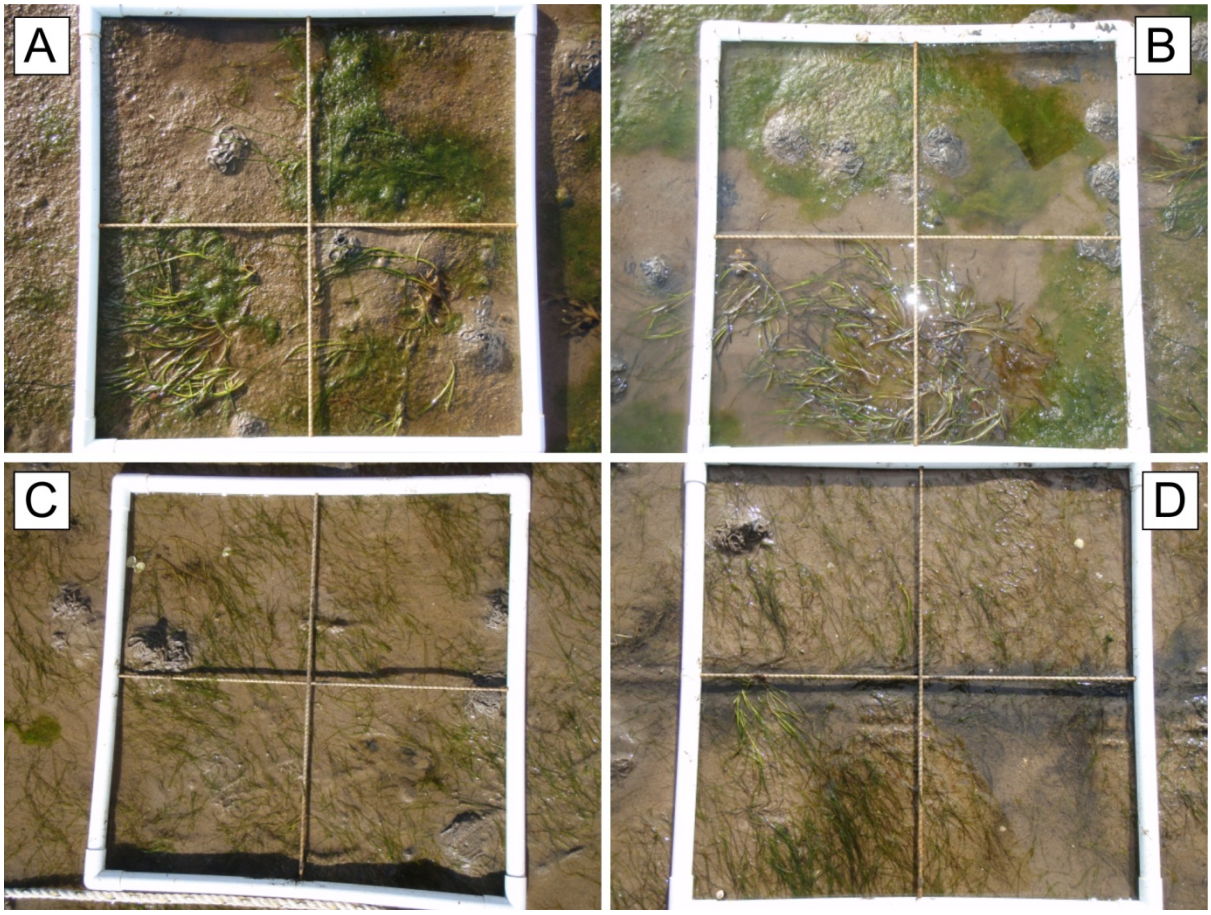

Figure 4.18. Examples of photographs of quadrats within survey area E (A – SA5_T1_Q01; B – SA5_T2_Q01; C – SA2_T3_Q01; D – SA2_T3_Q04).

Table 4.10. Summary of quantitative data in survey area E - Sub-Areas 2 and 5 (mean ±1 S.D.).

Survey Area E	**All**	**SA5**	**SA2**
Eelgrass Cover (%)	**33.2** (±15.2)	**30.8** (±14.8)	**38.0** (±15.5)
Shoot Density (ind./0.0625 m^2)	**58.6** (±57.9)	**30.0** (±12.8)	**115.8** (±70.6)
Frond Length (cm)	**18.6** (±5.4)	**21.3** (±4.2)	**13.1** (±2.6)

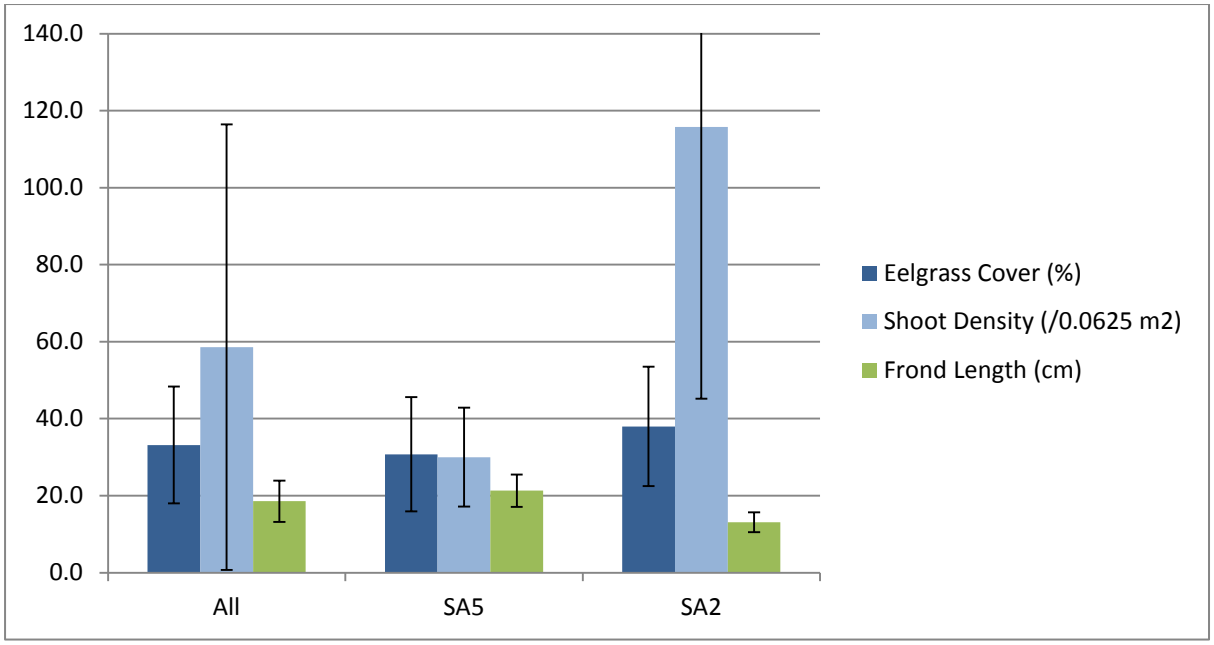

Figure 4.19. Mean eelgrass cover (%), shoot density (ind/0.0625 m^2) and frond length (cm) along the three transects (SB_E_SA5_T1, SB_E_SA5T2 and SB_E_SA2_T3) in survey area E (Error Bars ± 1 S.D.).

4.2.4 Survey area F

The eelgrass in survey area F was sparse overall and only one section could be surveyed using quadrats to avoid a lot of zero counts (for all three parameters). The plants were all *Z. noltei* and confined to the south-west corner of the bay (Figure 4.20). The quadrat transect was laid along the dense patch along the eastern fringe of the patch to ensure decent cover along the entire transect. The results are given in Table 4.11, Figure 4.21 and in Appendix 5).

The mean eelgrass cover was approximately 20%, which was higher than the overall cover across the site. The large number of shoots (c. 50 ind./0.0625 m^2) with the short frond lengths (c. 6 cm in length) confirms the presence of *Z. noltei* plants in this area (Figure 4.22).

The photographs illustrate the presence of Fucoid algae in survey area F (Figure 4.22). These plants were present on rocky outcrops across the site but also along the fringe of the bay.

Table 4.11. Summary of quantitative data in survey area F (mean ±1 S.D.).

Survey Area F	**SB_F_SA1**
Eelgrass cover (%)	**17.7** (±13.1)
Shoot density (ind./0.0625 m^2)	**48.5** (±34.1)
Mean frond length (cm)	**6.4** (±2.4)

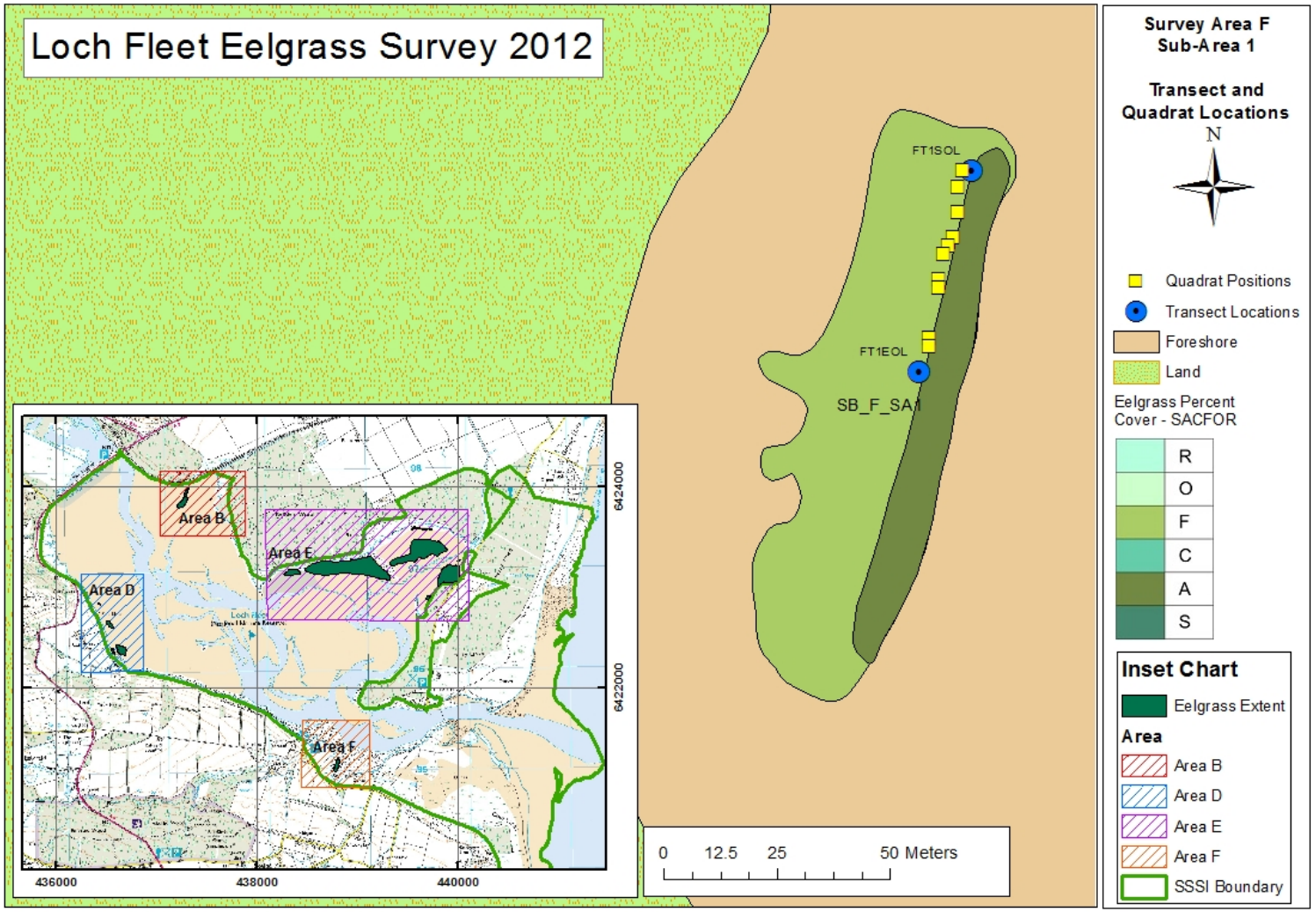

Figure 4.20. The positions of the quadrats in survey area F (yellow squares - quadrat sample location; blue circles – start and end of transect lines).

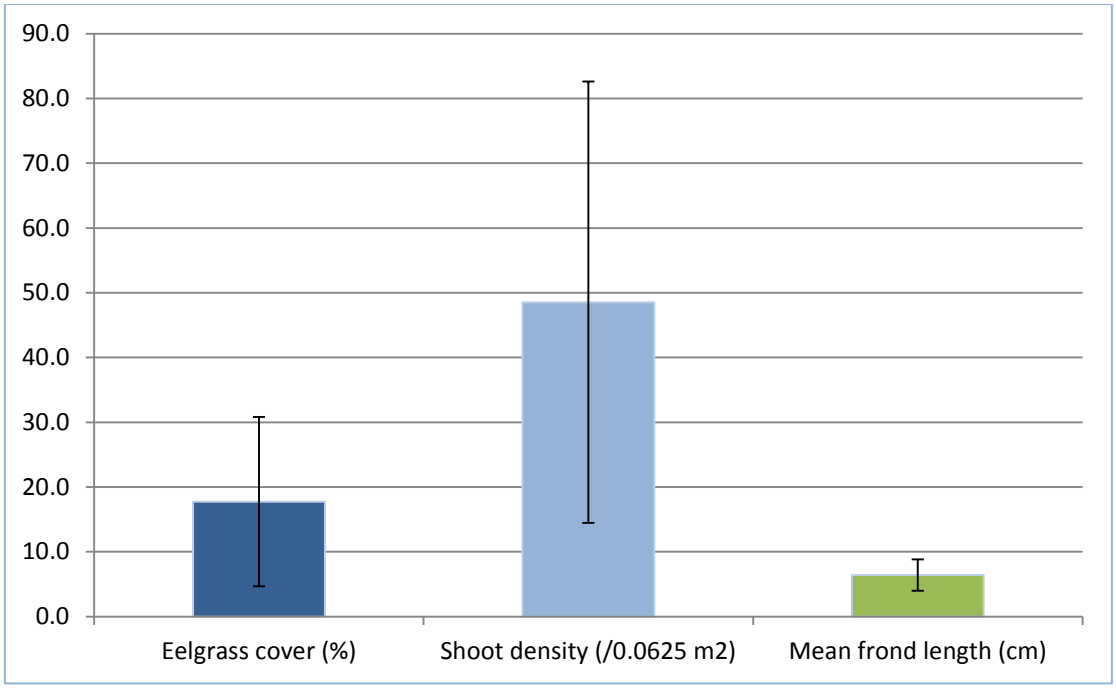

Figure 4.21. Mean eelgrass cover (%), shoot density (ind/0.0625 m^2) and frond length (cm) along the transect in survey area F (Error Bars ± 1 S.D.).

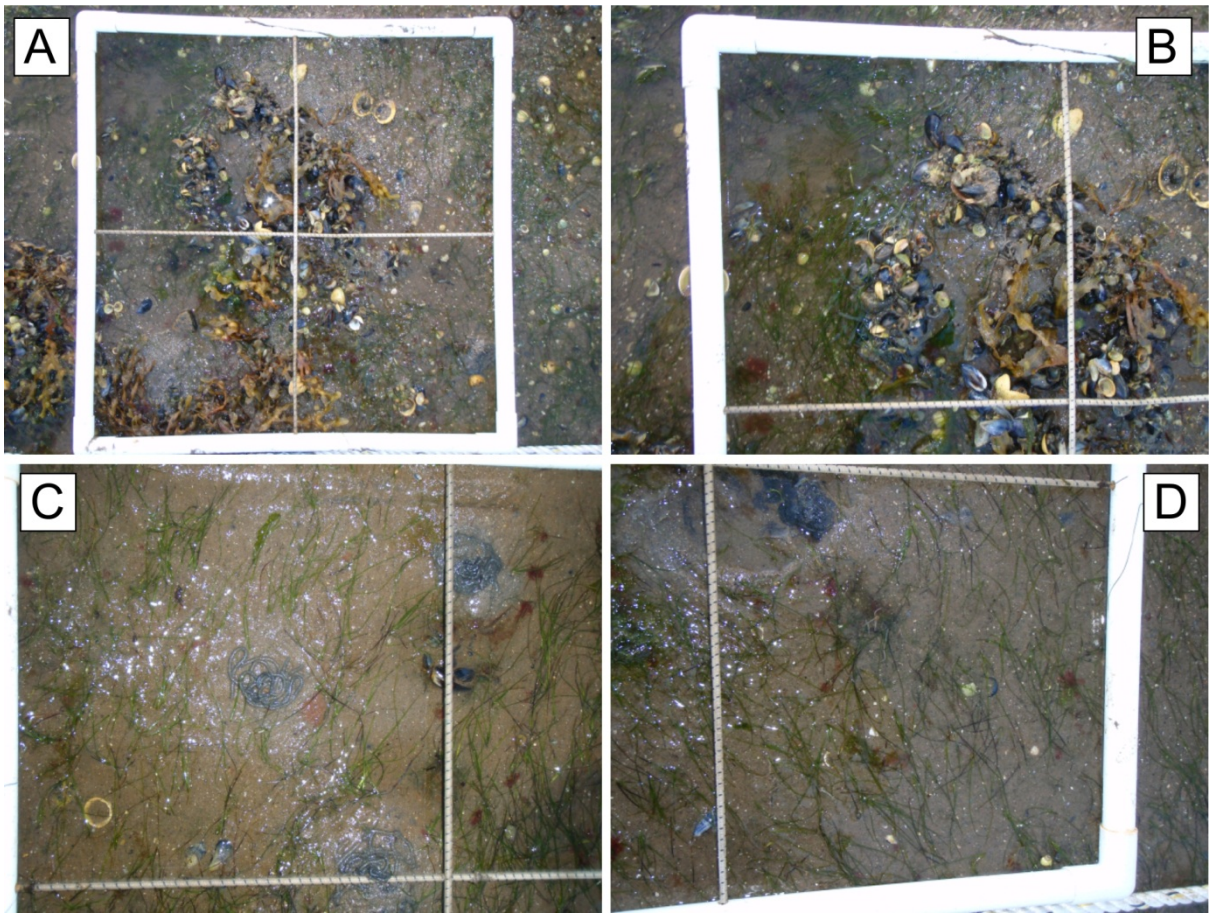

Figure 4.22. Examples of photographs of quadrats within survey area F (A – SA1_T1_Q01; B – SA1_T1_Q01; C – SA1_T1_Q08; DB – SA1_T1_Q04).

5. DISCUSSION

5.1 Eelgrass species and the extent of eelgrass beds in Loch Fleet

5.1.1 Eelgrass species in Loch Fleet

The Loch Fleet surveys in 2000 and 2006 reported the presence of three *Zostera* species in the estuary; *Z. angustifolia* and *Z. noltei* during the 2000 survey (SNH, 2000) and *Z. marina* during the 2006 survey (SNH, 2006b). The eelgrass survey in 2012 confirmed the presence of both *Z. angustifolia* and *Z. noltei* in the Loch Fleet estuary.

The 2012 survey also established *Z. angustifolia* and *Z. noltei* forming three different types of eelgrass beds in the Loch Fleet estuary; 1) *Z. angustifolia* beds; 2) mixed *Z. angustifolia* and *Z. noltei* beds; and 3) *Z. noltei* beds. In 2000 the beds were reportedly either *Z. angustifolia* beds or mixed *Z. angustifolia* and *Z. noltei* beds, but no *Z. noltei* beds were recorded.

Cleator (1993) reported two kinds of eelgrass community in Scotland; the mixed *Z. angustifolia* and *Z. noltei* community and the Z. *marina* community with the former being principally found in the east coast lochs. The current overall distribution of the plants therefore appear to agree with those suggested by Cleator (1993) but the communities are more complex (three community types rather than one) than was originally reported.

5.1.2 Eelgrass bed extents in Loch Fleet

The overall extents of the eelgrass beds in Loch Fleet have decreased considerably between 2000 and 2012 but the composition and positions of the beds have also changed.

Estimating the decline in eelgrass bed extent over the last 12 years was challenging as the original maps were not digitised and appear to have been drawn by hand. The estimated decline (overall and by area) is therefore a rough approximation. However, by importing the original 2000 eelgrass extent data and re-drawing these extents in the Loch Fleet GIS, it was possible to estimate the differences in eelgrass extents in 2000 and 2012 (Table 4.12 and Figure 4.23).

The current estimate of the overall decline in eelgrass bed extent from 2000 to 2012 is approximately 85 %. The largest declines were found along the Mound causeway, along the western/southern coastline and at Creag Bheag with reductions of 100 %, 97.5 % and 97 % respectively. The smallest decline is found in the bay between Balblair Wood and Ferry Wood with a decline of 70 % overall.

Table 4.12. Comparing Loch Fleet eelgrass extent and coverage in 2000 and 2012.

Survey Area	Eelgrass Cover (Hectares) 2000	Eelgrass Cover (Hectares) 2012	Percent Reduction
Survey Area A + B	24.378	0.621	97.5
Survey Area C	14.606	0	100.0
Survey Area D	36.412	1.102	97.0
Survey Area E	72.785	21.526	70.4
Survey Area F	7.489	0.407	94.6
Loch Fleet Total	**155.67**	**23.656**	**84.8**

In terms of the change in composition one mixed *Z. noltei* and *Z. angustifolia* bed and five main *Z. angustifolia* beds as well as a number of small eelgrass patches were reported in 2000. The former was only apparent after importing and re-drawing the 2000 extent revealing a mixed bed in survey areas A and B (SNH, 2000). The composition of eelgrass beds was not assessed in 2006 (SNH, 2006b).

In 2012 one *Z. noltei* bed, five mixed *Z. angustifolia* and *Z. noltei* beds and nine *Z. angustifolia* beds were recorded (Figure 4.23). Both the composition and size of the eelgrass beds have changed since the last extent survey in 2000. Of particular note is that one eelgrass bed recorded in 2000 was not recorded at all in 2012 (survey area C) and one mixed bed had moved as well as being reduced in size (survey area A). Several other beds have also moved and reduced in size (e.g. in survey areas D and E). It is possible that the root systems are still in place in the sediment at the original positions and that the beds will recover given suitable environmental conditions over the next few years but regular monitoring of the beds will be required to assess any such developments.

There are many factors potentially affecting the health of these eelgrass beds. These will be discussed further below.

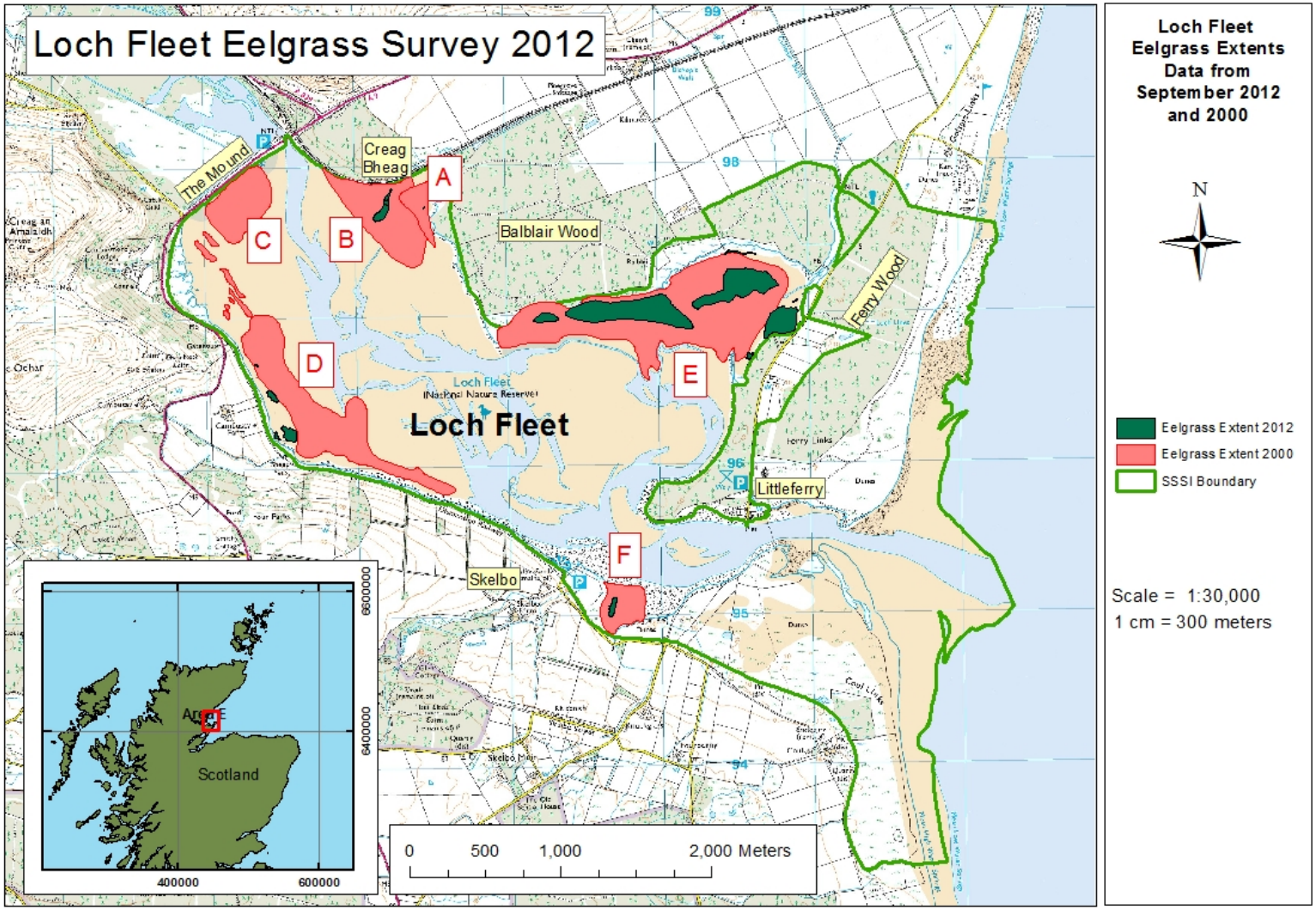

Figure 4.23. Eelgrass extent in Loch Fleet in 2000 and 2012.

5.2 Current known factors affecting the eelgrass habitats in the UK

5.2.1 Disease

The largest natural loss of *Zostera* spp. has been attributed to what is known as the "wasting disease", which wiped out extensive areas in the North Atlantic in the early 1930's (e.g. Giesen *et al.*, 1990; Cleator, 1993; NIHAP, 2003). This disease has in part been attributed to the fungus *Labyrinthula macrocystis*. This organism is probably naturally present at low levels but undergoes occasional large-scale outbreaks for reasons which are still not fully understood (Giesen *et al.*, 1990). It is possible that severe eelgrass losses occur only when the plants are under stress from some other factor such as temperature. Populations of *Zostera* spp. have not returned to pre-wasting disease levels, possibly due to further anthropogenic impacts (Chesworth *et al.*, 2008), although there is some suggestion that even under reduced anthropogenic impacts recovery is slow (Valdermarsen *et al.*, 2010).

It has been shown through laboratory and field studies that *Z. noltei* and *Z. marina* are equally susceptible to *L. macrocystis* infection (Cleator, 1993). However, as *Z. noltei* grows further up the shore, where *L. macrocystis* is known to be less virulent, natural levels of infections are correspondingly low and therefore less likely to infect *Z. noltei* (Cleator, 1993).

Z. angustifolia is believed to be less susceptible to the wasting disease than *Z. marina*. In 1930s the intertidal populations of *Z. marina* (which should perhaps have been recorded as *Z. angustifolia*) were uninfected by the wasting disease, partly as the plants could reproduce by seed before the disease killed the plants (Cleator, 1993).

The eelgrass bed within Loch Fleet SSSI does not currently appear to be affected by this or any other disease. The fronds on the vast majority of plants appeared healthy. There was some darkening of tips in survey area E Sub-Area 5 but otherwise the plants appeared healthy.

5.2.2 Indirect physical disturbance

Zostera spp. typically rely on relatively stable sediments and occur in physically-sheltered environments such as shallow inlets and lagoons. The plants stabilize the sediment within the beds and the canopy of leaves reduces current flow (Davison and Hughes, 1998). However, seagrass are vulnerable to changes in the sedimentary regime and the construction of seawalls and causeways have the potential to change these processes (Davison and Hughes, 1998; NIHAP, 2003). Loss of intertidal seagrass habitat can occur due to land reclamation not only through direct loss of habitat but also due to the additional impact of changes in the sedimentary regime leading to erosion or smothering during the resettlement of suspended sediments.

Smothering and erosion of seagrass, particularly *Z. noltei*, has been shown to be particularly damaging (Cabaco, 2007). Both burial and erosion resulted in the decrease of shoot density with a total shoot loss of all shoots when a sediment cover of more than 4 cm was present for 2 weeks (Cabaco, 2007).

There is no evidence of any large sedimentary changes as a result of any recent developments within Loch Fleet SSSI. Mapping has shown little change in the quantity of sediment as well as the locations of channels and islands in the basin (SNH, 2006a). However, there was a change in the management of the Mound causeway sluice gates at the end of 2000 (Hendry and Edwards, 2012), which may have caused some changes in the tidal basin. Prior to 2000 the water levels inside the sluice gates were controlled manually by a sluice-gate keeper (since 1819) but since 2001 the sluice gates have not been managed (for a variety of reasons). This change is believed to have caused some changes in the

habitats inside the Mound causeway but also caused a build-up of silt in the vicinity of the sluice system (Hendry and Edwards, 2012).

It is currently unclear whether any changes have occurred outside the sluice gates as a result of the change in the sluice-gate operation and management. However, the disappearance of the large eelgrass bed along and east of the Mound causeway (survey area C; see section 4 above) means that any changes or developments within or around the basin have to be considered. It is of particular interest that this large eelgrass community has disappeared during the period 2000 and 2012, immediately after and coinciding with the alteration in the sluice-gate management.

It is possible that the sedimentary regime within the loch has changed since 2001 resulting in higher sediment deposition in some areas, including survey area C, and therefore reducing the ability of the plants to survive. The salinity distribution within the basin may also have changed during this period and as salinity is known to affect both seed germination and survival rates (see Borum *et al*., 2004), any alterations in the chemical or sedimentary environment could affect the health and survival rates of several taxa within the basin.

Additional survey work including salinity measurements and sediment pathway studies would allow a better understanding of the environment to be established. It may also be worth considering a return to a managed sluice gate operation at the Mound causeway to assess whether the eelgrass communities in this part of the Loch Fleet tidal basin will return.

5.2.3 Direct physical disturbance

Direct physical disturbance includes, for example, affects by moorings, anchoring, dredging and propeller scars (e.g. Walker *et al.*, 1989; Hastings *et al.*, 1995; Francour *et al.*, 1999; Rhodes *et al.*, 2005; Collins *et al*., 2010). The severity and frequency of these types of disturbance are additional factors to consider (NIHAP, 2003). Where this disturbance is repeated due to constant dragging of a mooring chain, repeated driving over a particular area of an intertidal bed or shellfish gathering, damage to eelgrass beds can be permanent or recovery can be slow through the removal of rhizomes and seeds as well as increased smothering of during the resettlement of suspended sediments created by the mechanical damage (Cleator, 1993; see also Cabaco, 2007). There was no evidence of any direct physical disturbance to the eelgrass beds within Loch Fleet. These factors are therefore not believed to affect the Loch Fleet eelgrass beds.

5.2.4 Natural events

Like all marine habitats, seagrass beds are subject to natural change. Beds of *Zostera* spp. are known to be spatially dynamic, and undergo natural fluctuations in populations, which may be precipitated by sediment transport regimes, grazing and weather events (Axelsson *et al.*, 2012a). The most likely natural occurrence are exceptional storm events or floods that can remove sediments, cause erosion of eelgrass beds and lead to large scale losses (Wyer *et al*., 1977; Den Hartog, 1987). Instances of storm damage may increase as a result of climate change.

The process of natural succession may be occurring within the Loch Fleet SSSI eelgrass beds. In Scotland, *Z. noltei* is near the northern limit of the known natural range and any additions to the typical stress levels on the plant at these high latitudes may simply reduce the ability of the plants to recover. However, the root systems may remain in the sediments and recovery might occur over the next few years (N.B. dwarf eelgrass typically undergoes a marked die-back in the winter months and may suffer complete loss of foliage but can regenerate both by seed set and rhizomal growth; Rae, 1979; Cleator, 1993).

5.2.5 Grazing

Zostera spp. are utilised by herbivorous wildfowl during the winter months. The effect of this grazing activity can have a severe impact on the biomass of intertidal *Zostera* spp. with biomass reduced by 90% of peak biomass in some places (Davison and Hughes, 1998). However, these impacts show a large degree of variation from site to site and winter to winter (Madsen 1988; Percival 1991; Portig *et al*., 1994).

Declines in populations of epiphyte grazers can indirectly affect the health of beds of *Zostera* spp. by allowing increased growth of fouling algae. Any factors (natural or anthropogenic) which reduce grazer populations or cause increased proliferation of algae may therefore have an indirect adverse impact on seagrass meadows. The factors most likely to cause such changes are pollution incidents (causing grazer mortality) or excessive nutrient enrichment (Davison and Hughes, 1998).

There were large numbers of Greylag Goose (100s) and other birds in Loch Fleet in September 2012 with the former seen in survey areas A, B and E in particular. Greylag Geese are known to feed on *Zostera* spp. (e.g. Pistorius *et al*., 2006). The vast numbers of birds together with sparse eelgrass communities may have resulted in grazing pressure which as subsequently reduced the number of eelgrass plants over the last 10 years. However, some additional information regarding the numbers and any changes in wildfowl and wader birds in the Loch Fleet estuary is required to assess these potential effects fully.

5.2.6 Increased turbidity

A range of factors can influence the light regime experienced by seagrass, but this is particularly evident in the subtidal zone (NIHAP, 2003). Therefore, factors affecting light attenuation of water will influence not only the depth limit of seagrass but whether they can survive in a particular area. The impact of eutrophication may be indirect due to the increase of other marine primary producers, resulting in a poorer light regime and, thus, growth, and can lead to the complete loss of the seagrass bed. This is primarily due to the poor competitiveness of *Zostera* spp. in high nutrient environments due to the high respiratory demands of its rhizome system.

Eutrophication may be a factor in the Loch Fleet estuary. There are several farms along the southern boundary of the estuary and west of Balblair Wood. There are also several streams leading into the estuary from areas immediately around the farms, some of which run near the eelgrass beds. Of note is that eelgrass was not found in any of the channels or dips affected by the streams apart from one, Sub-Area 4 in survey area B (only three plants found in total). Whether it is the freshwater input, increased nutrient levels or other factors influencing the eelgrass remains unknown but these factors should all be taken into consideration. Additional sampling of salinity, phosphorus and nitrogen and pH as a minimum would be recommended to assess the concentrations and levels of the various parameters in the Loch Fleet estuary.

The activity of the lugworm *Arenicola marina* has been cited as the cause for the decline of *Z. noltei* in the Dutch Wadden Sea (Philippart, 1994). With an increased density of this polychaete worm, the sediment turnover reached a level where the continual coverage of shoots with sediment caused widespread reduction. Another polychaete, the ragworm *Hediste diversicolor* has also been cited as a factor for the failure in transplants of *Z. noltei* due to the burrowing activities of the worm (Hughes, 2000). *A. marina* was widespread across the Loch Fleet estuary in 2012 but further research is required to assess whether these polychaetes actually threaten the health of eelgrass beds.

5.2.7 Pollution

Seagrass is considered relatively insensitive to oil pollution (NIHAP, 2003), though the impact depends on a number of factors - the type of oil, degree of weathering and the nature of the habitat. Intertidal beds are considered more vulnerable to this source of pollution than subtidal beds and impacts may be greater on the flora and fauna associated with seagrass in subtidal beds.

Herbicides clearly have the potential to affect eelgrass and have been reported as being implicated in the decline of *Z. noltei* in the German Wadden Sea (Bester, 2000) though these were not directly applied and resulted from general runoff from the hinterland. More direct application of herbicides in the control of alien species has the potential to cause damage.

Z. marina has been shown to accumulate tributyltin and it was speculated that other metals and organic pollutants are also likely to be absorbed in a similar way (Cleator, 1993). A number of heavy metals (mercury, nickel and lead) and organic substances have been shown to reduce the fixation of nitrogen in *Z. marina* and this may affect the viability of plants, particularly in nutrient poor environments (Cleator, 1993). These elements and substances are furthermore likely to be passed on along the food chain to primary consumers including the wildfowl known to graze on eelgrass (Cleator, 1993).

It is unclear as to the levels of herbicides entering the Loch Fleet estuary but it would be yet another factor to assess further. The run off from the farms around the loch and from areas around the River Fleet could potentially contain herbicides detrimental to the eelgrass communities in Loch Fleet. Additional sampling to assess the levels of herbicides in the estuary and in the River Fleet is therefore recommended.

5.2.8 Nutrient enrichment

Nutrient enrichment has several sources but the two main sources are from domestic sewage discharge and nutrients associated with agricultural land runoff (see Cleator, 1993). Nutrient enrichment may initially increase production in eelgrass (Tubs and Tubs, 1983; Roberts *et al*., 1984; Cleator, 1993). However, high nitrate concentrations have been implicated in the decline of mature plants of *Z. marina*. In addition, during conditions of increased nitrate concentrations and decreased light availability the meristems of *Z. marina* plants deteriorated (Cleator, 1993). Phytoplankton blooms, resulting from nutrient enrichment, have shown to reduce biomass and depth penetration but this is primarily affecting *Z. marina* (Cleator, 1993).

Laboratory experiments on nutrient enrichment showed plants of *Z. marina* being more sensitive to *L. macrocystis* and succumbing to infection whilst other plants not exposed to increased nutrient concentrations remained healthy (Cleator, 1993).

The issue of eutrophication was discussed above under several headings (e.g. grazing and turbidity) and appears to be a potential factor affecting the eelgrass in Loch Fleet. Sampling to assess the levels of nutrients in the estuary is therefore recommended.

5.2.9 Alien species

Two alien species have been identified to be cause for concern in terms of potential impact on eelgrass in the UK at present (NIHAP, 2003). Cordgrass *Spartina anglica* colonises the upper part of mudflats and is considered a threat to the upper limit of *Zostera* spp (NIHAP, 2003). This may be a direct effect of *Zostera* spp. replacement (Percival *et al*., 1998) or the indirect effects of altered currents and sedimentation patterns (Butcher, 1941). This taxon

has been recorded in Scotland but currently not as far north as the Moray Firth (RAFTS, 2013).

The Japweed (*Sargassum muticum*) is another alien introduction to several areas in the UK including Strangford Lough (Davison, 1996) and Studland Bay (Axelsson *et al*., 2012a). However, it is a subtidal species and less likely to cause a threat to the intertidal taxa. In the subtidal there is the potential for competition for space between *S. muticum* and subtidal *Zostera* spp*.* as *S. muticum* tends to be a 'space-filler', it may be a greater threat to *Zostera* spp. where beds have been denuded and colonisation by *Sargassum* prevents re-colonisation by *Zostera* spp. (NIHAP, 2003).

Another potential factor is blanket weed which is found in similar environments as *Z. angustifolia* in particular (water-logged dips and channels) and appears to compete for space with the eelgrass (pers. comms). Blanket weed was common across Loch Fleet but particularly abundant in survey aresa C and E. In addition to competing for space blanket weed has been shown to affect invertebrate fauna and the feeding of wildfowl and waders in Poole Harbour (Axelsson *et al*., 2012).

The increase in green seaweeds forming blankets has in part been attributed to eutrophication but additional research is required in this field to determine the cause of these features but the competition for space with eelgrass appears to be considerable in Loch Fleet.

5.2.10 Climate change and sea level changes

Summary predictions for temperature and sea level rise as a result of global warming have been modelled by the MONARCH project (Harrison *et al*., 2001; NIHAP, 2003). The prediction of increased summer temperatures, may lead to an increased level of desiccation in the intertidal area, restricting the distribution of the intertidal species. *Z. angustifolia* may be more vulnerable than *Z. noltei*, although the taxonomy of these two species requires clarification to fully assess these potential treats*.* It has also been speculated that a rise in water temperatures together with a reduction in irradiation would increase stress levels as there would be a reduction in the amounts of available fixed carbon (Cleator, 1993). Whether these factors directly affects the Loch Fleet eelgrass beds is difficult to determine but consideration of all factors including climate change is required when assessing the change in eelgrass health and extent within Loch Fleet.

Sea level rise as a result of predicted global warming, is likely to have a number of effects. The lower limit of *Zostera* spp. in the sub-tidal is likely to be restricted (NIHAP, 2003). Whether this is accompanied by an increase in the upper limit will depend on a number of factors (e.g. suitable habitat is available above the bed for colonisation). The sediments in Loch Fleet appear stable with little change over time (SNH, 2006a, b). However, any continued rise in sea level is likely to lead to greater instability of sediments reducing the potential suitable habitat in the intertidal area. This redistribution of sediments may affect the distribution of *Zostera* spp. in Loch Fleet and surrounding areas.

5.3 Conclusions

The eelgrass survey in Loch Fleet SSSI in September 2012 established the presence of two species of eelgrass within the estuary; *Z. angustifolia* and *Z. noltei*. These two species form three different types of eelgrass communities in the estuary; 1) *Z. angustifolia* beds; 2) mixed *Z. angustifolia* and *Z. noltei* beds; and 3) *Z. noltei* beds.

The extents of the eelgrass beds in Loch Fleet have decreased considerably between 2000 and 2012 but the composition and positions of the beds also appear to have changed during this period.

Overall the decline in eelgrass extent between 2000 and 2012 has been estimated to be approximately 85 %, a real term decrease from 155.7 hectares in 2002 compared to 23.7 hectares in 2013 (caution required as the estimate has been acquired from comparisons between 2000 hand-drawn maps and 2012 digital maps). Compared to 2000 all the beds are reduced in size with the largest declines found along the Mound causeway, along the western/southern coastline and at Creag Bheag with reductions of 100 %, 97.5 % and 97 % respectively. The smallest decline is found in the bay between Balblair Wood and Ferry Wood with a decline of 70 % overall.

Of particular note is that one eelgrass bed, along the Mound causeway, recorded in 2000 was not recorded at all in 2012 (survey area C). It is possible that the root systems remain in the sediment and that the beds will recover given ultimate environmental conditions over the next few years but monitoring of the beds will be required to assess any such changes.

The change in composition also appears to have occurred across the estuary. In 2000 there were five *Z. angustifolia* beds and one mixed *Z. noltei* and *Z. angustifolia* bed as well as a number of small patches of *Z. angustifolia*.

In 2012 there was one *Z. noltei* bed, five mixed *Z. angustifolia* and *Z. noltei* beds and nine *Z. angustifolia* beds. The position of the 2000 mixed bed has changed but it has also been reduced in size (survey area A). Several other beds have also changed position and have been reduced in size (e.g. in survey areas D and E). The compositions, positions and sizes of the eelgrass beds in Loch Fleet therefore seem to have changed since the last extent survey in 2000 (N.B. some caution required as these results have been derived from comparisons between 2000 hand-drawn maps and 2012 digital maps).

The decline in eelgrass beds in Loch Fleet over the last 12 years could be linked to several natural and anthropogenic factors including grazing, eutrophication, herbicides, blanket weed, salinity and sedimentary regime changes. However, the lack of environmental, biological and chemical data, particularly in relation to the Loch Fleet tidal basin, prevents comparisons and therefore any certain conclusions to be made.

Establishing a current environmental baseline at Loch Fleet would therefore be of considerable interest. Regular monitoring of the eelgrass beds as well as additional water sampling to assess the levels of nutrients, salinity, herbicides and particle pathway surveys would be beneficial in establishing the factors controlling the apparent decline of eelgrass in the Loch Fleet estuary but also allow the natural cycle of the eelgrass present to be determined.

In addition, however, consideration has to be given to the potential link between the decline in eelgrass and the change in the Mound causeway sluice-gate management at Loch Fleet. A return to a manually controlled sluice-gate system has already been suggested in an attempt to allow the alder woodland habitat to recover (Hendry and Edwards, 2012). If this is approved careful monitoring of the eelgrass bed along the Mound is recommended as a manually controlled sluice-gate system may allow some of the eelgrass beds within Loch Fleet to return.

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APPENDIX 01. PLANT CRIB – BRITISH EELGRASS SPECIES

Attribute	*Zostera noltei*	*Zostera angustifolia*	*Zostera marina*
Rhizomes	0.5-1 mm thick; cortex with vascular bundles in its innermost layers	1-2 mm thick; cortex with 2 vascular bundles in its outer layers	2-5 mm thick; cortex with 2 vascular bundles in its outer layers
Leaves of sterile roots	(4-) 6-20 (>20) cm long × up to 1 mm wide, emarginate	15-30 cm long × 2 mm wide in summer (shorter and c. 1 mm wide in winter); tip obtuse and rounded when young emarginate later	20-50 (-200) cm long × (2-) 5-10 mm wide; tip rounded and mucronata when young, sometimes emarginate later where exposed
Leaves of fertile roots	(not stated)	4-15 cm long, × 2-3 mm wide	Shorter and narrower, sometimes emarginate
Sheaths	Open	Closed when young (splitting later)	Closed when young (splitting later)
Flowering stems	Simple or with 1-2 branches near base	10-30 cm, branched	Up to 60 cm, much branched
Inflorescence	3-6 cm in sheltered areas, averages below 2 cm when exposed	8-11 cm in sheltered areas, averages below 2.5 cm when exposed	(4-) 9-12 (-14) cm in sheltered areas, averages 5 cm when exposed
Retinaculae	Present	Absent	Absent
Stigma	Shorter than style	About as long as style	1-2 × style
Seeds	c. 2 mm	2.5-3 mm	3-3.5 mm

from Evans, 1988

APPENDIX 02. FIELD SURVEY LOG – MANUAL FIXES OF EELGRASS EXTENTS

Loch Fleet Seagrass Survey

Seagrass Extent Survey Log - manual GPS back-up data (Garmin GPS 72H)

Positions are WGS84 Latitude and Longitude (ddmm.mmm)

Client	Scottish Natural Heritage					Job Number
Location	Loch Fleet					Vessel
Survey	Loch Fleet Seagrass Survey					Date
Site	Sub-Area	Manual	Date	Time	Latitude (N)	Longitude (W)
Name		Waypoint		(GMT)	ddmm.mmm	ddmm.mmm
SB_D	1	AA	15/09/2012	15:17	57 56.470 N	004 04.350 W
SB_D	1	BB	15/09/2012	15:24	57 56.441 N	004 04.319 W
SB_D	1	CC	15/09/2012	15:30	57 56.434 N	004 04.279 W
SB_D	1	DD	15/09/2012	15:34	57 56.467 N	004 04.317 W
SB_D	2	AA	15/09/2012	16:07	57 56.328 N	004 04.153 W
SB_D	2	BB	15/09/2012	16:09	57 56.290 N	004 04.159 W
SB_D	2	CC	15/09/2012	16:11	57 56.311 N	004 04.242 W
SB_D	2	DD	15/09/2012	16:12	57 56.348 N	004 04.243 W
SB_D	2	EE	15/09/2012	16:14	57 56.342 N	004 04.196 W
SB_D	3	AA	15/09/2012	17:13	57 56.564 N	004 04.422 W
SB_D	3	BB	15/09/2012	17:12	57 56.559 N	004 04.416 W
SB_D	3	CC	15/09/2012	17:15	57 56.562 N	004 04.434 W
SB_D	3	DD	15/09/2012	17:14	57 56.566 N	004 04.437 W
SB_D	4	AA	16/09/2012	15:25	57 56.298 N	004 04.257 W
SB_D	4	BB	16/09/2012	15:41	57 56.304 N	004 04.290 W
SB_D	4	CC	16/09/2012	15:44	57 56.325 N	004 04.303 W
SB_D	4	DD	16/09/2012	15:43	57 56.325 N	004 04.281 W
SB_D	4	EE	16/09/2012	15:42	57 56.311 N	004 04.273 W
SB_F	1	AA	16/09/2012	17:24	57 55.693 N	004 02.033 W
SB_F	1	BB	16/09/2012	17:25	57 55.683 N	004 02.013 W
SB_F	1	CC	16/09/2012	17:26	57 55.698 N	004 01.997 W
SB_F	1	DD	16/09/2012	17:27	57 55.743 N	004 01.981 W
SB_F	1	EE	16/09/2012	17:28	57 55.753 N	004 02.003 W
SB_F	1	FF	16/09/2012	17:30	57 55.731 N	004 02.015 W
SB_B	1	AA	17/09/2012	09:28	57 57.200 N	004 03.538 W
SB_B	1	BB	17/09/2012	09:29	57 57.201 N	004 03.543 W
SB_B	1	CC	17/09/2012	09:31	57 57.164 N	004 03.586 W
SB_B	1	DD	17/09/2012	09:33	57 57.162 N	004 03.563 W
SB_B	2	CC	17/09/2012	09:31	57 57.164 N	004 03.586 W
SB_B	2	DD	17/09/2012	09:33	57 57.162 N	004 03.563 W
SB_B	2	EE	17/09/2012	09:44	57 57.128 N	004 03.607 W
SB_B	2	FF	17/09/2012	09:46	57 57.117 N	004 03.566 W
SB_B	3	EE	17/09/2012	09:44	57 57.128 N	004 03.607 W
SB_B	3	FF	17/09/2012	09:46	57 57.117 N	004 03.566 W
SB_B	3	GG	17/09/2012	09:54	57 57.109 N	004 03.645 W
SB_B	3	HH	17/09/2012	09:58	57 57.085 N	004 03.644 W
SB_B	3	II	17/09/2012	09:56	57 57.095 N	004 03.657 W
SB_B	3	JJ	17/09/2012	10:02	57 57.096 N	004 03.589 W

Site Name	Sub-Area	Manual Waypoint	Date	Time (GMT)	Latitude (N) ddmm.mmm	Longitude (W) ddmm.mmm
SB_B	4	AA	18/09/2012	08:30	57 57.138 N	004 03.317 W
SB_B	4	BB	18/09/2012	08:31	57 57.134 N	004 03.326 W
SB_E	1	AA	18/09/2012	10:10	57 56.821 N	004 00.825 W
SB_E	1	BB	18/09/2012	10:11	57 56.825 N	004 00.804 W
SB_E	1	CC	18/09/2012	10:12	57 56.833 N	004 00.799 W
SB_E	2	AA	18/09/2012	10:51	57 56.775 N	004 00.976 W
SB_E	2	BB	18/09/2012	10:54	57 56.688 N	004 01.009 W
SB_E	2	CC	18/09/2012	10:57	57 56.719 N	004 00.815 W
SB_E	2	DD	18/09/2012	11:01	57 56.798 N	004 00.800 W
SB_E	2	EE	18/09/2012	11:02	57 56.801 N	004 00.836 W
SB_E	2	FF	18/09/2012	11:03	57 56.805 N	004 00.896 W
SB_E	2	GG	18/09/2012	11:05	57 56.797 N	004 00.930 W
SB_E	3	AA	18/09/2012	11:20	57 56.991 N	004 01.082 W
SB_E	3	BB	18/09/2012	11:24	57 56.995 N	004 01.277 W
SB_E	4	AA	19/09/2012	07:38	57 56.612 N	004 01.113 W
SB_E	4	BB	19/09/2012	07:39	57 56.617 N	004 01.131 W
SB_E	4	CC	19/09/2012	07:36	57 56.637 N	004 01.122 W
SB_E	4	DD	19/09/2012	07:37	57 56.635 N	004 01.088 W
SB_E	4	EE	19/09/2012	07:38	57 56.623 N	004 01.100 W
SB_E	5	AA	19/09/2012	08:32	57 56.766 N	004 02.032 W
SB_E	5	BB	19/09/2012	08:49	57 56.741 N	004 02.230 W
SB_E	5	CC	19/09/2012	08:53	57 56.737 N	004 02.162 W
SB_E	5	DD	19/09/2012	09:00	57 56.796 N	004 02.227 W
SB_E	5	EE	19/09/2012	09:10	57 56.765 N	004 02.357 W
SB_E	5	FF	19/09/2012	09:21	57 56.803 N	004 02.142 W
SB_E	5	GG	19/09/2012	09:32	57 56.806 N	004 02.051 W
SB_E	5	HH	19/09/2012	09:47	57 56.800 N	004 01.998 W
SB_E	5	II	19/09/2012	10:03	57 56.803 N	004 01.833 W
SB_E	5	JJ	19/09/2012	10:12	57 56.830 N	004 01.695 W
SB_E	5	KK	19/09/2012	10:15	57 56.804 N	004 01.699 W
SB_E	5	LL	19/09/2012	10:18	57 56.795 N	004 01.740 W
SB_E	5	MM	19/09/2012	10:30	57 56.793 N	004 01.813 W
SB_E	5	NN	19/09/2012	10:45	57 56.839 N	004 01.727 W
SB_E	5	OO	19/09/2012	10:50	57 56.803 N	004 01.633 W
SB_E	5	PP	19/09/2012	11:00	57 56.722 N	004 01.496 W
SB_E	5	RR	19/09/2012	11:05	57 56.816 N	004 01.906 W
SB_E	5	SS	19/09/2012	11:10	57 56.811 N	004 02.190 W
SB_E	6	AA	19/09/2012	09:18	57 56.767 N	004 02.510 W
SB_E	6	BB	19/09/2012	09:38	57 56.745 N	004 02.403 W
SB_E	6	CC	19/09/2012	09:41	57 56.767 N	004 02 486 W
SB_E	6	DD	19/09/2012	09:31	57 56.738 N	004 02.569 W
SB_E	6	EE	19/09/2012	09:28	57 56.734 N	004 02.545 W

Site Name	Sub-Area	Manual Waypoint	Date	Time (GMT)	Latitude (N) ddmm.mmm	Longitude (W) ddmm.mmm
SB_E	7	AA	19/09/2012	11:20	57 56.862 N	004 01.295 W
SB_E	7	BB	19/09/2012	11:22	57 56.837 N	004 01.429 W
SB_E	7	CC	19/09/2012	11:26	57 56.818 N	004 01.483 W
SB_E	7	DD	19/09/2012	11:31	57 56.809 N	004 01.505 W
SB_E	7	EE	19/09/2012	11:33	57 56.793 N	004 01.461 W
SB_E	7	FF	19/09/2012	11:35	57 56.806 N	004 01.406 W
SB_E	7	GG	19/09/2012	11:37	57 56.813 N	004 01.339 W
SB_E	7	HH	19/09/2012	11:42	57 56.816 N	004 01.260 W
SB_E	7	II	19/09/2012	11:47	57 56.867 N	004 01.290 W
SB_E	7	JJ	19/09/2012	12:20	57 56.916 N	004 01.291 W
SB_E	7	KK	19/09/2012	12:24	57 56.936 N	004 01.262 W
SB_E	7	LL	19/09/2012	12:32	57 56.936 N	004 01.099 W
SB_E	7	MM	20/09/2012	07:34	57 56.830 N	004 01.229 W
SB_E	7	NN	20/09/2012	07:41	57 56.849 N	004 01.024 W
SB_E	7	POO	20/09/2012	07:52	57 56.879 N	004 00.924 W
SB_E	7	PP	20/09/2012	08:00	57 56.928 N	004 01.014 W

APPENDIX 03. FIELD SURVEY LOG – QUADRAT TRANSECT POSITIONS

Loch Fleet Seagrass Survey
Seagrass Transect Survey - Transect Locations (from GPS 72H)
Positions are WGS84 Latitude and Longitude (ddmm.mmm)

Client	Scottish Natural Heritage					Job Number	J/12/318
Location	Loch Fleet					Vessel	Intertidal
Survey	Loch Fleet Seagrass Survey					Date	September 2012
Site Name	Sub-Area	Transect Number	Date	Time^ (GMT)	Latitude (N) ddmm.mmm	Longitude (W) ddmm.mmm	Comments
SB_B	1	1	17/09/2012	17:28	57 57.198 N	004 03.542 W	Sandflat
					57 57.174 N	004 03.566 W	
SB_B	3	2	18/09/2012	07:13	57 57.141 N	004 03.573 W	Sandflat
					57 57.114 N	004 03.585 W	
SB_D	2	1	16/09/2012	07:41	57 56.348 N	004 04.242 W	Sandflat
					57 56.337 N	004 04.196 W	
SB_D	2	2	16/09/2012	09:52	57 56.320 N	004 04.211 W	Sandflat
					57 56.314 N	004 04.161 W	
SB_D	2	3	16/09/2012	10:01	57 56.299 N	004 04.196 W	Sandflat
					57 56.313 N	004 04.238 W	
SB_E	5	1	20/09/2012	08:48	57 56.798 N	004 01.874 W	Mudflat
					57 56.796 N	004 01.920 W	
SB_E	5	2	20/09/2012	09:53	57 56.798 N	004 02.047 W	Mudflat
					57 56.793 N	004 02.097 W	
SB_E	2	3	20/09/2012	11:26	57 56.734 N	004 00.911 W	Sandflat
					57 56.721 N	004 00.956 W	
SB_F	1	1	16/09/2012	17:43	57 55.746 N	004 01.986 W	Sandflat with gravel
					57 55.722 N	004 01.997 W	

APPENDIX 04. FIELD SURVEY LOG – QUADRAT POSITION LOG

Loch Fleet Seagrass Survey
Seagrass Quadrat Survey Log
Positions are WGS84 Latitude and Longitude (ddmm.mmm)

Client	Scottish Natural Heritage							Job Number	J/12/318
Location	Loch Fleet							Vessel	Intertidal
Survey	Loch Fleet Seagrass Survey							Date	September 2012
Site Name	Transect Number	Sub-Area Number	Sample Number	Quadrat Number	Time (GMT)	Date	Latitude (N) ddmm.mmm	Longitude (W) ddmm.mmm	Comments
SB_D	1	2	13	1	07:48	16/09/12	57 56.347 N	004 04.238 W	
SB_D	1	2	14	2	07:57	16/09/12	57 56.346 N	004 04.234 W	
SB_D	1	2	15	3	08:11	16/09/12	57 56.345 N	004 04.230 W	
SB_D	1	2	16	4	08:20	16/09/12	57 56.343 N	004 04.225 W	
SB_D	1	2	17	5	08:22	16/09/12	57 56.342 N	004 04.223 W	
SB_D	1	2	18	6	08:24	16/09/12	57 56.340 N	004 04.217 W	
SB_D	1	2	19	7	08:29	16/09/12	57 56.340 N	004 04.215 W	
SB_D	1	2	20	8	08:36	16/09/12	57 56.338 N	004 04.212 W	
SB_D	1	2	21	9	08:40	16/09/12	57 56.337 N	004 04.208 W	
SB_D	1	2	22	10	08:44	16/09/12	57 56.337 N	004 04.204 W	
SB_D	2	2	23	1	08:59	16/09/12	57 56.318 N	004 04.205 W	
SB_D	2	2	24	2	09:10	16/09/12	57 56.318 N	004 04.201 W	
SB_D	2	2	25	3	09:14	16/09/12	57 56.318 N	004 04.198 W	
SB_D	2	2	26	4	09:20	16/09/12	57 56.316 N	004 04.192 W	
SB_D	2	2	27	5	09:24	16/09/12	57 56.316 N	004 04.187 W	
SB_D	2	2	28	6	09:32	16/09/12	57 56.316 N	004 04.182 W	
SB_D	2	2	29	7	09:38	16/09/12	57 56.316 N	004 04.179 W	
SB_D	2	2	30	8	09:41	16/09/12	57 56.314 N	004 04.176 W	
SB_D	2	2	31	9	09:45	16/09/12	57 56.315 N	004 04.170 W	
SB_D	2	2	32	10	09:49	16/09/12	57 56.314 N	004 04.168 W	
SB_D	3	2	33	1	10:02	16/09/12	57 56.300 N	004 04.200 W	
SB_D	3	2	34	2	10:04	16/09/12	57 56.301 N	004 04.202 W	
SB_D	3	2	35	3	10:07	16/09/12	57 56.301 N	004 04.203 W	
SB_D	3	2	36	4	10:11	16/09/12	57 56.303 N	004 04.209 W	
SB_D	3	2	37	5	10:14	16/09/12	57 56.303 N	004 04.210 W	
SB_D	3	2	38	6	10:17	16/09/12	57 56.305 N	004 04.215 W	
SB_D	3	2	39	7	15:53	16/09/12	57 56.306 N	004 04.217 W	
SB_D	3	2	40	8	16:08	16/09/12	57 56.305 N	004 04.220 W	
SB_D	3	2	41	9	16:16	16/09/12	57 56.309 N	004 04.228 W	
SB_D	3	2	42	10	16:19	16/09/12	57 56.310 N	004 04.232 W	
SB_F	1	1	47	1	17:52	16/09/12	57 55.746 N	004 01.988 W	
SB_F	1	1	48	2	17:59	16/09/12	57 55.744 N	004 01.989 W	
SB_F	1	1	49	3	18:03	16/09/12	57 55.741 N	004 01.989 W	
SB_F	1	1	50	4	18:05	16/09/12	57 55.738 N	004 01.990 W	
SB_F	1	1	51	5	18:12	16/09/12	57 55.737 N	004 01.991 W	
SB_F	1	1	52	6	18:16	16/09/12	57 55.736 N	004 01.992 W	
SB_F	1	1	53	7	18:17	16/09/12	57 55.733 N	004 01.993 W	
SB_F	1	1	54	8	18:21	16/09/12	57 55.732 N	004 01.993 W	
SB_F	1	1	55	9	18:27	16/09/12	57 55.726 N	004 01.995 W	
SB_F	1	1	56	10	18:30	16/09/12	57 55.725 N	004 01.995 W	
SB_B	1	1	63	1	17:30	17/09/12	57 57.198 N	004 03.542 W	
SB_B	1	1	64	2	17:38	17/09/12	57 57.197 N	004 03.543 W	
SB_B	1	1	65	3	17:42	17/09/12	57 57.196 N	004 03.544 W	
SB_B	1	1	66	4	17:45	17/09/12	57 57.195 N	004 03.546 W	
SB_B	1	1	67	5	17:49	17/09/12	57 57.194 N	004 03.548 W	
SB_B	1	1	68	6	17:54	17/09/12	57 57.192 N	004 03.549 W	
SB_B	1	1	69	7	17:58	17/09/12	57 57.190 N	004 03.550 W	
SB_B	1	1	70	8	18:03	17/09/12	57 57.190 N	004 03.551 W	
SB_B	1	1	71	9	18:06	17/09/12	57 57.188 N	004 03.554 W	
SB_B	1	1	72	10	18:09	17/09/12	57 57.186 N	004 03.556 W	
SB_B	1	1	73	11	18:13	17/09/12	57 57.185 N	004 03.558 W	
SB_B	1	1	74	12	18:19	17/09/12	57 57.182 N	004 03.559 W	
SB_B	1	1	75	13	18:22	17/09/12	57 57.181 N	004 03.558 W	
SB_B	1	1	76	14	18:28	17/09/12	57 57.178 N	004 03.562 W	
SB_B	1	1	77	15	18:34	17/09/12	57 57.177 N	004 03.563 W	

Site Name	Transect Number	Sub-Area Number	Sample Number	Quadrat Number	Time (GMT)	Date	Latitude (N) ddmm.mmm	Longitude (W) ddmm.mmm	Comments
SB_B	2	3	78	1	07:17	18/09/12	57 57.140 N	004 03.575 W	
SB_B	2	3	79	2	07:18	18/09/12	57 57.140 N	004 03.576 W	
SB_B	2	3	80	3	07:23	18/09/12	57 57.139 N	004 03.576 W	
SB_B	2	3	81	4	07:25	18/09/12	57 57.138 N	004 03.577 W	
SB_B	2	3	82	5	07:29	18/09/12	57 57.135 N	004 03.578 W	
SB_B	2	3	83	6	07:34	18/09/12	57 57.133 N	004 03.579 W	
SB_B	2	3	84	7	07:38	18/09/12	57 57.132 N	004 03.580 W	
SB_B	2	3	85	8	07:44	18/09/12	57 57.131 N	004 03.580 W	
SB_B	2	3	86	9	07:48	18/09/12	57 57.129 N	004 03.581 W	
SB_B	2	3	87	10	07:52	18/09/12	57 57.126 N	004 03.582 W	
SB_B	2	3	88	11	07:54	18/09/12	57 57.124 N	004 03.583 W	
SB_B	2	3	89	12	07:56	18/09/12	57 57.123 N	004 03.583 W	
SB_B	2	3	90	13	07:58	18/09/12	57 57.122 N	004 03.583 W	
SB_B	2	3	91	14	08:01	18/09/12	57 57.121 N	004 03.581 W	
SB_B	2	3	92	15	08:05	18/09/12	57 57.119 N	004 03.584 W	
SB_E	1	5	103	1	08:52	20/09/2012	57 56.799 N	004 01.875 W	
SB_E	1	5	104	2	08:58	20/09/2012	57 56.799 N	004 01.878 W	
SB_E	1	5	105	3	09:03	20/09/2012	57 56.799 N	004 01.880 W	
SB_E	1	5	106	4	09:06	20/09/2012	57 56.799 N	004 01.884 W	
SB_E	1	5	107	5	09:10	20/09/2012	57 56.799 N	004 01.893 W	
SB_E	1	5	108	6	09:16	20/09/2012	57 56.798 N	004 01.895 W	
SB_E	1	5	109	7	09:22	20/09/2012	57 56.797 N	004 01.904 W	
SB_E	1	5	110	8	09:25	20/09/2012	57 56.798 N	004 01.908 W	
SB_E	1	5	111	9	09:30	20/09/2012	57 56.798 N	004 01.912 W	
SB_E	1	5	112	10	09:38	20/09/2012	57 56.797 N	004 01.915 W	
SB_E	2	5	113	1	10:06	20/09/2012	57 56.796 N	004 02.051 W	
SB_E	2	5	114	2	10:12	20/09/2012	57 56.795 N	004 02.055 W	
SB_E	2	5	115	3	10:18	20/09/2012	57 56.797 N	004 02.061 W	
SB_E	2	5	116	4	10:24	20/09/2012	57 56.796 N	004 02.069 W	
SB_E	2	5	117	5	10:28	20/09/2012	57 56.797 N	004 02.073 W	
SB_E	2	5	118	6	10:32	20/09/2012	57 56.796 N	004 02.078 W	
SB_E	2	5	119	7	10:38	20/09/2012	57 56.796 N	004 02.083 W	
SB_E	2	5	120	8	10:42	20/09/2012	57 56.791 N	004 02.077 W	
SB_E	2	5	121	9	10:47	20/09/2012	57 56.793 N	004 02.077 W	
SB_E	2	5	122	10	10:52	20/09/2012	57 56.793 N	004 02.097 W	
SB_E	3	2	130	1	11:29	20/09/2012	57 56.734 N	004 00.911 W	
SB_E	3	2	131	2	11:37	20/09/2012	57 56.733 N	004 00.917 W	
SB_E	3	2	132	3	11:41	20/09/2012	57 56.731 N	004 00.924 W	
SB_E	3	2	133	4	11:46	20/09/2012	57 56.729 N	004 00.925 W	
SB_E	3	2	134	5	11:53	20/09/2012	57 56.729 N	004 00.929 W	
SB_E	3	2	135	6	11:59	20/09/2012	57 56.729 N	004 00.932 W	
SB_E	3	2	136	7	12:03	20/09/2012	57 56.726 N	004 00.936 W	
SB_E	3	2	137	8	12:10	20/09/2012	57 56.724 N	004 00.942 W	
SB_E	3	2	138	9	12:18	20/09/2012	57 56.722 N	004 00.949 W	
SB_E	3	2	139	10	12:22	20/09/2012	57 56.723 N	004 00.951 W	

APPENDIX 05. FIELD SURVEY LOG – QUADRAT SURVEY DATA

Loch Fleet Seagrass Survey **J/12/318**
Quadrat Survey field log - biology recording log

Client	Scottish Natural Heritage
Location	Loch Fleet
Survey	Loch Fleet Seagrass Survey

Seagrass Bed Name	Transect Number	Sub-Area	Sample Number	Quadrat Number	Distance along transect (m)
SB_D	1	2	13	1	6
SB_D	1	2	14	2	9
SB_D	1	2	15	3	15
SB_D	1	2	16	4	21
SB_D	1	2	17	5	22
SB_D	1	2	18	6	28
SB_D	1	2	19	7	32
SB_D	1	2	20	8	36
SB_D	1	2	21	9	39
SB_D	1	2	22	10	43
SB_D	2	2	23	1	6
SB_D	2	2	24	2	12
SB_D	2	2	25	3	15
SB_D	2	2	26	4	21
SB_D	2	2	27	5	24
SB_D	2	2	28	6	28
SB_D	2	2	29	7	33
SB_D	2	2	30	8	35
SB_D	2	2	31	9	41
SB_D	2	2	32	10	45
SB_D	3	2	33	1	7
SB_D	3	2	34	2	9
SB_D	3	2	35	3	11
SB_D	3	2	36	4	17
SB_D	3	2	37	5	19
SB_D	3	2	38	6	23
SB_D	3	2	39	7	28
SB_D	3	2	40	8	31
SB_D	3	2	41	9	42
SB_D	3	2	42	10	47

Seagrass Bed Name	Transect Number	Sub-Area	Sample Number	Quadrat Number	Distance along transect (m)
SB_F	1	1	47	1	5
SB_F	1	1	48	2	8
SB_F	1	1	49	3	12
SB_F	1	1	50	4	18
SB_F	1	1	51	5	22
SB_F	1	1	52	6	24
SB_F	1	1	53	7	28
SB_F	1	1	54	8	33
SB_F	1	1	55	9	42
SB_F	1	1	56	10	44
SB_B	1	1	63	1	3
SB_B	1	1	64	2	5
SB_B	1	1	65	3	7
SB_B	1	1	66	4	10
SB_B	1	1	67	5	12
SB_B	1	1	68	6	14
SB_B	1	1	69	7	18
SB_B	1	1	70	8	22
SB_B	1	1	71	9	25
SB_B	1	1	72	10	32
SB_B	1	1	73	11	36
SB_B	1	1	74	12	38
SB_B	1	1	75	13	41
SB_B	1	1	76	14	45
SB_B	1	1	77	15	47
SB_B	2	3	78	1	2
SB_B	2	3	79	2	3
SB_B	2	3	80	3	4
SB_B	2	3	81	4	8
SB_B	2	3	82	5	14
SB_B	2	3	83	6	15
SB_B	2	3	84	7	17
SB_B	2	3	85	8	19
SB_B	2	3	86	9	23
SB_B	2	3	87	10	27
SB_B	2	3	88	11	33
SB_B	2	3	89	12	34
SB_B	2	3	90	13	35
SB_B	2	3	91	14	39
SB_B	2	3	92	15	45

Seagrass Bed Name	Transect Number	Sub-Area	Sample Number	Quadrat Number	Distance along transect (m)
SB_E	1	5	103	1	2
SB_E	1	5	104	2	4
SB_E	1	5	105	3	7
SB_E	1	5	106	4	11
SB_E	1	5	107	5	18
SB_E	1	5	108	6	23
SB_E	1	5	109	7	32
SB_E	1	5	110	8	35
SB_E	1	5	111	9	37
SB_E	1	5	112	10	41
SB_E	2	5	113	1	4
SB_E	2	5	114	2	9
SB_E	2	5	115	3	15
SB_E	2	5	116	4	22
SB_E	2	5	117	5	27
SB_E	2	5	118	6	30
SB_E	2	5	119	7	34
SB_E	2	5	120	8	38
SB_E	2	5	121	9	45
SB_E	2	5	122	10	50
SB_E	3	2	130	1	1
SB_E	3	2	131	2	6
SB_E	3	2	132	3	13
SB_E	3	2	133	4	17
SB_E	3	2	134	5	20
SB_E	3	2	135	6	24
SB_E	3	2	136	7	27
SB_E	3	2	137	8	35
SB_E	3	2	138	9	43
SB_E	3	2	139	10	45

Date	Photograph Yes/No	Sample Yes/No	Seagrass (1/1) (%)	Number of shoots (1/4)	New shoots Y/N
16/09/2012	Y	N	0	0	
16/09/2012	Y	N	0	0	
16/09/2012	Y	Y	40	34	
16/09/2012	Y	N	0	0	
16/09/2012	Y	N	0	0	
16/09/2012	Y	N	15	8	
16/09/2012	Y	Y	10	13	
16/09/2012	Y	N	8	16	
16/09/2012	Y	N	0	0	
16/09/2012	Y	Y	5	3	
16/09/2012	Y	N	12	23	Y
16/09/2012	Y	N	25	18	Y
16/09/2012	Y	Y	8	20	Y
16/09/2012	Y	N	15	24	
16/09/2012	Y	N	15	40	Y
16/09/2012	Y	N	20	28	
16/09/2012	Y	N	10	14	
16/09/2012	Y	N	20	30	
16/09/2012	Y	N	4	9	
16/09/2012	Y	N	15	27	
16/09/2012	Y	N	30	45	
16/09/2012	Y	N	12	31	Y
16/09/2012	Y	N	22	40	
16/09/2012	Y	N	30	24	
16/09/2012	Y	N	8	33	
16/09/2012	Y	Y	60	60	Y
16/09/2012	Y	Y	50	211	Y
16/09/2012	Y	N	30	160	Y
16/09/2012	Y	N	25	19	
16/09/2012	Y	N	12	16	

Date	Photograph Yes/No	Sample Yes/No	Seagrass (1/1) (%)	Number of shoots (1/4)	New shoots Y/N
16/09/2012	Y	N	40	88	Y
16/09/2012	Y	N	15	36	Y
16/09/2012	Y	N	0	0	
16/09/2012	Y	Y	30	111	Y
16/09/2012	Y	N	8	33	Y
16/09/2012	Y	N	0	0	
16/09/2012	Y	N	10	24	Y
16/09/2012	Y	Y	30	83	Y
16/09/2012	Y	N	8	29	Y
16/09/2012	Y	N	40	71	Y
17/09/2012	Y	Y	5	24	Y
17/09/2012	Y	N	3	11	Y
17/09/2012	Y	N	15	23	Y
17/09/2012	Y	N	20	35	Y
17/09/2012	Y	N	20	56	Y
17/09/2012	Y	N	25	75	Y
17/09/2012	Y	N	5	51	Y
17/09/2012	Y	N	5	35	Y
17/09/2012	Y	N	5	32	Y
17/09/2012	Y	N	5	46	Y
17/09/2012	Y	N	10	82	Y
17/09/2012	Y	N	15	40	Y
17/09/2012	Y	Y	30	111	Y
17/09/2012	Y	N	40	144	Y
17/09/2012	Y	Y	35	103	Y
18/09/2012	Y	N	8	3	
18/09/2012	Y	N	8	6	
18/09/2012	Y	N	0	0	
18/09/2012	Y	N	0	0	
18/09/2012	Y	Y	10	15	
18/09/2012	Y	N	8	11	
18/09/2012	Y	Y	35	23	
18/09/2012	Y	N	35	27	
18/09/2012	Y	N	5	12	
18/09/2012	Y	N	5	10	
18/09/2012	Y	N	0	0	
18/09/2012	Y	N	3	3	
18/09/2012	Y	N	3	8	
18/09/2012	Y	N	20	21	
18/09/2012	Y	Y	10	10	

Date	Photograph Yes/No	Sample Yes/No	Seagrass (1/1) (%)	Number of shoots (1/4)	New shoots Y/N
20/09/2012	Y	Y	35	30	Y
20/09/2012	Y	N	40	20	
20/09/2012	Y	N	30	14	
20/09/2012	Y	N	20	21	
20/09/2012	Y	Y	35	15	
20/09/2012	Y	N	60	35	
20/09/2012	Y	N	20	14	
20/09/2012	Y	N	20	37	
20/09/2012	Y	Y	75	65	
20/09/2012	Y	N	35	30	
20/09/2012	Y	Y	30	36	
20/09/2012	Y	N	40	42	
20/09/2012	Y	Y	20	36	
20/09/2012	Y	N	25	28	
20/09/2012	Y	Y	15	17	
20/09/2012	Y	N	22	48	
20/09/2012	Y	N	30	18	
20/09/2012	Y	N	18	27	
20/09/2012	Y	N	25	30	
20/09/2012	Y	N	20	37	
20/09/2012	Y	Y	60	164	Y
20/09/2012	Y	N	40	107	Y
20/09/2012	Y	Y	40	91	Y
20/09/2012	Y	N	50	197	Y
20/09/2012	Y	N	20	80	Y
20/09/2012	Y	N	40	125	Y
20/09/2012	Y	N	30	49	Y
20/09/2012	Y	Y	60	255	Y
20/09/2012	Y	N	20	51	Y
20/09/2012	Y	N	20	39	

					Job Number	J/12/318
					Vessel	Intertidal
					Date	September 2012
Blade lengths (cm)					Average blade length (cm)	Comments
						Sparse eelgrass - 0-5%, Zostera found in standing water (channels/dips on the sandflat. Other fauna/flora incl A. marina, Fucoids, C. edule, Enteromorpha/Cladophora, Macoma?
13.8	13.0	9.0	17.5	12.0	13.06	
5.5	4.5	20.0	12.0	15.5	11.5	
22.0	18.0	19.5	12.7	10.0	16.44	
28.5	19.5	12.0	12.7	13.0	17.14	
8.6	5.5	14.5	6.6	10.5	9.14	
15.0	11.0	10.0	4.0	4.5	8.9	Sparse eelgrass - 0-5%, Zostera found in standing water (channels/dips on the sandflat. Other fauna/flora incl A. marina, Fucoids, C. edule, Enteromorpha/Cladophora, Macoma?
13.5	22.0	15.5	9.0	7.0	13.4	
7.0	16.5	9.0	5.0	11.0	9.7	
12.5	6.0	10.0	10.5	9.5	9.7	
11.0	12.5	10.0	4.5	6.0	8.8	
9.5	16.6	13.0	11.5	17.0	13.52	
11.5	14.5	4.0	9.5	12.0	10.3	
14.0	12.5	10.0	11.5	8.0	11.2	
3.0	10.5	15.5	3.5	8.0	8.1	
15.5	14.5	14.0	19.0	10.0	14.6	
6.0	5.5	4.0	6.0	4.5	5.2	Sparse eelgrass - 0-5%, Zostera found in standing water (channels/dips on the sandflat. Other fauna/flora incl A. marina, Fucoids, C. edule, Enteromorpha/Cladophora, Macoma?
13.0	8.5	9.0	5.5	7.0	8.6	
9.0	21.0	16.0	18.5	15.5	16	
4.5	10.5	12.0	16.0	10.0	10.6	
5.5	4.5	4.5	5.0	4.0	4.7	
12.0	8.0	7.0	7.0	9.5	8.7	
6.5	7.5	8.5	10.0	9.0	8.3	
3.5	8.0	9.0	7.0	7.0	6.9	
14.0	8.5	4.5	4.0	12.0	8.6	
14.5	6.5	5.0	6.0	21.0	10.6	

Blade lengths (cm)					Average blade length (cm)	Comments
8.5	7.5	6.5	6.5	8.0	7.4	Patchy eelgrass bed - 0-10%, Zostera found in standing water (channels/dips on the sandflat. Zostera dark green, small shoots - maybe Z. noltei but samples need to be analysed. No adult Z. angustifolia. Other fauna/flora incl A. marina, Fucoids, C. edule, Enteromorpha/Cladophora, Mussels
9.5	5.5	6.5	5.5	9.0	7.2	
9.5	5.0	6.5	6.0	5.5	6.5	
9.0	6.5	6.5	7.0	8.5	7.5	
7.5	8.5	4.5	12.0	7.5	8	
6.0	5.5	6.5	6.0	7.5	6.3	
5.5	10.5	8.5	6.0	6.0	7.3	
5.0	9.0	10.0	6.5	9.0	7.9	
7.5	8.0	6.5	8.5	9.5	8	Eelgrass bed - 5-10%, characterised by Z. noltei and sparse Z. angustifloia. Zostera found in standing water (channels/dips on the sandflat. Zostera dark green, small shoots - believed to be Z. noltei but samples need to be analysed.. Other fauna/flora incl A. marina, Enteromorpha/Cladophora, Mussels
9.0	9.5	11.5	3.0	8.0	8.2	
6.0	10.0	7.5	3.5	6.5	6.7	
10.0	9.5	9.5	9.5	8.0	9.3	
10.0	12.5	17.5	9.5	8.0	11.5	
7.5	14.0	9.0	4.0	11.0	9.1	
5.5	10.0	3.0	7.5	6.0	6.4	
6.5	5.5	7.5	6.5	13.0	7.8	
8.5	7.0	6.5	8.5	7.5	7.6	
8.5	6.5	4.0	6.5	8.0	6.7	
8.0	10.5	10.0	3.0	6.5	7.6	
11.0	11.0	9.5	4.0	7.5	8.6	
9.5	9.5	9.5	6.5	8.5	8.7	
8.0	12.5	10.5	8.0	10.0	9.8	
12.5	11.5	8.0	10.0	6.0	9.6	
19.0	17.5	26.0	9.0	12.0	16.7	Eelgrass bed - 5 (-10)%, characterised by Z. angustifolia. Zostera found in standing water (channels/dips on the sandflat. Other fauna/flora incl A. marina, Enteromorpha/Cladophora,
21.0	17.0	15.5	18.0	25.0	19.3	
24.0	12.5	21.0	21.5	18.0	19.4	
26.0	12.5	7.5	12.0	10.5	13.7	
23.5	13.5	30.5	25.5	25.0	23.6	
23.0	21.0	19.5	13.5	25.0	20.4	
16.0	13.0	23.0	5.0	25.0	16.4	
18.0	12.0	19.5	14.5	13.5	15.5	
					0	
16.0	15.0	5.0			7.2	
13.0	10.0	6.0	21.0	11.0	12.2	
30.0	24.0	20.5	18.5	20.0	22.6	
19.5	24.0	20.0	24.0	14.5	20.4	

Blade lengths (cm)					Average blade length (cm)	Comments
29.5	24.0	21.5	20.0	26.0	24.2	Deep mud (15 cm) over hard layer. Zostera angustifolia abundant across the transect (30-40%). Blanket weed is also characteristic of this sub-area with 30% overall. A.marina is also present
21.5	28.5	25.5	19.5	25.0	24	
17.0	30.0	21.5	35.0	18.0	24.3	
26.5	25.5	20.0	17.0	22.5	22.3	
15.0	19.5	28.5	16.5	25.0	20.9	
24.0	30.0	31.5	23.0	28.5	27.4	
21.0	21.5	20.5	21.0	19.0	20.6	
24.5	21.0	31.0	24.0	23.0	24.7	
19.5	16.5	23.0	25.0	20.0	20.8	
18.5	30.0	17.0	18.5	18.0	20.4	
14.5	15.0	22.0	15.0	18.0	16.9	Deep mud (15 cm) over hard layer. Zostera angustifolia abundant across the transect (30-40%). Blanket weed is also characteristic of this sub-area with 30% overall. A.marina is also present. Darkening of most plants (tips and fronds)
24.0	17.5	32.0	38.5	26.5	27.7	
21.0	24.0	19.0	17.0	20.0	20.2	
21.0	16.0	13.0	21.5	19.5	18.2	
21.5	16.5	18.5	16.0	12.5	17	
23.0	23.0	24.0	21.5	18.5	22	
22.5	29.5	19.0	44.0	24.0	27.8	
19.0	19.0	16.0	31.0	10.5	19.1	
14.0	10.0	16.5	13.5	15.5	13.9	
20.5	15.0	13.5	11.5	7.0	13.5	
15.0	14.0	13.0	9.0	6.5	11.5	Sandflat (muddy sand) hard under foot. Zostera angustifolia abundant across the transect (30-40%). Characterised by both Z. angustifolia and Z. noltei plants. Blanket weed is also present of this sub-area with 10% overall. A.marina is also present.
9.5	10.0	12.0	8.5	7.5	9.5	
9.0	8.0	8.0	19.5	16.0	12.1	
10.5	11.0	13.0	17.5	16.5	13.7	
15.5	7.5	9.0	14.5	14.5	12.2	
19.5	11.0	18.5	10.5	13.0	14.5	
19.0	19.5	14.5	14.5	19.0	17.3	
13.5	10.0	8.0	8.0	17.5	11.4	
12.0	12.0	13.0	11.5	9.5	11.6	
14.5	14.5	17.5	19.0	21.0	17.3	

Other fauna (in quadrats)								
Arenicola marina	Blankett weed	*Red algae*	*Burrow*	*Fucus* spp.	*Heterosiphonia*	*Mussels*	*Cerastoderma edule*	*Crab*
P	P (60%)							
P	P (10%)							
	P (5%0	P	P					
P	P							
	P	P						
P	P							
P	P (10%)	P						
	P (50%)	P						
P								
	P	P						
P								
P		P						
P		P						
P								
P	P (30%)							
P	P							
P	P (60%)							
	P			P				
P								
	P (10%)							
			P					
P								
P			P					
P								
P	P (5%)							
P	P (10%)				P			

Other fauna (in quadrats)								
Arenicola marina	Blankett weed	*Red algae*	*Burrow*	*Fucus* spp.	*Heterosiphonia*	*Mussels*	*Cerastoderma edule*	*Crab*
				P		P	P	
						P	P	
P						P		
	P (15%)					P	P	
P						P	P	
P				P				
				P			P	
P							P	
	P (5%)							
P				P				
	P (5%)					P		
						P		
								P
P								
	P (5%)							
P						P		
P	P (5%)							
P								
	P (20%)							
P	P (15%)							
	P (70%)							
P								
P	P (40%)							
P	P (40%)							
	P (35%)							
P	P (5%)							
P	P (40%)							
P	P (70%)							
	P (80%)							
P								
P	P (45%)							
	P (80%)							
	P (15%)							

Other fauna (in quadrats)								
Arenicola marina	Blankett weed	*Red algae*	*Burrow*	*Fucus* spp.	*Heterosiphonia*	*Mussels*	*Cerastoderma edule*	*Crab*
P	P (20%)							
	P (30%)							
	P (30%)							
	P (70%)							
P	P (5%)							
P	P (20%)							
	P (5%)							
	P (10%)							
P								
	P (5%)							
P	P (25%)							
P	P (10%)							
P	P (50%)							
	P (5%)							
P	P (30%)							
P	P (5%)							
P	P (50%)							
P	P (20%)							
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