Scottish Natural Heritage
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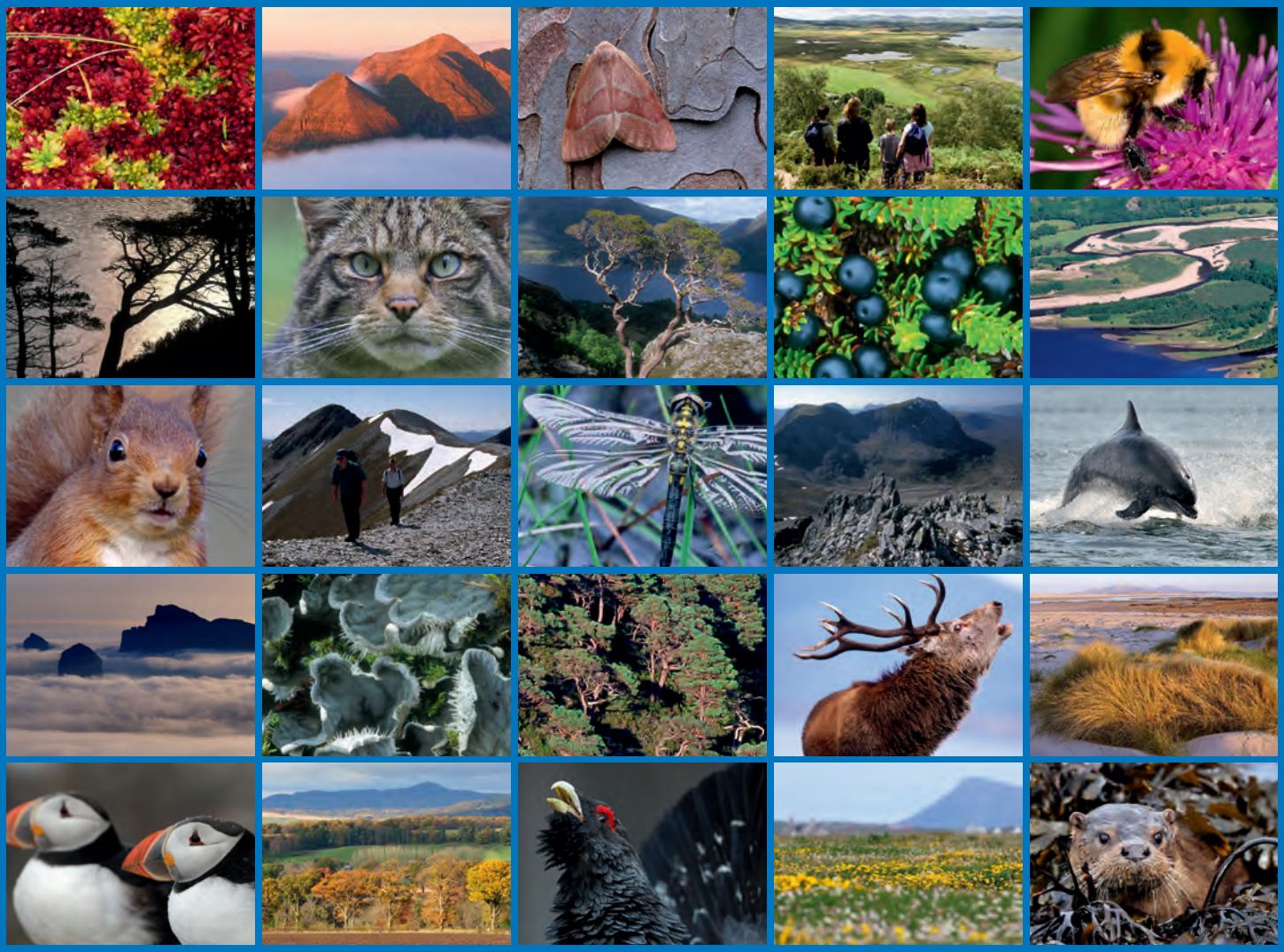
Control of New Zealand pygmyweed (Crassula helmsii) at Mochrum Lochs SSSI: phase III, 2009 – 2010



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Control of New Zealand pygmyweed (*Crassula helmsii*) at Mochrum Lochs SSSI: phase III, 2009 – 2010

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COMMISSIONED REPORT

Summary

Control of New Zealand pygmyweed (*Crassula helmsii*) at Mochrum Lochs SSSI: phase III 2009 – 2010

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Background

New Zealand pygmyweed (*Crassula helmsii*) is a non-native, invasive, aquatic plant species, which is particularly competitive within the drawdown zone of standing water bodies. It is able to regenerate from very small fragments and tolerate periods of desiccation. These attributes have resulted in the rapid colonisation and dominance of *C. helmsii* over native species in standing water bodies throughout mainland Britain.

C. helmsii was recorded in Mochrum Loch in 2004. The Mochrum Lochs site is designated as a SAC due to the international importance of its bog habitats. Mochrum Lochs SSSI is designated for features of interest that include oligotrophic lochs, blanket bog and breeding bird assemblages. The SSSI includes three water bodies: Castle Loch, Black Loch and Mochrum Loch, along with extensive areas of wetland. *C. helmsii* is present in Mochrum Loch, so a programme of control measures, including use of weed control fabric to shade areas of *C. helmsii*, and targeted spot herbicide application, was initiated. The ongoing programme aims to reduce the biomass of this species and ultimately to eradicate it.

Main findings

- In September 2009, Castle and Black Lochs remained free of *C. helmsii*.
- Application of herbicide to *C. helmsii* in Mochrum Loch, in March 2009, appears to have had only a limited effect on the areas of *C. helmsii* treated.
- Surveys of transects at Mochrum Loch in September 2009 showed the recovery of native macrophyte species, such as *Eleocharis palustris* and *Isoetes lacustris,* to pre-control levels, but also demonstrated some recovery of *C. helmsii.*
- In March 2010, coverage of habitat at Mochrum Loch by *C. helmsii* was recorded as 96% less than it had been prior to the beginning of the project in September 2007.
- Due to the invasive nature of the plant and its ability to spread from small fragments, it is anticipated that further measures will be required to continue to control the growth and spread of *C. helmsii* within Mochrum Lochs SSSI.

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Table of Contents **Page**

Acknowledgements

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1. INTRODUCTION

New Zealand pygmyweed (*Crassula helmsii*) is an invasive, non-native plant, which grows in standing water, marginal and wetland habitats, where it is able to establish and spread rapidly. *C. helmsii* is a monoecious perennial (Preston and Croft, 1997), which regenerates from small fragments, and can rapidly colonise and dominate a plant community. Due to its highly competitive nature and ability to produce dense stands of vegetation, it is believed to be a significant threat to native species of aquatic and riparian vegetation, in the sites to which it is introduced (Kemp and Birkinshaw, 2005). A native of Australia, Tasmania and New Zealand, the species was first sold in Britain as a plant suitable for outdoor ponds in 1927 (Preston and Croft, 1997). The timing of its first release to the wild is unknown, but a naturalised population was recorded in 1956 (Laundon, 1961; in Preston and Croft, 1997). Available records suggest that the distribution of *C. helmsii* increased most rapidly in its distribution between 1980 and 1990 (Willby, 2008). However, although rate of spread appears to have decreased in recent years, C. *helmsii* has been recorded areas of conservation importance, such as Brown Moss, Swanholme Lakes and Hatchet Pond in England (Kemp and Birkinshaw, 2005). In Scotland, there are records for 53 populations, of which it is likely that 45-50 remain extant (Willby, 2008).

C. helmsii is present in Mochrum Lochs Special Area of Conservation (SAC), where it was first recorded during Site Condition Monitoring (SCM) in 2004. This site is situated in south-west Scotland (Figure 1, Appendix 1). It is designated an SAC due to the international importance of its blanket bogs and blanket bog depressions on peat substrates. Mochrum Lochs Site of Special Scientific Interest (SSSI) is of national importance for its standing waters and associated aquatic ecology. Breeding birds and blanket bog are also notified under the SSSI. The standing water feature of interest includes Mochrum Loch, Castle Loch and Black Loch (Figure 2, Appendix 1), as these standing waters were judged to be the best examples of lowland oligotrophic waters in the District.

Mochrum Loch supports macrophyte species typical of oligotrophic to mesotrophic lake types, including *Isoetes lacustris*, *Littorella uniflora* and *Lobelia dortmanna*. In addition to these three isoetid species, Black Loch also supports a fourth plant of this type, *Subularia aquatica*. However, a number of the macrophyte species observed in the Loch are more usually associated with eutrophic conditions, e.g. *Lemna minor* and *Potamogeton crispus*. Elevated levels of total phosphorus (TP) and algal blooms have been recorded in Mochrum Loch, indicating that nutrient enrichment is occurring within the water body. This may exacerbate the problem of growth of *C. helmsii* in the Loch, as invasive non-native plants may become a greater problem in enriched water bodies, if they have strategies for dealing with low or variable levels of CO_2 in the water column (e.g. the ability to use bicarbonate or respiratory CO_2), and/or are able to assimilate nutrients through the leaves. As *C. helmsii* tolerates a variety of conditions, from nutrient-poor and acidic, to eutrophic or calcareous (Preston and Croft, 1997), this suggests that *C. helmsii* may be adapted in such ways.

Due to the presence of *C. helmsii* in Mochrum Loch, the SSSI is in unfavourable condition. It is therefore necessary to attempt to eradicate the species from this site. As *C. helmsii* is a threat to biodiversity, it is included in the Species Action Framework (SAF) (http://www.snh.gov.uk/protecting-scotlands-nature/species-action-framework/).This initiative was developed to support delivery of the requirements of the Nature Conservation (Scotland) Act 2004 and the Scottish Biodiversity Strategy. Since SAF promotes targeted management of *C. helmsii*, it was appropriate to undertake management of *C. helmsii* under the SAF programme.

Phase I of the project was undertaken in 2007/2008 (ECUS, 2013a). Castle Loch and Black Loch were checked for the presence of *C. helmsii*, but it was not recorded. The distribution of *C. helmsii* in Mochrum Loch was investigated, as were the distribution and abundance of

the native macrophyte species. Methods for management of the *C. helmsii* were considered and shading using WCF was selected as the method of control which would be used in the first instance. WCF was installed in March 2008 and left in place for at least 6 months. On its removal, it was found that of the 10,000 m^2 of cover by *C. helmsii*, only 359 m^2 remained. Although this represented a 96% reduction in cover, there remained a population of plants from which *C. helmsii* could recolonise much of the available habitat of Mochrum Loch, so in March 2009 targeted herbicide treatment was undertaken to attempt to arrest growth of this species (ECUS, 2013b). However, given the remaining extent of colonisation and robust nature of this species, it was expected that further measures would be necessary in 2009/10. The objective of this project remains the eradication of *C. helmsii* from this site.

The aims of phase III of the project were as follows:

- to determine the distribution and abundance of *C. helmsii* at Mochrum Loch
- to survey Castle Loch and Black Loch to search for *C. helmsii*
- to assess success of treatment of *C. helmsii* and regeneration of native species in the fixed transects
- to design and implement a plan for management of *C. helmsii* in phase III, based on the results of survey
- to make recommendations for future management of *C. helmsii* at this site.

2. METHODS

2.1 Survey methods

Surveys were undertaken in phase 1 of this project (2007/2008) (ECUS, 2013a), in order to provide information for the management plan, and to allow monitoring of the effects of management of *C. helmsii*. Work included the following:

- an initial survey of the aquatic vegetation of the Mochrum Lochs complex, including Mochrum Loch, Black Loch and Castle Loch, to give baseline data on the native aquatic plant communities and to map areas of *C. helmsii* infestation
- transect surveys of aquatic vegetation in Mochrum Loch, to form a baseline for future monitoring of the effects of control strategies.

In phase 2 of this project (2008/2009) (ECUS, 2013b), further surveys were undertaken in March 2009 as follows:

- a survey of Mochrum Loch to record the extent and location of remaining areas of *C. helmsii* requiring treatment, following installation and subsequent removal of WCF
- a survey of the fixed transects to monitor effects of WCF on *C. helmsii* and regeneration of native species.

Within the present phase of the project, phase 3, the following surveys were undertaken:

- a survey of Castle Loch and Black Loch, to check whether there had been any colonisation of these water bodies by *C. helmsii* since the earlier surveys
- recording of locations and extent of *C. helmsii* which had been shaded using WCF and the area of fabric deployed
- recording of remaining patches of *C. helmsii* treated with herbicide in March 2010.

The timings of the different elements of the overall project, including the surveys, are presented in Table 1 (Appendix 2) and methodologies used for the present stage of the project are detailed below.

2.1.1 Survey for C. helmsii in Mochrum Loch, Castle Loch and Black Loch in autumn 2009

Survey of Mochrum Loch for *C. helmsii* after a season of growth, following weed control measures, was undertaken on 7th and 8th October 2009. Survey of Castle Loch (6th October, 2009) and Black Loch (30th September, 2009), for *C. helmsii*, was also undertaken to establish whether any spread of *C. helmsii* into these water bodies had occurred since the original surveys in 2007.

Surveys were carried out by a pair of surveyors walking the perimeter of each water body, surveying from the exposed margins to the littoral area, up to a water depth of 1 m. Further survey by boat was carried out, to detect any *C. helmsii* colonising deeper areas. The occurrence of *C. helmsii* was recorded using a GPS handset, as was extent, where the latter exceeded 0.25 m^2. For areas of cover of less than 0.25 m^2, the extent of colonisation was nevertheless recorded as 0.25 m^2. In locations where *C. helmsii* was very frequent, but not completely dominant, the overall area where colonisation was taking place and the percentage cover by *C. helmsii* within that area were estimated. The actual area of colonisation by *C. helmsii* was then calculated using these two variables and logged for that point.

2.1.2 Survey for C. helmsii in Mochrum Loch in March 2010

Survey for *C. helmsii* was undertaken at Mochrum Loch, between 9th and 14th March 2010, as part of the ongoing programme of control measures. The survey was carried out alongside the control works (i.e. area by area around the Loch), according to the methodology used for the autumn 2009 survey, described in Section 2.1.1.

2.1.3 Transect surveys in Mochrum Loch in September 2009

In Mochrum Loch in 2007, transects were placed in a range of habitats within the depth range found to be most affected by *C. helmsii* colonisation in the baseline survey (i.e. 0 – 1 m depth). Where the littoral area shelved gently, transects extended perpendicular to the shore. Where the littoral area shelved steeply, transects extended parallel to the shore. Six 2 m x 10 m transects were examined. Each transect was comprised five contiguous 2 m x 2 m quadrats. The vegetation present was recorded as percentage cover of each quadrat. Percentage bare substrate, substrate composition and average water depth were also recorded. Locations of transects are presented in Figure 3 (Appendix 1) and Table 2 (Appendix 2).

In order to allow comparisons to be made between the results of different surveys, the positions of transects were recorded using GPS and digital photography. The locations of transects were fixed using "Ground Mark" markers. Due to the rocky and uneven nature of the substrate around the perimeter of the loch, placement of the markers was subject to ground condition and the locations of the markers relative to the transects are detailed in Table 3 (Appendix 2).

Surveys of transects were repeated on 17th and 18th March, 2009, in order to monitor the changes in macrophyte communities following implementation of control measures for *C. helmsii*. This work was carried out early in the year, so further survey of the transects following the growing season was recommended, in order to assess the recovery of the native plant communities. As part of the present phase of the project, surveys of the transects were therefore undertaken on 29th September, 2009.

2.2 Removal of remaining weed control fabric

A small (2 m^2) patch of WCF, which had been left *in situ* to control an area of vigorously growing *C. helmsii* in the north west bay of Mochrum Loch (ECUS, 2009), was removed from the site on 29th September, 2009. Care was taken to remove all traces of *C. helmsii* from the fabric before transportation from the site, and the fabric was disposed of from the ECUS Office in Sheffield, *via* normal refuse collection procedures.

2.3 Further control measures undertaken in March 2010

Following survey in September and October 2009, recommendations for a continued programme of control of *C. helmsii* in Mochrum Loch were made to SNH, including late season herbicide application, and deployment of WCF to larger areas of *C. helmsii* growth in autumn/winter 2009. However, due to cold conditions over the winter months and the resulting freezing of the Loch, it was not possible to undertake this work until March 2010.

2.3.1 Application of weed control fabric

WCF was applied to areas colonised by *C. helmsii* around Mochrum Loch in March 2010, concentrating on larger areas of colonisation and areas which were submerged. The fabric was laid between 9th and 12th March, 2010. The location of each area covered by fabric was recorded using a GPS unit and an estimate was made of the extent of *C. helmsii* at that

point. The area of fabric used to cover it was also recorded. An approximate total of 484 m^2 of fabric was deployed around the perimeter of the Loch, to cover an estimated 164 m^2 of *C. helmsii*. The locations of the fabric deployed are shown in Figure 4 (Appendix 1). An example of WCF installed over an area of *C. helmsii* is shown in Plate 1 (Appendix 3).

The fabric used was composed of rolls of 2.5 m width and was installed using the methodology developed during previous installations (ECUS, 2013b). Large stones were used to secure the fabric and prevent it from moving during the time it would be left in place. These stones were mainly taken from the bed of the Loch, or from the bank, where areas of loose rock were available. In order to minimise the physical effort required, and to reduce the area on which the works would have an impact, these rocks were taken from as close to the areas to be covered by fabric as possible.

Where one width of fabric was insufficient to cover a mat of *C. helmsii,* lengths of fabric were laid side by side, with an overlap of approximately 0.5 m. The overlapping section was weighed down with stones. WCF was also laid to extend beyond the limit of *C. helmsii* colonisation by approximately 0.5 m.

Stones were laid end to end around the perimeter of the fabric and along the joins. This was done in order to prevent light reaching the vegetation below the fabric. Stones were also used to weigh down the centre of fabric lengths, in order to prevent excessive abrasion of the fabric through the action of wind and waves.

2.3.2 Application of herbicide

The herbicide glyphosate was used to spot-treat small and scattered areas of *C. helmsii*. Appropriate environmental conditions for spraying were defined by the manufacturer as being dry, with low wind speeds and temperatures exceeding 5 ^oC. Application of herbicide was undertaken on 12th and 13th March, when the weather was suitable. A BASIS-registered and NCPT certified (PA 1 and PA 6) contractor (Neil Dyson, Woodscapes Ltd.) provided advice and carried out herbicide treatment whilst accompanied by an ECUS ecologist. Locations of *C. helmsii* treated with herbicide in March 2010 are shown in Figure 5 (Appendix 1).

Spot-application of glyphosate, in the form of Roundup Biactive, was carried out using a knapsack sprayer with a polijet nozzle, on *C. helmsii* growing in emergent and terrestrial locations. A total of 700 ml of formulation was applied at a rate of 5 l ha^{-1}, treating an area of approximately 1400 m^2. Roundup Biactive is a soluble concentrate containing 360 g l^{-1} glyphosate, present as 480 g l^{-1} (41.1% w/w) of the isopropylamine salt of glyphosate.

Spot-application of dichlobenil, in the form of Luxan dichlobenil granules, was undertaken in areas where *C. helmsii* was found growing submerged, and in the area of shoreline expected to be regularly inundated or subject to wave action. A total of 11 kg of granules was used, applied at a rate of 85 kg ha^{-1}, treating an area of approximately 1295 m^2. Luxan dichlobenil granules are a solid granule application of dichlobenil, containing 6.5% dichlobenil ISO (i.e. 65 g kg^{-1}).

Where vegetation was within the area of shoreline subject to inundation or wave action, but exposed at the time of survey, both chemicals were used and therefore the sum of the area treated with each chemical does not represent the total area treated, but exceeds it. The area treated using either or both chemicals was estimated to be approximately 1500 m^2 in total. The total area of *C. helmsii* treated with herbicide was estimated to be approximately 188 m^2. The herbicide application therefore covered an area eight times larger than the total area of *C. helmsii* treated. This is due to the application of herbicide to very small patches of *C. helmsii*, with larger patches of *C. helmsii* covered by fabric rather than treated with

herbicide, i.e. the smaller the area of *C. helmsii* colonisation treated, the greater the relative size of the margin of ground around the plants sprayed. Whilst care was taken to keep herbicide application to a minimum, an element of over-treatment was considered necessary, to ensure that each patch of *C. helmsii* was fully treated. In addition, when spot-treating such small areas of plant colonisation, the practicalities of application rendered such over-treatment inevitable.

3. RESULTS

3.1 Surveys for *C. helmsii*

3.1.1 Survey of Castle Loch and Black Loch in autumn 2009

Survey of Castle Loch and Black Loch in 2009 revealed no colonisation by *C. helmsii* within these water bodies. Species recorded in Black Loch and Castle Loch are included in Appendix 2 (Tables 4 and 5 respectively). A bloom of blue-green algae was noted on Castle Loch at the time of survey.

3.1.2 Survey of Mochrum Loch in autumn 2009

The locations of *C. helmsii* recorded during the survey of Mochrum Loch in September/October 2009 are shown in Figure 6 (Appendix 1). The distribution of *C. helmsii* from the March 2009 surveys is also provided for comparison (Figure 7, Appendix 1).

A total area of 516 m^2 of *C. helmsii* was recorded. There had therefore been an increase in cover since March 2009, when it had been estimated as 359 m^2. During the survey, the area covered by each individual record of *C. helmsii* was only recorded if it was greater than 0.25 m^2. For the purposes of the calculation of total area covered, any record without an area logged was assumed to be 0.25 m^2 (in line with the estimate from the March survey), however, many of these records were of very small plants, covering a much smaller area than this, so the estimate of overall area covered is likely to be a significant over-estimate.

As observed during the surveys of March 2009, coverage of habitat by *C. helmsii* ranged from small, single plants (as illustrated in Plate 2, Appendix 3), to larger patches or strips of colonisation, up to a maximum coverage of an area of approximately 20 m^2. However, areas larger than 10 m^2 were very infrequent and the majority of patches of colonisation recorded were less than 0.25 m^2. The distribution of *C. helmsii* across the Loch as a whole was similar to that seen during the March 2009 surveys, however, the patches were more frequent in September 2009, with many occurring in areas in which fabric had been deployed previously and which remained free of *C. helmsii* in March 2009. Plates 3 and 4 (Appendix 3) show *C. helmsii* growing in areas which had been treated with WCF.

3.1.3 Survey of Mochrum Loch in March 2010

The locations of *C. helmsii* recorded during the survey of Mochrum Loch in March 2010 are shown in Figure 8 (Appendix 1). A total area of 352 m^2 of *C. helmsii* was recorded by the surveyors. As for the March and September 2009 surveys, the area covered by each individual record of *C. helmsii* was documented only if it was greater than 0.25 m^2, and any records representing an area of colonisation which was less than this threshold were assumed to be 0.25 m^2 for the purpose of calculating the total area. The estimate of total area is therefore likely to be a significant over-estimate.

Distribution was similar to that seen in September/October 2009, however the estimate of the total area of colonisation by *C. helmsii* was smaller in March 2010. At the time of survey, levels of water in the Loch were very low compared with those of previous surveys. Much of the *C. helmsii* material detected was on an extended shoreline, where vegetation was exposed. A number of taxa appeared to be affected by frosting and had a covering of strandline vegetation, debris and silt. Due to the difficulties this posed for surveying, some areas of *C. helmsii* may therefore not have been detected, or may have been under-recorded.

3.2 Transect surveys

Data recorded from surveys of transects, in September 2009, are included in Appendix 2 (Tables 6 – 11), along with information on transect locations. A list of taxa found over all transect surveys is presented in Table 12 (Appendix 2).

3.2.1 Native macrophyte species

The diversity of plants recorded was greater than that seen in the September 2007 surveys, and species such as *Eleocharis palustris* and *Isoetes lacustris* had recovered to similar levels of cover to those seen prior to *C. helmsii* control, demonstrating that treated areas are revegetating successfully. In addition, species not recorded in the September 2007 surveys, such as *Littorella uniflora* and *Elatine* species, were recorded at significant levels of cover. Plates 5, 6 and 7 (Appendix 3) show native vegetation regenerating in areas which previously supported *C. helmsii*, but which were treated with WCF.

3.2.2 Crassula helmsii

The percentage cover of habitat by *C. helmsii* observed in transect surveys in September 2007, March 2009 and September 2009 is shown in Table 13 (Appendix 2). In September 2007, percentage cover ranged from 0 to 95%, with more than half of quadrats exhibiting cover values of more than 50%. By March 2009, cover values ranged from 0 to 3% and two transects were free from *C. helmsii*. In September 2009, cover had increased since March 2009, ranging from 0 to 25%. However, although cover had increased in transects 2 to 5, no *C. helmsii* was recorded in transects 1 and 6.

Whilst there was an increase in cover of substrate by *C. helmsii* in transects 2 to 5, cover values over all transects remained significantly lower than those recorded in the survey of September 2007, prior to implementation of control measures. Three quadrats remained free from *C. helmsii* from September 2007 to September 2009. At transects 1 and 6, where *C. helmsii* was recorded as present, albeit in low density (1 – 3% cover) in the surveys of March 2009, *C. helmsii* was absent during the September 2009 transect surveys.

4. DISCUSSION

4.1 Recovery of native macrophyte species

The increase in species diversity recorded in the September 2009 transect survey from that recorded in September 2007, teamed with the recovery of some native species to levels of cover similar to those recorded in 2007, suggests that the control measures for *C. helmsii* have not had a lasting detrimental effect on the native flora. However, monitoring of the recovery of the native flora should continue, in order to confirm the effects of the control measures on the native plant communities.

Of particular note is the recording of *Elatine* species at the Loch, possibly of both species native to the UK, *Elatine hexandra* and *Elatine hydropiper*. Neither species was recorded at Mochrum Loch during the previous surveys for this project. Both *Elatine* species are plants of the shallow margins and drawdown areas of lakes and reservoirs, and appear to be particularly successful when banks of previously inundated mud or silt are exposed, resulting in germination of dormant seeds (Preston & Croft, 1997). *E. hydropiper* is a nationally scarce species that has been recorded with increased frequency in Scotland over recent years. The appearance of *Elatine* species in these surveys demonstrates the success of native species regenerating from the seed bank, once dense mats of *C. helmsii* have been removed.

4.2 Control of *C. helmsii*

The increase in cover of habitat by *C. helmsii* in four of the six transects, from March to September 2009, combined with the overall increase in the total cover of *C. helmsii* in Mochrum Loch (516 m^2 in September, compared to 359 m^2 in March 2009) shows that *C. helmsii* had begun to recover over the summer growing season, from the control measures implemented earlier in the year. The extent to which *C. helmsii* may have declined following herbicide treatment in March 2009 is unknown. However, as the larger areas of *C. helmsii* cover were found at the same locations as in the March survey, it is clear that in most areas, herbicide treatment failed to completely eradicate *C. helmsii* where it was present in well-established patches. The absence of *C. helmsii* from transects 1 and 6, where it was recorded growing at low levels in March 2009, suggests that herbicide treatment of smaller patches may have been more successful, however, this could also be due to suboptimal habitat conditions in these areas, or part of a cycle of colonisation and failure (ECUS, 2013b), and further monitoring would be necessary to draw firm conclusions.

It was also noted that *C. helmsii* was growing again in areas treated previously by shading with WCF. However, the small and scattered nature of most of these plants was indicative of washed in material rooting in these areas, rather than a general regrowth of *C. helmsii* from material shaded using WCF. This colonisation and spread from fragments in previously treated areas is likely to continue, as long as small but significant areas of *C. helmsii* growth remain. However, as the treatment programme continues and progresses, it is anticipated that the source of fragments will decline slowly.

Despite the increase in coverage of habitat by *C. helmsii* observed from March to September 2009, coverage remained significantly lower than had been noted prior to the commencement of the treatment programme. Areas of colonisation of habitat by *C. helmsii* in September 2007 are shown in Figure 9 (Appendix 1). The area of habitat colonised was 10,000 m^2 in September 2007, but 516 m^2 in September 2009. This change represents a 95% reduction in coverage by *C. helmsii*. Following a full growing season, this indicates a successful level of control of *C. helmsii* within Mochrum Loch, which greatly reduces the potential for spread of the plant into neighbouring water bodies and wetland.

Survey of *C. helmsii* within Mochrum Loch in March 2010 was undertaken primarily to inform and guide the further control measures to be implemented at that time, rather than to monitor change. A significant increase in the area of colonisation by *C. helmsii* between October 2009 and March 2010 was not anticipated, as suppression of growth of *C. helmsii* would be expected as a result of low temperatures and short daylight hours over the winter months. As *C. helmsii* does not senesce in winter, the area was not expected to decrease. However, the area of habitat colonised by *C. helmsii* decreased from 516 m^2 in September 2009, to 352 m^2 in March 2010. The latter figure is similar to that recorded in March 2009 and represents an overall reduction in coverage of 96% since September 2007.

The reason for the observed decrease in area colonised between the September/October 2009 and March 2010 surveys is unclear. There may have been a genuine decrease in the area colonised by the plant, due to the hard winter conditions experienced over the intervening period. However, presence of dying and decaying vegetation, because of low water levels in March 2010, may have resulted in under-recording of *C. helmsii*. It is interesting to note that the coverage by *C. helmsii* detected in March 2010 was very similar to that recorded in March 2009, when coverage was approximately 359 m^2. The reasons for this are unknown, but may include chance, management strategy or seasonal growth and die back.

4.3 Loch water levels

During the September 2009 survey, it was noted that Mochrum Loch experiences rapid fluctuations in water level, not obviously linked with ambient weather conditions. For example, when transect surveys were undertaken on 29th September, 2009, water levels were very high, with established terrestrial plant communities submerged in some locations. On returning to the site on 7th and 8th October, to undertake *C. helmsii* survey over the entire Loch, water levels were considerably lower, with patches of *C. helmsii* frequently seen still growing in submerged form on exposed areas of shoreline.

The outflow of the Loch is utilised in a small hydropower scheme and water levels are regulated to some extent for this purpose. Anecdotal evidence from the operators of the hydropower scheme suggests that water levels in the Loch are higher in summer, when less power is required, and lower in winter, when the increased seasonal demand for electricity results in greater use of the hydropower scheme.

C. helmsii is able to tolerate rapid fluctuations in water levels better than many native species of the same niche, so the present regime may favour the proliferation of *C. helmsii*. However, if water levels in the Loch can be controlled, this could be turned to the advantage of the continued management of *C. helmsii.* As dichlobenil is no longer licensed for use in or near water, any future herbicide treatment of *C. helmsii* must be with glyphosate. As glyphosate can only be applied to exposed vegetation, water levels could be lowered to facilitate treatment of *C. helmsii* along the margins and in the zone which is normally littoral habitat.

5. CONCLUSIONS

5.1 Success of control measures to date

From the results of the surveys, it can be seen that the control measures for *C. helmsii* to date have had a beneficial effect on the plant communities of Mochrum Loch. Cover by *C. helmsii* has been reduced, whilst native species are recovering following treatment. The increase in diversity of native species is a positive outcome, however, the occurrence of some of the species found may be transient, as they act as pioneer species on the bare ground exposed by the shading by WCF and may be replaced by other species as the natural succession in these areas progresses.

The reduction in *C. helmsii* from approximately 10,000 m^2 to 516 m^2 over the duration of the control programme to date represents a considerable reduction in coverage by the plant, and thereby a reduction of the impact of the plant on the Loch. It also represents a substantial decrease in the risk of spread of *C. helmsii* from Mochrum Loch into the adjacent water bodies and wetlands of the SSSI, and the continued absence of *C. helmsii* from Castle and Black Lochs may be due to this lowering of risk.

Shading using WCF appears to have been a very successful method of control, significantly reducing the levels of *C. helmsii* in areas where the plant had been present in dense stands.

The effectiveness of the herbicide treatment is difficult to judge from the data available, however, it is expected that spraying of emergent material with glyphosate will have been more successful in controlling *C. helmsii* than the application of dichlobenil granules to submerged material. The success of dichlobenil granules at controlling patches of submerged *C. helmsii* may be greater in bays with predominantly silty substrate rather than in rocky areas.

However, the increase in area of coverage by *C. helmsii* over one growing season from 359 m^2 in March 2009 to 516 m^2 in September 2009 shows the necessity for further action to continue to control and reduce the infestation of this plant within Mochrum Loch. Therefore recommendations for a continued programme of control for *C. helmsii* on Mochrum Loch are outlined below.

5.2 Recommendations for a programme of continued control of *C. helmsii* in Mochrum Loch

It is recommended that monitoring and control of *C. helmsii* in Mochrum Lochs SSSI is continued in order that the successful reduction in infestation by the plant is maintained and improved upon. Control measures would be expected to continue to include use of WCF and glyphosate. It is thought likely that without continued monitoring and control, levels of *C. helmsii* would again increase across Mochrum Loch, possibly reaching pre-control levels within 5 – 10 years (Clarke, 2009). The recovery of the native flora should also be monitored in order to inform future management of *C. helmsii* at other sites of botanical interest.

The water level regime of Mochrum Loch, whether natural or controlled, can potentially have a considerable effect on both the proliferation of *C. helmsii* within the water body and the control options available. It is therefore recommended that the current regulation regime of the Loch is investigated and the possibilities of using regulation of water levels within the control strategy for *C. helmsii* considered.

A ban on the sale of dichlobenil-based herbicide for use in or near water came into effect on 16th March, 2009, and the use-up period of one year for existing stocks ended on 16th March, 2010. The final use of dichlobenil to control *C. helmsii* on Mochrum Loch was

therefore undertaken on 14th March, 2010 and there is now no herbicide available for the treatment of submerged *C. helmsii.* In order to treat *C. helmsii* growing along the area of the shoreline subject to wave action most effectively, a trial of the use of the natural cereal-based adjuvant "TopFilm", in combination with the glyphosate application to emergent material should be considered, as this would be expected to limit the quantity of herbicide being washed off the plant.

6. REFERENCES

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Preston, C. D., & Croft, J. M. 1997. *Aquatic Plants in Britain and Ireland*. Harley Books, Colchester, England, 365 pages.

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APPENDIX 1: MAPS

Figure 1. The location of Mochrum Lochs SSSI

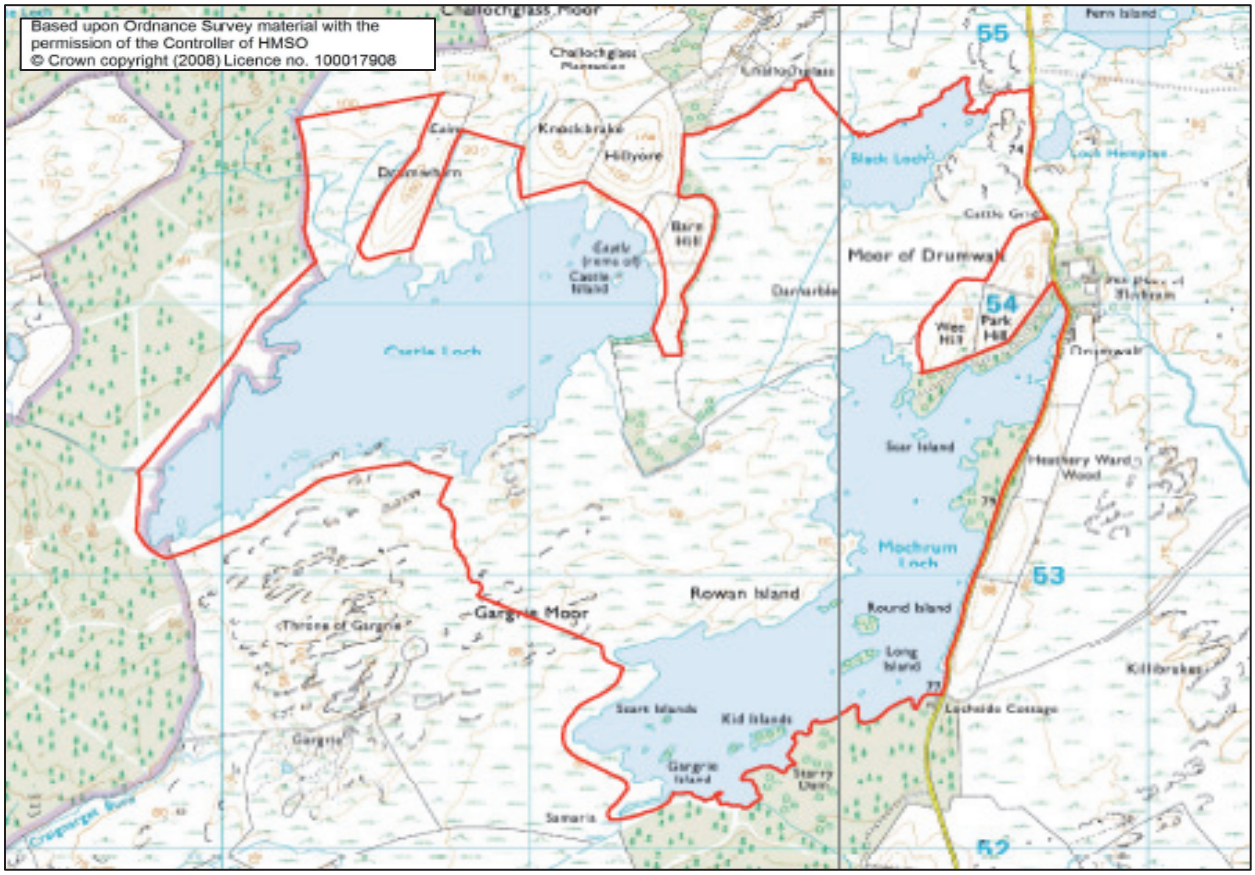

Figure 2. The boundary of Mochrum Lochs SSSI

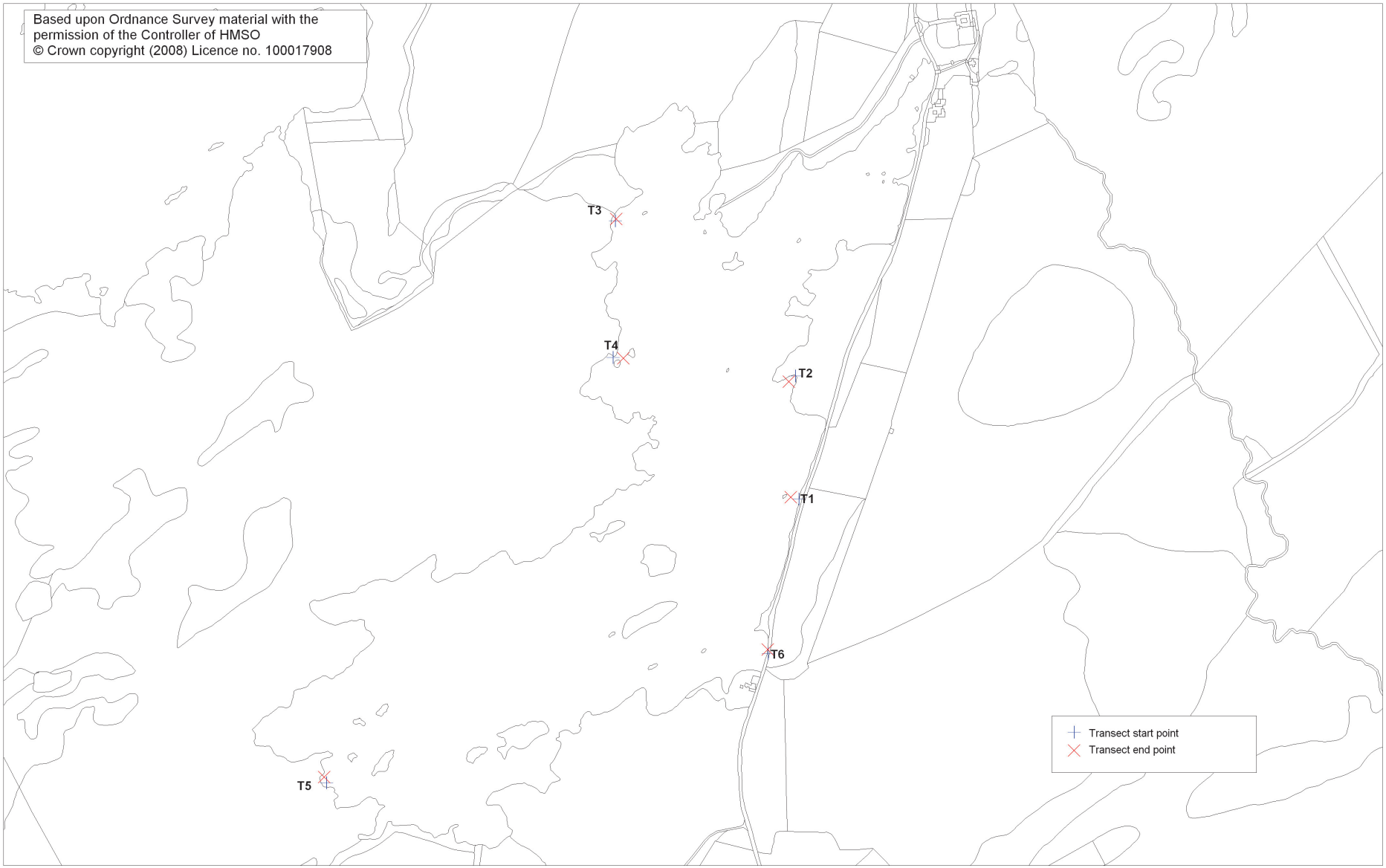

Figure 3. Locations of transects

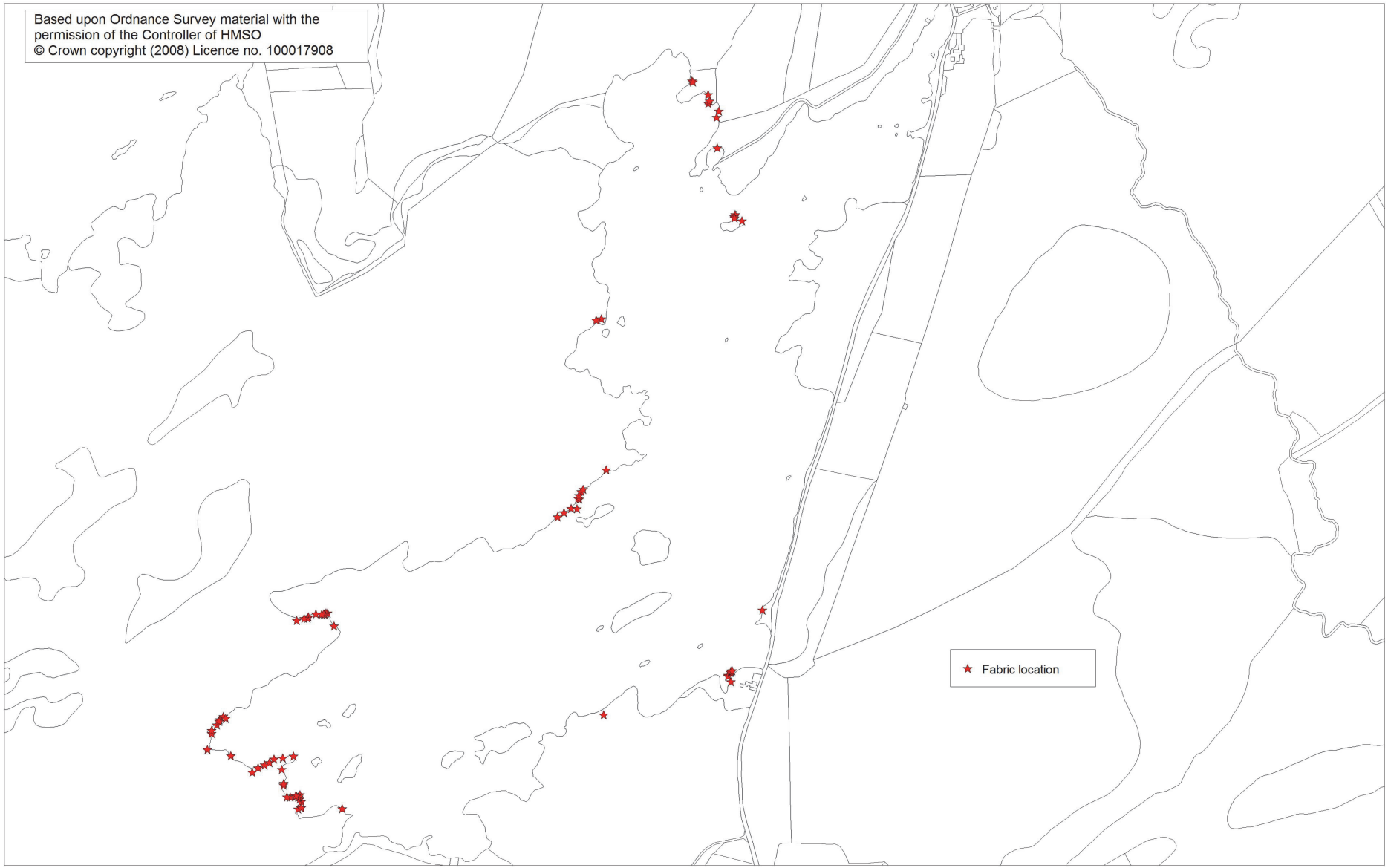

Figure 4. Locations of weed control fabric installed during March 2010

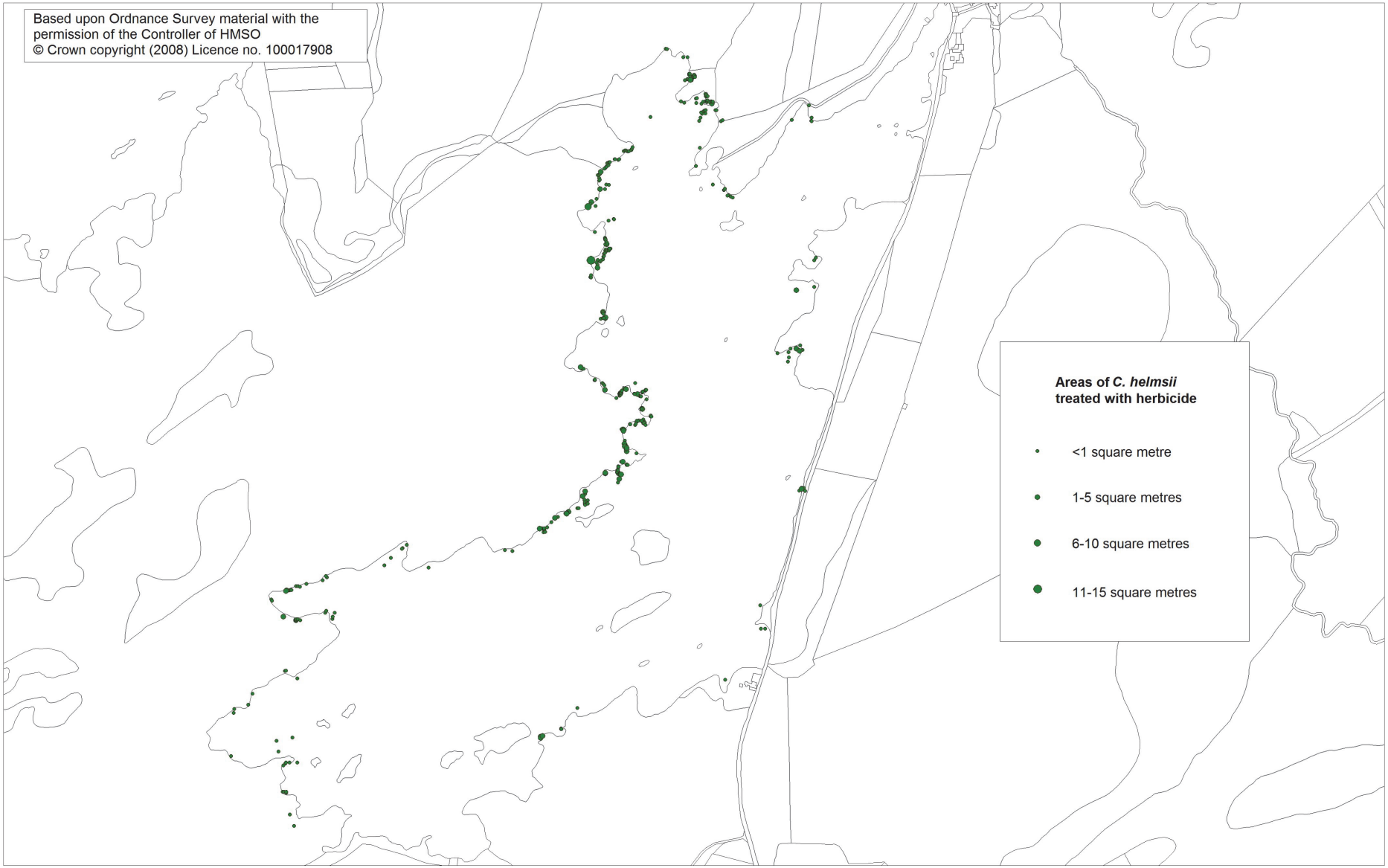

Figure 5. Locations of C. helmsii treated with herbicide during March 2010

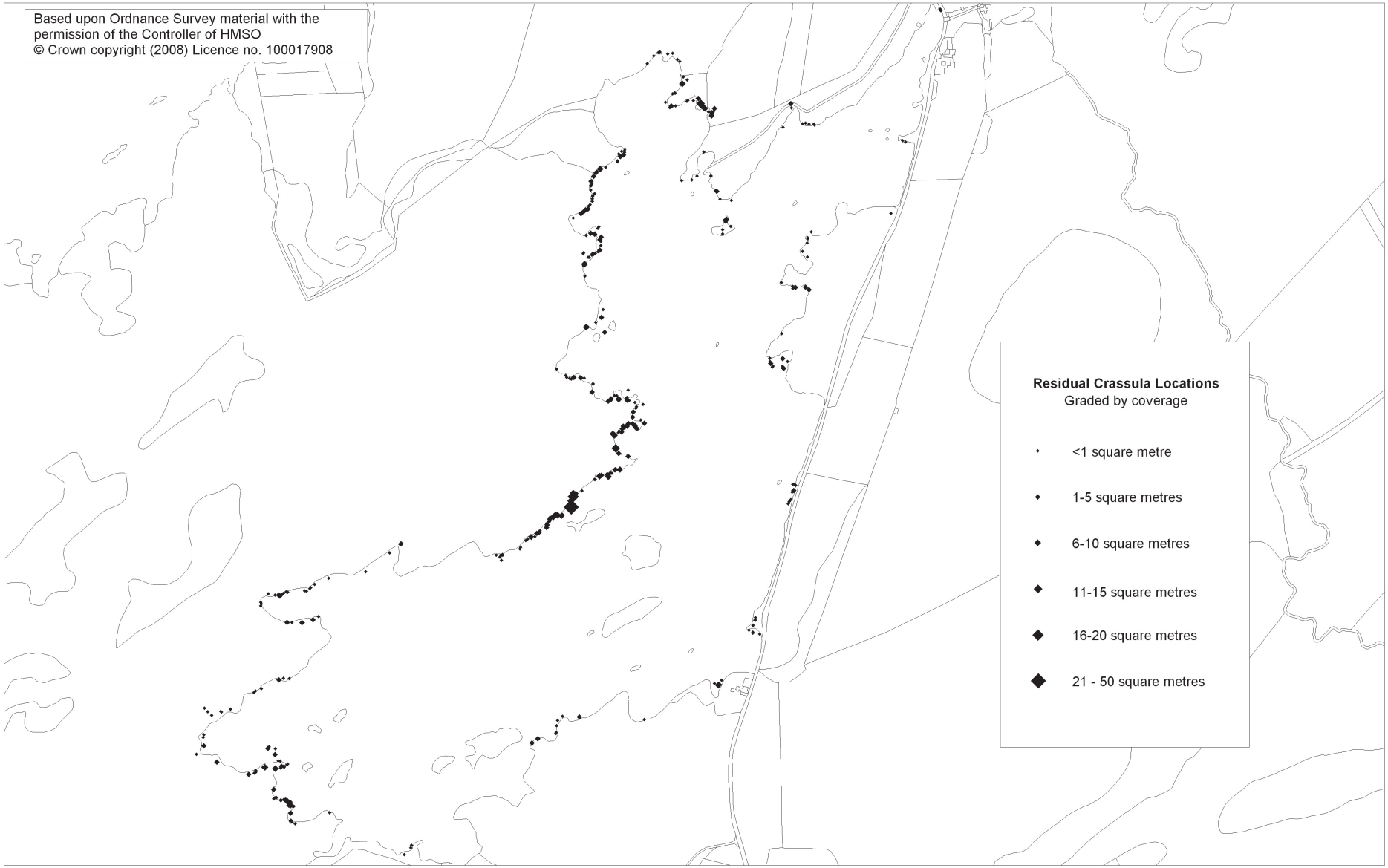

Figure 6. Locations of residual C. helmsii recorded during September 2009

Figure 7. Locations of residual C. helmsii recorded during March 2009

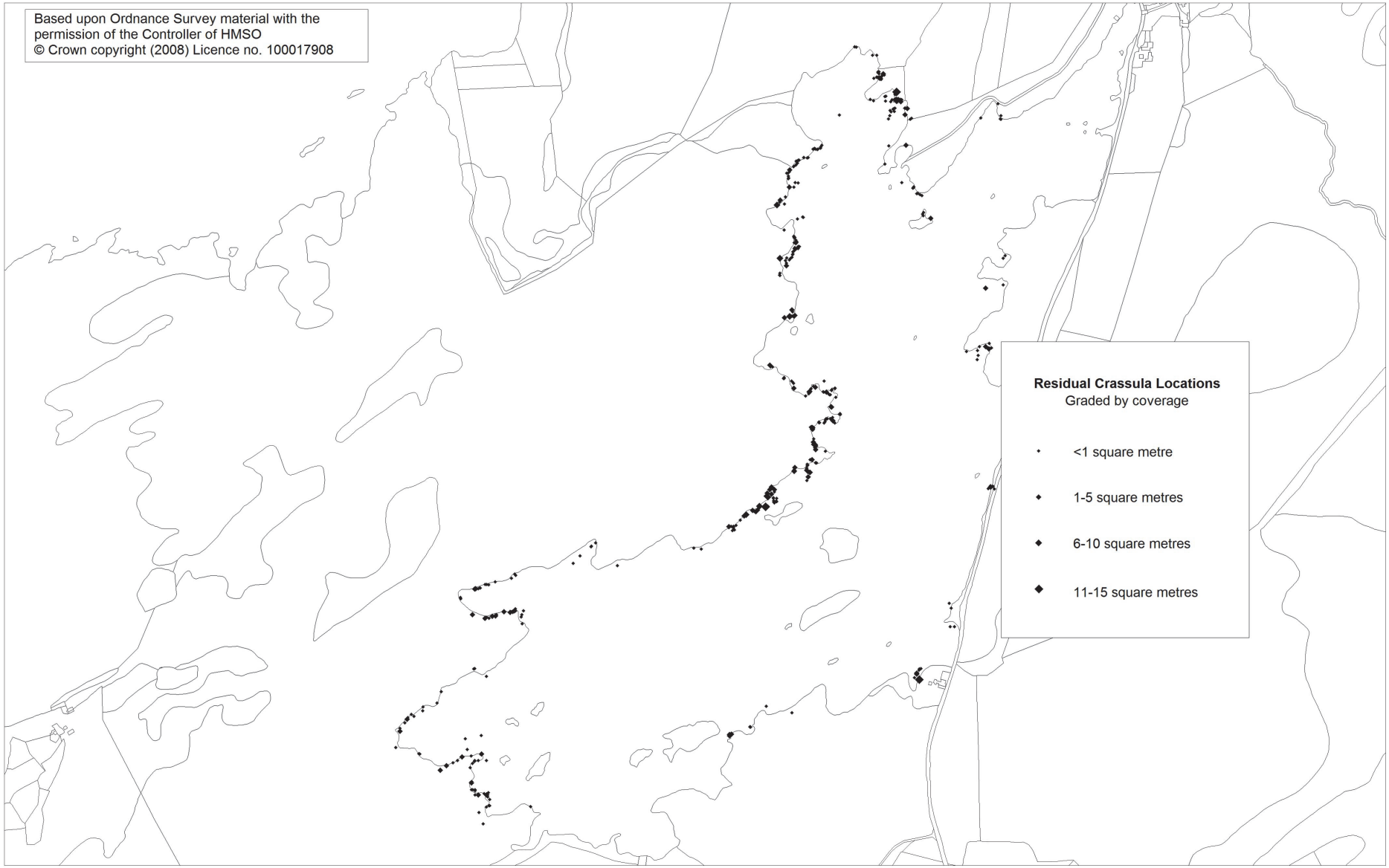

Figure 8. Locations of C. helmsii recorded during March 2010 prior to control works

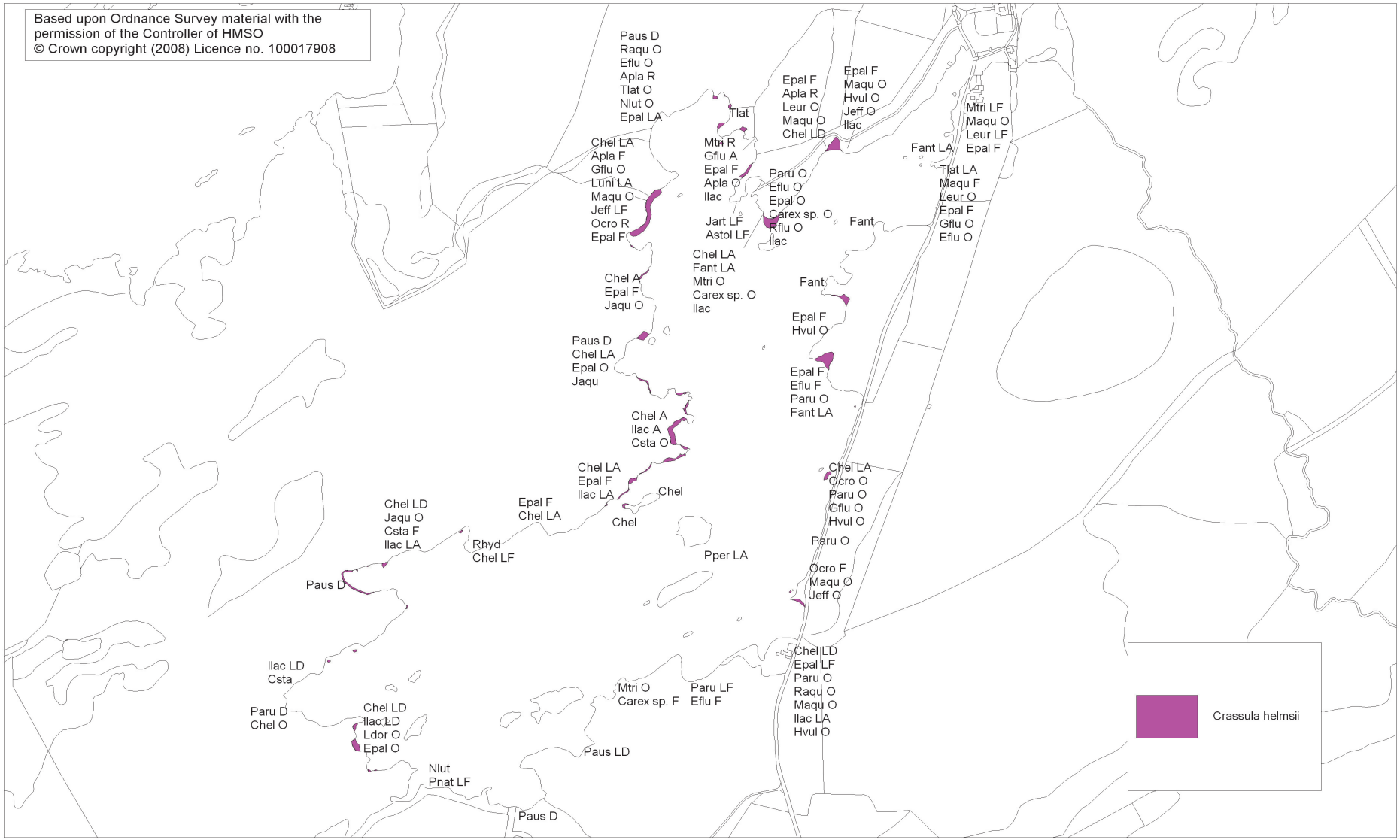

Figure 9. Areas of C. helmsii colonisation on Mochrum Loch, September 2007

APPENDIX 2: TABLES

Table 1. Phases of the programme of survey and control of C. helmsii at Mochrum Lochs SSSI to March 2010

Task	Date
Baseline aquatic vegetation survey of Mochrum Loch, Castle Loch and Black Loch	September 2007
Initial transect surveys, Mochrum Loch	September 2007
Installation of WCF on Mochrum Loch	March 2008
Removal of WCF from Mochrum Loch	December 2008 and March 2009
Survey of *C. helmsii* in Mochrum Loch	March 2009
Repeat transect survey on Mochrum Loch	March 2009
Spot herbicide application on Mochrum Loch	March – April 2009
Repeat transect survey on Mochrum Loch	September 2009
Survey of *C. helmsii* in Mochrum Loch	September – October 2009
Survey for C. helmsii in Castle Loch and Black Loch	September – October 2009
Installation of weed control fabric on Mochrum Loch	March 2010
Spot herbicide application on Mochrum Loch	March 2010

Table 2. Locations of transects

Transects	**Start point**		**End point**		**Survey Date**
	X	Y	X	Y	
1	230418.93	552965.26	230399.58	552970.56	29/09/2009
2	230410.81	553254.14	230395.20	553241.55	29/09/2009
3	229987.69	553618.13	229989.0	553623.0	29/09/2009
4	229987.0	553618.0	230006.05	553296.90	29/09/2009
5	229309.97	552299.14	229303.71	552313.06	29/09/2008
6	230346.00	552602.00	230345.00	552612.00	29/09/2008

Table 3. Locations of transects in relation to markers

Transect Number	**Location of transect in relation to marker**
1	Transect = marker to small willow on island
2	No marker – ground too marshy. Transect from centre of bay to most prominent rock
3	Marker = midpoint of transect
4	Marker in trees, start point of transect = 2 m lakeward from marker
5	Marker = midpoint of transect
6	Marker = midpoint of transect

Table 4. Species list for Black Loch

Scientific name	**Common name**
Alisma plantago aquatica	Water plantain
Baldellia ranunculoides	Lesser water plantain
Caltha palustris	Marsh marigold
Carex rostrata	Bottle sedge
Cladium mariscus	Great fen sedge
Eleocharis multicaulis	Many-stalked Spike-rush
Eleocharis palustris	Common spike-rush
Eleogiton fluitans	Floating club-rush
Equisetum fluviatile	Water horse-tail
Fontinalis antipyretica	Willow moss
Hydrocotyle vulgaris	Marsh Pennywort
Isoetes lacustris	Quillwort
Juncus bulbosus	Bulbous rush
Juncus effusus	Soft rush
Littorella uniflora	Shoreweed
Lobelia dortmanna	Water lobelia
Menyanthes trifoliata	Bog bean
Nymphaea alba	White water lily
Phalaris arundinacea	Reed canary-grass
Phragmites australis	Common reed
Potamogeton natans	Broad-leaved pondweed
Ranunculus flammula	Lesser spearwort
Subularia aquatica	Awlwort

Table 5. Species list for Castle Loch

Scientific name	**Common name**
-	Blue-green algae
-	Filamentous green algae
Agrostis stolonifera	Creeping bent
Callitriche hamulata	Intermediate water-starwort
Caltha palustris	Marsh marigold
Eleocharis sp.	Spike rush
Fontanalis antipyretica	Willow-moss
Glyceria fluitans	Floating sweet-grass
Hottonia palustris	Water violet
Isoetes lacustris	Quillwort
Juncus acutiflorus	Sharp-flowered rush
Juncus bulbosus	Bulbous rush
Juncus effusus	Soft rush
Lythrum salicaria	Purple loosestrife
Mentha aquatica	Water mint
Menyanthes trifoliata	Bog bean
Nymphaea alba	White water lily
Oenanthe crocata	Hemlock water-dropwort
Phalaris arundinacea	Reed canary-grass
Potamogeton crispus	Curled pondweed
Potamogeton natans	Broad-leaved pondweed
Potamogeton obtusifolius	Blunt-leaved pondweed
Potamogeton pecinatus	Fennel pondweed
Potamogeton perfoliatus	Perfoliate pondweed
Ranunculus flammula	Lesser spearwort

Table 6. Transect 1 data, September 2009

Transect number	1				
Transect type	Shore perpendicular				
Survey date	29/09/2009				
Photograph number	263				
Transect start	NX3041852965				
Transect end	NX3039952970				
	Quadrat				
Species	**1**	**2**	**3**	**4**	**5**
Alisma plantago aquatica					
Callitriche hamulata					
Callitriche hermaphroditica					
Carex rostrata					
Crassula helmsii					
Elatine species					
Elatine species (*hexandra*?)			15	20	40
Elatine species (*hydropiper*?)					
Eleocharis palustris					
Fontinalis antipyretica					
Galium species					
Hydrocotyle vulgaris					
Isoetes lacustris	0.1	5	70	80	60
Juncus bulbosus					
Juncus effusus					
Lemna minor					
Littorella uniflora					
Moss species					
Myosotis species					
Oenanthe crocata					
Peplis portula					
Persicaria sp.					
Phalaris arundinacea					
Potamogeton crispus					
Ranunculus aquatilis agg.					
Ranunculus flammula					
Substrate (%)	100	100	100	100	100
Silt					
Sand			35	40	50
Gravel			30	30	15
Pebble	40	40			
Cobble	20	60	15	10	5
Boulder	10				
Bedrock	30		20	20	30
Water depth (m)	0.45	0.55	0.55	0.8	0.1
% bare substrate	99	95	85	20	30

Table 7. Transect 2 data, September 2009

Transect number	2				
Transect type	Shore perpendicular				
Survey date	29/09/2009				
Photograph number	262				
Transect start	NX3041053254				
Transect end	NX3039553241				
	Quadrat				
Species	**1**	**2**	**3**	**4**	**5**
Alisma plantago aquatica			50	70	55
Callitriche hamulata					
Callitriche hermaphroditica					
Carex rostrata	20				
Crassula helmsii	5	25	15		0.5
Elatine species					
Elatine species (*hexandra*?)					
Elatine species (*hydropiper*?)					
Eleocharis palustris	50	60	25		15
Fontinalis antipyretica					
Galium species	10	15			
Hydrocotyle vulgaris	1	1			
Isoetes lacustris					
Juncus bulbosus					
Juncus effusus					
Lemna minor					
Littorella uniflora					
Moss species					
Myosotis species					
Oenanthe crocata					
Peplis portula					
Persicaria species					
Phalaris arundinacea					
Potamogeton crispus			0.5	1	
Ranunculus aquatilis agg.					
Ranunculus flammula		5			
Substrate (%)	181	181	100	100	100
Silt	80	80			
Sand			7		
Gravel	1	1			
Pebble			7	5	3
Cobble			70	90	95
Boulder			1		
Bedrock	100	100	15	5	2
Water depth (m)	0.1	0.1	0.25	0.4	0.45
% bare substrate				29	

Table 8. Transect 3 data, September 2009

Transect number	3				
Transect type	Shore parallel				
Survey date	29/09/2009				
Photograph number	76				
Transect start	NX2998753618				
Transect end	NX2998953623				
	Quadrat				
Species	**1**	**2**	**3**	**4**	**5**
Alisma plantago aquatica	0.1				
Callitriche hamulata		1			
Callitriche hermaphroditica			0.1		
Carex rostrata					
Crassula helmsii	17	1	20	2	
Elatine species					
Elatine species (*hexandra*?)					
Elatine species (*hydropiper*?)					
Eleocharis palustris	10	10	15	2	
Fontinalis antipyretica	3	5		5	1
Galium species		2			
Hydrocotyle vulgaris	1	1			
Isoetes lacustris					
Juncus bulbosus			15		
Juncus effusus	10	2		1	1
Lemna minor	<0.1	<0.1			
Littorella uniflora					
Moss species			5	1	
Myosotis species	1				
Oenanthe crocata					
Peplis portula	1		15	10	0.5
Persicaria species				5	3
Phalaris arundinacea					
Potamogeton crispus					
Ranunculus aquatilis agg.					
Ranunculus flammula	5	3	15		
Substrate (%)	100	100	100	100	100
Silt/peat		10			
Sand			10		
Gravel	5			10	
Pebble	10	10		10	10
Cobble	35	20	40	40	50
Boulder	10	10			10
Bedrock	40	50	50	40	30
Water depth (m)	0.25	0.1	0.1	0.1	0.1
% bare substrate					

Table 9. Transect 4 data, September 2009

Transect number	4				
Transect type	Shore perpendicular				
Survey date	29/09/2009				
Photograph number	84				
Transect start	NX2998753618				
Transect end	NX3000653296				
	Quadrat				
Species	**1**	**2**	**3**	**4**	**5**
Alisma plantago aquatica	5	1	0.1		2
Callitriche hamulata					
Callitriche hermaphroditica					
Carex rostrata					
Crassula helmsii	10				
Elatine species					
Elatine species (*hexandra*?)					
Elatine species (*hydropiper*?)					
Eleocharis palustris					
Fontinalis antipyretica	5				
Galium species					
Hydrocotyle vulgaris	2				
Isoetes lacustris					>2
Juncus bulbosus					
Juncus effusus					
Lemna minor					
Littorella uniflora		2		20	35
Moss species					
Myosotis species					
Oenanthe crocata					
Peplis portula	10				
Persicaria species					
Phalaris arundinacea					
Potamogeton crispus		0.1			
Ranunculus aquatilis agg.		0.1			
Ranunculus flammula		0.1		1	
Substrate (%)	100	100	100	100	100
Silt		40	30	20	28
Sand	5	35	30	40	70
Gravel					
Pebble	5				
Cobble	80	5	10	10	2
Boulder		5	10	20	
Bedrock	10	15	20	10	
Water depth (m)	0.15	0.6	0.75	0.75	0.75
% bare substrate	68	99.7	99.8	69	56

Table 10. Transect 5 data, September 2009

Transect number	5				
Transect type	Shore perpendicular				
Survey date	29/09/2009				
Photograph number	85				
Transect start	NX2930952299				
Transect end	NX2930352313				
	Quadrat				
Species	**1**	**2**	**3**	**4**	**5**
Alisma plantago aquatica					
Callitriche hamulata					
Callitriche hermaphroditica					
Carex rostrata	1				
Crassula helmsii		0.5		0.1	
Elatine species					
Elatine species (*hexandra*?)					
Elatine species (*hydropiper*?)	0.5	5			
Eleocharis palustris	20	20	15	10	10
Fontinalis antipyretica					
Galium species					
Hydrocotyle vulgaris					
Isoetes lacustris					
Juncus bulbosus					
Juncus effusus					
Lemna minor				<0.1	
Littorella uniflora		0.1		20	20
Moss species		5		5	5
Myosotis species					
Oenanthe crocata					
Peplis portula	5	0.1			
Persicaria species					
Phalaris arundinacea					
Potamogeton crispus					
Ranunculus aquatilis agg.					
Ranunculus flammula	3				
Substrate (%)	100	100	100	100	100
Silt/Peat	5	10	80	60	40
Sand	85	80			10
Gravel					10
Pebble					
Cobble	10	10	10	5	10
Boulder			10	20	
Bedrock				15	30
Water depth (m)	0.45	0.5	0.45	0.55	0.55
% bare substrate	70.5	69.3	84	64.7	65

Table 11. Transect 6 data, September 2009

Transect number	6				
Transect type	Shore parallel				
Survey date	29/09/2009				
Photograph number	86				
Transect start	NX3034652602				
Transect end	NX3034552612				
	Quadrat				
Species	**1**	**2**	**3**	**4**	**5**
Alisma plantago aquatica	1	0.1	0.5		0.5
Callitriche hamulata					
Callitriche hermaphroditica					
Carex rostrata					
Crassula helmsii					
Elatine species					
Elatine species (*hexandra*?)					
Elatine species (*hydropiper*?)					
Eleocharis palustris					
Fontinalis antipyretica		0.1	0.5	0.5	5
Galium species					
Hydrocotyle vulgaris			0.5	0.1	
Isoetes lacustris					
Juncus bulbosus					
Juncus effusus					
Lemna minor					
Littorella uniflora					
Moss species					
Myosotis species					
Oenanthe crocata		0.1			
Peplis portula					
Persicaria species					
Phalaris arundinacea	1	0.1		1	1
Potamogeton crispus					
Ranunculus aquatilis agg.	0.1		1		0.5
Ranunculus flammula					
Substrate (%)	100	100	100	100	100
Silt					
Sand	10	2		5	
Gravel	20	7	10	5	10
Pebble	45	60	40	30	10
Cobble	20	30	40	40	50
Boulder	5	1	10	20	30
Bedrock					
Water depth (m)	0.5	0.55	0.6	0.45	0.6
% bare substrate	97.9	99.6	97.5	98.4	93

Table 12. Taxa recorded in all transects in Mochrum Loch

Taxa	Common name
Alisma plantago aquatica	water-plantain
Callitriche hamulata	intermediate water-starwort
Callitriche hermaphroditica	autumnal water-starwort
Carex rostrata	bottle sedge
Crassula helmsii	New Zealand pygmyweed
Elatine species	waterwort sp.
Elatine species	waterwort
Eleocharis palustris	common spike-rush
Fontinalis antipyretica	willow moss
Galium species	bedstraw
Hydrocotyle vulgaris	marsh pennywort
Isoetes lacustris	quillwort
Juncus bulbosus	bulbous rush
Juncus effusus	soft-rush
Lemna minor	common duckweed
Littorella uniflora	shoreweed
	moss species
Myosotis species	forget-me-not
Oenanthe crocata	hemlock water-dropwort
Peplis portula	water-purslane
Persicaria species	bistort
Phalaris arundinacea	reed canary-grass
Potamogeton crispus	curled pondweed
Ranunculus aquatilis agg.	common water-crowfoot
Ranunculus flammula	lesser spearwort

Table 13. Percentage cover of C. helmsii in quadrats during the original survey and in 2009

	Quadrat no.														
	September 2007					March 2009					September 2009				
Transect	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
1	60	35	5	0	0	3	1	0	0	0	0	0	0	0	0
2	90	90	70	35	20	0	0	0	0	0	5	25	15	0	0.5
3	85	95	95	85	75	1	0.1	0.1	0	0	17	1	20	2	0
4	90	90	75	10	0	1	0	0	0	0	10	0	0	0	0
5	75	55	70	65	45	0	0	0	0	0	0	0.5	0	0.1	0
6	45	45	65	25	25	1	1	0	0	0	0	0	0	0	0

APPENDIX 3: PLATES

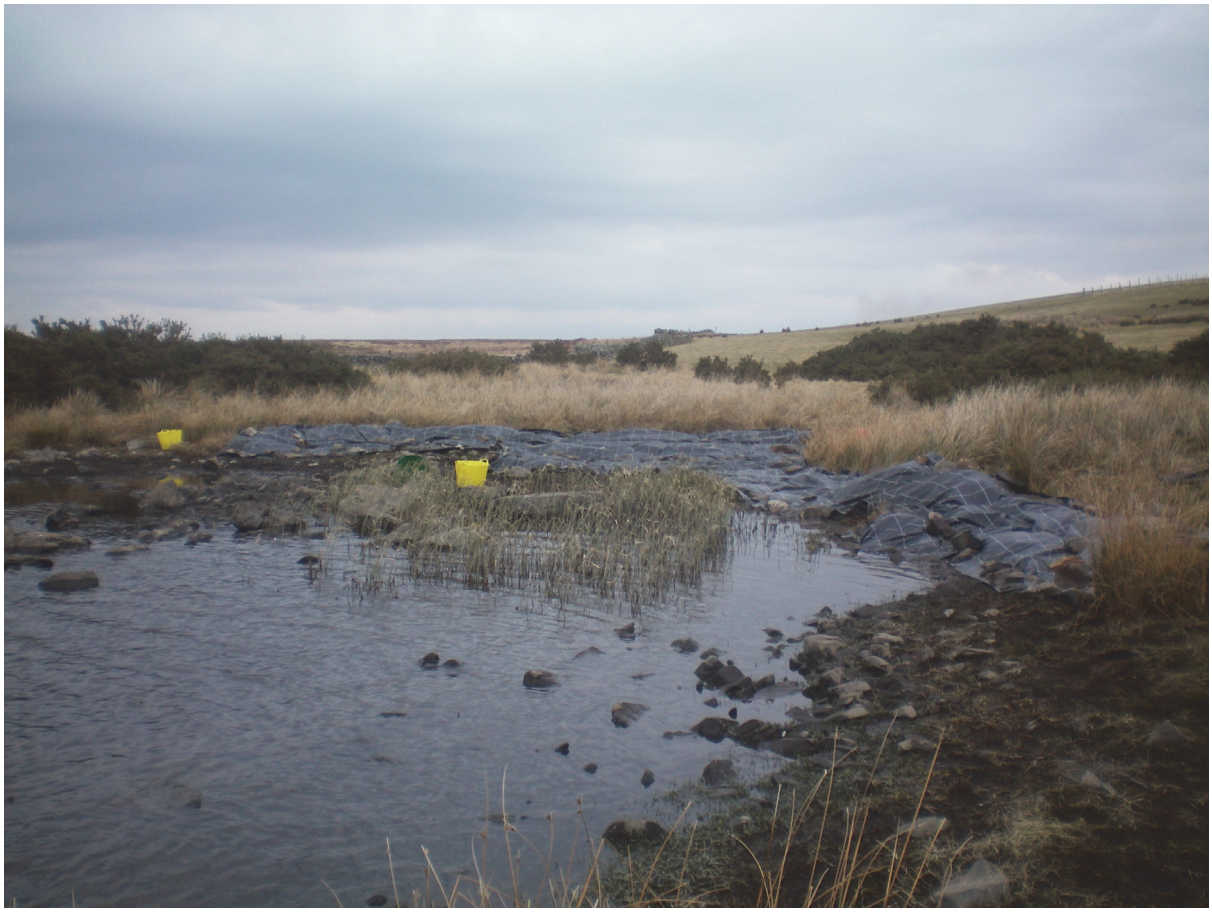

Plate 1. WCF installed over an area supporting C. helmsii

Plate 2. Small, single C. helmsii plant

Plate 3. C. helmsii growing in submerged habitat which had been treated with WCF

Plate 4. C. helmsii growing in area above that which was treated with WCF

Plate 5. Regeneration of native plants in an area which had been treated with WCF

Plate 6. Native vegetation colonising an area which had been treated with WCF

Plate 7. Native vegetation emerging from an area previously treated with WCF

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