

***Crassula helmsii* in the New Forest**

**Final report on the status, spread and impact
of this non-native invasive plant, and the
efficacy of control techniques following a
3-year trial**



**Prepared by Freshwater Habitats Trust for the New Forest Non-
Native Plants Project on behalf of Hampshire and Isle of Wight
Wildlife Trust**

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Cover photo:

Wootton drinking pond - the bright green 'lawn' is the rare native plant pillwort *Pilularia globulifera*, but *Crassula helmsii* is also present throughout the pond. Grazing pressure and poaching of this temporary pond by livestock breaks up the sward and creates bare ground which allows space for native New Forest pond specialists, like pillwort, in spite of the *Crassula*.

Non technical summary

This report has been prepared on behalf of the New Forest Non-Native Plants Project. The report brings together work which has been ongoing since 2009 investigating New Zealand Pigmyweed *Crassula helmsii* in the New Forest, Hampshire, UK. The report is divided into three sections: Part A describes the history, current distribution and spread of *C. helmsii* in the New Forest; Part B summarises our current understanding of the potential impacts of *C. helmsii* on the flora and fauna of the New Forest; and Part C presents the results of plant and invertebrate surveys following three years of trials and four years of plant and invertebrate surveys to investigate the potential for treatments to control *Crassula helmsii* in New Forest ponds.

Part A: History, current distribution and spread of *C. helmsii* in the New Forest

C. helmsii was first recorded in the New Forest in 1976 in a roadside pond adjacent to houses. Sporadic records were made at various other sites within the New Forest Special Area for Conservation (SAC) thereafter, but no comprehensive data existed on its distribution. In 2000, 194 ponds (including some ditches) in the New Forest were surveyed by volunteers and staff as part of a Hampshire and Isle of Wight Wildlife Trust project (Crutchley and Wicks, 2001). Of these, 76 (39%) were found to contain *C. helmsii* and concerns were raised that *C. helmsii* may pose a significant and increasing risk to these important freshwater habitats. These waterbodies and an additional 385 sites (total 579) were surveyed by Dr Naomi Ewald and trained volunteers from University of Sussex in 2009/2010. In total 116 (20%) were found to contain *C. helmsii*; including spread to 13 ponds which were not infected in 2000.

These investigations have shown that this distribution, whilst widespread, is concentrated in areas around car parks, dwellings and lay-bys, strongly suggesting that the main route of introduction is via accidental or deliberate release by people. Spread from these points of introduction, in the majority of cases, is via running water along ditches or surface flooding into adjacent ponds.

Since 2010, new sites for *C. helmsii* continue to be identified each year. These follow the same pattern as suggested by the previous survey, i.e. introduced by people or spread via water to an adjacent site. The vast majority of sites visited by the author which are not easily accessed from a car park or dwelling do not currently have *C. helmsii*. The only exception to this rule is where vehicles and/ or equipment have been used which are likely to have come from an infected site. To date approximately 700 waterbodies have now been visited, of which 18% are known to contain *C. helmsii*.

Part B: Potential impacts of *C. helmsii* on the flora and fauna of the New Forest

The New Forest ponds are of exceptional quality for wildlife, identified as an important feature of the New Forest SAC and supporting many species which have significantly declined elsewhere in the UK and Europe. In 2009 and 2010 further investigations were made to understand the potential impacts of *C. helmsii* on native flora and fauna in New Forest ponds.

On average over two thirds of ponds surveyed had less than 70% cover of *C. helmsii* and over a third of ponds had less than 30% *C. helmsii* cover. Therefore, although widely distributed less than a third of ponds could be described as heavily infested (>75%).

The degree to which *C. helmsii* dominated a site was shown to be correlated with a number of different factors, including pH and availability of nutrients. At low pH, the extent of *C. helmsii* was apparently limited, and at nutrient rich sites the extent of *C. helmsii* at a pond was greater. However, confounding factors, such as time since introduction, the complexity and structure of the native plant community, and the presence of other competitively dominant native plant species, mean that it is not possible to attribute any one factor to the

limited extent of *C. helmsii* at some sites. Further research to answer these questions would be of value.

Dominance of *C. helmsii* was shown to have a significant effect on the availability of bare ground and the abundance of native plant species. For every 10% increase in the amount of *C. helmsii* the amount of bare ground decreased by 6% and the amount of native vegetation by 5%. We could find no evidence that dominance of *C. helmsii* alone had caused the extinction of any plant species. There was anecdotal evidence at one site where native plant species of conservation importance were no longer recorded, but this could not be attributed solely to the presence of *C. helmsii*, but to an overall deterioration in conditions at the site from poor water quality.

Many ponds in the New Forest are grazed by commoners' livestock, which is an essential element of the management of these ponds for rare and threatened native species. The intensity of this grazing pressure at some sites maintains an open sward in the pond margin and creates patches of bare ground essential for the germination and growth of native plants. Without this grazing pressure *C. helmsii* is likely to become dominant but the quality of the ponds would decline regardless because other dominant native species would also increase.

There was no significant difference between pond macroinvertebrate communities in ponds with and without *C. helmsii*.

Part C: Investigating the potential for treatments to control *Crassula helmsii* in New Forest ponds

In 2011 the New Forest Non-Native plants project began trials of three different control techniques to determine whether it would be possible to eliminate *C. helmsii* from the New Forest. These methods were (i) a traditional herbicide technique and two novel approaches – (ii) hot foam and (iii) dye treatments.

Treatments were applied in the summer/winter of 2011, 2012 and 2013. In the following February of each year the ponds were re-visited to record the percentage cover of *C. helmsii*, bare ground and cover of native plant species. From May– July a full survey of percentage cover of *C. helmsii*, plant species and pond macroinvertebrate communities was undertaken.

- Within 6 months of the first treatment, the cover of *C. helmsii* had been significantly reduced but not eliminated by the herbicide treatment (on average 84% reduction). The effect of the other techniques was not significant (hot foam: reduced by 12%, aquatic dye: reduced by 14%, control group: increased by 8%).
- Within 1 year of the first treatment, the cover of *C. helmsii* had returned to pre-treatment levels, for all treatments. There was no difference in the composition or abundance of native plant and invertebrate communities.
- In late summer 2012, treatment was incomplete due to adverse weather conditions. Only the aquatic dye treatment was successfully applied during 2012 because the ponds did not dry out enough for hot foam or herbicide treatments.
- An interim survey was conducted in spring 2013, following the incomplete treatments in 2012. This showed that there was no difference in the cover of *C. helmsii* from the previous survey. A slight, but non-significant increase in *C. helmsii* cover may have been caused by the very wet conditions during the summer of 2012, favouring the growth of *C. helmsii*.
- A full survey in summer 2013 showed a significant reduction in *C. helmsii* in some ponds. This difference cannot be attributed to a treatment type, because no treatments were undertaken in 2012 on these ponds. However, the reduction may be linked with increased grazing pressure due to very dry conditions in spring/early summer of 2013.

- Full treatments using herbicide, hot foam and aquatic dye were completed in the summer/winter of 2013.
- Hot foam treatment caused a significant reduction in *C. helmsii* initially but cover had returned to pre-treatment levels within 5 months.
- Herbicide had been very effective and may have helped to completely eradicate *C. helmsii* from an acidic pond, where natural conditions had caused *C. helmsii* to decline without treatment. Apart from this site, at the end of the trial period patches of *C. helmsii* had reappeared in all herbicide treatment ponds.
- No treatment can be considered to be fully successful, because eradication has not been confirmed in any of the ponds in the trial as a result of the treatment alone. Results have shown that under these circumstances fragments will re-colonise a pond to the same or greater extent than before.
- Treatments did not negatively impact upon cover of native plants in this trial or the presence and cover of priority plant species.
- The cover of native plant species and the amount of bare ground fluctuates naturally between seasons and between years. Without grazing to maintain an open sward, the presence of *C. helmsii* could disrupt this ebb and flow, by displacing species in years when the cover of bare ground is high, and the cover of native species naturally low.

Conclusions

The distribution and spread of *C. helmsii* in the New Forest is now well understood. As a priority, biosecurity protocols for staff working within the New Forest SAC should be updated and adhered to, to prevent spread to uninfected/ isolated ponds. On-going public awareness campaigns for visitors to the New Forest National Park and homeowners within the park should focus on preventing introduction to currently uncontaminated sites.

Our understanding of the impact of *C. helmsii* on native flora and fauna in the New Forest is increasing. *C. helmsii* has wide tolerance limits, but is clearly less dominant at the edge of these limits and its dominance may be determined by the composition and structure of the existing native plant community. Grazing pressure is critical in limiting the dominance of *C. helmsii* at some ponds particularly where these ponds naturally dry out during the summer months; wet summers unsurprisingly encourage greater growth, whilst a reduction in growth follows a dry summer.

Therefore, whilst many ponds with *C. helmsii* maintain a diverse flora and fauna factors such as increasing nutrients from pollution, climate change and a reduction in grazing pressure due to changes in the socio-economy of the New Forest are likely to result in greater dominance of *C. helmsii* and corresponding reduction in the cover of native plant species. Whilst not observed during this study this could weaken the integrity of native plant communities and ultimately results in the decline and extinction of native plants. Even without the presence of *C. helmsii*, these factors would have a significant detrimental impact on the quality of these ponds for wildlife.

A significant reduction in *C. helmsii* was observed following treatment with herbicide and hot foam to a lesser extent, but to date none of the treatments alone have been effective in eradicating *C. helmsii* at a site. *C. helmsii* was able to re-grow to the same or greater extent following treatment which is highly undesirable in ponds which contain species with high conservation value.

Natural conditions at a pond (e.g. pond acidity) may be important in limiting growth of *C. helmsii* and under these circumstances application of herbicide onto dry patches of *C. helmsii*, where there is no submerged growth, may be effective in eradicating the plant from the pond. This combination of factors are unlikely to occur at more than a handful of sites, but identifying these ponds will be important in targeting effective action.

In permanent ponds, fragments of *C. helmsii* from deeper water re-colonised the pond margin, therefore, both hot foam and herbicide treatments could only be used to eradicate *C. helmsii* in ponds which dry out completely. Eradication was not possible even following multiple treatments in the same year; therefore success may only be possible with repeat treatments over a number of years. The unpredictability of the UK climate and re-colonisation of *C. helmsii* from adjacent sites means that planning a successful eradication programme is unfeasible in the New Forest at this time.

Further research and other control options should be explored, but in the interim, prevention of spread and monitoring to ensure that grazing is sufficient to maintain an open sward for native plant communities will be needed to maintain the quality of these ponds for biodiversity until an effective control treatment is found.

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1. Background

1.1 Hampshire and Isle of Wight Wildlife Trust

Hampshire and Isle of Wight Wildlife Trust (HIWWT) is the leading nature conservation charity in the two counties of Hampshire and the Isle of Wight. With support from over 27,000 members and 900 volunteers, HIWWT works to protect wildlife and wild places, managing 48 nature reserves, running 3 education centres and offering advice to landowners and land managers. HIWWT is part of a UK-wide partnership of 47 local Wildlife Trusts, with a collective membership of more than 800,000 people working together to conserve our precious natural heritage.

1.2 Freshwater Habitats Trust

Freshwater Habitats Trust (formerly Pond Conservation) is a UK national charity which aims to protect freshwater life for everyone to enjoy. FHT is an evidence-based charity, with a strong science grounding, that works to protect life in all freshwaters, including those that are small and undervalued, like headwater streams, ponds, flushes and ditches. We undertake research, practical projects, policy analysis and awareness raising, usually working in partnership with people, communities and organisations, to get the best results for freshwater wildlife. FHT has 20 staff and associates, 350 members and works with a network of several hundred volunteers across the country. FHT was commissioned by Hampshire and Isle of Wight Wildlife Trust to undertake field trials to test control methods for *Crassula helmsii*.

1.3 The New Forest Non-Native Plants Project

The New Forest Non-Native Plants Project (NFNPP) aims to stop the spread of invasive non-native plants in The New Forest area, particularly along watercourses and in wetland habitats.

The objectives of The New Forest Non-Native Plants Project are to:-

- identify where non-native invasive plants are a problem, particularly within river valleys and wet habitats;
- arrange for control work to be undertaken by volunteers and contractors;
- commission research into control methods;
- raise awareness of the need to control invasive non-native plants and to prevent them spreading into our countryside.

The NFNPP is hosted by Hampshire and Isle of Wight Wildlife Trust (HIWWT) and supported by a partnership of local and national organisations. The NFNPP was set up in 2009 and a full time Project Officer is employed by HIWWT to liaise with landowners, raise awareness of the problems caused by invasive non-native plants and arrange for practical control work to be undertaken. Recognising the need for invasive non-native plants to be eradicated at the catchment scale the Project Officer co-ordinates control programmes and provides advice, encouragement and practical help to landowners and land managers.

1.4 *Crassula helmsii* project

This report has been prepared on behalf of the New Forest Non-Native Plants Project. It brings together work which has been ongoing since 2009 investigating New Zealand Pigmyweed *Crassula helmsii* in the New Forest, Hampshire, UK.

C. helmsii has been identified as a major threat to UK freshwaters (Dawson and Warman 1987, Huckle 2007, Dawson and Leach 1999). It is easily spread from fragments of stem

and in some circumstances it forms extremely dense stands of vegetation (OEPP/ EPPO 2007). Conflicting and often anecdotal evidence has led to uncertainty about the ability of *C. helmsii* to dominate sites, the impact of *C. helmsii* on native flora and fauna, the mode of transport between sites and the rate of spread (Langdon et al 2004, Newman 2004, Denton 2013, CABI 2014).

Given the number of protected pond habitats and associated species in the New Forest the threat of *C. helmsii* is a serious issue in the New Forest which is recognised by failures to meet Water Framework Directive (WFD) objectives and failure to achieve Favourable Condition in some Site of Special Scientific Interest (SSSI) units.

Implementing effective conservation management strategies to protect and restore the New Forest ponds was unfeasible given the uncertainties about the extent and spread. In addition, choosing an appropriate management tool was difficult, when few studies exist on the efficacy of treatment techniques in the field and even fewer studies have explored the impact of treatment on non-target native plants and invertebrates (Stone 2002, Lockton 2010). This was critical given the species of conservation importance known to occur in the ponds in spite of the presence of *C. helmsii*.

Hampshire and Isle of Wight Wildlife Trust commissioned Freshwater Habitats Trust to undertake research to answer the following elements: a) collect and collate data on the history, current distribution and spread of *C. helmsii* in the New Forest; b) collate information to better understand the potential impacts of *C. helmsii* on the flora and fauna of the New Forest; and c) undertake replicated field trials of three different control treatments over four years (three treatment years) to investigate the potential for treatments to control *Crassula helmsii* in New Forest ponds without long term detrimental effects on non-target native species.

1.5 The importance of New Forest pond communities

The New Forest in Southern England is an area of extensive semi-natural landscape encompassing a mosaic of woodland, heathland, mire, grassland, riverine and coastal habitats. It is in fact the largest area of lowland heathland in Europe and the largest area of deciduous woodland in Britain, maintained by a traditional local commoning and pastoral economy. In recognition of its importance for biodiversity it is designated as a National Park, Special Area of Conservation (SAC), Special Protection Area (SPA), Ramsar site and Site of Special Scientific Interest (SSSI). The New Forest has also been recognised as an Important Bird Area, Important Plant Area, Important Fungus Area, Important Stonewort Area and an Important Area for Ponds (IAP).

The New Forest supports over 1000 individual ponds greater than 1m² and up to 2 ha in size within the National Park boundary and many thousand more trackway pools. The ponds support an outstanding number of uncommon plant and invertebrate species, including many Biodiversity Action Plan species (40% of UK Biodiversity Action Plan ponds species). Great crested newt (*Triturus cristatus*) and floating water plantain (*Luronium natans*) (listed on Annex II of the Habitats Directive) have both been recorded here. Some species, including Hampshire-purslane *Ludwigia palustris*, bog hair-grass *Deschampsia setacea*, the beetle *Graptodytes flavipes*, fairy shrimp *Chirocephalus diaphanus* and the tadpole shrimp *Triops cancriformis* have national strongholds in New Forest ponds (in the case of *T. cancriformis* the New Forest is one of only two sites in the UK). Over 20 Red Data Book vascular plants have been recorded in the New Forest ponds, one of which is an endemic hybrid, the New Forest water-crowfoot *Ranunculus x novae-forestae*, and one in three ponds has been shown to contain at least one Red Data Book macroinvertebrate species.

The New Forest is known to contain at least two pond habitat types listed under Annex 1 of the Habitats Directive (oligotrophic waters containing very few minerals of sandy plains: *Littorelletalia uniflorae* (3110) and oligotrophic to mesotrophic standing waters with vegetation of the *Littorelletalia uniflorae* and/or of the *Isoeto-Nanojuncetea* (3130)) and many ponds support elements of the Mediterranean Temporary Pond (3170) type. The importance and quality of the ponds of the New Forest is recognised by their inclusion as special features of the New Forest SAC (Wright and Westerhoff 2001). In a recent survey 89% of New Forest ponds surveyed qualified as Priority Ponds as defined by the UK Pond BAP (Ewald 2014).

It is worth noting that the quality of these ponds is in contrast with the rest of lowland England where around 80% of ponds are now considered to be in poor or very poor condition, primarily as a result of poor water quality (Williams *et al.* 2010). Their quality is maintained because of lack of pollution and on-going low input management resulting from the pastoral economy of this area. Commoners' stock (mostly cattle and ponies, but also pigs and donkeys) and deer graze extensively over the New Forest (Figure 2.1). This grazing is the key to maintaining pond diversity. Many ponds are known to be hundreds of years old and yet they still retain early successional habitats.

Ponds form naturally, including tree falls, floodplain pools, bog ponds and compacted depressions, but many were also created as a by-product of man's activities. Ponds were created for reasons as variable as providing drinking water for stock, as a result of mineral extraction (marl and gravel), development of tracks and roads and from bombing during World War II. Their diversity of type is also related to the unique geology of the New Forest which is formed from a series of strata including Tertiary clays and sands, covered in many areas by more recent Pleistocene gravels. As a result the ponds show great variation in chemistry and hydrology, e.g. pH 3.5 – 8.5, conductivity 15 - 500 μ S, area 1m² – 2 ha and average depth 10 cm – +2 m (Ewald 2008).

1.6 New Zealand Pigmyweed *Crassula helmsii*

C. helmsii (Figure 2.2) is a perennial plant which is found in many different aquatic habitats; lakes, gravel pits, canals, ditches, inland and coastal wetlands, marshes, swamps, temporary ponds and permanent ponds. It has rather stiff succulent bright green stems and opposite leaves which are between 4 and 24mm in length and 0.5 to 2mm in width. It can be distinguished from similar looking species by the pointed leaf tips and 1mm collar where the leaves join the stem. In summer (July to September), small (<4mm) white or occasionally pink flowers are borne on stems which arise from the leaf axils (CABI 2014).

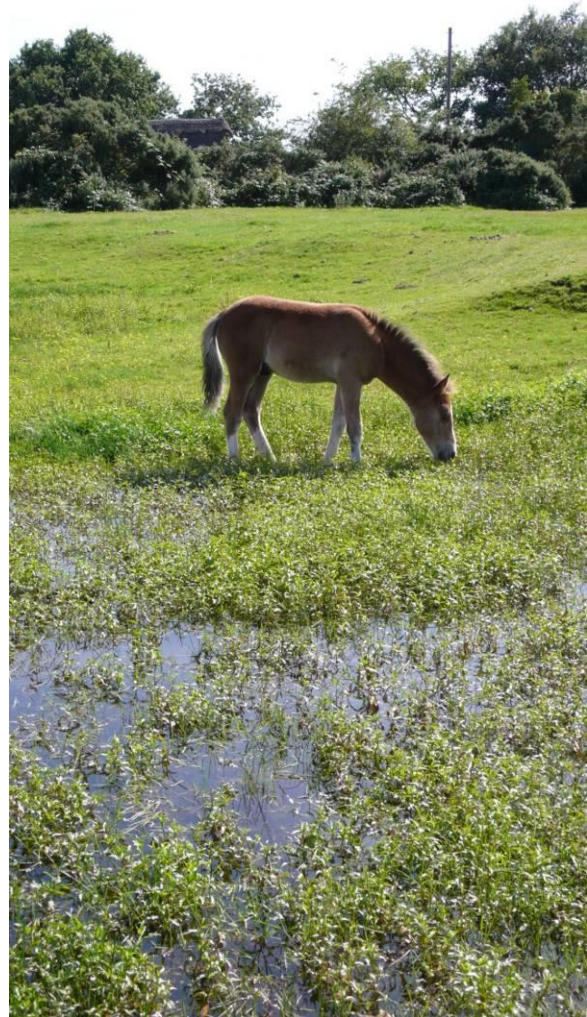


Figure 2.1: A New Forest pond with very high conservation value grazed by commoners' livestock.

A native of Australia and New Zealand, the plant is tolerant of a wide range of environmental conditions (Leach and Newman 2001). It continues to grow throughout the year and can withstand both temporal drought and deep water conditions. The submerged form (up to 3m deep) can grow to 1.3m; whilst on the pond margin it can produce a dense mat of c.10cm shoots (Sheppard *et al* 2006). In certain conditions it can also form a floating mat over the water surface (Langdon *et al* 2004).

Under certain conditions *C. helmsii* will form thick stands of 100% cover, which may cause negative environmental and economic impacts, for example reduction in cover of native plants or loss of native plant species from a site. The likelihood of *C. helmsii* becoming dominant at the expense of other species is thought to

increase where other stress factors such as eutrophication and pollution are already causing habitat degradation (Lockton 2010). Aside from biodiversity impacts the presence of large quantities of *C. helmsii* may impact upon water flow and in waterbodies used for recreation may render the lake not fit for purpose (CABI 2014).

C. helmsii was bought into this country in 1911 as a pond oxygenating plant and was first recorded in the wild in 1956 in a pond in Essex (Dawson and Warman 1987). It is not thought to set seed in this country but will grow vegetatively from as little as a 5 mm fragment of stem (CAPM-CEH 2004). This ability means that it is easily transferred between ponds and it has now been recorded in 885 hectads in the UK (BSBI Maps Scheme, accessed 29/03/2013). More recent authors (e.g. Crawley 2005) have observed that the rate of spread had now slowed down, and the BSBI Maps Scheme data show that it is no longer amongst the top 100 most rapidly spreading species in Britain.



Figure 2.2: *C. helmsii* covering the bare ground of a temporary pool in the New Forest.

2. Part A: History, current distribution and spread of *C. helmsii* in the New Forest

The aim of this element of the work was to establish the extent to which the non-native invasive plant *C. helmsii* had spread across the New Forest and whether there was any pattern to its distribution which would help to inform future management strategies.

2.1 History of *C. helmsii* in the New Forest

C. helmsii was first recorded in the New Forest at Buddle Green, North Gorley on the edges of a shallow pond (SU161118) by Paul Bowman on the 18th July 1976. The BSBI has provided data on the distribution of *C. helmsii* in the New Forest, including previously unavailable data. Figure 2.1 shows that there was an exponential rate of increase between 1976 and 1995.

By 1995, 41 distinct sites were known to have *C. helmsii*. However, with ad-hoc recording such as this, it was difficult to gain a complete understanding of the extent of *C. helmsii* in the New Forest.

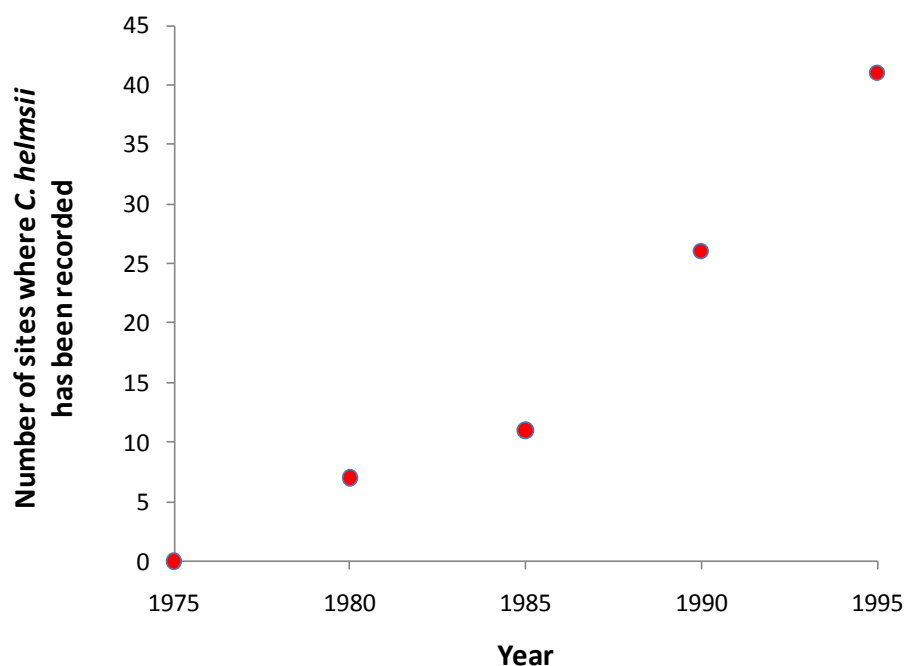


Figure 2.1: Cumulative increase in the number of ponds with *C. helmsii* recorded in the New Forest between 1975 and 1995.

A survey by Hampshire and Isle of Wight Wildlife Trust in 2000, found that 39% of water bodies surveyed (76 out of 194) within or adjacent to the New Forest SAC contained *C. helmsii* (Crutchley and Wicks 2001). Affected ponds were clustered together and it was suggested that ponies may be acting as a vector between ponds. It was also noted that the ponds with *C. helmsii* were located near to houses, car parks, forest paths and roads.

There was concern that *C. helmsii* was spreading rapidly across the New Forest, but the 2000 survey visited less than 10% of the total pond resource and led by volunteers there was a chance that the survey was biased towards ponds which were easy to access. A more comprehensive survey was required to understand better the distribution and spread of *C. helmsii* in the New Forest.

2.2 Method to assess the distribution of *C. helmsii* in the New Forest

In 2009/2010, 194 ponds from the 2000 survey were revisited. Some of these ponds (76 ponds) had *C. helmsii* in 2000 and were resurveyed to determine if *C. helmsii* was still present. The remainder did not have *C. helmsii* in 2000 and were resurveyed to determine spread.

An additional 385 ponds were surveyed which had not been previously surveyed for *C. helmsii*. Site selection was not chosen a priori but was based on covering as large an area as possible on foot and surveying ponds as they were encountered.

Surveys were undertaken by the author and a team of trained volunteers from the University of Sussex. Volunteers collected a sample of *C. helmsii* if found for verification by the author.

2.3 Results of *C. helmsii* distribution survey

In 2009/ 2010 a total of 579 ponds were surveyed for *C. helmsii*, approximately 60% of the New Forest resource. Of these, 116 (20%) contained *C. helmsii* (Figure 2.2). The remaining 463 ponds (80%) were free from *C. helmsii*.

C. helmsii was not recorded from 11 ponds which had previously been flagged as infected in 2000. These sites were clustered around Brockenhurst and recorded by the same individual in 2000. It was not possible to determine whether *C. helmsii* has disappeared from these sites, but it is probably more likely that it was misidentified during the 2000 survey.

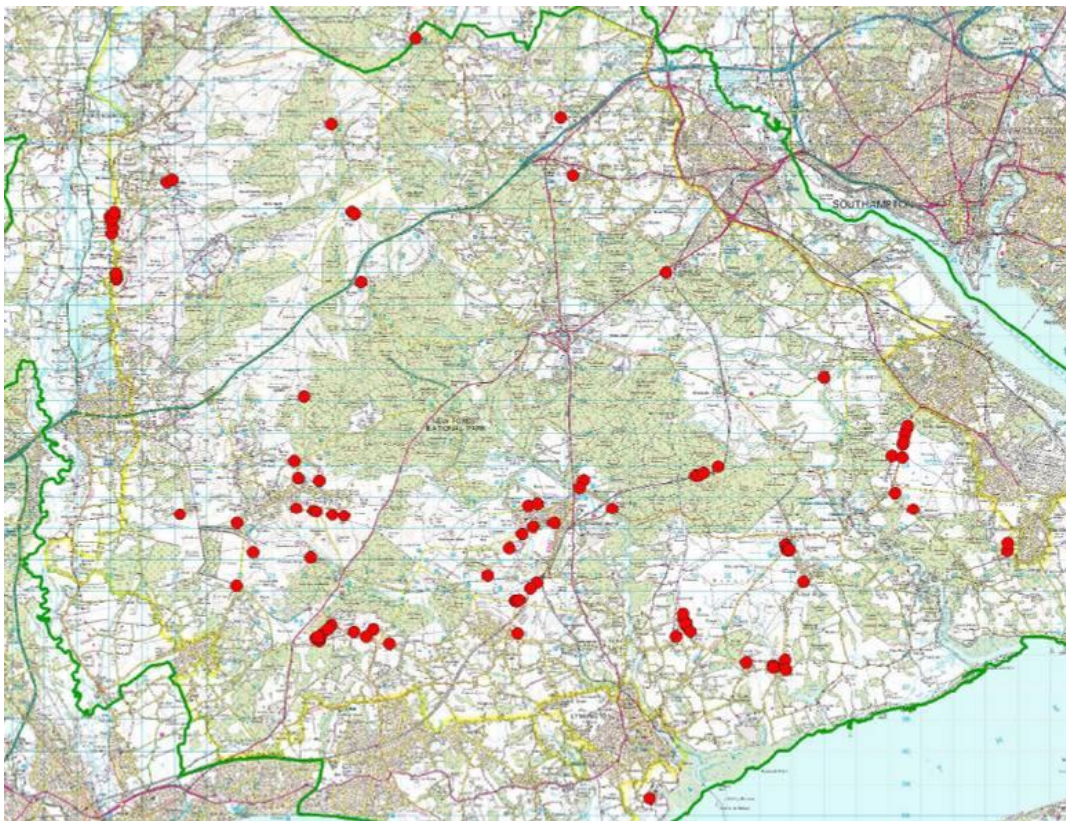


Figure 2.2. Distribution of *C. helmsii* in New Forest ponds based on a survey of c. 600 ponds (Ewald 2009).

C. helmsii had spread to 13 ponds which were previously uninfected in 2000. Of these, 6 were connected to infected ponds via a ditch. The remaining sites were close to car parks or habitation or had been visited in recent years to undertake management work.

2.4 Discussion on the distribution and spread of *C. helmsii* in the New Forest

Although geographically widespread, *C. helmsii* is distributed in a distinct pattern associated with public access which suggests that the primary route of introduction is likely to be accidental or deliberate release by people. It would appear that new sites become colonised through direct introduction, or spread from the primary sites via connectivity with infected sites by ditch/ channel or a thin layer of surface water where poaching by ponies between adjacent waterbodies creates the connection for spread (Ewald 2013). There was no evidence that livestock were responsible for spread between unconnected ponds as ponds in close proximity to infected sites were not infected.

Although the rate of spread is slower than initially feared (Crutchley and Wicks 2001), since 2010, new sites for *C. helmsii* continue to be identified each year. These follow the same pattern as suggested by the previous survey, i.e. introduced by people or spread via water to an adjacent site. The vast majority of sites visited by the author which are not easily accessed from a car park or dwelling do not currently have *C. helmsii*. The only exception to this rule is where vehicles and/ or equipment have been used which are likely to have come from an infected site. To date approximately 700 waterbodies have now been visited, of which 18% are known to contain *C. helmsii*. The priority must be for raising awareness and prevention of spread to currently uninfected sites by better biosecurity protocols.

3. Part B: Potential impacts of *C. helmsii* on the flora and fauna of the New Forest

The aim of this element of the work was to determine factors affecting the dominance of *C. helmsii* within ponds and assess the impact of *C. helmsii* on native plant and invertebrate communities.

3.1 Assessing the impact of *C. helmsii* on New Forest pond communities

The New Forest ponds are of exceptional quality for wildlife, identified as an important feature of the New Forest SAC and supporting many species which have significantly declined elsewhere in the UK and Europe.

Despite concerns, few experiments have been conducted to investigate what impact *C. helmsii* has on native flora and fauna. There are some anecdotal accounts of its impact on notable flora in the New Forest. At Hatchet Pond Triangle in 1986, *C. helmsii* was recorded along with pillwort *Pilularia globulifera*, but the latter had disappeared by the 1999 survey. Both Hampshire purslane *Ludwigia palustris* and slender marsh-bedstraw *Galium constrictum* were recorded from Hill Top Pond in 1976, but by 1986 *C. helmsii* was abundant and only *L. palustris* remained. By 1999, only *C. helmsii* was present (Byfield, A. pers. comm. in Crutchley and Wicks 2001).

Langdon *et al.* (2004) have shown that *C. helmsii* can suppress the germination of native plants by up to 83%; however, there was no significant loss of plant species. They also found that the developmental stage of great crested newts *Triturus cristatus* at hatching was unaffected whether eggs were laid on *C. helmsii* or on another plant, whilst smooth newt *Triturus vulgaris* eggs, were at a later developmental stage on hatching when they were laid on *C. helmsii*.

Because of the potential threat posed by *C. helmsii*, many organisations are attempting to eradicate it. There is, however, no published evidence for this point of view and concerns are being raised that options for control will conflict with the conservation interest of the site. Answers to these questions are clearly a priority for research.

3.2 Methods to assess the impact of *C. helmsii* on native flora and fauna

During the 2009 survey a random selection of 100 ponds were categorised according to the extent of *C. helmsii* they contained; 'low' less than 30% cover, 'medium' 30-60% cover and 'high' greater than 60%.

Of these, 8 ponds were selected in each category and a limited number of pond characteristics recorded; pH, conductivity (μS) and degree of grazing pressure (1-low, to 5-high), to determine whether the density of *C. helmsii* could be attributed to one of these characteristics.

An enclosure experiment was conducted to determine whether grazing had a significant effect on the abundance of *C. helmsii*. This work was a continuation of the MSc research work conducted by Ian Stone (University of Bournemouth). Four ponds were selected which contained greater than 75% *C. helmsii* cover. Enclosure fences were erected in March 2009 to create areas of pond where there was no grazing pressure from livestock. The enclosures were positioned to include both bank top and submerged vegetation. For full details of the experimental design refer to Stone (2009).

To determine whether *C. helmsii* was having a significant effect on composition of native plant and invertebrate communities, a different set of four ponds were selected which had more than 75% *C. helmsii* cover, and four ponds were chosen which did not support *C. helmsii*.

For both the enclosure and impact surveys, ponds were surveyed during the autumn of 2009 using the following methodology:

- a survey of the percentage cover of plant species, within 5 randomly placed quadrats.
- a timed 3-minute net survey for macroinvertebrates.
- invertebrate rarity scores were calculated based on UK distribution and status (Chad and Extence 2004).

During baseline surveys in 2011, 24 ponds were surveyed and the cover of *C. helmsii* assessed by randomly placing five quadrats (0.25m²) within the outer edge of the pond. The percentage area covered by other native plant species and bare ground were also recorded. The cover of *C. helmsii* was correlated with the cover of native plant species and the availability of bare ground.

3.3 Results and discussion of investigations to determine the impact of *C. helmsii* on native flora and fauna

Although recognising that these investigative studies were based on a small number of replicated sites, they are the first data available assessing the impact of *C. helmsii* on the native flora and fauna of the New Forest and give direction to future research.

On average over two thirds of ponds surveyed had less than 70% cover of *C. helmsii* and over a third of ponds had less than 30% *C. helmsii* cover (Figure 3.1). Therefore, although widely distributed less than a third of ponds could be described as heavily infested (>75%).

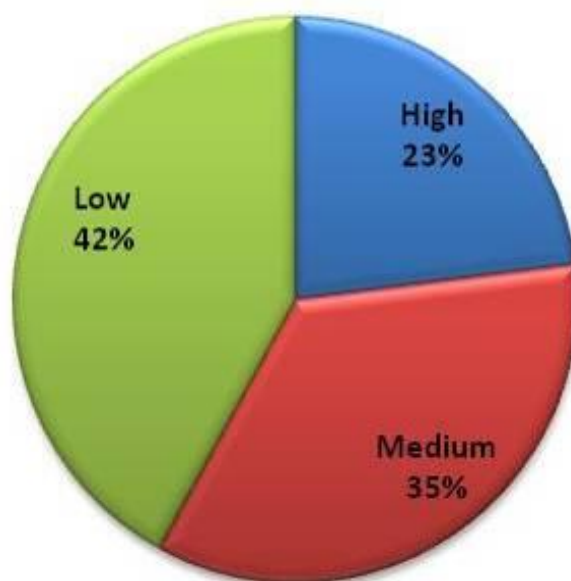


Figure 3.1. The proportion of New Forest ponds (n=100) in each of three categories assessing the abundance of *C. helmsii*. Low' less than 30% cover, 'medium' 50-70% cover and 'high' greater than 75%.

The degree to which *C. helmsii* dominated a site was shown to be influenced by a number of different factors. Of the 24 ponds surveyed, 8 ponds in each abundance category had on average 84% (high), 61% (medium) and 26% (low) abundance cover of *C. helmsii*.

Ponds with less than 30% cover of *C. helmsii* had a pH of less than 6.5 and those with more than 75% cover had a pH of more than 6.0 (Figure 3.2). Ponds with medium cover between 50-70% *C. helmsii* had the highest pH between 6.5 and 7.6. This may indicate that at low pH *C. helmsii* can be present but is unable to dominate. However, values were spread across a

wide range and there was overlap in the pH of ponds in High and other categories. As such the only significant difference in pH was between low and medium categories (Kruskall-Wallis $H=15.10$, $p=0.001$).

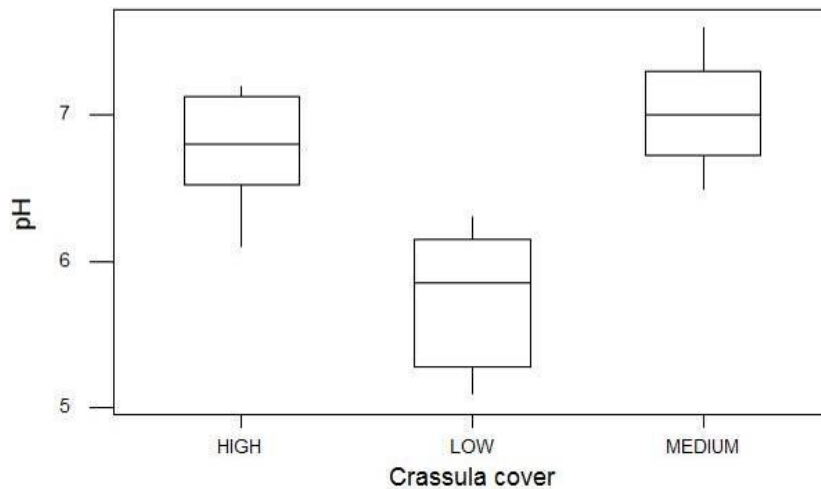


Figure 3.2. The median, minimum and maximum values for pH of New Forest ponds (n=24) in each of three categories assessing the abundance of *C. helmsii*. Low' less than 30% cover, 'medium' 50-70% cover and 'high' greater than 75%.

Ponds with less than 30% cover of *C. helmsii* had a conductivity of less than 130 μS and those between 50-70% *C. helmsii* a conductivity between 78 μS and 155 μS (Figure 3.3). Ponds with high cover above 75% *C. helmsii* had the highest conductivity, greater than 150 μS . High conductivity can occur as level of natural ions (e.g. calcium) increase, but may also increase with the addition of polluting nutrients (e.g. phosphates and nitrates). *C. helmsii* may be unable to dominate where nutrient levels are naturally very low, which would also suggest that as water quality declines with increasing levels of nutrients, the abundance of *C. helmsii* may increase. However, as for pH values were spread across a wide range and there was overlap in the conductivity of ponds in Low and Medium categories. As such the only significant difference in pH was between low, medium categories and high *C. helmsii* (Kruskall-Wallis $H=15.22$, $p<0.001$).

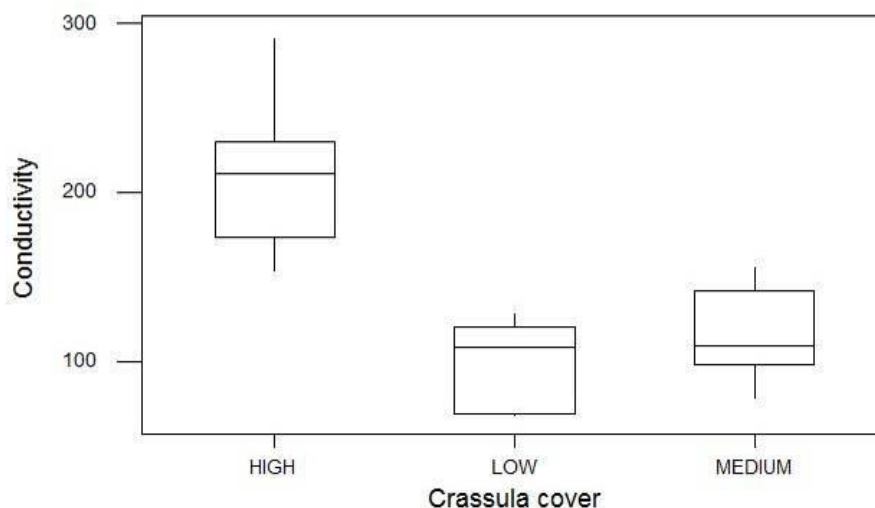


Figure 3.3. The median, minimum and maximum values for conductivity (μS) of New Forest ponds (n=24) in each of three categories assessing the abundance of *C. helmsii*. Low' less than 30% cover, 'medium' 50-70% cover and 'high' greater than 75%.

The results suggest that in combination pH and conductivity may determine to some extent the ability of *C. helmsii* to dominate a site (Figure 3.4). There was no significant correlation between pH and conductivity in the ponds ($R^2=0.051$, $p=0.289$) but ponds with low pH and low conductivity were classified as having 'Low' abundance of *C. helmsii* (<30%). Ponds with moderate *C. helmsii* (50-70%) had generally higher pH and low or high conductivity. In ponds where *C. helmsii* dominated (>75%) ponds had a wider range of pH but generally higher conductivity.

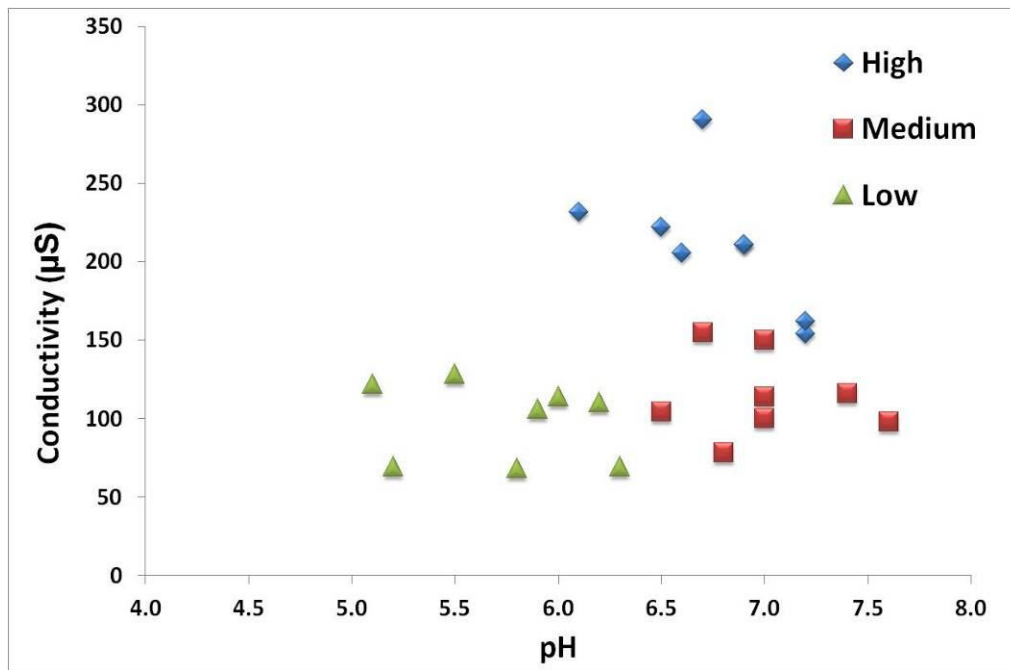


Figure 3.4. Correlation between pH and conductivity (μS) of New Forest ponds ($n=24$) in each of three categories assessing the abundance of *C. helmsii*. 'Low' less than 30% cover, 'medium' 50-70% cover and 'high' greater than 75%.

A further pattern was observed in the abundance of *C. helmsii* and the degree of grazing pressure at ponds (Figure 3.5). Ponds with the lowest abundance of *C. helmsii* also had the highest grazing pressure, whilst those with the most abundant *C. helmsii* cover had the lowest grazing pressure. Logically these results make sense but grazing pressure is heavily correlated with pond permanence and substrate type, which were not investigated in this survey.

Whilst these results are interesting, we recognise that other confounding factors, such as time since introduction, the complexity and structure of the native plant community, and the presence of other competitively dominant native plant species, mean that it is not possible to attribute any one factor to the limited extent of *C. helmsii* at some sites. Further research to answer these questions would be of value.

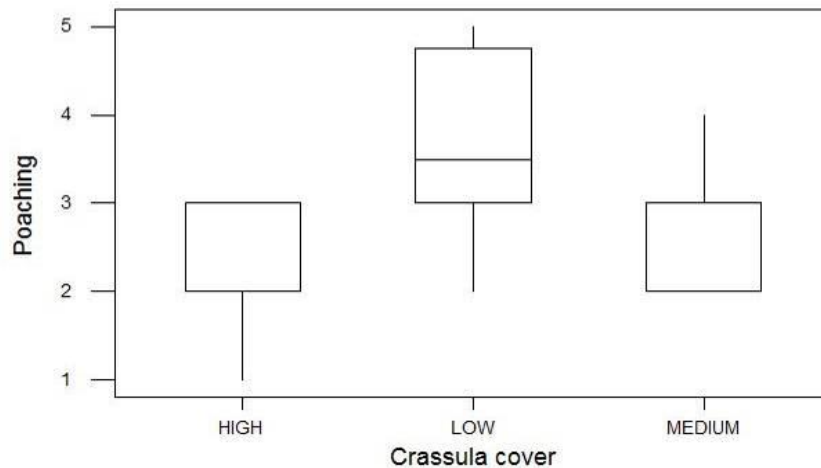


Figure 3.5. The median, minimum and maximum values assessing poaching of New Forest ponds (n=24) in each of three abundance categories for *C. helmsii*. Low' less than 30% cover, 'medium' 50-70% cover and 'high' greater than 75%.

Exclosure experiment to look at the suitability of grazing as a management tool to control *C. helmsii* was inconclusive. The results confirmed how important grazing was as a tool for conservation of New Forest ponds because it suppresses the growth of all dominant species but was unable to detect any effect on *C. helmsii* specifically.

Assessment of plant species showed that within the enclosure where grazing was excluded, the area of bare ground decreased and the area of native plant species and *C. helmsii* increased (Figure 3.6). At the same time the area occupied by species of conservation importance decreased. The variability between ponds and between quadrats within individual ponds meant that the results were only significant for the change in the area of bare ground ($T=5.34$, $P=0.013$).

There was no difference in the number or rarity of aquatic macroinvertebrate species within or outside the fenced area.

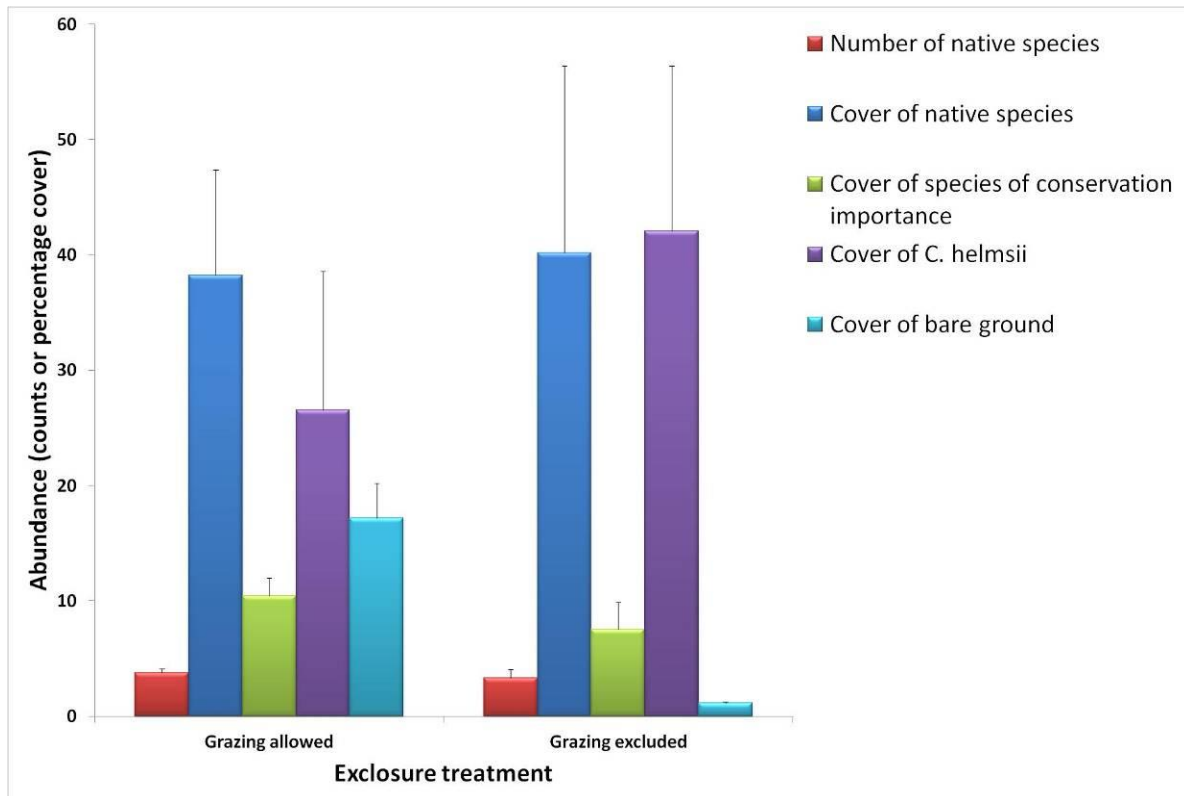


Figure 3.6. Mean (\pm SE Mean) for the number and percentage cover of all native plant species, the cover of plant species of conservation importance and the percentage cover of *C. helmsii* and bare ground.

Evidence from the baseline survey of ponds ($n=24$) in 2011 showed that an increase in the cover of *C. helmsii* was correlated with a significant loss in the area of bare ground and reduction in the cover of native species (Figure 3.7). However, these results also suggest that grazing pressure may be sufficient at some sites to maintain a partially open sward for bare ground specialist plant and animal species, in spite of the presence of *C. helmsii*.

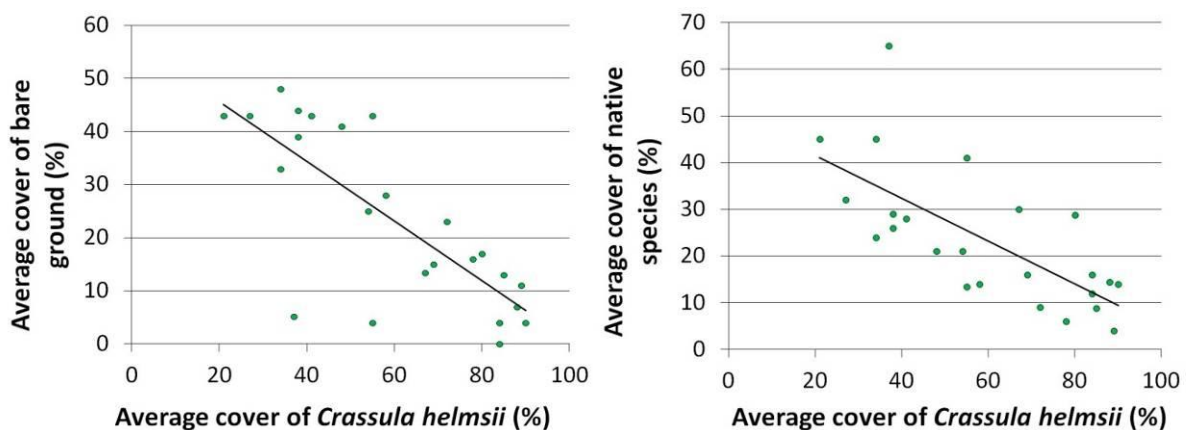


Figure 3.7. Evidence suggests that as the cover of *C. helmsii* increases the cover of bare ground ($r = 0.771$, $n = 24$, $p < 0.0001$) and native species ($r = 0.70$, $n = 24$, $p < 0.0001$) significantly decreases.

Dominance of *C. helmsii* was shown to have a significant effect on the availability of bare ground and the abundance of native plant species. For every 10% increase in the amount of *C. helmsii* the amount of bare ground decreased by 6% and the amount of native vegetation by 5%.

A comparison of ponds (n=4) with and without *C. helmsii* showed that presence of *C. helmsii* resulted in a reduction in the abundance of native plant species but did not have a significant effect on the number of plant species, invertebrates or species rarity scores (Figure 3.8). We could find no evidence that dominance of *C. helmsii* alone had caused the extinction of a plant species during the course of any of these investigations. However, the impact on native plant communities is likely to be detrimental in the long term.

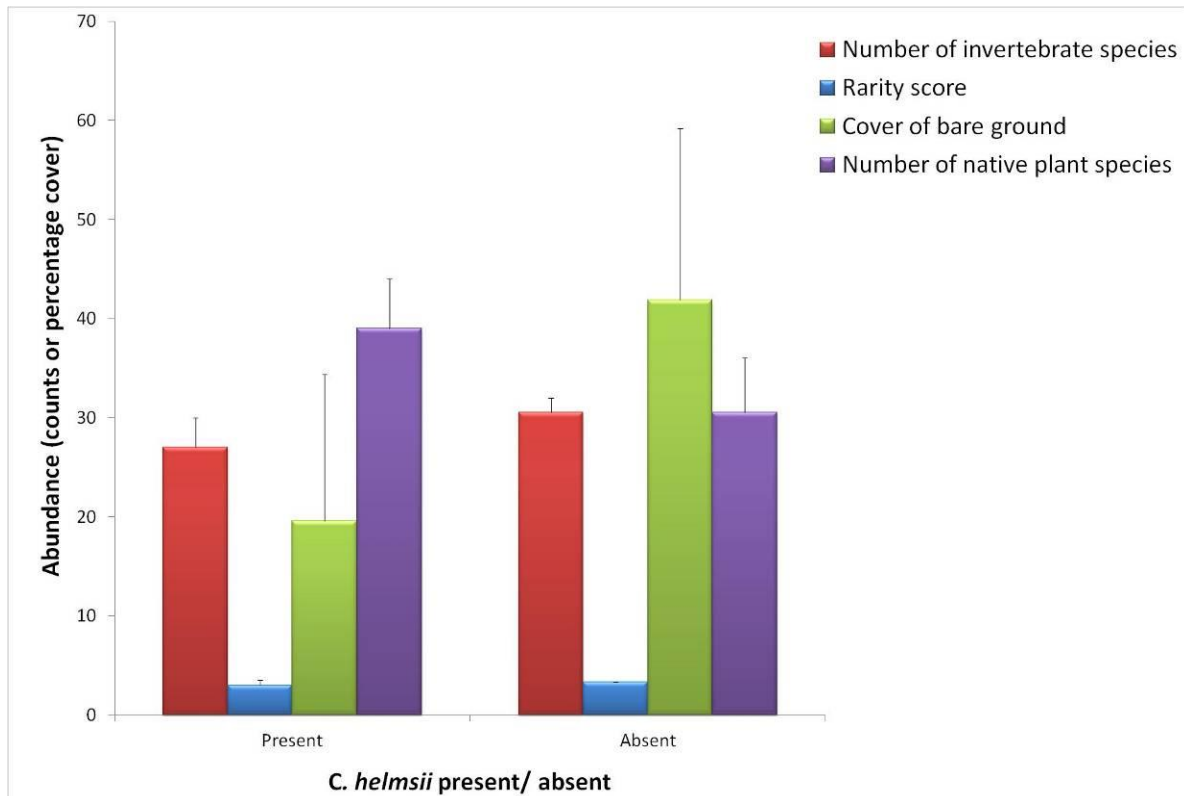


Figure 3.8. Difference in plant and invertebrate communities in ponds with and without *C. helmsii* (n=4).

4. Part C: Investigating the potential for treatments to control *C. helmsii* in New Forest ponds

The New Forest trials aimed to understand better the effectiveness of different control techniques on the invasive non-native plant New Zealand Pigmyweed *Crassula helmsii* and non-target native plants and invertebrates through replicated experimental design. The results would inform the management approach to *C. helmsii* in the New Forest and would also prove useful to control programmes elsewhere in the UK and abroad.

4.1 Controlling *C. helmsii*

Once dominant at a site, it was thought to be almost impossible to fully eradicate *C. helmsii* (NERC 2002), indeed previous attempts using chemical and mechanical techniques have been met with little success (Stone 2002; Lockton 2010).

However, with correct use of (i) herbicide and the development of novel techniques ((ii) hot foam and (iii) aquatic dye) and recognition that *C. helmsii* is concentrated in specific areas of the New Forest (Ewald 2011) there was a possibility that with the correct protocol, an effective control programme could be developed.

While the primary aim of the work was to establish the ability of control techniques to reduce and eliminate *C. helmsii*, the second equally important aim was to quantify impacts of treatments on non-target species of plants and animals. Concerns were beginning to be raised that the treatment itself could lead to the loss of native species. If the treatment failed to eradicate *C. helmsii* it could then take advantage of newly created bare ground to the detriment of native species (Lockton, 2012).

In some ponds in the New Forest, the presence of grazing animals appears to reduce the dominance of *C. helmsii* and break up the sward, creating bare patches where scarce native species can continue to grow in spite of the presence of the invasive species. Therefore, in the New Forest, it was particularly important that any treatment chosen should not cause more damage to the pond than leaving it alone.

The presence of a non-native species is, at the very least, undesirable and if a suitable eradication or control method were available then it would be beneficial, especially within protected sites where *C. helmsii* is likely to co-occur with species of conservation importance. For the treatment to be successful, three main objectives would need to be fulfilled:

- A successful technique would **remove *C. helmsii* completely** in as short an amount of time as possible.
- If the course of treatment was not successful in eliminating *C. helmsii*, **the invasive plant should not re-grow** and dominate to the same or greater extent than before the treatment began.
- The treatment would **not have a long-term adverse impact** on native flora and fauna.

4.2 Methods to assess techniques to control *C. helmsii* in the New Forest

In 2011 the New Forest Non-Native Plants Project (Hampshire and Isle of Wight Wildlife Trust) began trials of three different control techniques to determine whether it would be possible to eliminate or control *C. helmsii* without causing unacceptable long-term levels of damage to non-target plants and animals.

4.2.1 Sites for survey

A total of 25 ponds were originally selected for the *C. helmsii* treatment trials. Six ponds were assigned to each treatment group and, as much as practicable, ponds in each treatment group were identified in close proximity to one another along with a control pond known to support *C. helmsii*, but where no treatment would take place.

Two semi-permanent ponds in the trial were treated with both hot foam (along the pond margin) and aquatic dye. Three ponds were removed due to individual characteristics which made them unsuitable for the treatment to which they were originally allocated. The results from these ponds have remained in the analysis for the years where they were included in the trials.

4.2.2 Control techniques

The methods selected for the trials were:

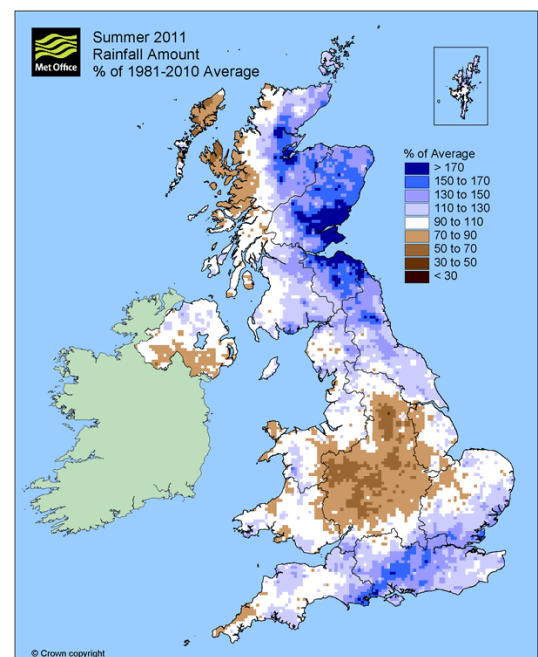
- (i) herbicide treatment - using Roundup Pro Biactive at a dose rate of 0.3 litres ha⁻¹ without the use of an adjuvant. Treatment was applied to dry ponds by Kingcombe Aquacare (<http://kingcombe.com>)
- (ii) biodegradable foaming agent - a combination of plant oils and sugars are mixed to form an alkyl polyglucoside molecule which is then mixed with water to form a foam. The system delivers a very hot foam mixture (above 97°C for 2 seconds or longer at lower temperatures) onto the target area of a dry pond. The foam allows the heat to remain in contact with the plant surface for longer than water alone with the intention that heat will rupture the plant cells and kill the plant. In 2011, Pearson Enterprises Ltd undertook the hot foam treatment developed by Weeding Technologies Ltd using a hand held trolley and hand-held lance powered by a tractor mounted generator (<http://weedingtech.com>). In August 2013 the hot foam treatment work was undertaken by LanGuard Ltd (<http://www.languard.co.uk>) and in September 2013 by Ecological Weeding Techniques (<http://www.ecoweedtech.co.uk>).
- (iii) aquatic dye – is designed to suppress the availability of light, with the intention of limiting photosynthetic activity. It was decided that the treatment may be most effective in the winter months when other plant growth is limited (*C. helmsii* is able to continue growing year round) and water depth is greatest, increasing the depth of black water between *C. helmsii* and the water surface. Dr Jonathan Newman undertook the dye treatment using a combination of Dyofix blue and black pond dyes (<http://www.ceh.ac.uk/staffwebpages/drjonathannewman.html>).

4.2.3 Timing of application

2011

- Hot foam treatments took place between 12th September 2011 and 16th September 2011.
- Herbicide treatments were undertaken on 22nd September 2011.
- Dye treatments were undertaken on 25th August at Waterslade Farm. The other dye treatments were applied on the 14th December 2011 along with a second application at Waterslade Farm.

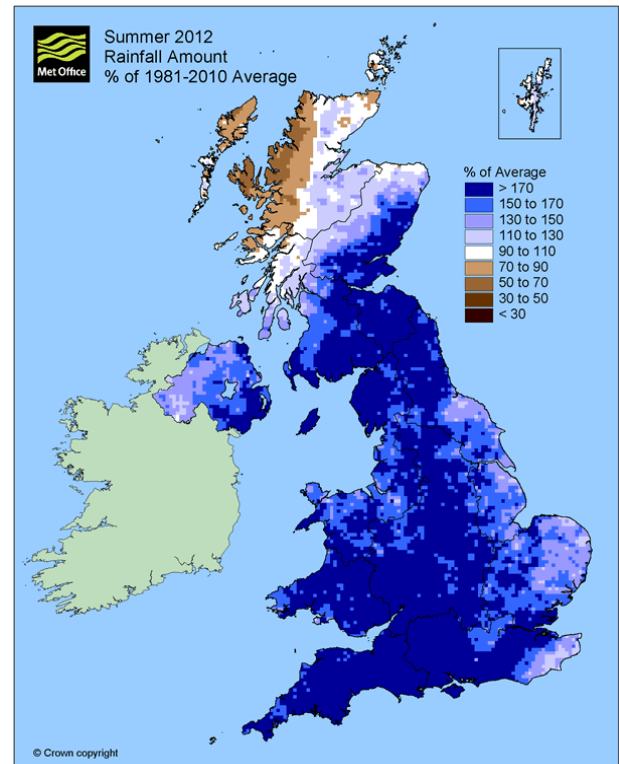
Figure 4.1. The rainfall record shows average annual values for the New Forest region in 2011 (Met Office 2013). Rainfall was above average and some ponds did not dry completely under these conditions – allowing only partial treatments in 2011.



2012

- Hot foam and herbicide treatments were due to take place in August and again in September 2012. All treatments were cancelled because the ponds did not dry out sufficiently (Figure 4).
- Dye treatments took place on 12th April 2012 and 14th December 2012.

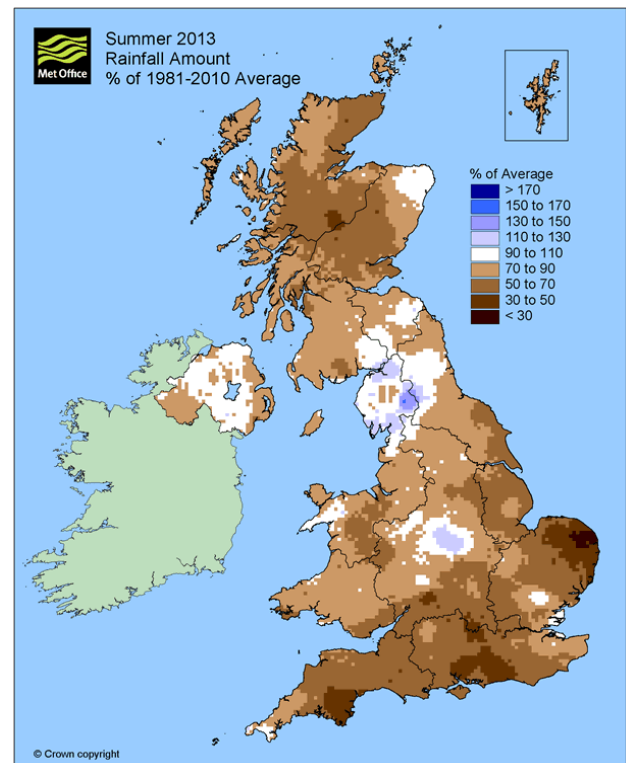
Figure 4.2. The rainfall record shows average annual values for the New Forest region in 2012 (Met Office 2013). Rainfall was greater than 170% of the expected average. No ponds dried out during this summer and hot foam and herbicide treatments were not possible.



2013

- Hot foam treatment was applied the week beginning 12th August and again the week beginning 16th September 2013.
- Herbicide treatment was applied on 20th August and again the week beginning 23rd September 2013.
- Dye treatments took place on 4th October 2013 and 17th December 2013.

Figure 4.3. The rainfall record shows average annual values for the New Forest region in 2013 (Met Office 2013). Rainfall was lower than the expected average. Most ponds had dried sufficiently for the first round of hot foam and herbicide treatment. By the second treatment some ponds had begun to fill and only partial treatment was possible. Several ponds in the aquatic dye treatment group were also dry during the summer.



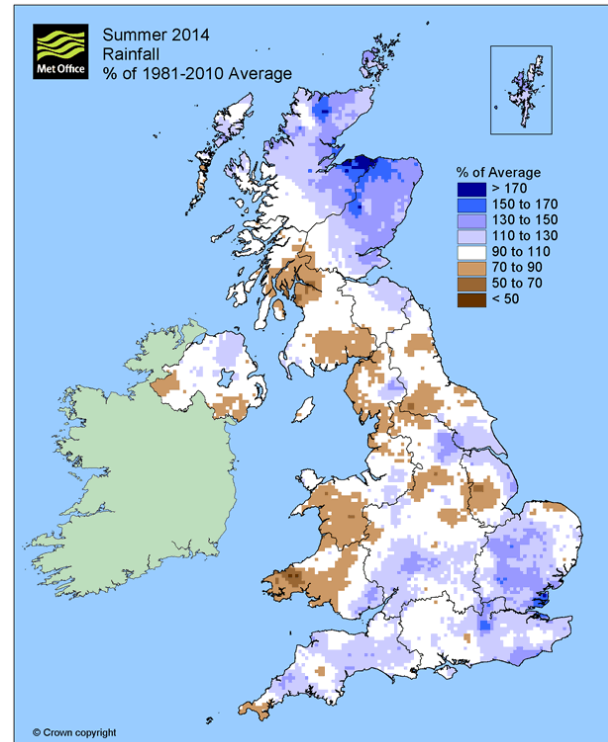
2014

No treatments applied.

Figure 4.4. The rainfall record shows average annual values for the New Forest region in 2014 (Met Office 2014). 2014 was an average year for the New Forest; rainfall was no more or less than expected.

Following the slightly wetter than average spring, most temporary ponds held water into early summer but then dried and were still dry by September 2014.

Permanent ponds held water throughout the summer although the drawdown zone of these ponds was exposed.



4.2.4 Plant survey

The aim of plant recording was to make a complete list of wetland plants present within the outer edge of the pond – the outer edge is defined as the upper level at which water stands in winter. Terrestrial plants within the winter water line were also recorded for completeness.

Plant surveys were undertaken in June/ July 2011, 2012, 2013 and 2014.

4.2.5 Standardised invertebrate survey

The aquatic invertebrate survey involved a standardised three minute hand-net sampling method developed for the National Pond Survey (Pond Action, 1998). All the main habitats in the pond were sampled. An additional 1 minute was spent looking for additional species on the water surface and under logs, etc. The sample was placed in a labelled bucket for later sorting in the laboratory. Identification was then taken to species level, except for true flies (Diptera) which would have required a more lengthy collection and identification process.

The advantage of this survey technique is that it is highly replicable and removes surveyor bias. It provides accurate information on the quality of the habitat and a baseline for future monitoring of the site.

Invertebrate surveys were undertaken in May 2011, 2012, 2013 and 2014 before the ponds dried down for the summer.

4.2.6 *Crassula helmsii* survey

To assess the dominance of *C. helmsii* 5 quadrats (0.25m²) were thrown within the outer edge of the pond. The percentage area covered by *C. helmsii*, other plant species and bare ground were recorded. Rather than placing the quadrats entirely randomly within the pond margin (as in the baseline survey) the quadrats were thrown randomly within the area where treatment had taken place - in some ponds only partial treatment had occurred in some years. Vegetation cover surveys were undertaken in June/ July 2011, 2012, 2013 and 2014.

The vegetation cover surveys were also repeated in the February following treatment i.e. February 2012, 2013 and 2014.

4.2.7 Impact of trials on localised and restricted plant species

In the last year of the project the impact of the treatments on priority New Forest plant species was a focus for survey. Prior to this, the presence of these species had been recorded but the total cover of all species had been combined rather than considering individual species.

In August 2013 and 2014, the area covered by priority species (pillwort *Pilularia globulifera*, coral necklace *Illecebrum verticillatum* and shoreweed *Littorella uniflora*) was assessed by measuring percentage cover in five 0.25m² quadrats placed over the areas where they occurred.

4.2.8 Analysis

We used analysis of variance (ANOVA) to look for differences between years within each treatment with a Bonferroni correction to take account of multiple tests, and post hoc Tukey's test to undertake pair wise comparisons between treatment years.

The conservation value of plant and invertebrate assemblages can be assessed (Table 4.1 (plants) and Table 4.2 (invertebrates)) and placed in one of four conservation categories (Very High, High, Moderate and Low). When assessing conservation value the pond is included in the *highest* conservation category it can go in to using *any* of the measures. In other words, if a plant assemblage had only six species but an SRI (Species Rarity Index) of 1.2 (because it had a rare plant) it would have **High** conservation value.

Table 4.1. Wetland plants: provisional categories for assessing the conservation value of ponds.

Low	Few wetland plants (less than or equal to 8 species) and no local species (i.e. SRI = 1.00).
Moderate	Below average number of wetland plant species (9-22 species) or SRI of 1.01-1.19.
High	Above average number of wetland plant species (more than or equal to 23 species) or a SRI of 1.20-1.49. No Nationally Scarce or Red Data Book (RDB).
Very High	Supports one or more Nationally Scarce or RDB species or a SRI of 1.50 or more, or an exceptionally rich plant assemblage (more than or equal to 40 species).

Table 4.2. Macroinvertebrates: provisional categories for assessing conservation value of permanent and semi-permanent lowland ponds.

Low	Few invertebrate species (0-10 species) and no local species (i.e. SRI = 1.00).
Moderate	Below average number of invertebrate species (11-32 species) or a SRI of 1.01-1.19.
High	Above average number of invertebrate species (33-49 species) or a SRI of 1.20-1.49. No Nationally Scarce or Red Data Book (RDB).
Very High	Supports one or more Nationally Scarce or RDB species or a SRI of 1.50 or more, and/or an exceptionally rich invertebrate assemblage (more than or equal to 50 species).

4.3 Impact of treatments on the cover of *C. helmsii*, the cover of native plant species and the area of bare ground

The following section reviews the impact of each treatment on the cover of *C. helmsii*, the cover of native plant species and the area of bare ground. Within each treatment group, the replicate was pond and so we tested for a significant difference between seasons, whilst also testing whether sites responded differently. In most cases the sites did respond differently and so each site has also been presented and analysed individually. A photographic record has been submitted as a separate annex document.

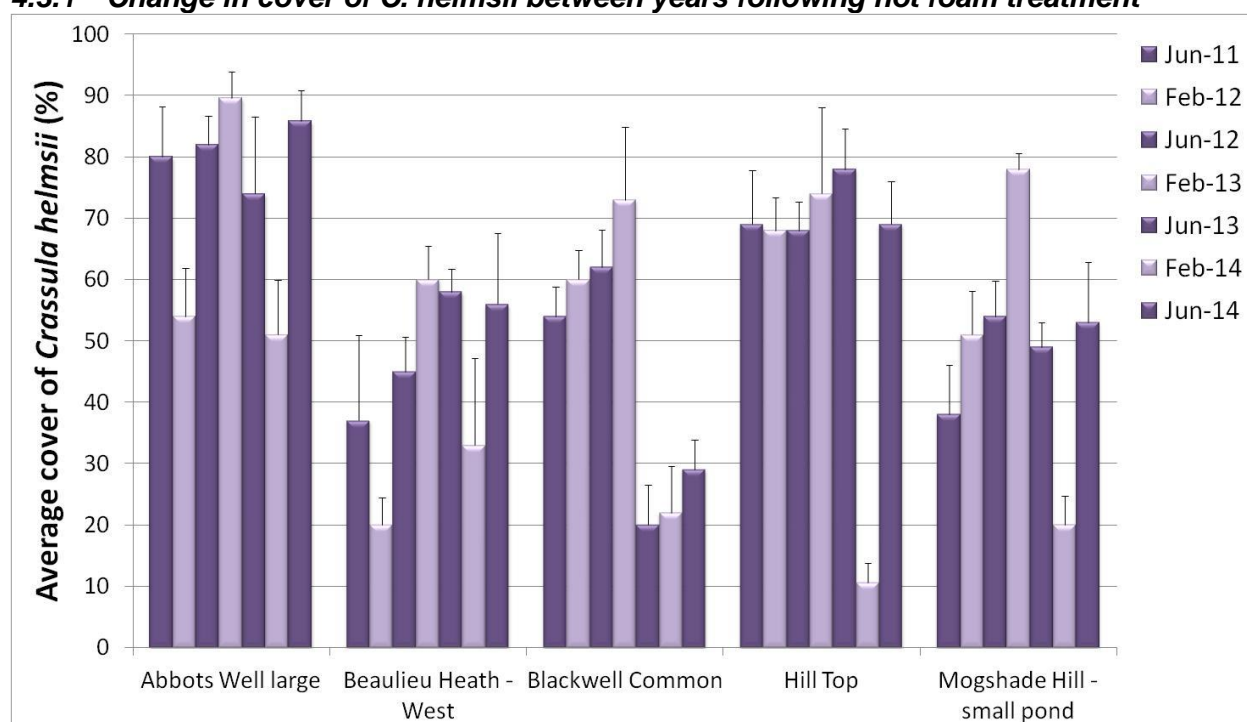
Hot foam

Application of hot foam treatment was incomplete. In 2011, Abbots Well (large) and Hill Top did not dry completely and hot foam could only be applied to part of the ponds. These ponds were also treated with aquatic dye in an attempt to overcome this issue. A single complete application (both ponds fully dried) was applied to Beaulieu Heath (west) and Blackwell Common. No treatment was applied to Mogshade Hill (small pond) - the pond was not added to the treatment group until the following year.

In 2012, a very wet summer prevented hot foam treatment on any pond.

In 2013 two treatments were applied in the same year. We marked out the extent of *C. helmsii* prior to treatment (using biodegradable marker spray) to help identify the area for treatment. Both Abbots Well (large) and Hill Top retained some water; both were treated with aquatic dye as well as hot foam. All other ponds in the group were treated completely in both applications as all three dried out during 2013.

4.3.1 Change in cover of *C. helmsii* between years following hot foam treatment



n.b. Mogshade Hill (small pond) was not treated with hot foam until summer 2013

C. helmsii was not eradicated from any sites using hot foam treatment. But, overall there was a significant difference between years and between sites in the cover of *C. helmsii* (Year $F_{6,140}=17.17$, $P<0.001$; Site $F_{4,140}=18.69$, $P<0.001$).

Partial treatment in 2011 resulted in a slight but not significant reduction in *C. helmsii* at Abbots Well (large) (33%) and Beaulieu Heath (west) (46%). The treatment at Blackwell Common and Hill Top did not impact upon *C. helmsii* and it was back to pre-treatment levels at all ponds by June 2012.

The abundance of *C. helmsii* peaked in February 2013 at all sites in the hot foam treatment group. This was correlated with the continual wet summer the year before which had encouraged growth but prevented hot foam treatment from taking place.

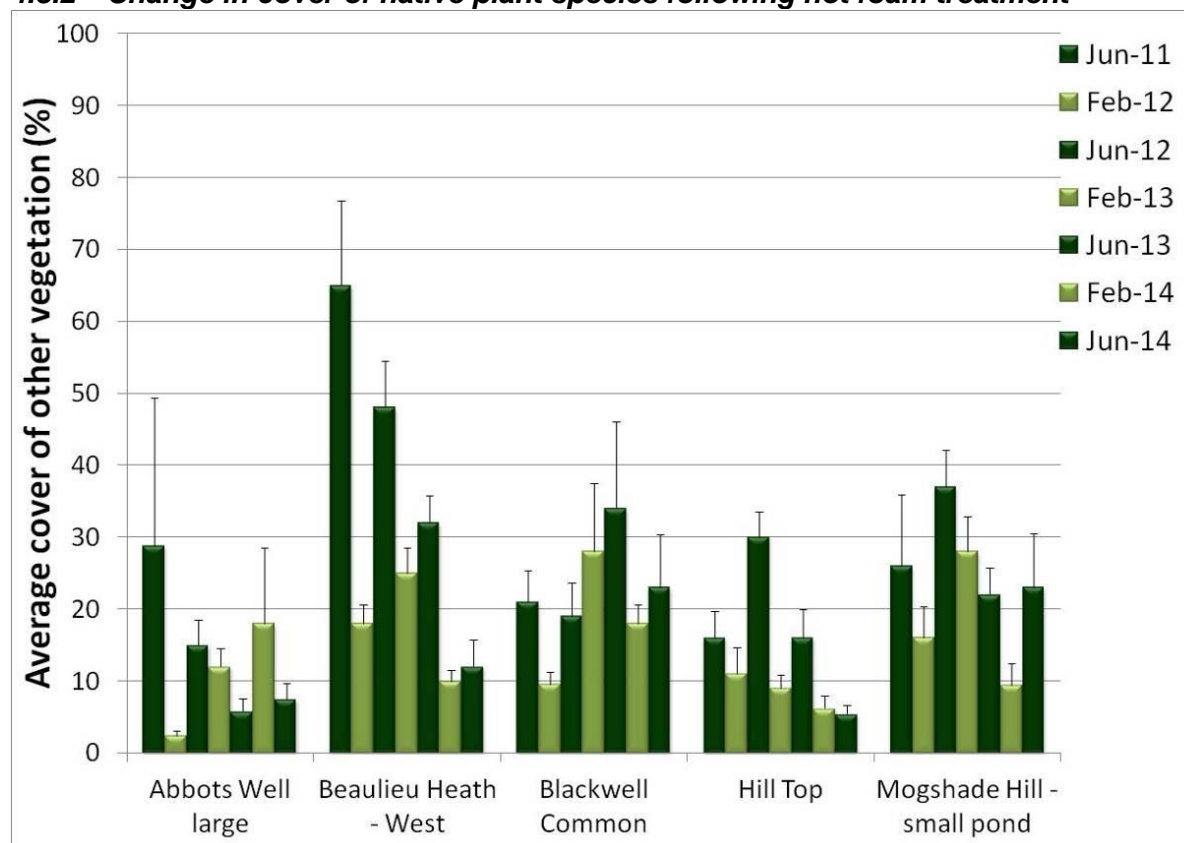
Between February and June 2013, there were no treatment effects because no treatment had occurred. However, at Blackwell Common and Mogshade Hill there was a significant reduction in *C. helmsii* (73% and 37% respectively). The dry summer had increased grazing pressure on these ponds and *C. helmsii* had been suppressed.

Foam treatment was able to take place on all ponds in the summer of 2013. Following this, there was a slight, but not significant reduction in the abundance of *C. helmsii* at both Abbots Well (43%) and Beaulieu Heath (west of road) (45%). At Blackwell Common (70%), Hill Top (86%) and Mogshade Hill (small pond) (74%), the amount of *C. helmsii* was significantly less in February 2014 than it had been in February 2013. However, it is worth noting that the significant decline at Blackwell Common occurred between February 2013 and June 2013, before the hot foam treatment was applied.

Failure to eradicate *C. helmsii* using hot foam had resulted in re-growth to pre-treatment levels in less than 5 months; by June 2014, the amount of *C. helmsii* was back to pre-treatment levels in all ponds. At Blackwell Common and Mogshade Hill (small pond) *C. helmsii* had not returned to the February 2013 peak, but it was increasing towards this level.

Hot foam had not had a significant effect on the cover of *C. helmsii*. The use of more than one treatment i.e. hot foam plus aquatic dye (Abbots Well large and Hill Top) was no better or worse than one treatment alone.

4.3.2 Change in cover of native plant species following hot foam treatment



There was a significant difference between years and between sites in the cover of non-target native plant species (Year $F_{6,140}=9.09$, $P<0.001$; Site $F_{4,140}=15.35$, $P<0.001$).

In most years and in most ponds, the cover of native species was generally lower in February compared with the previous June surveys. *C. helmsii* did not show the same fluctuation as it grows year round; one of the reasons it has a competitive edge

Following partial treatment in 2011, the only pond to have lost a significant amount of native plant cover by February 2012 was Beaulieu Heath (west) (72%). Although Abbots Well had lost over 90% of the June 2011 average; the variation in cover in 2011 meant the result was not significant. By June 2012 cover had returned to pre-treatment levels; although at Abbots Well (large) and Beaulieu Heath (west) the area of native plant species was lower (non-significant result). At Hill Top, the area of native species had increased significantly (doubled).

The percentage cover of native plant species fluctuated erratically between years, even when no treatment had been applied, and there was no significant difference following the use of hot foam. The ebb and flow of native species in response to changes in climate and grazing between years is as expected. The concern is that at some point, the increasing cover of *C. helmsii* could prevent this natural stochasticity from occurring.

Hot foam treatment was applied to all ponds in summer/ autumn 2013. There was no significant difference in the cover of native species in either the February or June surveys compared with the cover in the previous year.

At Beaulieu Heath (west) the cover of native species recorded in the summer surveys (June) declined significantly between years. Of all the ponds in this treatment group, Beaulieu Heath (west) had the greatest cover of native plants at the start of the trial, and therefore had more to lose. The decline in cover cannot be directly related to the treatment because the decline was also observed between years when there was no treatment. The reduction in cover of native species at this pond was mirrored by an increase in the cover of *C. helmsii* and the area of bare ground.

Overall, the hot foam treatment had not had a significant negative effect on the cover of native species.

4.3.3 Impact of hot foam treatment on localised and restricted plant species

Assessing the impact of treatment on priority plant species was difficult due to the variation between quadrats within the same pond:

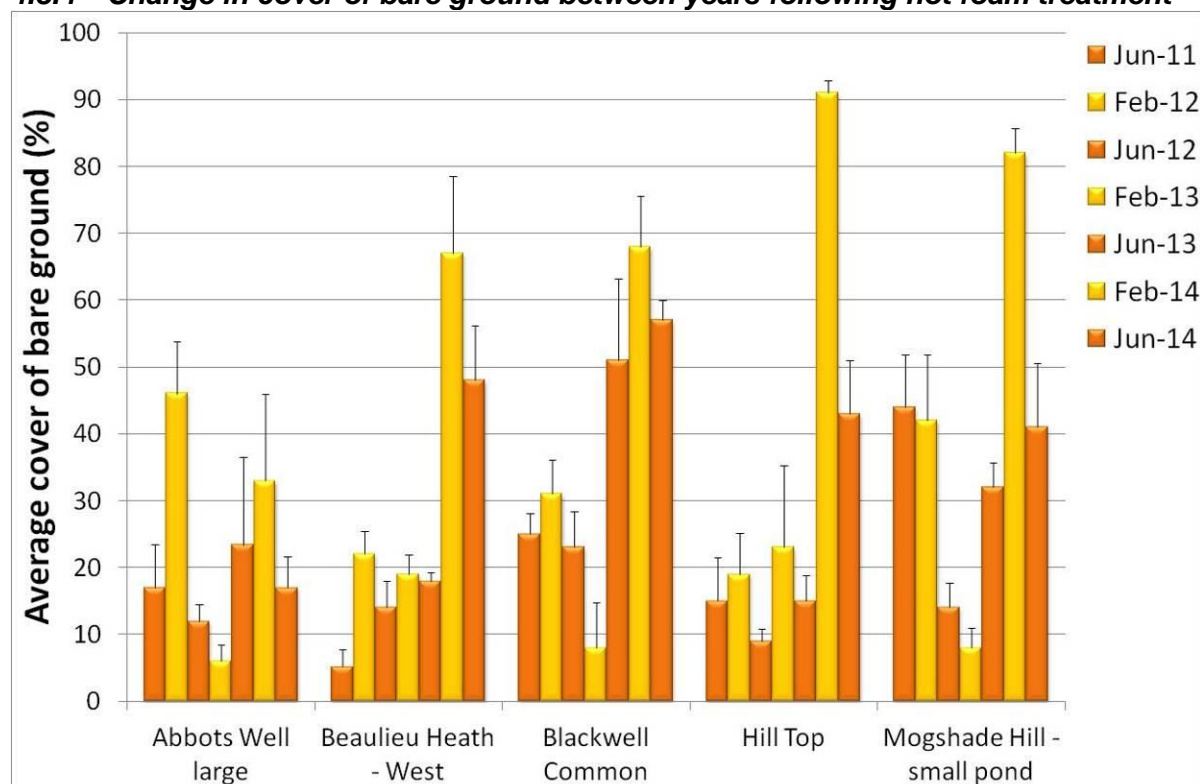
- Quadrats could not be placed randomly because the plants of interest would be missed.
- Quadrats placed in the same location as the previous year showed significant differences because plant growth was inconsistent between years and the area of maximum growth moved around the pond, not because of the treatment effect.

Results are therefore given anecdotally.

- Shoreweed *Littorella uniflora* appeared to be unaffected by the hot foam treatment.
- Coral necklace *Illecebrum verticillatum* was sparse in the ponds in this treatment group and remained the same before and after treatment.
- Pillwort *Pilularia globulifera* had increased substantially at Beaulieu Heath (west), following hot foam treatment in 2013 (**photo to right**).



4.3.4 Change in cover of bare ground between years following hot foam treatment



There was a significant difference in the area of bare ground between years and the pattern was repeated across different sites (Year $F_{6,140} = 35.47$, $P < 0.001$; Site $F_{4,140} = 3.39$, $P = 0.011$).

Significant differences in the area of bare ground between surveys were observed in all but Abbots Well (large) pond; although the lack of bare ground in February 2013 was similar to other ponds in the group. The decrease in bare ground corresponded with the peak in *C. helmsii* in February 2013 due to the wet conditions encouraging growth and not to any treatment effect. By June 2013 due to dry conditions and heavy poaching, the area of bare ground had increased significantly at Blackwell Common and Mogshade Hill (small). Weather conditions, grazing and poaching of the pond margin are able to create bare patches in spite of the presence of *C. helmsii*.

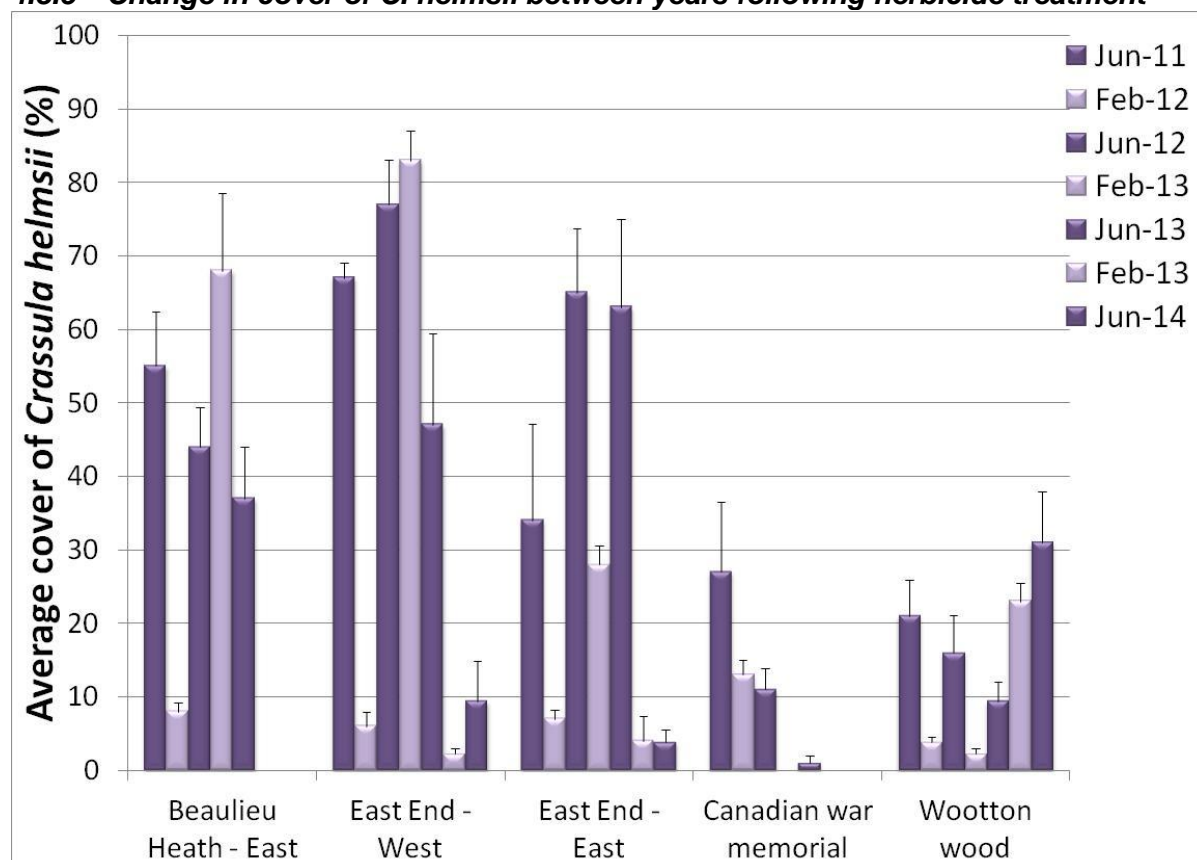
Following treatment in 2013 the area of bare ground in February 2014 had increased significantly at Beaulieu Heath (west), Hill Top and Mogshade Hill. By June of the same year, only Beaulieu Heath (west) still had significantly more bare ground than there had been in the previous year. At Hill Top and Mogshade Hill (small) the area of bare ground had returned to pre-treatment levels. Interestingly, at Blackwell Common and Mogshade Hill the increase in bare ground created by the combination of weather and grazing pressure in the previous year was maintained.

In conclusion, Hot Foam had not been significant in reducing the cover of *C. helmsii*, but had also not had a detrimental effect on native flora. In the New Forest the combination of different weather conditions

Herbicide

In 2011 herbicide treatment was applied once to all ponds in the group. Treatment was complete because they had fully dried in 2011 apart from at the Canadian war memorial pond which is a permanent pond with a broad draw down zone. In 2012, a very wet summer prevented herbicide treatment on any pond. In 2013 all ponds were treated at least once with herbicide, by the second treatment some ponds had begun to fill and only partial treatment was possible.

4.3.5 Change in cover of *C. helmsii* between years following herbicide treatment



Overall, there was a significant difference between years and between sites in the cover of *C. helmsii* (Year $F_{6,140} = 43.27$, $P < 0.001$; Site $F_{4,140} = 39.86$, $P < 0.001$).

In February 2012, at Beaulieu Heath (east) there had been a significant (85%) reduction in the cover of *C. helmsii* following treatment in 2011. By June 2012 this cover had returned to pre-treatment levels. No treatment occurred in 2012 and there was no significant difference in *C. helmsii* cover by 2013. Treatment in 2013 was very successful (only one treatment was applied at this pond) and by February 2014, no *C. helmsii* was recorded. This was reported with a note of caution as the pond still held water and establishing absence was difficult. However, by June, when the pond was dry, *C. helmsii* was still recorded as absent.

Beaulieu Heath (east) was revisited in August 2014. Several discrete patches of *C. helmsii* have now been recorded in the pond. These have either re-grown from fragments buried in the soil, or been introduced from adjacent areas – at this site there are multiple interconnected winter wet depressions over an area of heavily grazed grassland, all of which contain *C. helmsii*. Whilst treatment in 2013 aimed to eradicate *C. helmsii* over the entire area, treatment was not complete. The plan was to re-treat areas that had been missed during the second application, but this was not possible due to heavy rain before the scheduled treatment date.

At East End (west) there was a significant reduction in *C. helmsii* following herbicide treatment in 2011 (91% by February 2012), and following treatment in 2013 (95% by February 2014). By June 2012 the cover of *C. helmsii* had returned to pre-treatment levels. This was partially attributed to incomplete treatment in 2011 - some patches of *C. helmsii* at the edge of the pond had been missed. Marking out the treatment area before treatment in 2013 allowed better covering of herbicide and although it had begun to re-grow by June 2014 there was significantly less *C. helmsii* than at the beginning of the trial (86% reduction).

East End (east) showed the same pattern; significant reduction following herbicide treatment (79% reduction by February 2012, 94% reduction by February 2014). As above there was no

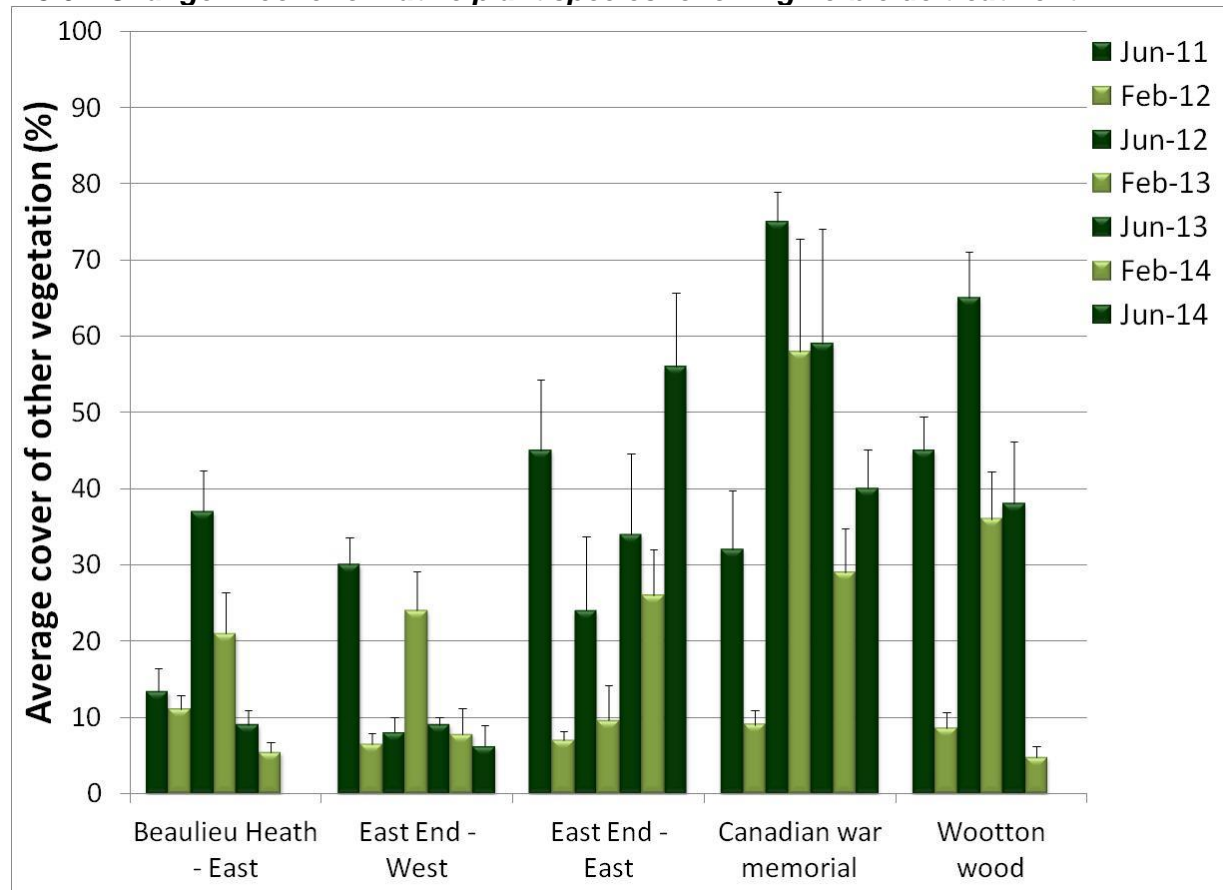
significant re-growth by June 2014. East End (west) and East End (east) were re-visited in August 2014. *C. helmsii* was re-turning to pre-treatment levels.

No *C. helmsii* was found at the Canadian war memorial pond in February 2013. This cannot be attributed to a treatment as no *C. helmsii* was applied in 2012. The pond is acidic and remained full during the summer of 2012. A small patch was found and treated with herbicide in summer 2013. No *C. helmsii* could be found in the February, June or August visit to the pond in spite of extensive searching.

At Wootton Wood there was no change in the amount of *C. helmsii*, between the start and end of the trial, but there was a significant reduction in cover by February 2013. This is a very large area and a nutrient rich site and *C. helmsii* appears to be responding to factors other than treatment, i.e. declining when the site is heavily poached and expanding during wet summers.

The net result, with the exception of Wootton Wood, was that on average there was a 94% reduction in *C. helmsii* in the herbicide treatment group by the end of the trial. However, without full eradication *C. helmsii* will re-grow to pre-treatment levels.

4.3.6 Change in cover of native plant species following herbicide treatment



There was a significant difference between years and between sites in the cover of non-target native species (Year $F_{6,140}=17.00$, $P<0.001$; Site $F_{4,140}=31.11$, $P<0.001$). Non-target native plant species are initially killed by herbicide, but recovery did occur following the first year of treatment. The results of the second year of treatment in 2013 were less clear. Temporary pond plant communities have a tendency to fluctuate between years, responding to changes in weather and poaching pressure. This masked the impact of herbicide treatment at some ponds and may be limiting the recovery at others. Another year of survey would be required to fully understand how the ponds have responded.

Beaulieu Heath (east) has largely been bare ground and *C. helmsii* cover since the start of the trial. In the wet summer of 2012 this increased to just below 40% cover on average. Grazing and poaching pressure had reduced this to below 10% by June 2013, regardless of treatment. In 2013 herbicide and further poaching pressure had removed all vegetation within the pond margin by June 2014. Native species were showing signs of recovery by the August 2014 visit.

East End (west) was dominated by *C. helmsii* at the start of the trial (only 30% native species cover). Herbicide treatment in 2011 significantly reduced *C. helmsii*, but also the cover of the remaining non-target native species. There was an increase to pre-treatment levels by 2013, but poaching had reduced this by the June survey. Cover has remained unchanged and at a low level since this time; the pond was either dominated by *C. helmsii* or bare ground. By August 2014 native plant species had begun to re-colonise (see below). There is no reason to think that the pond will not recover to pre-treatment levels by 2015, this is still likely to be dominated by *C. helmsii*.

At East End (east) there was a significant reduction in native species cover following the first treatment in 2011, but with steady recovery to pre-treatment levels since this time. This pond is very ephemeral and grazing pressure is less than East End (west) which may have allowed faster recovery.

The only significant difference in the cover of native plant species at the Canadian war memorial pond was following the first treatment in 2011. A larger area of the pond was treated at this time, and this had recovered by the following season. Treatment in 2013 was concentrated on a specific area of the pond, leaving the remaining site unaffected. Whilst cover of native species was reduced in this area of the pond it had begun to recover by the 2014 survey.

Herbicide treatment at Wootton Wood was very effective and both *C. helmsii* and native non-target species were significantly reduced. There was a peak in the cover of native species during the wet summer of 2012; recovery to pre-treatment levels. Although no native plants were recorded in randomly placed quadrats in the June 2014 survey, they were beginning to return by the August 2014 visit. There is no reason to think that the pond will not recover to pre-treatment levels by 2015, this is still likely to be dominated by *C. helmsii*.

4.3.7 Impact of herbicide treatment on localised and restricted plant species

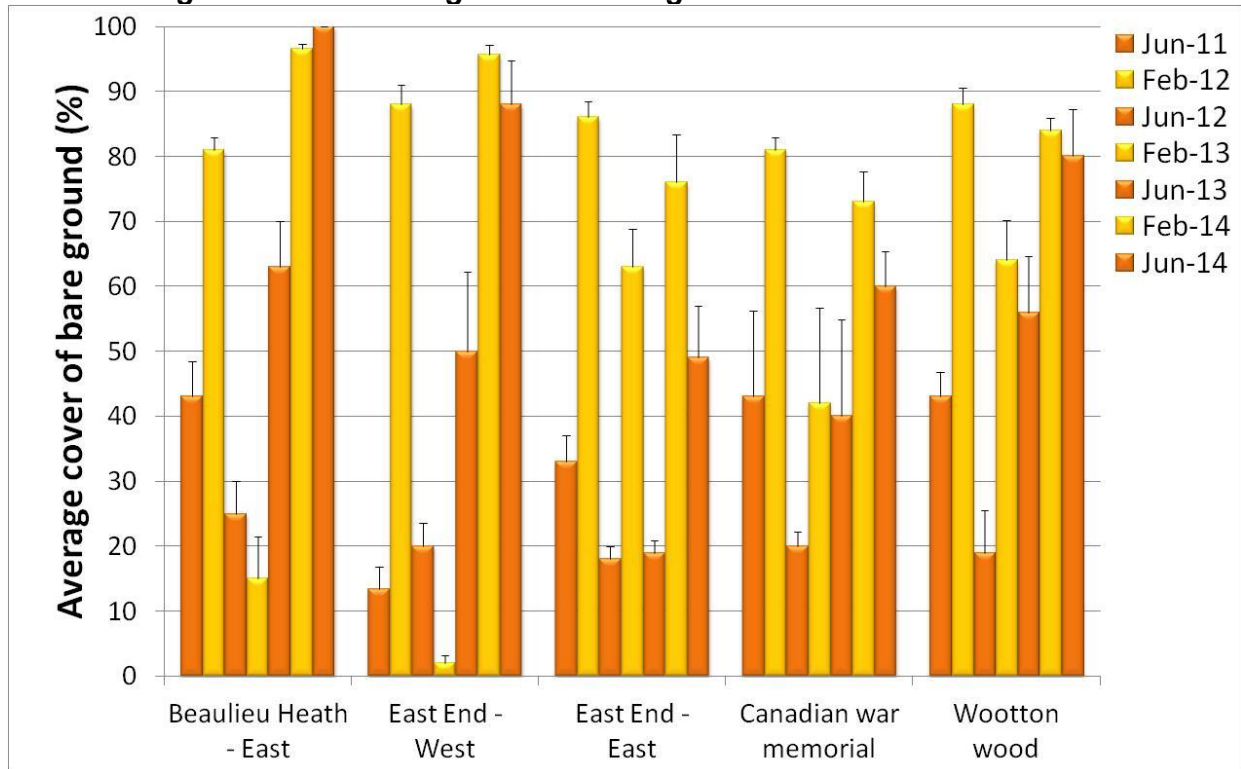
The impact of herbicide treatment on plant species of interest is reported anecdotally.

- At Beaulieu Heath (east) there was no vegetation recorded during the random placing of quadrats in the February 2014 survey. By August 2014, plants had begun to re-grow including patches of *L. uniflora* and *I. verticillatum*.
- At East End (west) large areas of the pond still supported little vegetation. However, cover of *I. verticillatum* was almost 100% in some quadrats (**photo right**). Yellow centaury *Cicendia filiformis* was also recorded for the third year in a row and in similar abundance regardless of treatment.
- East End (east), Wootton Wood and the Canadian war memorial pond did not support the priority plants or had sparse areas of *L. uniflora* which could not be assessed in light of treatment effects.



Herbicide did not appear to have a significant negative effect on non-target native species, but the ponds in this group are heavily grazed and the species used to experiencing periods of heavy disturbance. The concern would be dominance by *C. helmsii* which prevents this natural ebb and flow, or continued use of herbicide which results in loss of priority species. Until a more effective method is found to control *C. helmsii*, natural variation in weather and poaching levels between years may be the best option available at this time for sustaining these populations.

4.3.8 Change in cover of bare ground following herbicide treatment

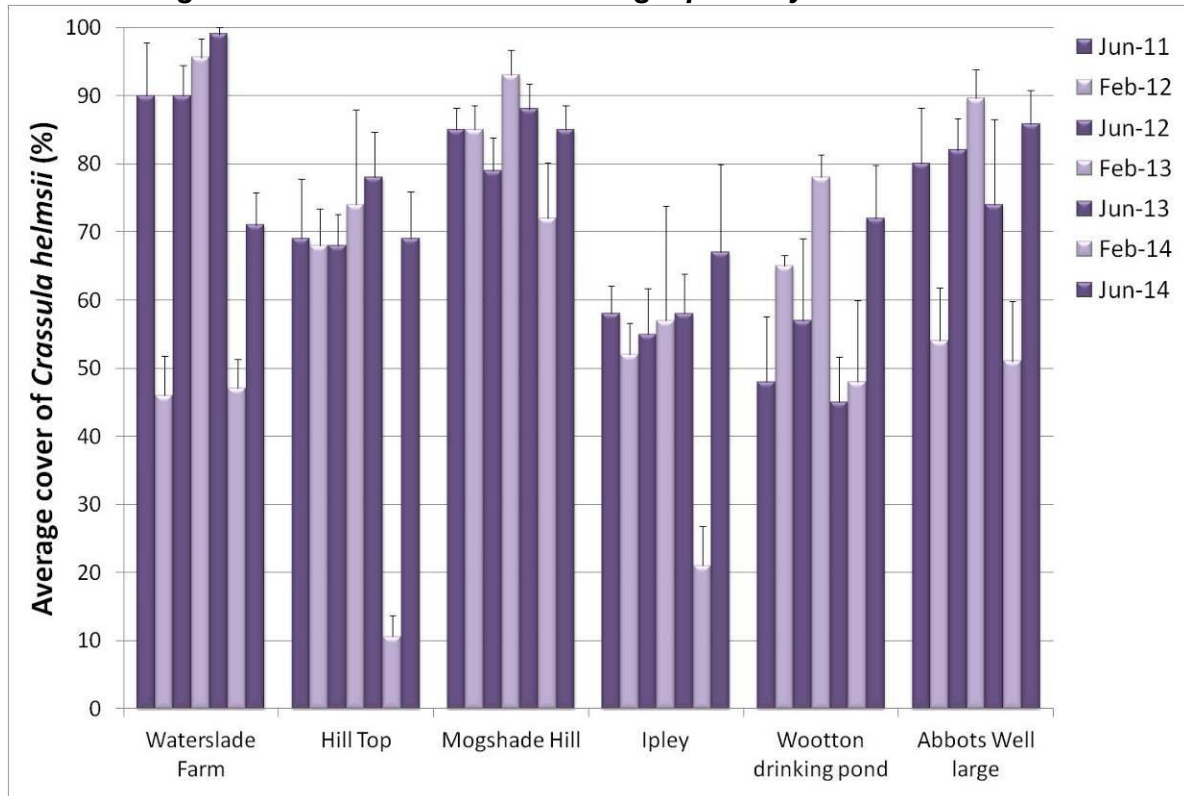


There was a significant difference between years and between sites in the area of bare ground in the herbicide treatment group (Year $F_{6,140}=81.01$, $P<0.001$; Site $F_{4,140}=6.89$, $P<0.001$). The difference between the amount of bare ground in spring and summer was even more marked than in the hot foam treatment ponds; a characteristic of these ponds regardless of the treatment.

At Beaulieu Heath (east) and East End (west) in the spring of 2013, following the wet summer of 2012, and also following a year when there was no herbicide treatment, there was significantly less bare ground than in 2011 and 2013. This corresponded with more *C. helmsii* at this time.

In all ponds the area of bare ground following herbicide treatment significantly increased. On average a 58% reduction following treatment in 2011 and a reduction of 47% following treatment in 2013. The amount of bare ground had returned to pre-treatment levels within 5 months following the 2011 treatment because of an increase in both *C. helmsii* and native species. However, by June 2014 the area of bare ground was still significantly higher than it had been at the start of the trial in all treatment groups. This is unlikely to be due to treatment effects alone because the same pattern was not observed in 2012, and may be attributed to the level of poaching ponds had experienced during the spring.

4.3.9 Change in cover of *C. helmsii* following aquatic dye treatment



Analysis of all data showed that there was a significant differences between years and sites in the cover of *C. helmsii* in sites treated with aquatic dye (Year $F_{6,140}=15.99$, $P<0.001$; Site $F_{4,140}=22.51$, $P<0.001$).

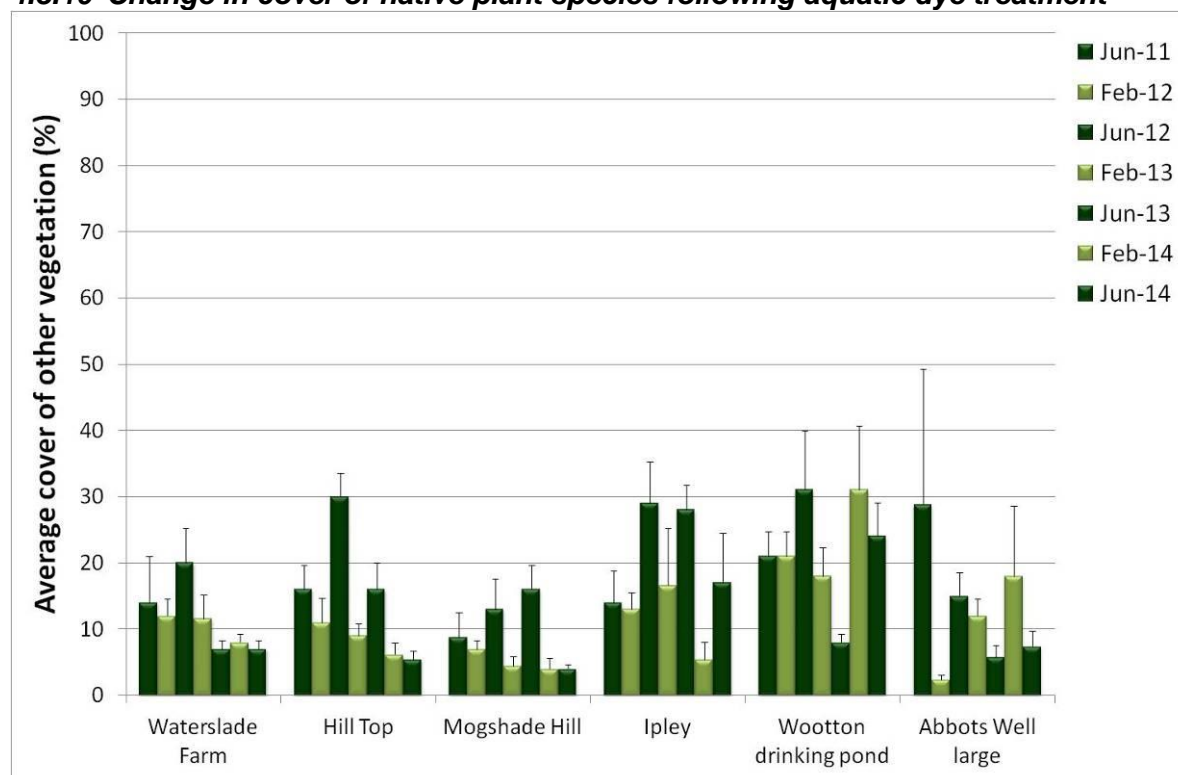
The significant reduction in *C. helmsii* at Waterslade Farm in February 2012 and again in spring 2014 was not as a result of dye application but due to activity by the landowner which was not part of the trial; mechanical removal in the first instance and use of herbicide in the second treatment. There was no change in the cover of submerged *C. helmsii*.

At Hill Top there was a significant reduction in cover of *C. helmsii* in February 2013. Again this difference could not be attributed to the dye. The pond dried down significantly in summer 2012 and foam treatment took place across a large proportion of the pond basin. The results of this are discussed in the hot foam treatment section.

The reduction in *C. helmsii* recorded at Ipley in February 2013 was the result of problems surveying the site when water levels were high. When reassessed in June 2013 it was apparent that a thick carpet of *C. helmsii* remained.

There has been no change in the abundance of *C. helmsii* as a result of aquatic dye treatment. The cover of *C. helmsii* was much more stable between years in these permanent/ semi-permanent ponds.

4.3.10 Change in cover of native plant species following aquatic dye treatment



There was a significant difference between years and between sites in the cover of non-target native species in the dye treatment (Year $F_{6,140}=5.68$, $P<0.001$; Site $F_{4,140}=10.42$, $P<0.001$).

Significant difference between surveys was primarily due to fluctuations in the cover of native plant species between spring and summer and not due to treatment effects. Differences at Hill Top and Abbots Well (large) are discussed in the hot foam treatment.

There were no significant differences in the cover of native plant species at Waterslade, Mogshade Hill, Ipley or Wootton drinking pond. The dip in cover at Wootton in February 2014 was due to very heavy poaching by cattle over the autumn of the previous year.

Following treatment, the situation was therefore generally no better or worse for native plant species.

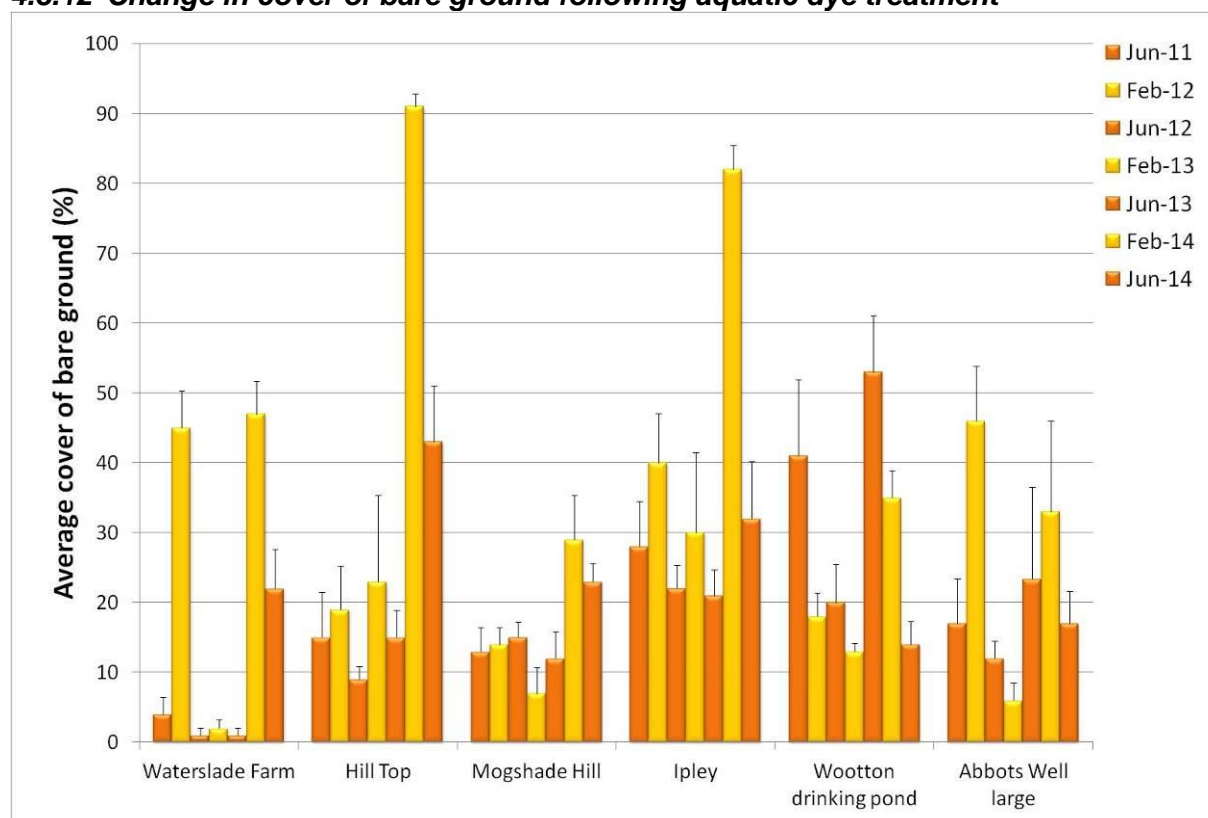
4.3.11 Impact of dye treatment on localised and restricted plant species

Priority species appeared to be unaffected by dye treatment in the sites where they occurred.

- At Mogshade Hill *L. uniflora* was abundant in the pond margin throughout the trial, regardless of *C. helmsii*.
- At Wootton drinking pond *P. globulifera* was abundant following the poaching the pond received in 2013 (**see cover photograph**).

Although not successful in controlling *C. helmsii*, the dye treatment had not adversely affected the presence or abundance of priority plant species.

4.3.12 Change in cover of bare ground following aquatic dye treatment



There was a significant difference between years and between sites in the cover of bare ground in the dye treatment (Year $F_{6,140}=34.81$, $P<0.001$; Site $F_{4,140}=17.16$, $P<0.001$). Seasonal differences, whilst still apparent, were much less in these semi-permanent ponds, compared with the temporary ponds in the other treatment groups.

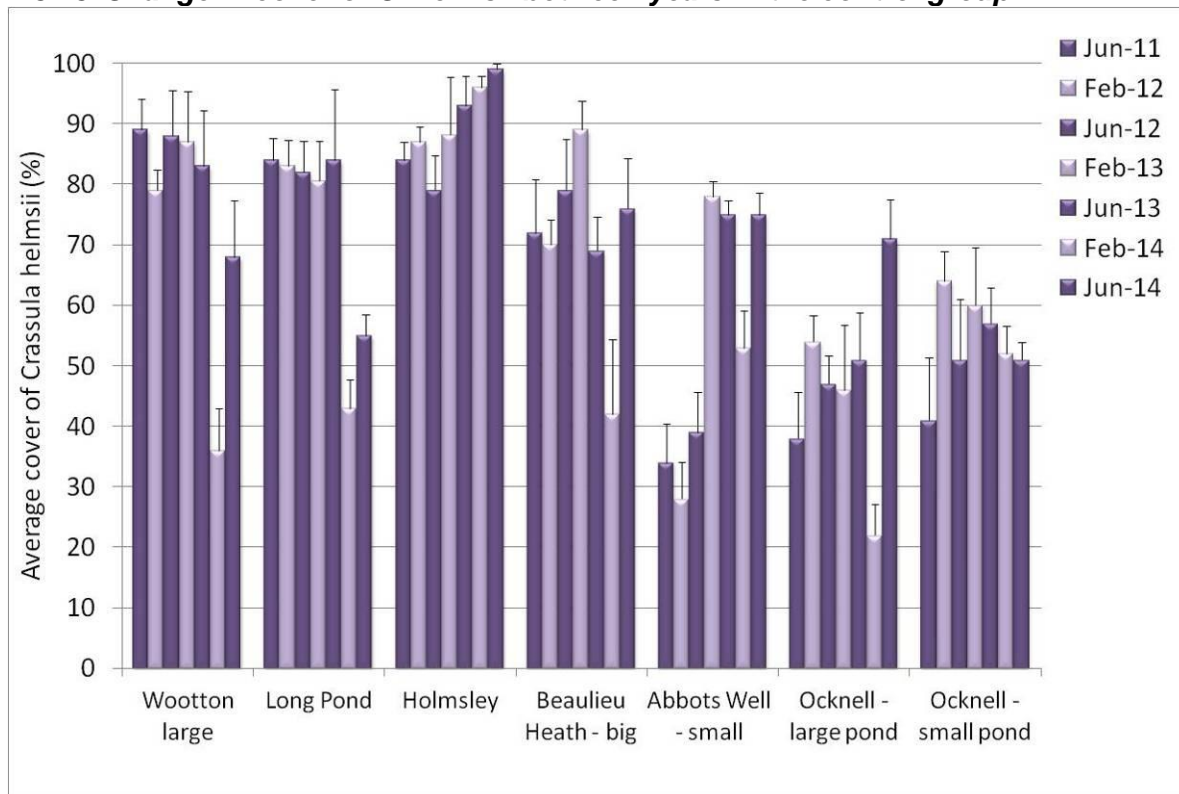
Waterslade Farm had significantly more bare ground (3 times as much) in 2012 and 2014, compared with the previous year, following removal of *C. helmsii* by means other than treatment with dye (mechanical and herbicide respectively). Hill Top pond had significantly more bare ground in February 2014 compared with any other year or season, over 3 times as much – a combination of environmental conditions and treatment.

At Mogshade Hill there was a significant increase in the area of bare ground in 2014 compared with the previous year. The dry summer of 2012 resulted in increased grazing pressure around the pond margin, but this was not enough to affect the abundance of *C. helmsii* or cover of native plant species. At Wootton drinking pond, bare ground was also created by cattle poaching the pond margin which resulted in an increase in *P. globulifera* in the following year.

The only other pond to show a significant difference between years was Ipley pond, almost twice as much bare ground as in February 2013. This is a difficult pond to survey because of the dark water and trampling of the pond edge may distort the results. When reassessed in June 2014 it was established that there had been no significant difference in the cover of bare ground as a result of the dye treatment.

Control group

4.3.13 Change in cover of *C. helmsii* between years in the control group

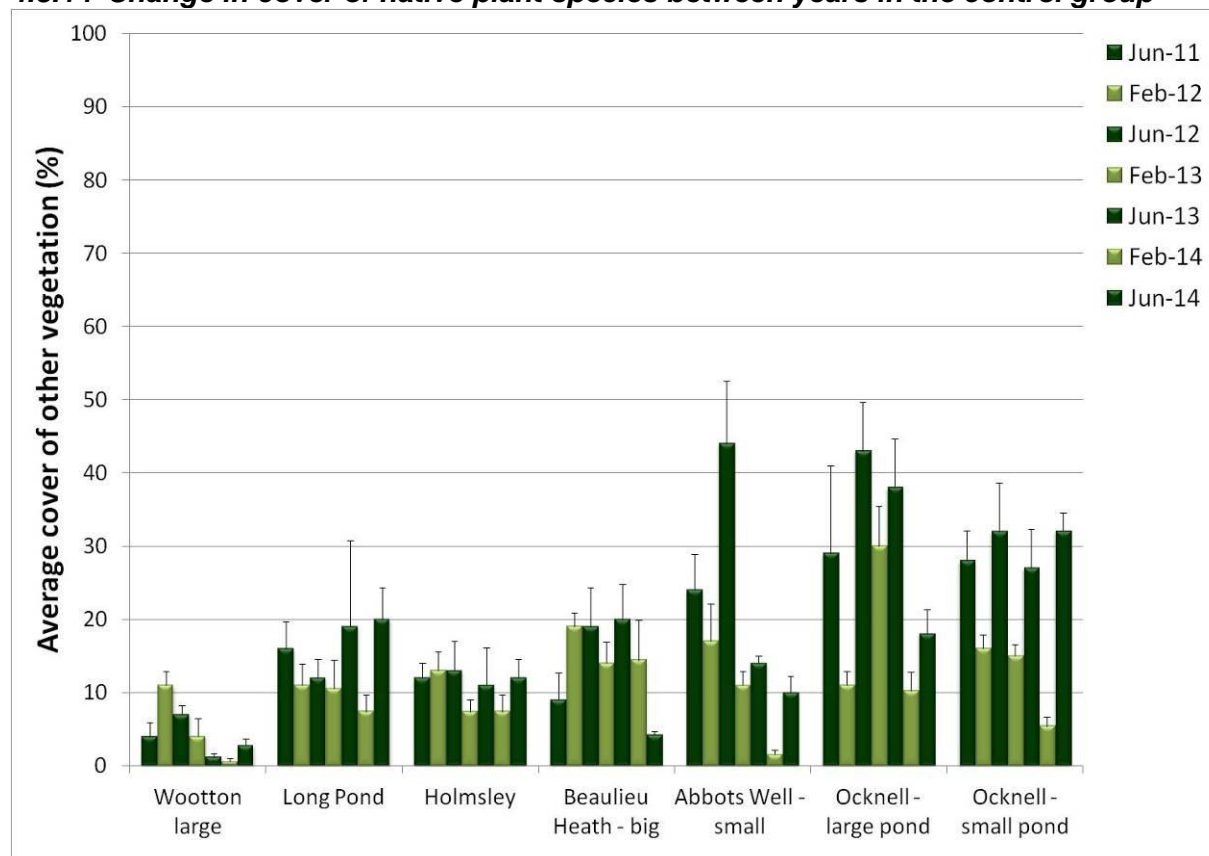


There was a significant difference between years and between sites in the cover of *C. helmsii* in the control group (Year $F_{6,196}=11.78$, $P<0.001$; Site $F_{36,196}=35.50$, $P<0.001$).

There was a significant decline in *C. helmsii* between February 2013 and February 2014 at Wootton (large) pond (59%) and Long Pond (47%). There were also declines although not significant at Beaulieu Heath (big pond) (53%), Abbots Well (small pond) (32%) and Ocknell (large pond) (52%). The cover of *C. helmsii* had returned to June 2013 levels by June 2014. At Holmsley Pond and Ocknell (small pond) there was no difference between any years.

Overall, the average decline in *C. helmsii* in ponds in the control group between February 2013 and February 2014 was 35%. Some declines in *C. helmsii* in the treatment groups must therefore be attributed to natural changes between years in response to weather conditions and grazing pressure. However, hot foam treatment ponds had double the reduction of *C. helmsii* compared with the control group. Herbicide treatment ponds had two thirds more reduction in *C. helmsii* compared with the control group. Therefore, some changes between years in the treatment groups is likely to be due to natural fluctuations between years, but ponds in the treatment groups lost more *C. helmsii* than ponds in the control group between those years.

4.3.14 Change in cover of native plant species between years in the control group



There was a significant difference between years and between sites in the cover of native plant species in the control group (Year $F_{6,196}=11.09$, $P<0.001$; Site $F_{36,196}=18.61$, $P<0.001$).

Differences between surveys were caused seasonal variation, i.e. native plant species grow more in the summer months. There was also between year variation; the wet summer of 2012 caused peak growth at Abbots Well (small pond), and increased poaching in 2014 at other ponds e.g. Wootton large and Beaulieu Heath (big pond) and Abbots Well (small pond).

Changes observed in treatment ponds in terms of cover of native species are therefore likely to reflect natural fluctuation, rather than treatment type.

4.3.15 Impact of changes between years on localised and restricted plant species in the control group

Both Wootton (large pond) and Holmsley are dominated by *C. helmsii*. Whilst both ponds were once significant for the presence of priority species the presence of *C. helmsii* is likely to be detrimental. Wootton (large pond) is nutrient rich and although livestock are regularly seen grazing *C. helmsii* from the pond, they do not seem to be able to suppress it because of the vigorous growth. Holmsley is not part of the Open Forest (not open to grazing by New Forest livestock), and is also nutrient rich. They are good examples of the threat posed by *C. helmsii* but also illustrate the value of the clean water habitats and grazing of other ponds in the New Forest as important tools in the control of this invasive weed and maintenance of some open ground for priority plant species.

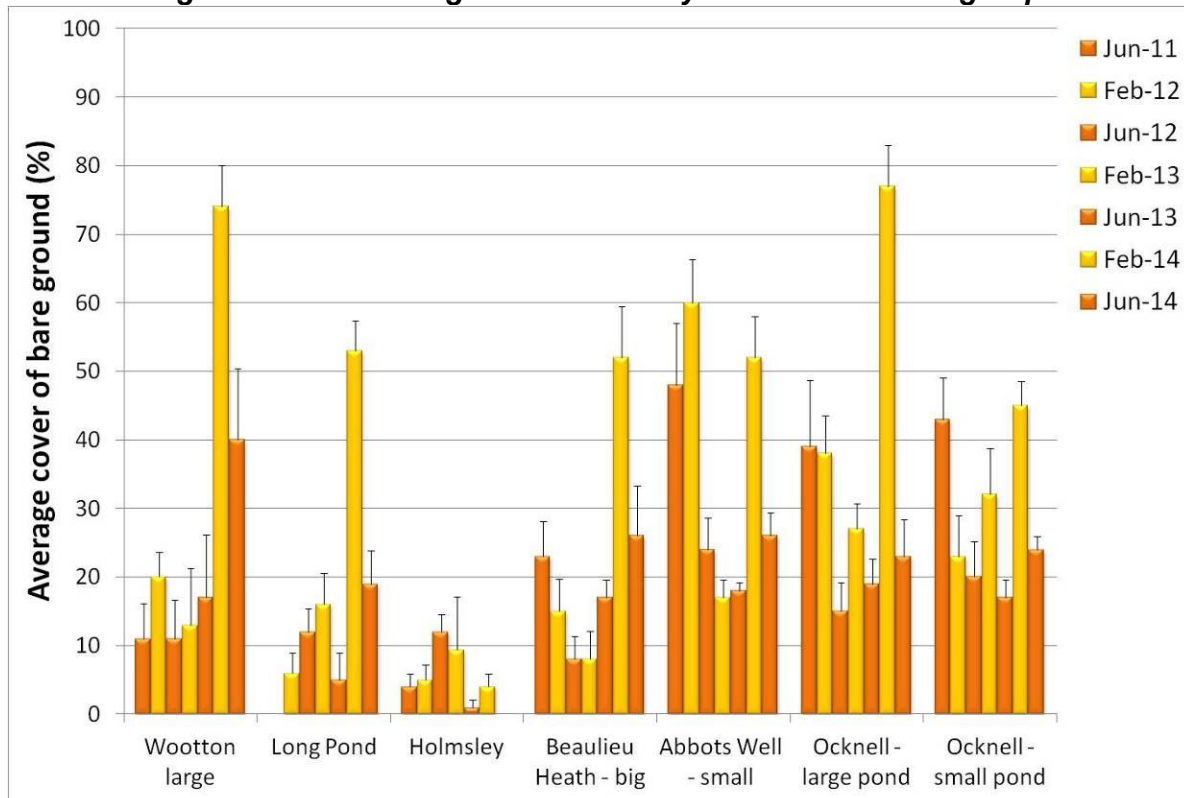
Other ponds in the control group:

- Beaulieu Heath (big pond) had abundant *L. uniflora* which was not suppressed by *C. helmsii* in the pond margin.

- Ocknell (large pond) and Ocknell (small pond) remain some of the most important ponds in the New Forest for priority species (including *P. globulifera*) in spite of the presence of *C. helmsii*.
- Long Pond (**see photograph below**) had abundant *L. uniflora* (foreground) and *P. globulifera* (bright green in background) throughout the trial in spite of the presence of *C. helmsii*.



4.3.16 Change in cover of bare ground between years in the control group



There was a significant difference between years and between sites in the amount of bare ground in the control group ponds (Year $F_{6,196}=41.62$, $P<0.001$; Site $F_{36,196}=28.96$, $P<0.001$).

Seasonal differences were apparent in the control group as they had been in the treatment groups, confirming this as a natural phenomenon. Differences between years in the treatment ponds cannot be linked solely to the treatment used. On average the amount of

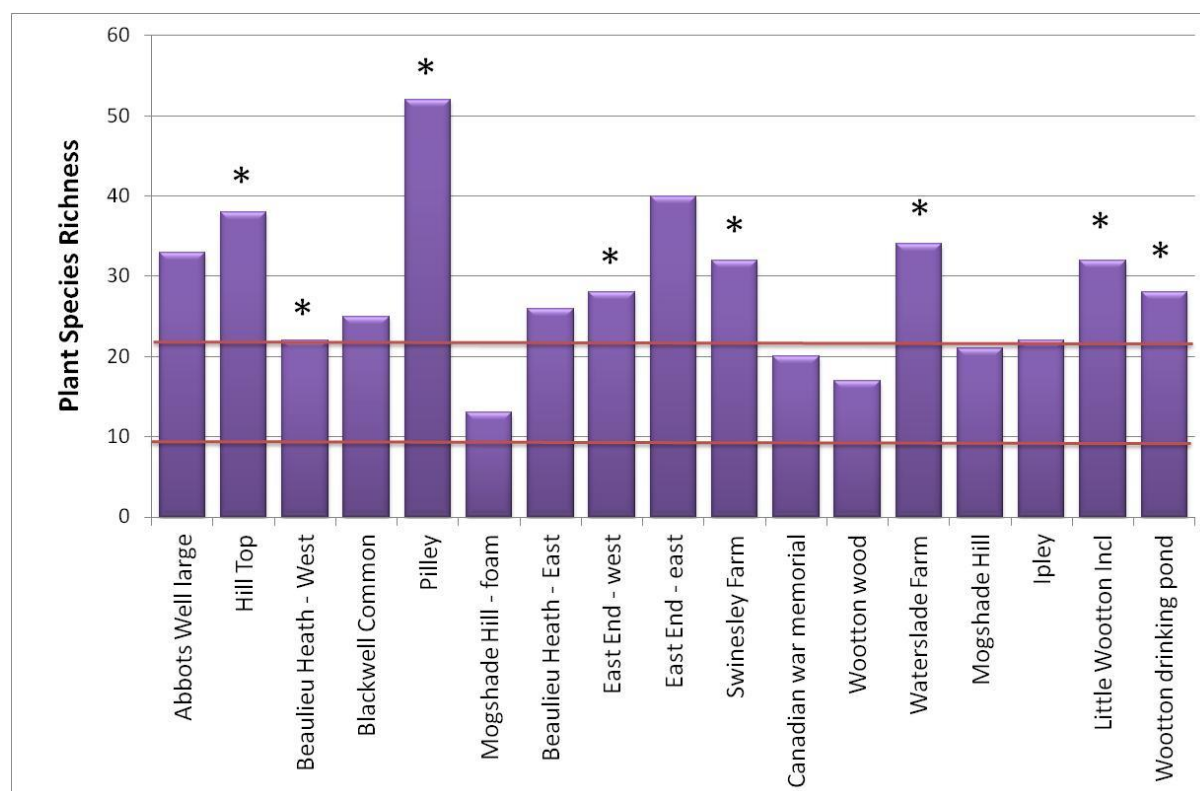
bare ground in February 2014 was almost 2.5 times the amount recorded in February 2013. By June 2014 the amount of bare ground was the same or slightly more than it had been in June 2013.

However, there were some treatment effects because the amount of bare ground created following hot foam treatment was 4.5 times the amount before the treatment, indicating that hot foam doubled the amount of bare ground above the background level of change. The amount of bare ground in the herbicide treatment was ten times the amount before treatment, indicating that herbicide produced four times more bare ground than the background level of change.

4.4 Impact of treatments on non-target native plant species

On completion of the baseline survey, the wetland plant results showed that 8 ponds in the treatment groups achieved very high conservation status, a further 4 ponds had high conservation status, whilst the remainder achieved moderate status (Figure 4.5). None of the ponds had low conservation value in spite of the presence of *C. helmsii*.

Figure 4.5. Conservation status of ponds in the *C. helmsii* trials based on the composition of plant species recorded 2011 - 2014.



n.b. Ponds with between 9 and 22 wetland plant species (indicated by horizontal lines on graph) are considered to have moderate conservation value. Ponds with more than 22 wetland plant species are considered to have high conservation value. Where there is a Nationally Scarce or Red Data Book plant species present, ponds are considered to have very high conservation value (asterisk).

All species recorded in July 2011 were found again and recorded as present in 2012, 2013 and 2014, regardless of the treatment. Therefore whilst treatments may have a temporary effect on abundance they did not result in the loss of any species from a pond.

After the July 2012 survey it was noted that whilst plant species composition was relevant to the overall conservation status of the pond, the method of recording (within the maximum

winter water line) did not fully capture the impact of the treatment on native species of conservation importance, because treatment may only have occurred in one area of the pond.

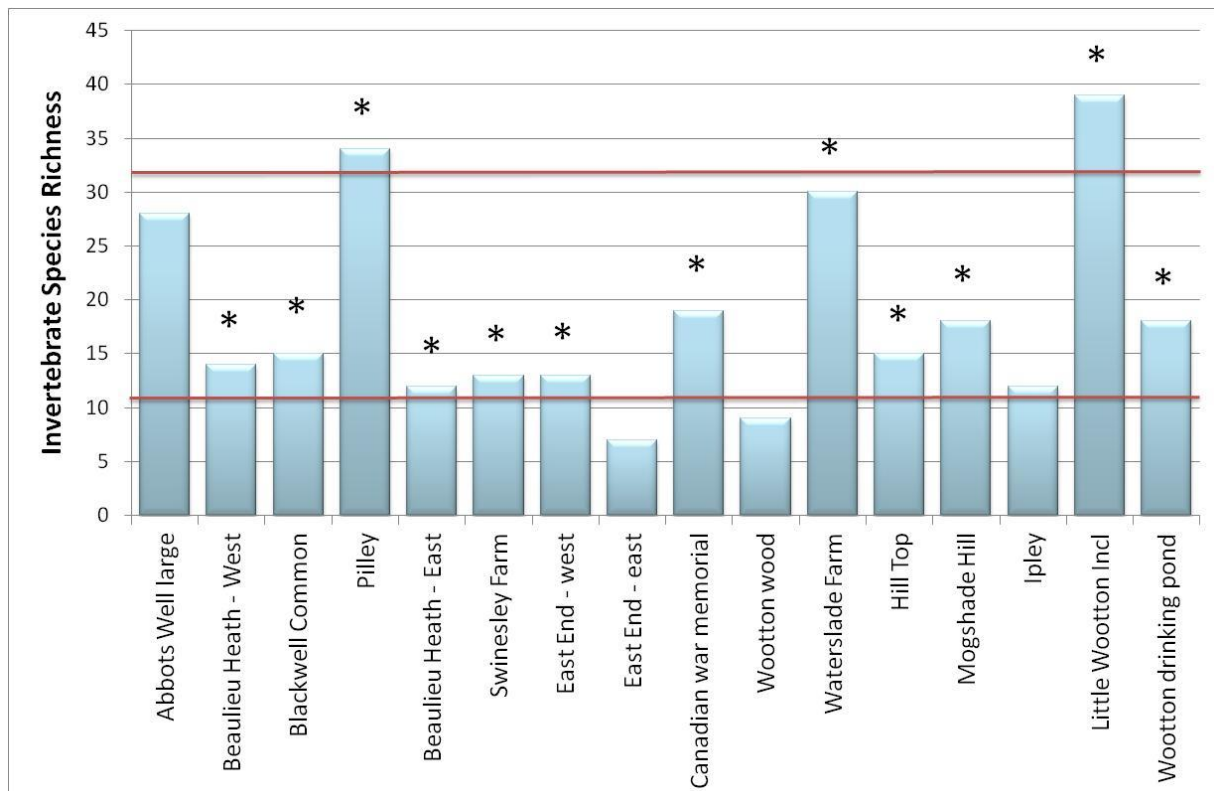
In August 2013 and August 2014, the percentage cover of species of conservation concern within each quadrat was measured in order to provide a baseline against which to measure change following treatment in 2013 and subsequent surveys in summer 2014. The results showed that seasonal rather than treatment effects determined the amount of cover of priority species, however, treatments had not had a significant negative impact on cover.

4.5 Impact of treatments on non-target macroinvertebrate species

The baseline survey of ponds in 2011 identified 97 invertebrate species, including 18 uncommon species (Figure 4.6). Based on macroinvertebrate species number and rarity, 2 of the treatment ponds would be considered to have moderate conservation value, whilst 12 ponds would be considered to have very high conservation value. The two ponds with low conservation value according to macroinvertebrate assessment were relatively recently filled on the day of survey, so this may not reflect their true value.

In total, since 2011, 108 species of macroinvertebrate have been recorded from the ponds in the trial, 17% of which have been species of conservation importance. Between years, the species composition of the ponds changed slightly, as species joined or left the pond community and differences in capture rate between years. However, treatment did not have any effect on the number of invertebrate species or community quality between years.

Figure 4.6. Conservation status of ponds in the *C. helmsii* trials based on the composition of macroinvertebrate species recorded 2011.



n.b. Ponds with between 11 and 32 aquatic macroinvertebrate species (indicated by horizontal lines on graph) are considered to have moderate conservation value. Ponds with more than 32 species are considered to have high conservation value. Where there is a Nationally Scarce or Red Data Book macroinvertebrate species present, ponds are considered to have very high conservation value (asterisk).

4.6 Weighing up the success of techniques to control *C. helmsii*

At present it appears as though the most successful treatment option for reducing the cover of *C. helmsii* is the use of herbicide, followed by hot foam. No treatment can be considered to be successful however, because eradication was not achieved in any of the ponds in the trial. Results have shown that re-colonisation by *C. helmsii* is very rapid and often to the same or greater extent than before treatment.

The effectiveness of glyphosate is dependent on a variety of factors, e.g. the number of applications, time of day and year, weather conditions, environmental conditions, application rate and the characteristics of the target plant (Hartzler *et al.* 2006). However, the results obtained here are similar to the results of trials treating *C. helmsii* at low biomass on emergent turves (Dawson 1996).

Personal observation noted that re-growth appeared to be from a limited number of fragments which had been missed by the first application, possibly because they had been buried in the soil by the poaching action of grazing livestock. There was also re-colonisation from patches of *C. helmsii* growing outside the area targeted by the application; either outside the pond margin or from submerged growth.

The effectiveness of hot foam is also dependent on the ponds drying out completely; in many ponds, thick wet mud, even during the dry season, will reduce the effectiveness of this technique to deliver water at the correct temperature.

The results of the dye treatment mirrored that of the control group which suggests that the treatment was not having an effect on the *C. helmsii*. Mechanical removal at Waterslade Farm was as effective in the short term as herbicide, but rapid colonisation prevents this from being an effective tool for eradication.

Treatments did not negatively impact upon cover of native plants in this trial, but results suggest that ongoing unsuccessful treatment could negatively impact on native species over time. The cover of native plant species and the amount of bare ground fluctuates naturally between seasons and between years in these ponds. The presence of *C. helmsii* if not controlled by grazing to maintain an open sward, could interrupt the delicate balance of these ponds, by displacing species in years when the cover of bare ground is high, and the cover of native species naturally low.

5. Conclusion

The distribution and spread of *C. helmsii* in the New Forest is now well understood. As a priority, biosecurity protocols for staff working within the New Forest SAC should be updated and adhered to, to prevent spread to uninfected/ isolated ponds. On-going public awareness campaigns for visitors to the New Forest National Park and homeowners within the park should focus on preventing introduction to currently uncontaminated sites.

Currently uninfected ponds can be placed into risk categories with the most vulnerable ponds being those close to habitation or visitor hubs such as car parks. Ponds within complexes where *C. helmsii* is already present are likely to become colonised in time, but a combination of grazing pressure and pond characteristics may prevent the dominance of *C. helmsii* at some sites. Deterioration of ponds due to pollution will have serious direct consequences on their wildlife value but is also likely to increase dominance of *C. helmsii*. Ponds with the highest biodiversity value should therefore be protected from both disturbance and pollution to minimise the risks from *C. helmsii*.

Our understanding of the impact of *C. helmsii* on native flora and fauna in the New Forest is increasing. *C. helmsii* has wide tolerance limits, but is clearly less dominant at the edge of these limits and its dominance may be determined by the composition and structure of the existing native plant community. Grazing pressure is critical in limiting the dominance of *C.*

helmsii at some ponds particularly where these ponds naturally dry out during the summer months; wet summers unsurprisingly encourage greater growth, whilst a reduction in growth follows a dry summer.

Therefore, whilst many ponds with *C. helmsii* maintain a diverse flora and fauna, factors such as increasing nutrients from pollution, climate change and a reduction in grazing pressure due to changes in the socio-economy of the New Forest are likely to result in greater dominance of *C. helmsii* and corresponding reduction in the cover of native plant species. Whilst not observed during this study this could weaken the integrity of native plant communities and ultimately results in the decline and extinction of native plants. Even without the presence of *C. helmsii*, these factors would have a significant detrimental impact on the quality of these ponds for wildlife.

A significant reduction in *C. helmsii* was observed following treatment with herbicide and hot foam, but to date none of the treatments have been effective in eradicating *C. helmsii* at a site. *C. helmsii* was able to re-grow to the same or greater extent following treatment which is highly undesirable in ponds which contain species with high conservation value. In permanent ponds, fragments of *C. helmsii* from deeper water re-colonised the pond margin, therefore, both hot foam and herbicide treatments could only be used to eradicate *C. helmsii* in ponds which dry out completely. Eradication was not possible following multiple treatments even in the same year; therefore successful treatment may only be possible with repeat treatments over a number of years. The ongoing treatment which would be required could also have a negative effect on native plant species. The unpredictability of the UK climate and re-colonisation of *C. helmsii* from adjacent sites means that planning a successful eradication programme is unfeasible in the New Forest at this time.

Further research and other control options should be explored, but in the interim, prevention of spread and monitoring to ensure that grazing is sufficient to maintain an open sward for native plant communities will be needed to maintain the quality of these ponds for biodiversity until an effective control treatment is found.

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