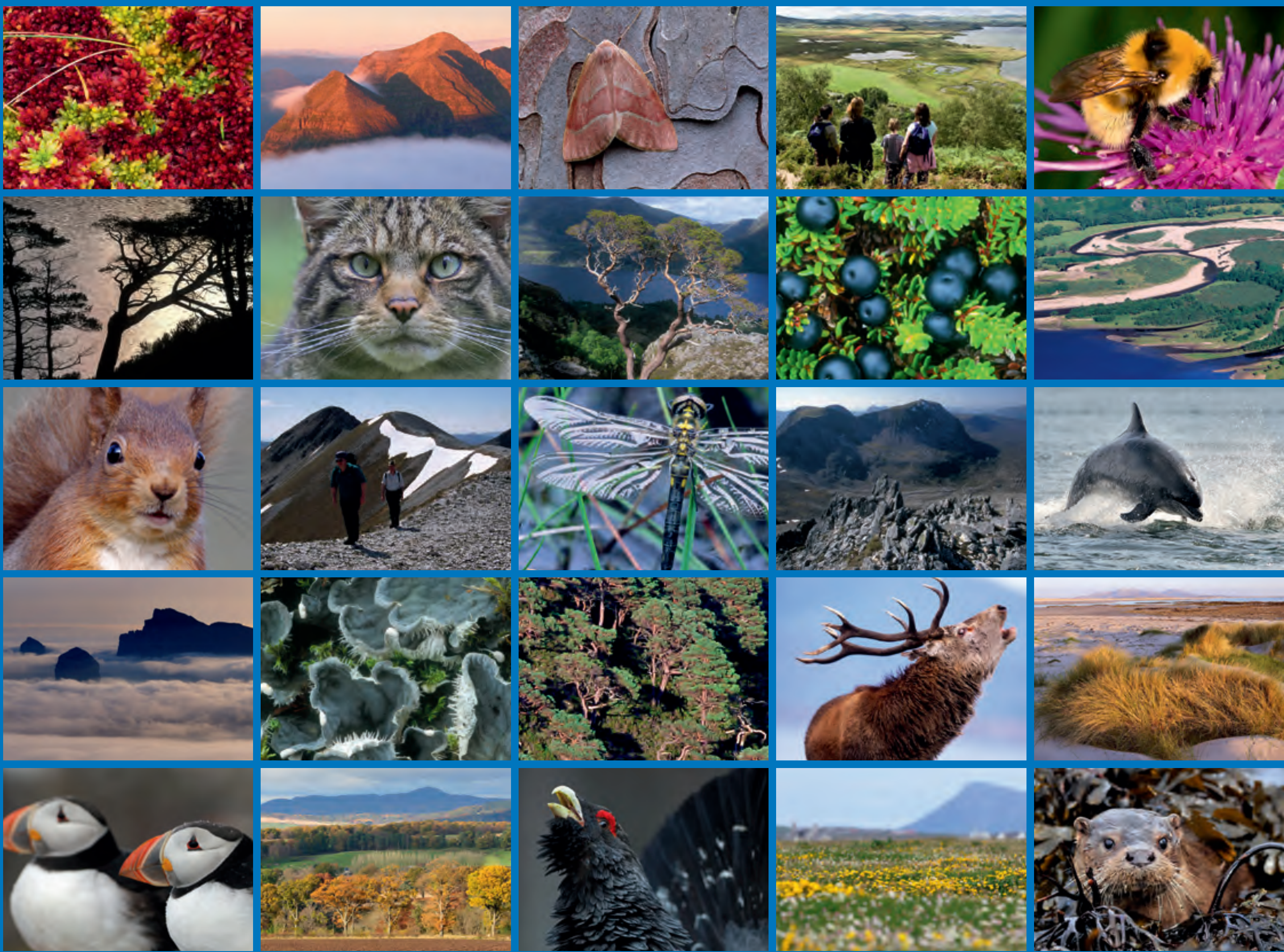
Scottish Natural Heritage
Commissioned Report No. 557

Experimental shading to control/eradicate Canadian waterweed



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COMMISSIONED REPORT

Commissioned Report No. 557

Experimental shading to control/eradicate Canadian waterweed

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COMMISSIONED REPORT

Summary

Experimental shading to control/eradicate Canadian Waterweed

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Background

Canadian waterweed *Elodea canadensis* is a cause of unfavourable condition in several designated standing water habitats throughout Scotland. Existing control methods are not considered to provide long-term control. Jute matting has been used successfully in Ireland to control a morphologically similar species (*Lagarosiphon major*). This study installed jute matting in Loch Libo in Renfrewshire, to assess its effectiveness in controlling *E. canadensis*.

Main findings

- Canadian waterweed is the dominant species at Loch Libo.
- Matting installed in September 2011 had substantially disappeared by April 2012. New matting, of a heavier weave was installed in single and double layers in May 2012.
- *E. canadensis* did not colonise the surface of the matting throughout the summer season.
- The frequency, cover and condition of *E. canadensis* was highly significantly lower below the surface of the matting compared to the control area, and was significantly lower below the double thickness compared to the single thickness of material.
- The frequency of *Lemna trisulca* increased highly significantly below both the single and double thickness of matting compared to the control areas; there was no significant difference in the levels of *L. trisulca* below the single and double thicknesses of material.
- No regrowth of native macrophyte species was recorded either on or through the matting.
- The matting was effective in supressing the growth of *E. canadensis*, but its ability to achieve long-term control of the species, or promote the regrowth of native species is not proven.
- The matting is shown to break down in freshwater systems, avoiding the need to remove shading material from treatment sites.
- Guidance on the sources and types of material suitable for use in different sites, and installation methods are provided.

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Table of Contents **Page**

1.	**INTRODUCTION**		**2**
	1.1	Aims of the project	2
	1.2	Scope of the project	2
	1.3	Structure of the document	2
2.	**BACKGROUND INFORMATION**		**4**
	2.1	*E. canadensis*	4
	2.2	Field Site	5
	2.2.1	Location and physical description	5
	2.2.2	History and land use	7
	2.2.3	Standing water and aquatic vegetation	7
3.	**INITIAL FIELD WORK AND EXPERIMENTAL DESIGN**		**8**
	3.1	Introduction	8
	3.2	Historical Information	8
	3.3	Initial Macrophyte Survey	8
	3.3.1	Methods	8
	3.3.2	Results	9
	3.4	Development of experimental design	12
	3.4.1	Rationale	12
	3.4.2	Irish experience of installation of jute matting	12
	3.4.3	Choice of shading material & attachment methods	12
	3.4.4	Sample locations	15
	3.4.5	Number and size of experimental treatments	15
4.	**INSTALLATION OF MATTING**		**16**
	4.1	Methods used for installation of matting in 2011	16
	4.2	Methods used for installation 2012	19
5.	**MONITORING SURVEYS**		**21**
	5.1	Early season checking of matting, spring 2012	21
	5.1.1	Methods	21
	5.1.2	Results	21
	5.2	End of Season Macrophyte Survey, Summer 2012	23
	5.2.1	Methods	23
	5.2.2	Results	23
	5.3	Protected Species	28
6.	**DISCUSSION**		**29**
	6.1	Longevity of the jute matting	29
	6.2	Efficacy of jute matting in controlling growth of *E. canadensis*	29
	6.3	Development of a native flora	30
	6.4	Installation methods	31
	6.5	Anchoring of Jute	31
	6.6	Resources	32
	6.7	Comparison of use of jute matting with other shading methods	33
7.	**GUIDANCE FOR FUTURE APPLICATIONS**		**34**
	7.1	Source of materials	34
	7.2	Choice of site	35
	7.3	Installation methods	35
8.	**REFERENCES**		**36**
APPENDIX A: PHOTOGRAPHS			**38**
APPENDIX B: LIMITS OF SHADED AREA			**41**

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1. INTRODUCTION

This report describes a trial using jute matting to control or eradicate *Elodea canadensis* Canadian waterweed. It provides background information about *E. canadensis*, summarises the findings of a field trial where jute matting was introduced to control *E. canadensis* and makes recommendations about the efficacy of jute matting as a control agent.

1.1 Aims of the project

Since 1842, when *E. canadensis* was first recorded in Britain (Preston *et. al.*, 2002), the species has expanded its range to become widespread throughout the UK. It has been identified as a cause of unfavourable condition in a number of designated standing water habitats in Scotland. Various control methods have been tried, but none have been found to be successful in the long-term. Recent work in Ireland (Caffrey *et. al.*, 2010), has shown that shading with jute matting can be successful in controlling another, morphologically similar, invasive aquatic plant; curly waterweed *Lagarosiphon major*. A review of possible control measures for *E. canadensis* undertaken for SNH (Vernon & Hamilton, 2011) suggested that jute matting might also have a role to play in controlling the species in Scotland. Consequently, SNH commissioned a study to investigate whether jute matting can assist in controlling or eradicating *E. canadensis*. This involved a trial installation of matting within Loch Libo in Renfrewshire.

The aims of the project were:

a) to use available data to identify a suitable location within the site for deployment of a benthic barrier;
b) to install a jute benthic barrier over sample infestations of *E. canadensis*;
c) to monitor the viability of plant material below the benthic barrier;
d) when *E. canadensis* is no longer viable, or is judged to be unlikely to become unviable, to remove the benthic barrier or assess the feasibility of leaving it in place to biodegrade;
e) to produce a final report on the project.

1.2 Scope of the project

The project was divided into a number of stages:

1. initial macrophyte survey to determine the distribution of *E. canadensis* at Loch Libo and identification of the location for installation of matting;
2. development of experimental design;
3. installation of matting 2011;
4. early season check of matting 2012;
5. installation of new matting 2012;
6. end of season macrophyte survey 2012.

1.3 Structure of the document

Section 2 provides some background information about *E. canadensis*, including an overview of its biology and reasons why it requires control in a Scottish context. Section 2 also provides background information about the field site chosen for the installation of matting; Loch Libo.

Section 3 sets out the initial field work that was undertaken to inform the experimental design. It includes details of the macrophyte survey that was undertaken, the selection of the experimental area within the loch, and identification of suitable shading material.

Section 4 sets out the field methods used for the installation of the matting in 2011 and 2012 and for monitoring the efficacy of the matting.

Section 5 provides the results of the monitoring exercises, identifying how the shading material had affected growth of *E. canadensis* and other macrophyte species.

Section 6 discusses the implications of the results, in terms of the likely efficacy of jute matting in controlling *E. canadensis*.

Section 7 provides some guidance on lessons learned for future applications of matting.

2. BACKGROUND INFORMATION

2.1 *E. canadensis*

The ecology and taxonomic history of *E.* canadensis, Canadian waterweed (or pondweed, as it has commonly been named in the past) has been well documented by a number of authors (e.g. Simpson 1984, 1986). The following provides a brief summary of the characteristics of the plant.

E. canadensis is a species native to North America and is one of three species of the genus *Elodea* that have been recorded from the British Isles. Guidance on the identification of the three species can be found in Simpson (1986) and Dadds & Bell (2008). Of the three species, *E. canadensis* is the longest established (Simpson, 1986) and most widely distributed (Preston *et. al.* 2002) within the British Isles. The first accredited record for *E. canadensis* on mainland Britain was in a lake at Duns Castle, Berwickshire in 1842, although there are earlier unsubstantiated records from locations in England (Simpson, 1986, Preston & Croft, 1997). Since that time it has expanded its range and has shown a substantial increase in distribution between 1930-69 and 1987-99 (as based on presence in 10 km squares). It has also been recorded from nearly 300 10 km squares in Scotland (Preston *et. al.,* 2006). It is widespread in lowland Scotland and throughout parts of the Highlands and Islands (Dadds & Bell, 2008).

E. canadensis is a shallowly-rooted plant that has long branching stems up to 3 m long with whorls of three leaves, which are strap like and unstalked (Dadds & Bell, 2008). It is a plant of moderate to high nutrient conditions, and is associated with areas of low water turbulence such as are found in canals, ponds and lakes. It prefers fine and silty substrates (Preston & Croft, 1997) and can be found growing at depths ranging from 0.15 – 4 m of water (Simpson, 1984). *E. canadensis* is a relatively light demanding plant with a high compensation point (Brown *et. al.*, 1974).

Only female plants have been recorded from the UK, although there were records for male plants in a pond on the Braid Hills dating from 1879 to 1903 (Simpson, 1986). The spread of the species is therefore totally reliant, in the UK, on vegetative propagation. The stems are brittle and detached stems quickly produce adventitious roots (Simpson, 1986). Its main period of growth is between mid-April to mid-September, but unlike many native species it can survive the winter as short unbranched stems that will continue limited growth. It can also survive under ice (Simpson, 1986) and can form winter buds or turions. This is in contrast to many native British species that rely fully on turions to survive the winter, and so are at a competitive disadvantage in the spring (Kunil, 1984).

E. canadensis is an early coloniser of new water bodies. The main method of colonisation is through water movement. There is some speculation that material can be carried between sites by birds (Simpson, 1986) and the author is aware of examples of where the introduction of the species can be directly linked to human actions.

The species is thought to show a cyclical pattern of growth; when it first enters a site it can show a rapid increase in distribution and biomass before reaching equilibrium within the site. Factors such as manual removal of the vegetation or increasing nutrient levels can act to trigger another period of rapid growth (Scott Wilson, 2009). *E. canadensis* can develop dense stands, which extend up to the water surface, creating shading of other, native species. It can also clog water bodies, reducing flow. This rapid expansion has been linked to concerns that it can out-compete native species, and particular concern has been raised about the possible effects of *E. canadensis* expansion upon populations of slender naiad *Najas flexilis*, a European Protected Species. However, the situation is not clear as many of the sites that support *N. flexilis* and *E. canadensis* are also thought to suffer from eutrophication (Scott Wilson, 2009).

The presence of *E. canadensis* at a high frequency is considered a detrimental aspect of a water body and the presence of invasive species is one of the most common reasons for standing water Sites of Special Scientific Interest (SSSIs) to be classed in unfavourable condition (Vernon & Hamilton, 2011). Consequently, the statutory agencies have reviewed the methods available to control or eradicate *E. canadensis* at sites. SEPA commissioned a review that focused upon practical measures to control *E. canadensis* at priority mesotrophic sites, several of which supported *N. flexilis* (Scott Wilson, 2009), whilst SNH commissioned a literature review of current or potential measures for controlling *E. canadensis* within all standing waters (Vernon & Hamilton, 2011). This identified a number of possible control measures that had been poorly researched for their efficacy against *E. canadensis*, such as the use of benthic shading.

2.2 Field Site

Loch Libo near Uplawmoor in Renfrewshire was chosen as the field site for installation of the matting. This site was selected by SNH as an example of a relatively small, accessible site that is considered to be in unfavourable condition owing to the presence of E. canadensis, but is not thought to be experiencing other pressures that might impact upon its status, e.g. eutrophication. Also, it is owned and managed by a single owner, Scottish Wildlife Trust, which means that decisions about methods and approaches can be quickly reached.

A brief summary of the site is provided below. Further background information about the Loch and its management can be found in the management plan for the reserve (Stewart & Smart, 2008).

2.2.1 Location and physical description

Loch Libo is based near the settlement of Uplawmoor in Renfrewshire, adjacent to the A736 Irvine/Barrhead Road (see Figure 2.1). It forms the main feature of the Loch Libo SSSI (see section 2.2.3). The Glasgow-Kilmarnock Railway line abuts the southern edge of the loch, whilst mature broad-leaved woodland adjoins the northern shore of the loch. Access to the site is via an unmanned pedestrian railway crossing.

Loch Libo is a relatively small, shallow, eutrophic loch, which lies in a valley that runs roughly NE/SW. The loch is around 540 m along its longest axis and around 154 m across the shorter axis, and has a surface area of 8.6 ha and a perimeter of 1.5 km (UK Lakes Database). The site is of fairly even depth, reaching a maximum depth of around 2 m, with one deeper area (c. 3 m) in the south-east corner (Gibson, 1975). The main inflow is the Thorter Burn, but the site is also fed by numerous springs located along the west shore (Stewart & Smart, 2008). Water leaves the loch via the Lugton Water.

The physical extent and depth of the water are thought to have changed over time. Stewart & Smart (2008) note that historic maps show the loch to be wider than it is today. Deposits of mud and silt to the south-west of the site suggest that it was longer in the past. Also, part of a medieval cart track on the north shore is now partially submerged at its western end, suggesting water levels have risen over time.

There are limited water quality data available, although the site is considered to be eutrophic. The Clyde River Purification Board collected samples from various locations around the loch in July 1989, and water quality was described as ‘excellent’ at that time (CRPB, 1989). The SNH Loch Survey (SNH, 1996) recorded the pH as 6.6, conductivity at 386 $\mu S\ cm^{-1}$, and alkalinity as 1.16 $meq\ L^{-1}$.

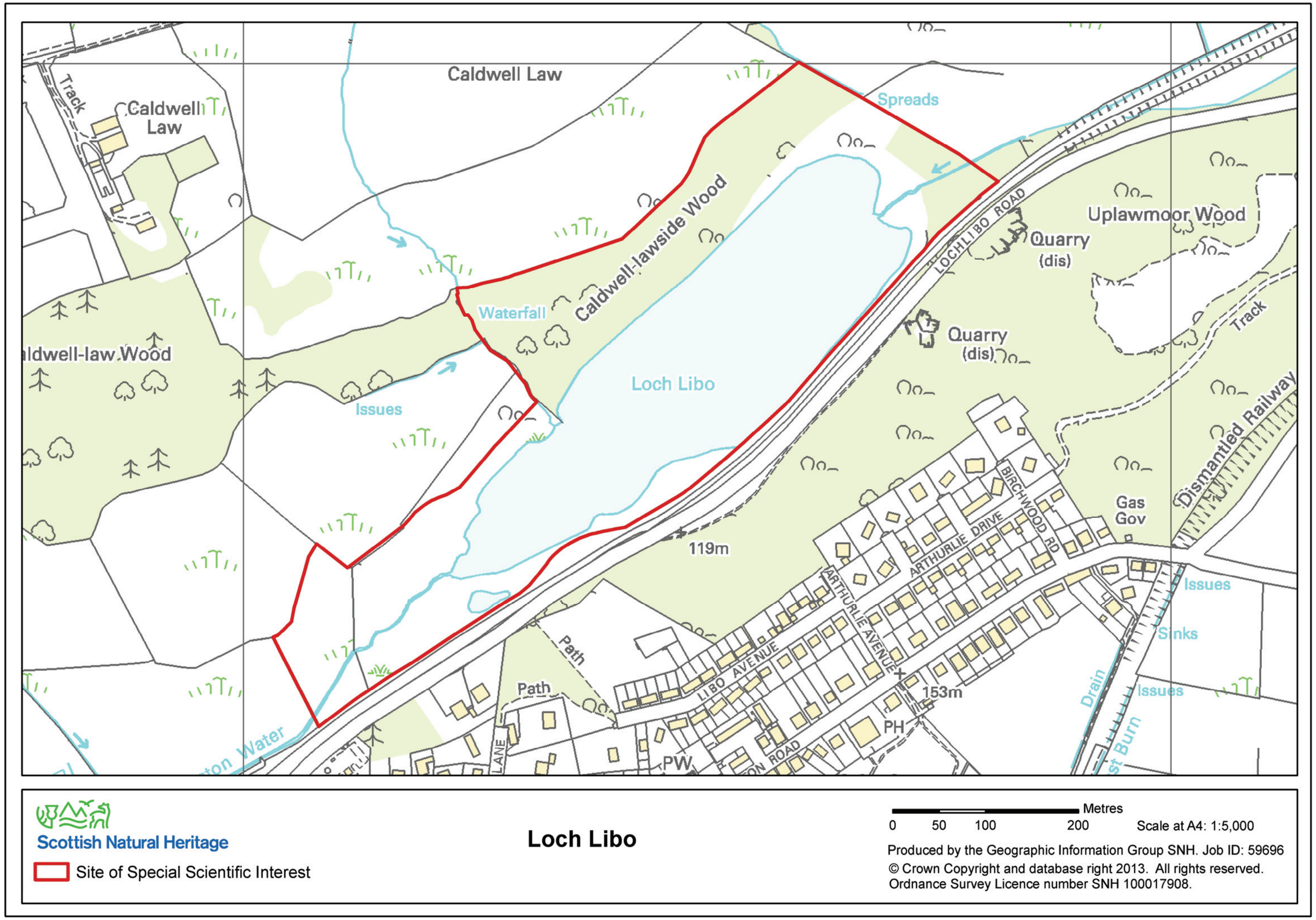

Figure 2.1: Loch Libo

2.2.2 History and land use

There is a history of mining in the late 18th and 19th Centuries. Coal was found at the south end of the loch around 1780. Following a flooding accident in 1793 mining was suspended, but the mine was reopened in 1830. Commercial mining ceased in the 1840s (Stewart & Smart, 2008).

The road along the south-eastern shore of the loch was built in 1820, with the railway line being completed around 50 years later (Railbrit, undated; Stewart & Smart, 2008). There are a number of older cart tracks along the north-western shore. Some of these were used to export reeds that were harvested at the loch (Stewart & Smart, 2008).

The loch is currently owned and managed by the Scottish Wildlife Trust (SWT), who purchased the site as a Nature Reserve in 1973 owing to the presence of three nationally rare plants. In addition, the Scottish Carp Group has exclusive fishing rights on the loch. Fishing is restricted to the eastern end of the loch.

2.2.3 Standing water and aquatic vegetation

In addition to being a SWT Nature Reserve, Loch Libo and surrounding land has been designated as a SSSI for its eutrophic loch feature. The SSSI citation describes Loch Libo as "*the best example of a eutrophic loch in East Renfrewshire.*" (SNH, 2007). The citation also notes the presence of the Nationally Scarce cowbane *Cicuta virosa*; nationally uncommon species including lesser tussock sedge *Carex diandra*, water sedge *Carex aquatilis*, slender tufted sedge *Carex acuta* and water parsnip *Berula erecta*; and locally uncommon species including greater tussock sedge *Carex paniculata*, and lesser pond sedge *Carex acutiformis*.

The loch has a well-developed emergent fringe around most of its shores. This is particularly extensive at the inflow and outflow streams and in a bay on the southern shore.

The method and date of introduction of *E. canadensis* into Loch Libo is not known, but it was well-established when the site was surveyed by the SNH Loch Survey in 1996.

Loch Libo has been assessed as part of SNH's Site Condition Monitoring programme in 2004 and 2009-10. Based on the 2004 data, the site was considered to be in unfavourable condition owing to the prevalence of *E. canadensis*. The site was re-assessed in 2009 and is again likely to be recorded as in unfavourable condition as a result of *E. canadensis* growth.

It is an objective of the SWT management plan to restore the eutrophic standing water feature to a favourable condition and maintain this status (Stewart & Smart, 2008).

3. INITIAL FIELD WORK AND EXPERIMENTAL DESIGN

3.1 Introduction

Suitable locations for the installation of the jute shading were identified through a combination of review of historical survey data and a new vegetation survey. The presence of protected animal species and several notable plant species at the site was also a material consideration, together with considering other users of the loch and nature reserve.

3.2 Historical Information

The most comprehensive survey of vegetation at Loch Libo was undertaken as part of the SNH Loch survey (1996). This produced a list of species present at the site with an assessment of their relative abundance. The assessment was based upon a shore survey of the loch, meaning that there was less detailed recording of species beyond c. 20 m from the loch shore.

The condition of Loch Libo SSSI was assessed by SNH in 2004 and 2009/10. These assessments recorded species found within three 100 m lengths of shoreline and associated deeper water (to approximately 75 cm in depth). Two of these sample areas were located on the southern shore, and one on the northern shore (see Section 4.1). Again, the data are limited to shore-based assessments of vegetation. It was a requirement of the contract that these areas were to be left undisturbed by the matting.

A number of notable plant species are known to occur around the shores of Loch Libo (see Section 2.2.3) (Smart, 2010). These species are mainly associated with the terrestrial areas around the loch or are found at the shallow margins. The surveyors were advised of the broad locations of these species so that these areas could be avoided when launching the boat.

3.3 Initial Macrophyte Survey

A new survey was undertaken to identify areas of the loch that supported *E. canadensis* and to gain further information about its abundance, distribution and associated species. During this survey the team also considered practical issues related to installation of the jute matting including whether it could be installed by people using snorkel equipment, and ways of fixing the matting to the bed of the loch. The survey was undertaken on 2nd September 2011 during conditions of mixed sunshine and cloud and little wind.

3.3.1 Methods

3.3.1.1 Vegetation and habitat

The majority of the loch shore supports extensive areas of emergent and marginal vegetation, which makes access to the water's edge difficult. Consequently, the submerged vegetation was sampled from a small inflatable boat.

A modified version of the SNH loch survey technique in open water was used (Lassiere, 1998). The boat was rowed around the whole perimeter of the loch, at varying distances from the shore. The submerged vegetation was sampled at frequent intervals using a double-rake head grapnel. This was supplemented by occasional viewing of the vegetation using a bathyscope. Qualitative assessments of species presence and abundance were made for each grab. Abundance was assessed using the five point DAFOR scale, as per the SNH Loch Survey method (Lassiere, 1998) where:

D = Dominant;
A = Abundant;

F = Frequent;
O = Occasional;
R = Rare

A more detailed assessment of the vegetation was made in the south-western outflow bay of the loch. The reasons for selecting this area are set out in Section 3.4.2.

The vegetation of the outflow bay was directly assessed by snorkelling. Initially, a series of transects were swum across and around the bay in order to identify the range of species present and variation in species distribution and abundance. This assessment revealed that the vegetation was broadly similar across the whole width of the bay. The bay was then sub-divided, by eye, into two roughly equal areas defined as lying to the north or south of the bay. Within each area, the vegetation presence and abundance within 20 0.5 m x 0.5 m quadrats was assessed. Species abundance within each quadrat was assessed using the four-point scale recommended for Site Condition Monitoring (JNCC, 2009) where:

0 = Not present;
1 = <25% of quadrat covered by species;
2 = 26 - <75% of quadrat covered by species;
3 = >75% of quadrat covered by species.

Other factors recorded were the depth of water, substrate type, extent of bare substrate in the quadrat, presence of filamentous algae and the height of the vegetation. A secchi disc was also used to determine light penetration.

3.3.1.2 Protected Species

There are records for water voles (*Arvicola terrestris*) and otters (*Lutra lutra*) at Loch Libo. Water voles are partially protected in Scotland, whilst otters are classed as European Protected Species. Prior to undertaking the survey, the areas likely to be affected by the works, principally the area of shoreline and bank where the boat was launched, were searched for signs of both species. The survey included looking for recognised signs of both species, such as water vole burrows, otter holts and lie-up places; otter spraints and water vole droppings; and signs of feeding activity such as chewed leaves and fish scales. A watching brief for these species was maintained during each survey and monitoring visit to the site.

3.3.1.3 Installation methods

The more detailed assessment of vegetation in the south-western outflow bay allowed for testing of practical issues related to installation. The survey work was undertaken by specialists using snorkel equipment. They assessed whether it would be possible to install the matting using snorkels, or whether full Scuba diving kit would be required. They also tested a number of commercially available pegs and pins to determine whether they would gain purchase in the loch substrate. A small length of Hessian cloth was also floated on the surface to investigate its properties in water.

3.3.2 Results

3.3.2.1 General characteristics

Loch Libo is a shallow loch. The site shelves relatively steeply around the shores, to achieve a maximum depth of c. 3 m, although the majority of the loch is fairly flat and around 2 m in depth (Gibson, 1975). No new bathymetric work was undertaken for this study. Light penetration appears to be good, and the secchi disc was still visible at maximum depth in the south-western bay.

The predominant substrate type over the centre of the loch is silt. Little bare substrate is present.

3.3.2.2 Submerged vegetation of Loch Libo

The submerged vegetation of the loch was similar throughout the site. The species recorded, together with their abundance throughout the loch are listed in Table 3.1. The submerged vegetation is dominated by *E. canadensis* at a high abundance, with *Lemna trisulca* (ivy-leaved duckweed), *Fontinalis antipyretica* (willow moss), *Potamogeton berchtoldii*[1] (small pondweed) and *Nitella flexilis a* stonewort species, also present.

Table 3.1: Species presence and abundance throughout Loch Libo

Scientific name	Common name	Abundance (DAFOR)
Elodea canadensis	Canadian waterweed	D
Lemna trisulca	Ivy-leaved duckweed	A
Fontinalis antipyretica	Willow moss	O
Potamogeton berchtoldii	Small pondweed	O
Nitella flexilis	Stonewort	F

3.3.2.3 South-western bay

The south-western bay is a shallow, relatively flat-bottomed area in the order of 1 m deep. It is bounded on the shore by dense beds of emergent species. Silt is the predominant substrate. This is unconsolidated material, which lies on the floor of the loch for depths of c. 70 cm and can readily be re-suspended. Little bare substrate is present owing to dense growths of vegetation.

Figures 3.1 – 3.2 show the frequency with which each species was recorded in each area. Frequency has been assessed as overall frequency i.e. the number of quadrats which contained that particular species (Figure 3.1), and also as relative frequency i.e. the number of times that a particular species was recorded in quadrats compared to the total number of species records from all quadrats (Figure 3.2).

E. canadensis dominates both the northern and southern portion of the bay, and *L. trisulca* also occurs at a high frequency. Within the randomly placed quadrats, *F. antipyretica* was only recorded in the southern part of the bay (although it was also present in the northern area outwith the quadrats). *N. flexilis* was also recorded at low frequency in both areas.

[1] Both small pondweed *Potamogeton berchtoldii* and lesser pondweed *Potamogeton pusillus* have been previously recorded from the site. All the material found during this survey has been assigned as *P. berchtoldii*. A voucher specimen has been collected.

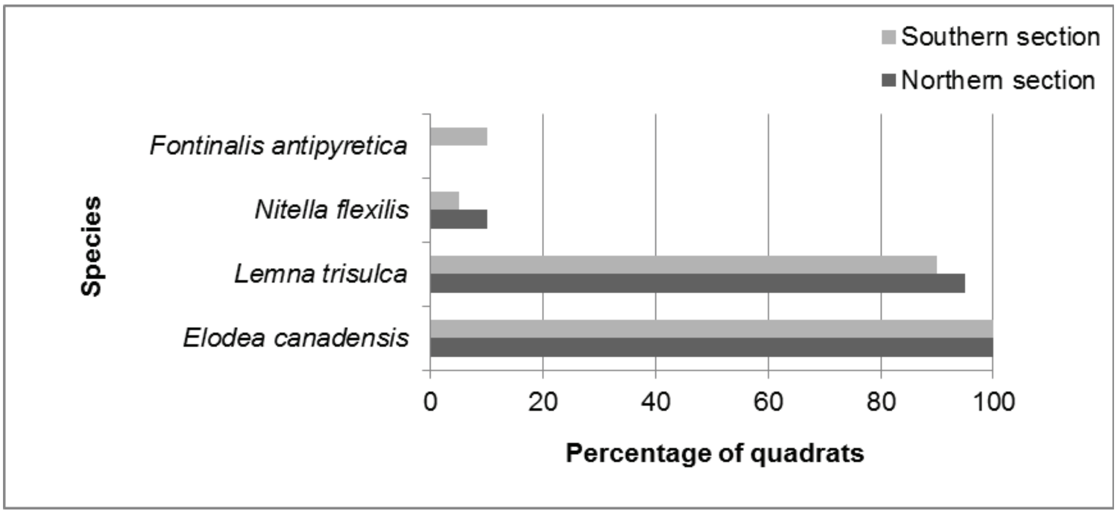

Figure 3.1: Frequency of species recorded from 20 quadrats in the south-western outflow bay

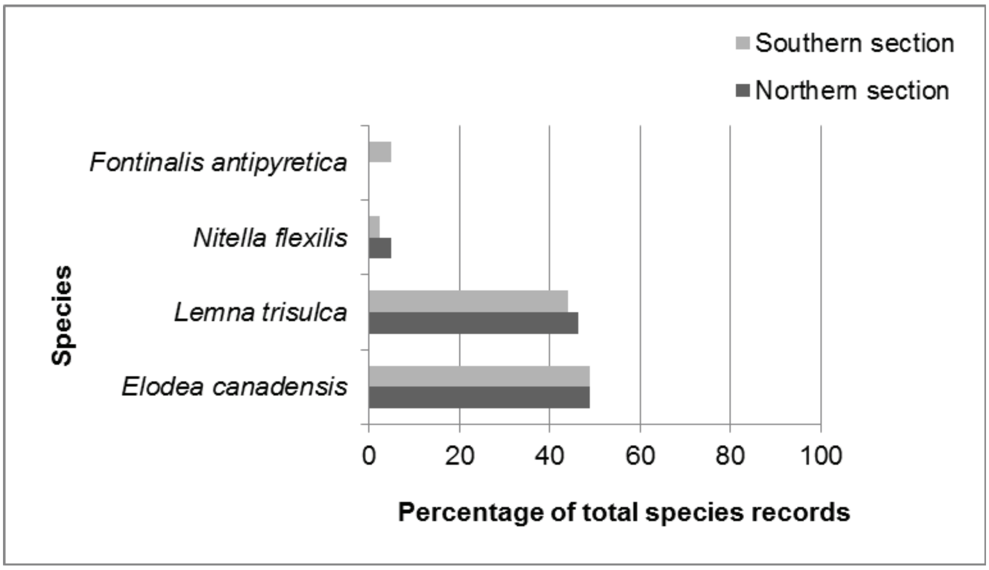

Figure 3.2: Relative frequency of species recorded from 20 quadrats in the south-western outflow bay

3.3.2.4 Protected & Rare Species

No signs of either water vole or otter were noted in the areas in which the trial took place.

None of the notable plant species were adversely affected by the works.

3.3.2.5 Installation methods

None of the pins and pegs tested was sufficiently long to provide anchorage through the tall beds of *E. canadensis* (which were around ± 1 m deep), or achieve purchase in the deep, unconsolidated silt. It was concluded that the shading material would need to be fixed to the bottom of the loch using a system of weights, rather than pins.

3.4 Development of experimental design

3.4.1 Rationale

The underlying principle was to undertake research that was scientifically robust and repeatable within the confines of the available resources.

The aim was to identify whether benthic shading, using a natural material, would reduce the presence and abundance of *E. canadensis*.

Secondary objectives were to identify whether native species would colonise or regrow in areas treated by the shading material; and to assess whether the shading material would break down in the loch.

The experimental design was informed by the preliminary survey of the site (described above), a review of existing information for the site, and a review of the experience of installing jute matting at Lough Corrib in Ireland (Caffrey *et. al.*, 2010). This included 'phone discussions with Dr Caffrey to obtain further information about some of the practical experiences of the installation process that have not been documented in published papers.

The rationale underpinning the choice of the following aspects of experimental design are provided below:

- choice of shading material & attachment methods;
- sample locations;
- number and size of experimental treatments.

3.4.2 Irish experience of installation of jute matting

The initial work at Lough Corrib involved the installation of over 8000 m^2 of jute material at seven locations (Caffrey *et. al.*, 2010). The minimum area treated was 100 m^2 and the maximum 5000 m^2. The jute was installed from the back of a specially modified boat, and was laid by a team of divers. Concrete weights were used to fix the material to the floor of the lough. Key findings from the research are:

- *Lagarosiphon major*, an invasive species that is morphologically similar to *E. canadensis* was found to die rapidly beneath jute matting.
- No *L. major* was found to grow through the matting.
- The species was found to disappear within approximately 8 months.
- Native charophyte species are able to grow through the jute matting within a period of around 4 months.
- Other native macrophyte species were also able to establish on the matting.

Further comments about lessons learned in Ireland and how they influenced the design of this research, are highlighted below.

3.4.3 Choice of shading material & attachment methods

A range of biodegradable products based on natural fibres are now available. These have been developed, primarily, for use in engineering and landscaping projects or as fabrics for upholstery, interior furnishings and manufacture. The main products are based on either jute or coir.

3.4.3.1 Jute

Jute is a natural fibre that is produced from plants of the *Corchorus* genus. The fibres, which are composed of cellulose and lignin, are collected from the bark of the plant and can be spun into coarse, strong threads. The resulting material is off-white to brown in colour. The majority of jute is extracted from white jute *Corchorus capsularis*, with lesser amounts abstracted from tossa jute *C. olitorius.* It is considered to be effective at assimilating and storing carbon dioxide; it has been estimated that a hectare of jute plants consumes about 15 tonnes of carbon dioxide and releases 11 tonnes of oxygen (Natural Fibres, 2009).

The biodegradable nature of jute fabrics has made it popular in recent years for use in landscaping projects. It is an effective means of stabilising soil, whilst allowing establishment of vegetation. They last for around 12 – 24 months. It is also used for upholstery, creation of 'eco-friendly' bags and for weaving coarse cloth and sacking, which means that there are a range of potential suppliers for different grades of material. Four classes of jute are identified for manufacturing purposes:

- hessian or burlap – this is made of good quality jute, is generally lighter than jute used for sacking and is used for making cloth and bags;
- sacking, which is made from lower grades of fibre and looser weave;
- canvas – which is the finest jute product, closely woven from the best grades of jute;
- jute yarn and twine (World Jute, 2011).

3.4.3.2 Coir

Coir fibre is used for similar purposes to jute. It is also a natural fibre that is biodegradable, but is extracted from the husk of coconuts *Cocos nucifera* rather than abstracted from the bark of a bush. It is the fibrous material found between the hard, internal shell and the outer coat of a coconut (Coir Institute, undated). Like jute, the fibres are composed of cellulose with some lignin. There are two varieties of coir; brown coir is harvested from fully ripened fruits; white coir is harvested from unripe coconuts, and has a lower lignin content. The fibres are usually spun to make yarn that is woven into mats or rope. Unlike jute, coir fibre is relatively waterproof. Coir-based products are used to aid in slope stabilisation and are being used increasingly as a soft-engineering option for protection and stabilisation of the banks of rivers and canals.

3.4.3.3 Selected material

The trials at Lough Corrib used jute sourced from a supplier in Ireland. The material was supplied in rolls 5.16 m wide and approx 900 m long. The weight of the weave was 187 grams per square metre (gsm). The cost (August 2011) was €0.39 m^{-2} or approximately €1,800 for a full roll plus approximately €400 delivery. As smaller quantities were required for this trial, other possible suppliers in mainland UK were sought. The aim was to identify a material that was:

- Biodegradable - to avoid the need to remove the material at the end of the trial;
- Made from renewable resources - some benthic barriers rely on the use of plastics or products generated from oil. SNH has a sustainable procurement policy which encourages reduced reliance on oil-based products.
- Woven at a similar density to the material used in Ireland to ensure that shading occurred, whilst allowing establishment of native species.

Potential materials and suppliers were identified through an internet search and discussions with builders' merchants. Relatively few potentially suitable products were identified as being produced in mainland UK.

Samples of a range of erosion control blankets designed for the construction industry were obtained from a number of suppliers. These were manufactured from either jute or coir. Several of these materials had a very open weave, which was not considered suitable to provide adequate shading.

The material selected for installation in 2011 was chosen as being most similar to the material which has been used in Ireland. It comprised a jute fabric manufactured from unbleached jute fibre. It is designed to degrade in 1 – 2 seasons and is recommended for use in areas where short term protection is required. It holds up to five times its own weight in water (Greenfix, 2009). The weight of the material is 305 gsm and it is supplied in rolls that weigh approximately 25 kg. The material is 1.22 m wide and approximately 68.58 m long. It can also be obtained in rolls of 3 m and 5 m width. Figure 3.3 shows a close up view of the material. Other pictures of the material are available in Appendix A.

Figure 3.3: Jute material installed in 2011

New material was installed in April 2012. Owing to concerns about the robustness and longevity of the matting installed in 2011 (see Section 5.1.2.1), new material was sourced from a supplier who manufactures materials for a variety of purposes including use in upholstery. This matting was of a heavier weave than had been used previously (approximately 550 gsm compared to 186 gsm used previously) (see Figure 3.4). The material was supplied in sections 183 cm wide and was pre-cut at the factory into 10 m lengths to facilitate easy installation.

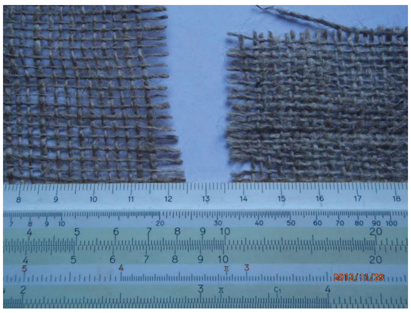

Figure 3.4: Comparison of jute matting installed in 2011 (left) and 2012 (right)

3.4.3.4 Attachment methods

The trial showed that the material would need to be weighted, rather than pinned, to the floor of the Loch. In Lough Corrib, a variety of anchoring techniques have been used. These include small concrete weights that are fixed with coat hangers onto the edge of the material at approximately 5 m intervals; and stones and large boulders collected from the edge of the Lough. These options were considered for Loch Libo, along with using weights made from sand bags, and using milk bottles containing stones or sand.

Loch Libo comprises mainly soft substrates, reducing the scope to collect stones, cobbles or boulders from the loch shore. It is also a small site, with no artificial hard substrates around its shores. For this reason, it was decided not to use any weights involving concrete. Some consideration was given to using milk bottles filled with a weighting material. As it was anticipated that the matting would biodegrade and so not need to be removed, it was decided that only biodegradable or inert materials would be used to weight the matting.

Commercial sand bags made from Hessian are available. These are generally filled with a fine, builder's sand. However, it was considered that this was a relatively expensive option, given the number of bags that were likely to be required. There was also concern that it might not be practical to carry the weight of the number of bags that might be needed.

It was decided to construct a number of small Hessian 'bags' containing washed gravel/ small stones. The bags were constructed using the same material as the sheeting. This was cut into small squares, stones were added, and the ends tied together using a biodegradable garden string (see Appendix A). The gravel was commercially available material, of varying sizes, available from garden centres for paths and was chosen as an inert material that was unlikely to influence water quality conditions in the loch.

3.4.4 Sample locations

The objective was to identify areas of the loch that supported *E. canadensis* at similar abundances and with similar associated species in order to pair sample sites with control sites.

The initial site survey, described in Section 3.3.2 of this report, showed that *E. canadensis* is the dominant species over most of the floor of the loch and appears to be present at a similar abundance throughout the site. Few associated species were recorded, and these were all present at low abundances. This meant that the sample and paired 'control' locations could be sited nearly anywhere within the loch.

It was decided to use the south-western outflow bay for both the sample shaded areas and corresponding control area (See Figure 4.1). This bay was chosen as:

- the bay was dominated by *E. canadensis* at high abundances;
- the area could easily be sub-divided into an 'experimental' and 'control' area that were very similar in terms of physical influences and vegetation composition;
- the bay is outwith the area used for carp fishing, and hence there was no risk of unintentional interference between the experiment and other uses at the site;
- access to the sample area from the shore is difficult owing to the presence of floating swamp vegetation, thus reducing the risks of unintentional interference with the sample areas;
- the site can be accessed easily by boat from the eastern end of the loch.

3.4.5 Number and size of experimental treatments

It was decided that a single shaded area would be created. This would be as large as possible to maximise the benefits of shading and reduce the extent of 'edge' effects around the perimeter of the shading material. Owing to limitations on the types of shading material that were commercially available, it was decided that a single weight of fabric would be installed in 2011.

Following an early season assessment of material installed in 2011 (see Section 5.1) it was decided to install a new area of matting of heavier weight in April 2012.

4. INSTALLATION OF MATTING

Matting was initially installed in late summer 2011. An early season check on this matting in spring 2012 showed that the matting had substantially decomposed, and new matting was installed in spring 2012. The methods used during both installations are described below.

4.1 Methods used for installation of matting in 2011

The shading was installed on 30th September & 1st October 2011. All equipment, including an inflatable boat, electric engine, shading material and bags of stones to pin the sheeting to the substrate, were carried to the site by hand.

The jute material had been pre-cut and folded into 11 m long lengths.

The material was installed in the northern half of the south-western outflow bay, leaving the southern half to be assessed as a control area. Figure 4.1 shows the location of the matting in relation to the Site Condition Monitoring sectors that are assessed by SNH.

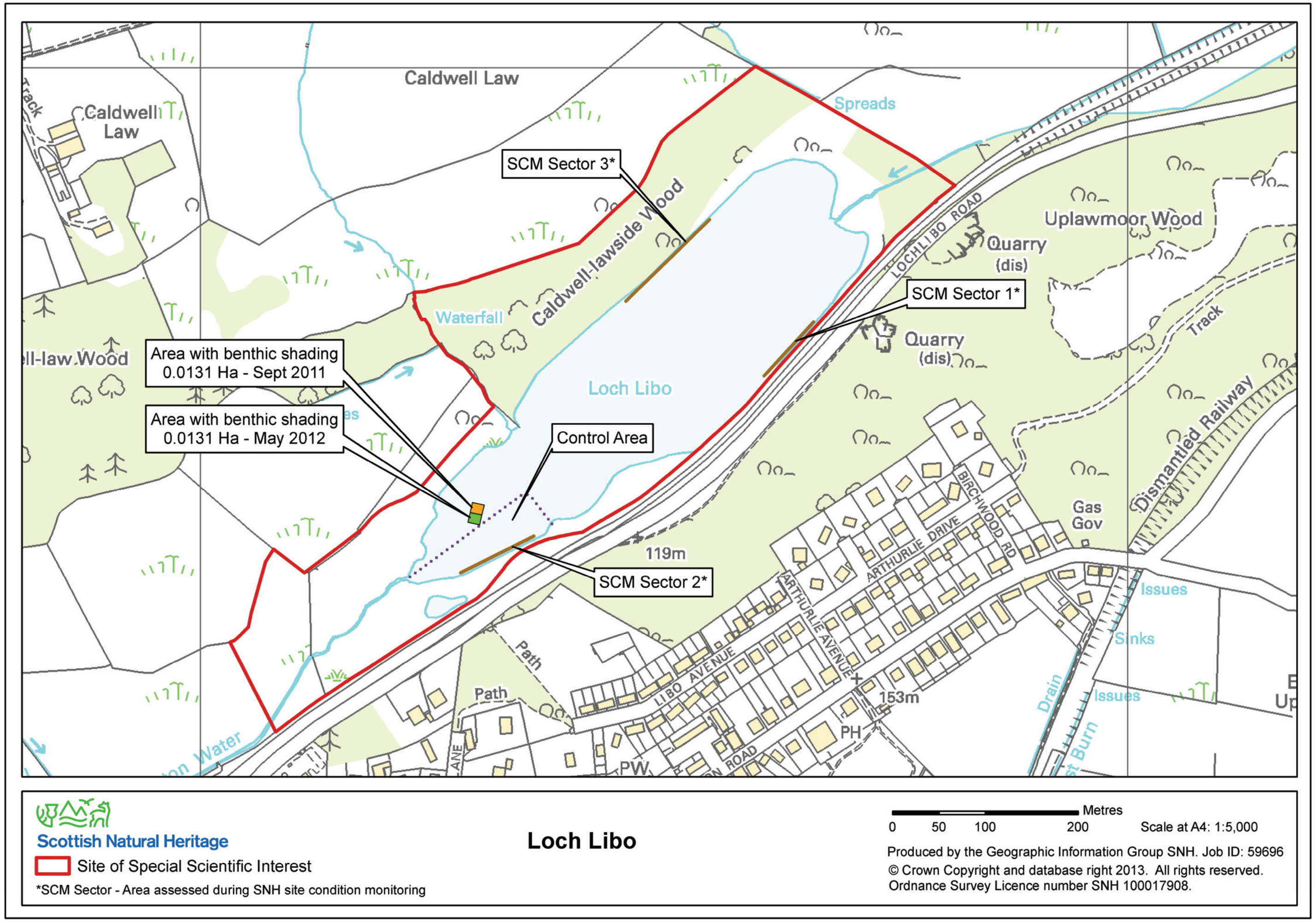

Figure 4.1: Location of sampling area

Each sheet of material was unfolded and floated out into position by the team of snorkellers (see Figure 4.2). Once in position, the material was positioned on the bed of the loch. It was then fixed in place using bags of stones along its edge and in the middle. It was hoped that it would be sufficient to place bags of stones at approximately 5 m intervals, but this did not provide adequate anchorage. This was partly owing to the height of the *E. canadensis* bed. Once all the sheets were installed in the desired positions, the snorkel team checked that there was adequate overlap between sheets and re-located bags of stones and fixing materials to ensure that the sheets were firmly secured. Bags were mainly positioned close to the edge of sheets, but some were also added to the middle of sheets to help pin the material more closely to the underlying *E. canadensis*. Air bubbles became trapped under the surface of the matting, which the snorkel team tried to eliminate by forcing the air through the weave of the material.

Figure 4.2: Snorkel team installing the jute matting

The sheets were arranged to create a rectangular area of cover (see Figure 4.3). The material was laid at a single thickness, other than where sheets overlapped to create a double thickness. The Grid Reference of each corner of the shaded area is provided in Appendix B. Sheets were overlapped to ensure that there was no light penetration between sheets (see Figure 4.4).

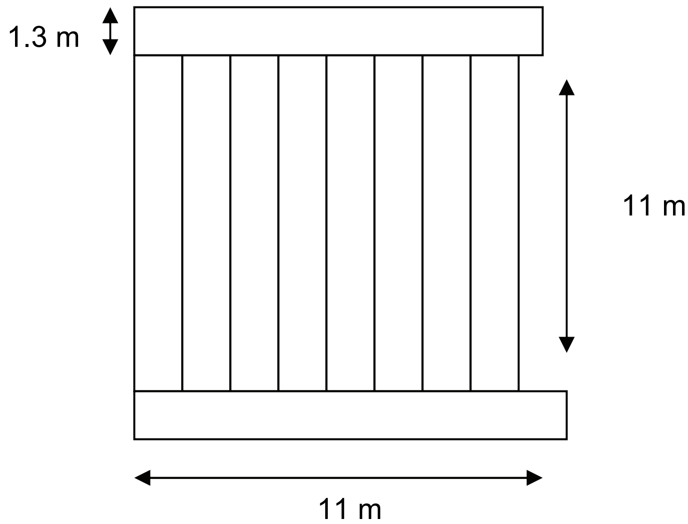

Figure 4.3: Arrangement of jute sheeting installed in autumn 2011 in Loch Libo

Figure 4.4: Overlap between adjoining sheets of jute matting

It was found that it was easier to position sheets if they were pre-soaked for approximately 5 - 15 minutes prior to laying them; otherwise the material sat on the water surface for some time and was difficult to fix to the bottom. Also, it increased the amount of air bubbles that became trapped below the sheets.

All of the material was installed in one day. On the second day, the snorkellers re-visited the site to assess whether the material had stayed in place overnight. Additional weighting material was taken to ensure that the edges of the sheets were adequately pinned to the substrate. This included cobbles collected from a small area of the edge of the loch. The extent of the shaded area was marked using four buoys.

Although water levels had increased by several centimetres in the night due to heavy rain, the sheets were still in place. Additional stones were added along the edges and in the middle of the sheets to ensure that they would stay in place over the winter.

It was noted that the height of the sheets had decreased slightly, as a result of the weight of material starting to pack down the *E. canadensis*. Air bubbles were noted below the surface of the material. This was assumed to be as a result of oxygen generated during photosynthesis. These bubbles could be readily removed by gently depressing the surface of the matting, which encouraged movement of the oxygen through the open weave of the material. It was anticipated that this would happen naturally once the bubbles reached a certain size.

Some stems of *E. canadensis* had settled onto the surface of the matting overnight.

4.2 Methods used for installation 2012

New material was installed on 12th May 2012, adjacent to, but outwith the area where matting had been installed in 2011 (see Figure 4.1 & Appendix B). Ten sheets were laid, two of which were laid over other sheets to create a double layer. Adjacent sheets were overlapped for a distance of between 20 – 30 cm. Eight sheets were laid parallel to each other in an approximately north – south position. Two sheets were laid across and on top of these sheets at 90^0 to create a double layer. As the sheets laid on top were only 10 m in length, they did not cover the full extent of the eight underlying rows (see Figure 4.5).

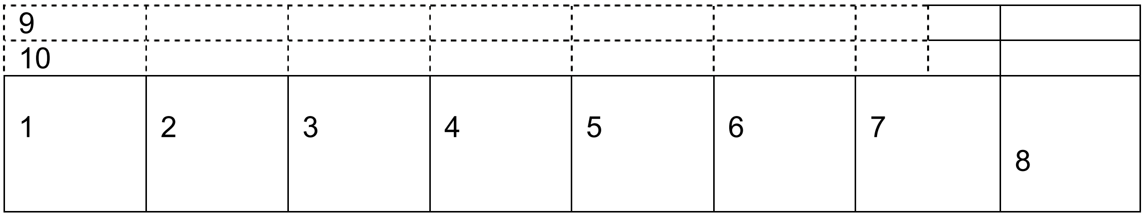

Figure 4.5: Illustration of the arrangement of jute matting 2012

The sheets were weighted to the substrate using small bags of gravel, as in 2011 (see above). The divers noted that the material settled more readily on the substrate and that air bubbles were not as obvious as they had been with the finer weight of jute used previously. Also, as the vegetation had died back over the winter it was easier for the material to lie closer to the substrate.

Visibility in the loch was very poor; the snorkel team had difficulty in seeing through the water for more than a few centimetres, and consequently much of the matting was installed by touch; it was not possible to make a clear visual check of the degree of overlap and to check that there were no gaps in the matting and it was not possible to take pictures owing to the poor visibility.

It had been hoped to check the matting the following day and to install additional anchoring material if required. However, the weather deteriorated, making it impossible to access the site by boat.

5. MONITORING SURVEYS

5.1 Early season checking of matting, spring 2012

5.1.1 Methods

The site was visited on 21st April 2012 in order to:

- check the condition and position of the matting installed in 2011;
- monitor the presence and condition of *E. canadensis* and other species at the start of the growing season.

A snorkel survey was carried out. Only fragments of matting were found within the sample area. It was concluded that the matting had disintegrated (see Section 5.1.2.1). Quadrat surveys were also conducted within the sample and control areas. Twenty quadrats ($0.25m^2$) were sampled in both the control and sample areas. The factors assessed were:

- height of the macrophyte bed;
- abundance of *E. canadensis*;
- condition of *E. canadensis;*
- evidence of regeneration of *E. canadensis;*
- presence and abundance of other species;
- extent of bare sediment visible.

An assessment of the condition of the matting was also made for quadrats within the sample area.

The condition of *E. canadensis* was assessed using a three-point scale where:
1 = *E. canadensis* is alive and intact;
2 = *E. canadensis* is decaying;
3 = *E. canadensis* is fully decomposed.

The degree to which the surface had become covered by sediment was assessed using a four-point scale where:
0 = none;
1 = present (covering 1 – 25% of the surface area of the quadrat);
2 = partially covered (covering 26 – 75% of the surface area of the quadrat);
3 = heavily covered (covering > 75% of the surface area of the quadrat).

Species abundance was assessed using the four-point scale recommended for Site Condition Monitoring (JNCC, 2009) where:
0 = not present;
1 = <25% of quadrat covered by species;
2 = 26 - <75% of quadrat covered by species;
3 = >75% of quadrat covered by species.

The condition of the jute matting was assessed on a four-point scale, where:
1 = intact;
2 = intact, easily torn;
3 = intact, disintegrates on contact;
4 = decomposed.

5.1.2 Results

5.1.2.1 Condition of jute matting

The matting had decomposed substantially over the 6 months that it had been in place. It was assessed as having fully decomposed (or disappeared) from 85% of the 20 quadrats.

In the remaining 15% of quadrats it was assessed as a mixture of disintegrating on contact and fully decomposed.   Figure 5.1 shows how the material had degraded.

Figure 5.1: Views of matting after immersion in Loch Libo for 6 months (a) in situ and (b) out of the water

5.1.2.2   Species presence and abundance

The species recorded within the sample and control sections are shown in Figure 5.2. Very few species were recorded, which is consistent with a survey early in the macrophyte growing season. The main difference in species occurrence was the presence of a small amount of moss, believed to be *Fontinalis antipyretica,* in the control section.

E. canadensis was recorded from all quadrats within the sample area. However, much of this *E. canadensis* did not appear to be rooted, although it showed signs of regeneration as evidenced by the presence of fresh green tips to shoots. By contrast, in the control area, *E. canadensis* was confirmed as rooted in 12 of the 20 quadrats. There were also differences in the height of the macrophyte beds in each area. *E. canadensis* in the control area formed a bed which varied in height between 50 – 60 cm, whilst in the sample area it was estimated to be in the order of 15 cm high.

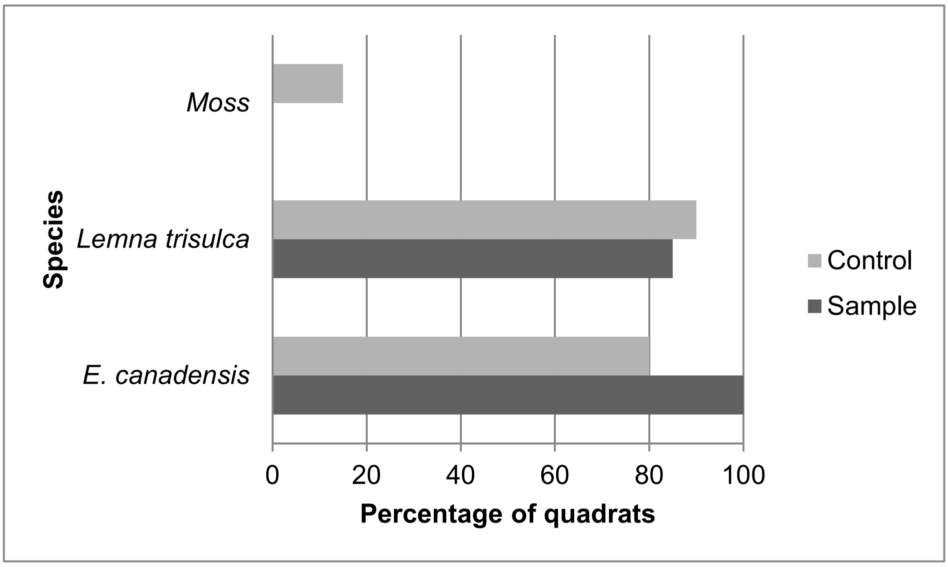

Figure 5.2: Frequency of occurrence of species in control and sample sections during early season monitoring visit

5.2 End of Season Macrophyte Survey, Summer 2012

5.2.1 Methods

The site was visited on 25th August 2012. Monitoring was undertaken by snorkel survey. Within both the sample and control areas macrophyte growth was recorded within 0.25 m^2 quadrats.

Within the area covered by the matting (sample area), surveyors placed a quadrat at random and recorded the following details:

- depth of quadrat;
- approximate height of macrophyte bed **on surface** of matting;
- percentage of quadrat vegetated on **surface** of matting;
- species present **on surface** of the matting, together with a broad assessment of abundance;
- extent of sediment on **surface** of matting;
- condition of matting;

An incision was then made in the surface of the matting and it was pulled back to observe the following features underneath:

- condition of *E. canadensis* **below** matting;
- presence and degree of sedimentation **below** matting;
- height of macrophyte bed **below** matting;
- presence of other species **below** matting together with a broad assessment of abundance.

The initial aim was to sample 20 quadrats in each of the areas covered by single and double thicknesses of material, but in practice it was not possible to determine, prior to cutting the matting, whether the quadrat was laid on a single or double thickness of material. Initially 20 quadrats were sampled. Sediment was allowed to settle and a further 20 quadrats were sampled – making a total of 40 quadrats within the sample area; 26 on single thickness material, 13 on double thickness material and 1 on treble thickness material.

Twenty quadrats were assessed in the control area. Features recorded were:

- depth of quadrat;
- approximate height of macrophyte bed;
- percentage of quadrat vegetated;
- species present, together with a broad assessment of abundance;
- extent of sediment.

5.2.2 Results

Data were collected from 40 quadrats within the sample area, distributed as follows:

- single thickness fabric – 26 quadrats
- double thickness fabric – 13 quadrats
- treble thickness fabric – 1 quadrat

The treble thickness sample has been removed from further analysis.

5.2.2.1 Quadrats

Data were collected from 40 quadrats within the sample area, distributed as follows:

- single thickness fabric – 26 quadrats
- double thickness fabric – 13 quadrats
- treble thickness fabric – 1 quadrat

The treble thickness sample has been removed from further analysis.

5.2.2.2 Condition of Jute Matting

The jute matting was found to have altered its location on the floor of the loch, having apparently drifted slightly towards the northern shore (precise distance not known, but in the order of c. 5 m). This movement had resulted in some buckling in the surface of the material in places, but the sheets had apparently moved as a single mass.

The material had retained its integrity, and was assessed as intact in all quadrats (score of 1 in all quadrats).

5.2.2.3 Sediment

The substrate over much of the loch is fine silt. Sediment was recorded at a high cover value in all the quadrats within the control area (score of 3 in all quadrats). By contrast, none of the quadrats on the surface of the matting had any noticeable sediment (cover score of 0 in all quadrats on both single and double-thickness matting).

5.2.2.4 Proportion of quadrat vegetated

The proportion of each quadrat that was vegetated was assessed using a three-point scale. Within the control area, all but one quadrat were given a score of 3, indicating that over 75% of the quadrat was covered by vegetation (i.e. the modal score was 3). By contrast, within the sample area, the modal score for vegetation cover on the matting was 1, indicating that less than 25% of each quadrat was vegetated. The statistical significance of these observed differences was assessed using a Fisher's exact test, and was found to be highly significant[2]. The modal scores were similar for the areas covered by single and double layers of material and there was no significant difference in these scores.

Figure 5.3 shows an example of the difference in vegetation between (a) a quadrat in the control area and (b) a quadrat on the matting.

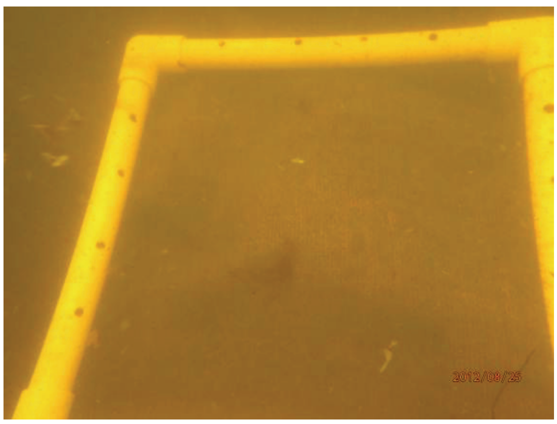

Figure 5.3: Examples of quadrats in (a) control area and (b) sample area on matting

[2] Two-tailed p value <0.0001 using Fisher's Exact test

5.2.2.5 Numbers and frequency of species present

Figure 5.4 shows the occurrence of each species in the control and sample areas including occurrence of species above and below the matting.

A greater number of macrophyte species were recorded from the control area (4) than the treatment areas (2).

The frequency of occurrence of *E. canadensis* was lower in all treatment areas when compared to the control area, and was lowest on top of the matting than underneath it for both treatments. By contrast, the frequency of *L. trisulca* was higher in both of the treatment areas than in the control area, and was highest below the matting (of either thickness) than above it. Further comments on these observations are provided below.

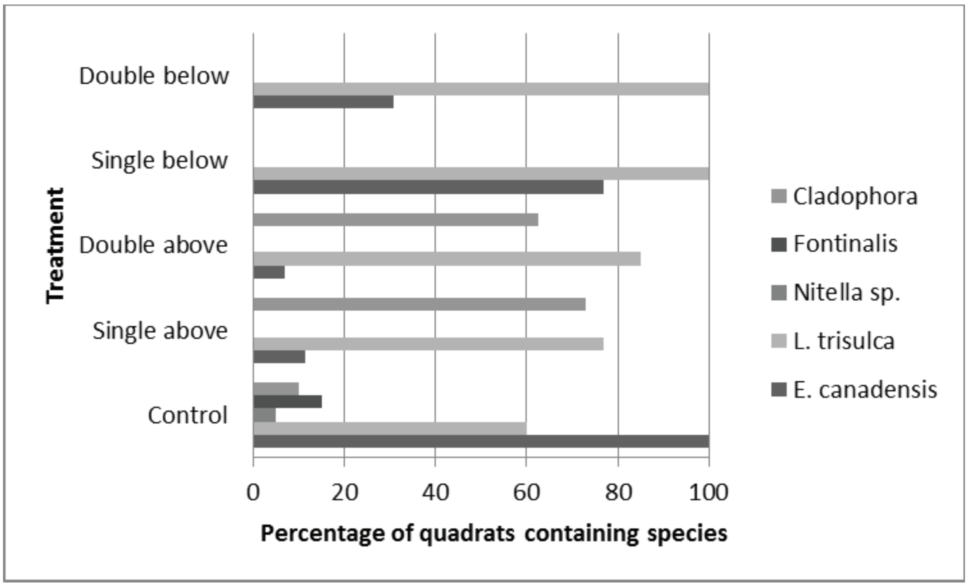

Figure 5.4: Percentage occurrence of each species within quadrats in the sample and control areas

5.2.2.6 *E. canadensis*

Table 5.1 summarises the modal cover of *E. canadensis* within quadrats for the control and treatment areas, including cover above and below the matting.

E. canadensis was present at a modal cover value of 3 in the control quadrats (score of 3 in 18 of the 20 quadrats). By contrast the modal score was 0 in the quadrats situated above both the single and double thicknesses of matting (score of 0 in 23 of 26 quadrats and 12 of 13 quadrats respectively). The cover of *E. canadensis* is highly significantly lower on the surface of the sample plots than in the control area ($p < 0.001$ Fisher's exact test). There was no significant difference between the cover of *E. canadensis* on the surface of the single or double layers of material.

The abundance of *E. canadensis* below the matting (both single and double thicknesses) was highly significantly lower than that found in the control plots ($p < 0.001$, Fisher's exact test). The levels of *E. canadensis* below the double layers of matting were significantly lower ($p = 0.009$ Fisher's exact test) than those recorded below the single thickness of material (modal cover score = 0 in 9 of 13 quadrats under double thickness compared to modal score = 3 in nine of 26 quadrats under single thickness); cover scores of 2 and 0 were both recorded in seven of the quadrats.

Table 5.1 Modal scores and range for proportion of each quadrat covered by E. canadensis

Treatment	Modal Cover Score	Range
Control (*n=20)*	3	(2 – 3)
Single thickness – above (*n=26)*	0	(0 – 2)
Double thickness – above (*n=13)*	0	(0 – 1)
Single thickness – below (*n=26*)	3	(0 – 3)
Double thickness – below (*n=13*)	0	(0 – 2)

The height of the *E. canadensis* beds both below the matting and in the control area was estimated. The mean height of *E. canadensis* in the control area was 0.375 m (range 0.1 – 0.5 m; Standard Deviation 0.112 m) compared to a mean of 0.225 m (range 0.2 – 0.3 m; Standard Deviation 0.117 m) under the single layer of matting and 0.1 m (Standard Deviation 0.04 m) under the double layer of matting[3]. These apparent differences were tested using a two-tailed t-test for independent samples. The difference in mean height of *E. canadensis* between the control area and under each treatment was found to be highly significant ($p < 0.0001$ in both cases). The difference in height of *E. canadensis* below the single and double layers of material was also highly significant[4].

There were highly significant differences in the condition of *E. canadensis* under the matting compared to that in the control area. Handfuls of the plant material were pulled out from below the matting and examined. These were mainly black, and decomposing with some green tips to stems (see Figure 5.5). The modal condition score was 2/3 – indicating that the *E. canadensis* was a mixture of decaying or fully decomposed. Material in the control area was healthy ($p<0.0001$ Fisher's exact test). There was also a significant difference between the condition of *E. canadensis* below the single thickness of material compared to the double thickness ($p = 0.0172$), with material below the double thickness showing a greater degree of degradation.

Figure 5.5: Example of decomposing E. canadensis extracted from below matting

5.2.2.7 *L. trisulca*

Table 5.2 summarises the modal cover of *L. trisulca* within quadrats for the control and treatment areas, including cover above and below the matting.

[3] Quadrats where *E. canadensis* was absent below the matting have been excluded from the assessment of mean height.
[4] t=6.933 for comparison of control with single layer of material; t=10.296 for comparison of control with double layer of material; and t=3.422 for comparison of single and double layers of material.

Table 5.2: Modal scores and range for proportion of each quadrat covered by L. trisulca

Treatment	**Modal Cover Score**	**Range**
Control (*n=20)*	1	(0 - 2)
Single thickness – above (*n=26)*	1	(0 – 2)
Double thickness – above (*n=13)*	1	(0 – 1)
Single thickness – below (*n=26*)	3	(0 – 3)
Double thickness – below (*n=13*)	0	(0 – 3)

The modal cover score for *L. trisulca* in the control area was 1, recorded in 11 of the 20 quadrats; it was not present (cover score 0) in eight of the quadrats. This is consistent with the levels of *L. trisulca* found on the surface of the matting (modal score of 1 recorded in 18 of the quadrats on the single thickness material and modal score of 1 on the double thickness matting recorded in 11 quadrats). There is no significant difference in the cover of *L. trisulca* on the surface of treated areas compared to the control.

By contrast, higher cover scores of *L. trisulca* were recorded under the matting. The modal cover score was 3 under the double thickness matting (recorded in six quadrats), and 2 below the single thickness matting (recorded in 12 quadrats). These differences are highly significant ($p < 0.0001$) for both the single and double thickness of material. There was no significant difference between the levels of *L. trisulca* under the single or double thickness of material.

The *L. trisulca* below the matting was found to be a mixture of healthy, green material, and material that was yellowing.

5.2.2.8 Cover of *Cladophora sp.*

Table 5.3 summarises the modal cover of *Cladophora* sp. within quadrats for the control and treatment areas, including cover above and below the matting.

Table 5.3: Modal scores and range for proportion of each quadrat covered by Cladophora

Treatment	**Modal Cover Score**	**Range**
Control (*n=20)*	0	(0 - 1)
Single thickness – above (*n=26)*	1	(0 – 3)
Double thickness – above (*n=13)*	0/1	(0 – 3)
Single thickness – below (*n=26*)	-	-
Double thickness – below (*n=13*)	-	-

Cladophora sp. was found in the control area and above the matting in the sample areas; it was not recorded below the matting. There was a significant difference in the levels of *Cladophora* sp. in the control areas compared to below the matting in the treated areas ($p<0.001$).

5.3 Protected Species

No signs of water voles or otter were noted from the survey area during any of the survey or monitoring visits.

6. DISCUSSION

6.1 Longevity of the jute matting

One reason for exploring the use of jute matting is that it is biodegradable. This means that, unlike other shading materials, it would not need to be removed from a site, but could be allowed to naturally degenerate. However, it needs to be able to retain its integrity long enough to achieve control of *E. canadensis* prior to decomposing.

Jute matting is recognised by the landscaping industry as a material that can provide short-term stability to surfaces prior to degradation. The technical specification for the material used during the first phase of this project indicates that the durability of the material (in a terrestrial setting) is in the order of 1 – 2 years (Greenfix, 2009).

The matting introduced for the first treatment in September 2011 was found to have lost its integrity by April 2012 and had broken into smaller sections. This contrasts with the situation in Lough Corrib, where jute matting of a similar specification was found to maintain its integrity for longer. It was considered to be fully functional for up to 7 months; by 10 months, the matting appeared intact, but could be relatively easily torn; and by 17 months it was visually intact, although it disintegrated on contact (Caffrey *et. al.* 2010).

The early break-down of the material in Loch Libo is thought to be due, in part, to movement within the loch. The sample areas were in the outflow bay of the Loch, and it is understood that water levels in the site can vary appreciably. As there were difficulties in fixing the shading directly to the floor of the loch (see section 4.4), it is possible that there was some vertical movement of the matting. The second treatment of material that was installed also showed some movement between installation and sampling. Support for this theory also comes from Ireland, where material introduced to a canal was found to lose its integrity within four months of installation. The site was near a sluice, and the movement of water was thought to be a contributory factor (Caffrey, *pers comm*).

Loch Libo is classified as a eutrophic water body (SNH website), whereas Lough Corrib is a mesotrophic site, so differences in water quality may also have contributed to the accelerated decomposition rate. The matting was installed in depths of up to 1.5 m in Loch Libo, this is much shallower than Lough Corrib, where much of the matting has been installed at depths of between 1.5 and 4 m (Caffrey, *pers comm*).

6.2 Efficacy of jute matting in controlling growth of *E. canadensis*

The jute matting installed in April 2012 was effective in limiting the growth of *E. canadensis* over the 4 month period that it was assessed. The surface of the matting did not become colonised by *E. canadensis* during the timescale of the project and the height and abundance of *E. canadensis* declined significantly below the surface of the matting.

The matting installed in April 2012 moved a short way from where it was placed, but even so, the frequency of *E. canadensis* below the matting was found to have declined (statistically highly significant). Prior to installation of the matting, 100% of quadrats within the sample area had contained *E. canadensis*. Also 100% of quadrats in the control area contained *E. canadensis*, whilst less than 80% of the quadrats under a single layer of matting and around 30% of quadrats below a double thickness of matting, contained *E. canadensis.* The degree of decline was statistically greater under the double thickness than the single thickness of material, although both showed a decline.

The first lot of matting installed in 2011 had decomposed by April 2012, but differences in the abundance of *E. canadensis* were recorded between the control and the area where the matting had been laid. Quadrats in the area where the jute had been laid had a significantly higher (p<0.0001) modal cover score of *E. canadensis* in April 2012, than the control. At that time levels in the control area were lower than recorded at the end of the summer (80% in April compared to 100% in August). This suggests that the matting may have acted to protect the *E. canadensis* winter months, preventing it from dispersing.

Both single and double layers of matting were observed to have a statistically significant effect on the presence and abundance of *E. canadensis*, although greater effects were experienced from the double layer than the single.

6.3 Development of a native flora

Installation of jute matting in Lough Corrib promoted the regeneration of native species, principally charophytes (Caffrey *et. al.* 2010). Regrowth of *Chara virgata* and *Nitella flexilis* was recorded from around 4 – 5 months after the matting was installed. These grew through the matting, and it was thought that they had developed from oospores within the sediment, and that the matting had stabilised the sediment sufficiently to allow their growth. It was hoped that regrowth of native macrophytes through the matting may also be experienced at Loch Libo, particularly as the pre-installation survey in 2011 identified the stonewort *Nitella flexilis* at low frequencies throughout the control and experimental areas.

No macrophyte species were observed growing through or on the surface of the matting, other than the free-floating *L. trisulca* (see below). Whilst plants were recorded in Lough Corrib 4 months after matting was installed, growth was noted up to 7 months after the material was installed. The material in Loch Libo had been in place for around 4 months over the main growth season when it was sampled. However, given the apparent movement of the shading material, it is possible that plants were unable to regenerate within one season.

The free-floating *L. trisulca* was recorded in around 80% of quadrats on the surface of the matting. This was higher than its frequency in the control area (found in 60% of quadrats), but was consistent with levels prior to installation of the matting, where it was recorded in around 90% of quadrats. *L. trisulca* was present in 100% of the quadrats under both the single and double-thickness of matting. The *L. trisulca* was so thick that it acted to further block light levels passing through the matting. As this is a free-floating species its distribution within a site can be easily affected by wind and currents. It is suggested that it may have got washed under the surface of the matting and become trapped.

Algae were also found on the surface of the matting. This was growing in and acting to block the holes in the material. (See Figure 6.1).

Figure 6.1: Example of algae developing on surface of matting

6.4 Installation methods

Installation methods were dictated, in part, by the physical conditions at the site. The site is used for carp fishing, which is confined to the eastern end of the loch, closest to the access point from the main road. To avoid interference with carp fishing the material was installed at the western end of the site. The site could not be accessed from the shore, necessitating use of a boat. All equipment, including an inflatable boat, electric engine, shading material and bags of stones to pin the sheeting to the substrate, were carried to the site by hand. This limited the amount of material that could be taken onto the site at any one time.

The method for installation of jute at Loch Libo worked well. Pre-soaking the material, by holding it in the water for 5 – 15 minutes prior to installation helped to speed up the rate at which the material sunk and could be placed.

Pre-cutting sheets to the required length also worked well. Installed sheets were in the order of 10 – 12 m in length, which was found to be a manageable size and weight of material to manipulate in the water. The width of material used was dictated by what is commercially available in the UK, but it was also close to the maximum width that could be accommodated within the inflatable boat. However, it did increase the number of pieces of material that needed to be installed, particularly as adjoining sheets need to be overlapped to avoid light entering at the edges. Using these techniques, an area in the order of 140 m^2 was installed in September 2011 and a similar amount of material was laid in May 2012.

This approach is similar to that used in Lough Corrib for treating small beds of *Lagarosiphon major* (<200 m^2), where pre-cut sheets of jute, each around 5 m x 15 m, are placed either from a boat or are brought by divers from the shore. Larger areas are treated by laying material from a boat-mounted dispenser on a purpose-modified boat, which is kept on the lough. Material is laid in 100 m-long strips (Caffrey *et. al.*, 2010).

During the first installation period at Loch Libo in September 2011, the material was laid on one day, and was checked the following day. This allowed the material to settle overnight and also allowed sediment levels in the water column to subside, improving visibility. Additional weights could then be transported to the site and added to areas where the fabric did not appear to be fixed sufficiently closely to the substrate. A similar approach was planned during the second installation phase in May 2012, but poor weather on the second day meant that the site could not be accessed and poor visibility on the first day hampered installation. Based on these experiences, it is suggested that a check should be made the day after installation to ensure that the material is flat and sufficiently anchored.

There was no fixed distance for the distribution of bags of stones and gravel. The installation team places weights as necessary to fix the material close to the surface of the *E. canadensis* bed.

Visibility was an issue during some of the site visits. The unconsolidated nature of the sediment, combined with the shallow depth of water meant that material was prone to re-suspension, either due to wind and wave action, or as a result of movement near the surface by the snorkel team (e.g. from fins).

6.5 Anchoring of Jute

There were difficulties in anchoring the jute within the loch. Movement of material is thought to have contributed, at least in part, to the rapid breakdown of material that was installed in 2011. This is supported by research in Ireland, where jute installed in a canal near a lock, which was subject to frequent fluctuations in level, was found to break down within approximately 4 months (Caffrey, *pers comm*).

Carp are present within Loch Libo. Although this species is known to uproot aquatic plants when feeding, there was no evidence that feeding action interfered significantly with the installed material. For example, the sheets of material installed in spring 2012 remained overlapping throughout the study. Had carp feeding interfered with the material it would be expected that some sheets would have come become separated from the main area. Some buckling of the edges of the material was noticed, but this is thought to have been attributable to the movement of the material.

The nature and depth of sediment at the site created challenges in terms of installation of the material. Silt beds in the sample and control areas were in the order of 0.7 deep, and comprised a fine, unconsolidated material, which was easily disturbed by swimming over the surface. *E. canadensis* beds extended for around a height of 0.5 m above the silt. None of the pins and pegs tested was sufficiently long to provide anchorage into the substrate. The most effective method was found to be weighting the sheets to the vegetation using small bags of stones, and handfuls of loose stones, which all had to be carried by hand to the site, and in the boat to the sample area. At other sites, it might be possible to collect naturally occurring hard substrates from around the loch shore and place these on shading material.

Various different approaches have been used in Ireland to fix matting to the substrate. Conditions at Lough Corrib are not identical to those at Loch Libo; although silt is present in some areas, this appears to be less deep (around 30 cm). Methods used to fix the matting in Lough Corrib include small concrete weights that are fixed with coat hangers onto the edge of the material at approximately 5 m intervals; and stones and large boulders collected from the edge of the Lough. Recently, the team has switched to the use of gravel, and small hessian bags of gravel, similar to the approach used at Loch Libo (Caffrey, *pers comm*).

Finding an effective method of fixing jute to the substrate of standing water bodies has also been a challenge in Lake Tahoe in America (L. Anderson, *pers comm*). As part of a project supported by the United States Department of Agriculture, different approaches to controlling *Myriophyllum spicatum* are being investigated, including the installation of three different types of benthic barrier, one of which is jute (USDA, 2013). There have been difficulties in getting the jute to stay anchored to the bottom, in spite of addition of extra weights post-installation (L. Anderson, *pers comm*).

6.6 Resources

Shading material can be commercially sourced from both landscaping contractors and also manufacturers of woven materials. Some suppliers will provide material cut to the required lengths. However, the material installed in 2011 had to be cut to length after delivery, and the material installed in 2012 had to be folded to enable easy installation.

Gravel and small stones to weight the shading were purchased from a high street garden centre (20 mm gravel). Hessian bags were constructed by hand to act as weights. The weight of the material made transportation to the site difficult and limited the amount of material that could be transported in the boat.

The installation of material was undertaken by a team of two snorkelers, with a backup team of two people. The backup team assisted with carrying material to the site, pre-soaking material and passing materials to the snorkel team. A team of 3 - 4 is likely to be the minimum size to be effective.

Each sheet took in the order of 15 minutes to install.

6.7 Comparison of use of jute matting with other shading methods

Shading operates by blocking light to plants, preventing photosynthesis. Plastic sheeting has been used to control New Zealand pygmyweed *Crassula helmsii* in Scotland. Plastic can be a difficult material to install; its buoyancy and impermeability mean that it is difficult to sink and fix to the bed of the waterbody (Caffrey and Acevedo, 2007). As plant material decomposes below the plastic it generates gases, which raise the sheeting up. The material is not biodegradable, and so needs to be removed from sites.

Various matting treatments are available commercially in the USA to assist in weed control in lakes used for recreational purposes. These use a variety of materials, often fitted to frames, which are designed to be removable after a few weeks.

The jute matting was relatively easy to install with a small team. In the shallow conditions at Loch Libo, it could be installed using a snorkel team, rather than using full sub-aqua equipment, which reduces the costs and scale of health & safety requirements.

Decomposition of jute matting at Loch Libo has been demonstrated, meaning that it does not need to be removed. The initial installation had substantially decomposed within 6 months. Whilst the second lot of material was still intact after 4 months, it had lost some of its strength since installation, and is anticipated to breakdown further over the winter months.

7. GUIDANCE FOR FUTURE APPLICATIONS

This study has shown that jute matting laid over the substrate of a loch can act to reduce the vigour and condition of growth of *E. canadensis*, but its ability to promote the development of a native flora is not proven. The following section provides guidance about techniques for installation of material.

7.1 Source of materials

Jute matting can be obtained from a variety of sources for different purposes. Potential materials and suppliers were identified through an internet search and discussions with builders' merchants. Relatively few potentially suitable products were identified as being produced in mainland UK.

The trials at Lough Corrib used jute sourced from Landfill Technology Ltd, in Co. Waterford, Ireland. The material is supplied in rolls which are 5.16m wide and approximately 900m long. The weight of the weave is 187 gsm. The cost (August 2011) was €0.39 m^{-2} or approximately €1,800 for a full roll, plus approximately €400 delivery. Further details can be obtained from www.landfilltechnology.ie.

The material used for the first phase of this trial was supplied by Greenfix, who produce a range of erosion control blankets for use in landscaping projects. Several of the products are made from natural fibres including coir, straw, hay and jute. Some of these are supplied pre-seeded to promote vegetation growth. Geo-Jute, which was used for this project, is manufactured from unbleached jute fibre. It is designed to degrade in 1 – 2 seasons and is recommended for use in areas where short term protection is required. It holds up to five times its own weight in water (Greenfix, 2009). The weight of the material is 186 gsm and it is supplied in rolls that are 46 m long weighing approximately 25 kg. It can also be obtained in rolls that are 5 m wide and 800 m long. The cost (August 2011) was £120/roll plus a carriage charge in the order of £15. It can also be obtained in rolls that are 5.13 m wide and 800 m long. Further details can be obtained from www.greenfix.co.uk.

Material used for the second phase of the project was supplied by Whaleys (Bradford) Ltd. This company provides a wide range of natural fabrics suitable for domestic and commercial use for manufacturing purposes. Four different grades of jute and hessian material are available: fine natural hessian (530 gsm); heavy jute (775 gsm); jute hessian natural (550 gsm); and jute tarpaulin (660gsm). The material used in this trial was Jute Hessian Natural, supplied at a cost (May 2012) of £1.31 per metre, with an additional nominal charge for cutting and rolling the material into 10 m long lengths. A carriage charge is also applied – depending upon the speed of delivery. All prices are excluding VAT. Material can be supplied at two widths (91 cm and 183 cm) and at any length. Further details can be obtained from www.whaleys.co.uk.

The lighter material (186 gsm) has been used successfully in Lough Corrib, but was found to break down quickly in Loch Libo. The choice of material in any subsequent control studies should be selected based upon the length of time that the material is required to retain its integrity, trophic status, and also be informed by the degree to which water levels are anticipated to fluctuate. It is suggested that in stable, oligotrophic – mesotrophic sites where short-term control is required, material of 186 gsm may be sufficient, based on the experiences in Ireland; however, based on the experiences at Loch Libo, heavier grade material should be used in situations that may be subject to more water movement or higher nutrient levels.

7.2 Choice of site

Based on the experiences at Loch Libo, the ideal characteristics of a site chosen for installation of matting would be:

- the site should either have a boat on it, or be located close to an access point that allows easy launching of a boat and transport of materials to the site;
- the site should have mono-dominant stands of *E. canadensis* that can be treated with minimum effect on native macrophytes;
- the site should have a viable source of native plant material;
- the *E. canadensis* beds should be located on firm substrates, or in areas of shallow or consolidated silt (less than 0.5 m is recommended). Placement in areas with deep silt are less likely to be successful;
- the material should be placed in areas where water movement is minimal.

7.3 Installation methods

The methods used during this study generally worked well; matting can easily be installed in depths of around 1.5 m by a snorkel team working from a boat. Deeper water may require sub-aqua support.

It is important that the material is fixed as closely as possible above the bed of the *E. canadensis*. The use of stones, gravels and weight bags appears to be effective, providing adequate quantities are used. Where possible, shading material should be installed on one day, and then re-checked within 2 – 3 days and extra weighting material added as necessary. This creates time for the jute to become fully waterlogged, for oxygen bubbles to escape from beneath the matting, and for the plants to become flattened prior to adding extra weights.

Where possible, the jute should be weighted using stones collected from the same site, to reduce the introduction of rock that is not local to the area. However, where this is not possible, natural materials that are relatively inert (e.g. gravels) should be used in preference to concrete.

The first installation of jute was carried out at the end of the growing season (in October 2011). This had the advantages that the beds of vegetation were clearly defined, water temperatures were relatively high, extending the length of time that people could work in the water, and the clarity of water was good. The disadvantage was that there was a lot of loose *E. canadensis* floating in the loch, which settled onto the surface of the material. By contrast, the second treatment was installed in May. Water temperatures were cool, limiting working time. The installation also coincided with the spring overturn and algal bloom, meaning that visibility in the water column was very poor. Providing that the material is firmly fixed, and is of a sufficient grade to withstand the winter period, it may be advisable to install the material at the end of the summer.

Material was laid in single and double layers. The condition of *E. canadensis* declined under both treatments, but greater effects were noted under the double thickness material. Whilst a thicker treatment of material may be more effective in controlling the *E. canadensis* it may also act to reduce light levels preventing germination of native species. A single layer of material has been used over much of Lough Corrib, but double layers of material have been laid in shallow bays to achieve the required control of *L. major*. Double layers of material are also being used in ponds in Ireland (Caffrey *pers comm).*

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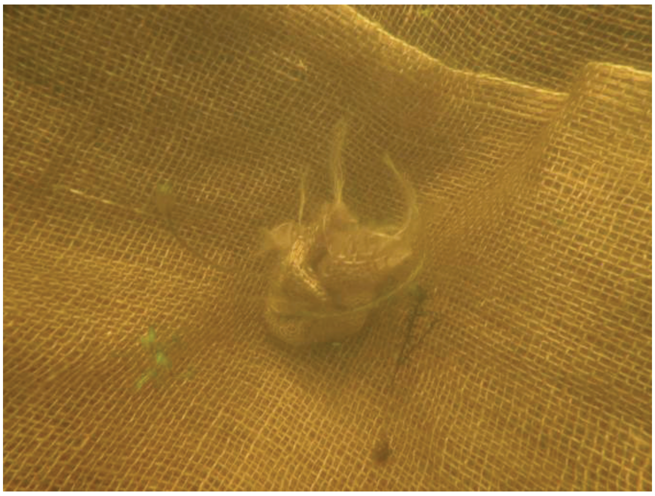
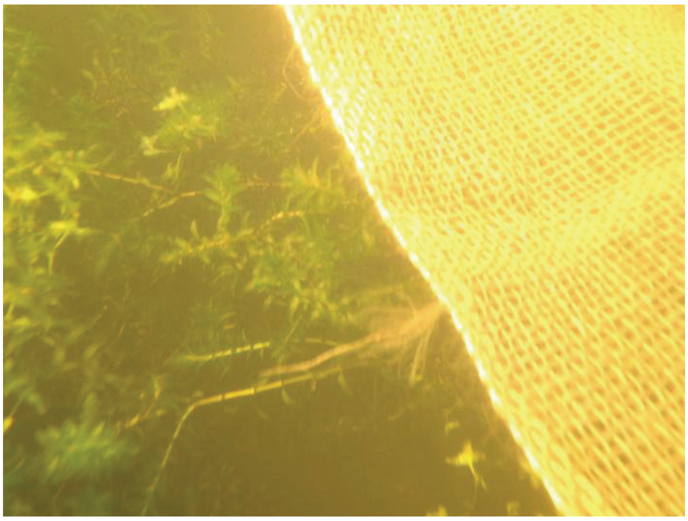
APPENDIX A: PHOTOGRAPHS

Rolls of jute as delivered from the supplier in 2011 (left) and creation of small, weighted bags for fixing jute matting to the substrate (right)

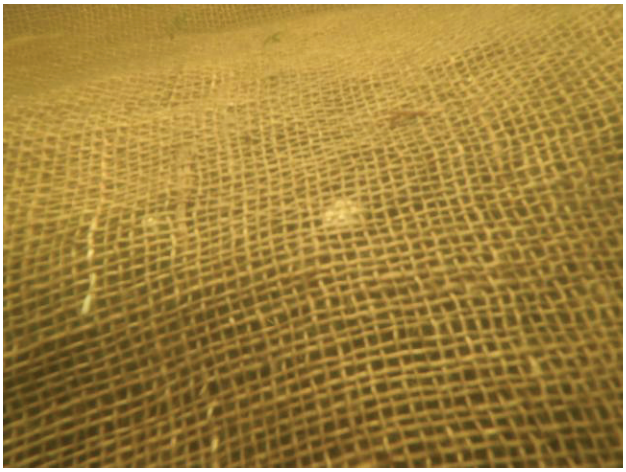
Divers towing jute matting out to required position from inflatable boat (2011)



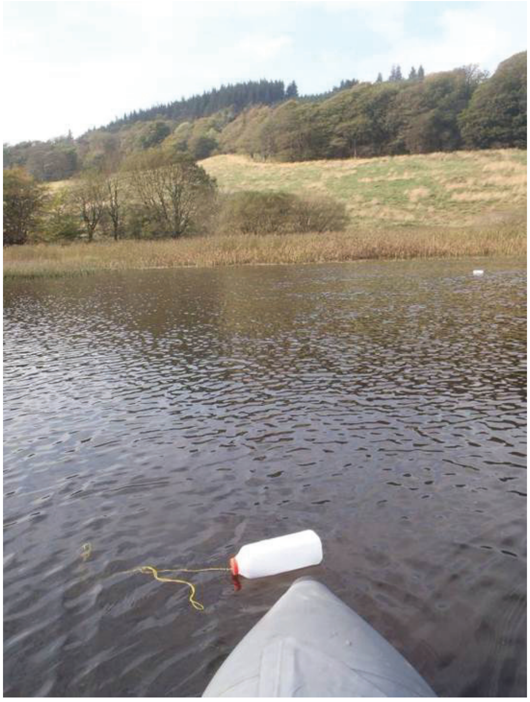
Small bag of stones pinning jute matting to substrate. Note presence of Lemna trisulca settling out on the surface of the matting (2011)



Edge of jute matting showing extent of plant growth that extends beyond it (2011)



Jute matting in situ. The pale circle in the middle of the photograph is air that has become trapped below the matting (2011)



Study area seen from the surface of the loch. The jute lies between the plastic buoys

Surface view of study area

APPENDIX B: LIMITS OF SHADED AREA

The following grid references define the outer corners of the shaded area:

2011	2012
NS 43312 55517 (± 9 m)	NS43290 55562
NS 43285 55525	NS43296 55529
NS 43289 55536	NS43301 55520
NS 43311 55518	NS43291 55515

Any apparent overlap in grid references from the GPS is owing to inaccuracies in readings on the day.

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