The effectiveness and cost efficiency of different pond restoration techniques for bearded stonewort and other aquatic taxa

Executive summary from a report on the Second Life for Ponds project at Hampton Nature Reserve in Peterborough, Cambridgeshire

The Froglife Trust
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Funded by SITA Trust through its Enriching Nature Programme
Aerial view of Hampton Nature Reserve

Manual clearance of a pond by Froglife volunteers

Mechanical clearance of a pond
1. Introduction to Hampton Nature Reserve

Hampton Nature Reserve in south Peterborough (UK) covers 126ha of unique landscape consisting of a series of over 300 ponds and their corresponding spoil heaps. These ponds are generally mesotrophic, calcium-rich and unpolluted, although farm run-off has had localised impacts.

The site is important for aquatic plants; it is the second most diverse site in England for stoneworts, supporting 10 species, including the critically endangered bearded stonewort *Chara canescens* which is found on only two sites in the UK. Bearded stonewort is associated with recently scraped sediments with a pH in excess of 8 and a positive redox potential. These conditions do not last long and bearded stonewort is lost early to succession, with stonewort dominated communities slowly changing in composition and giving way to increased pondweed presence and eventually swamp vegetation. Accordingly bearded stonewort has declined dramatically in terms of both distribution and dominance since new pond creation ceased. However, stonewort oospores remain viable for over 100 years, indicating that stonewort colonies can be regenerated following management, provided that the water quality remains high.

The site supports exceptional assemblages of aquatic invertebrates, in terms both of number of species and the representation of rarities, and many of the ponds in the complex qualify as Priority Ponds for invertebrates. Interest is taxonomically widespread, but overwhelmingly the greatest interest lies in the water beetles, with more than 120 species recorded.

The whole site qualifies as a Flagship Ponds site and a key reptile site, both under multiple criteria. It also hosts a variety of Biodiversity Action Plan priority mammal species including several species of bat and a large and widespread population of water voles. However, the reserve is most famed for supporting the largest extant population of great crested newt *Triturus cristatus* in Great Britain and possibly in Europe, estimated as up to 30,000 adults. The site is designated as a Site of Special Scientific Interest (SSSI) and as a Special Area of Conservation (SAC) on account of the size of its great crested newt population, the diversity and abundance of its stoneworts, and the presence of bearded stonewort.

2. Objectives of the Second Life for Ponds Project

Bearded stonewort has declined in abundance and reduced in distribution on the reserve and is now considered to be in Unfavourable Condition by Natural England. Accordingly, conservation action was required to halt and reverse this decline. Furthermore, the unique superabundance of ponds on the reserve presented the opportunity to conduct research into the effectiveness of a wider range of management techniques than would normally be feasible for achieving this goal. However, due to the high value of the ponds to other taxa it was also important to monitor the effects of these restoration techniques on the wider ecological community.

There are therefore two mutually beneficial sets of objectives for this project. The first two objectives relate exclusively to the conservation benefit of the restoration works to the Hampton Nature Reserve:

1. To implement the restoration and creation of ponds for the recolonisation of bearded stonewort *Chara canescens* on Hampton Nature Reserve.
2. To monitor changes, either positive or negative, within the important existing non-target taxa, including other aquatic plants and stoneworts, aquatic invertebrates, great crested newts and water voles.

These objectives will inform future management work and pond restoration cycles on Hampton Nature Reserve. Furthermore, given the extreme rarity of bearded stonewort nationally, and the importance of the reserve for other non-target species, changes to the site have a disproportionate impact on UK biodiversity targets.
The other two objectives relate to the research value of the project for evidence-based conservation:

3. To evaluate four different pond management techniques - new pond creation, complete mechanical restoration, partial mechanical restoration and partial manual restoration - against a control of non-intervention, in terms of:
   i) their effectiveness for bearded stonewort *C. canescens* recolonisation.
   ii) their side-effects on non-target taxa, including other aquatic plants and stoneworts, aquatic invertebrates, great crested newts and water voles.
   iii) their effect on water and substrate chemistry, and how these correlate with target and non-target taxa.
   iv) the cost-effectiveness of each restoration technique, considering both bearded stonewort *C. canescens* independently and the holistic effects of restoration on non-target taxa.

4. To disseminate the results of the project and encourage land managers to use proven evidence-based conservation techniques on their sites.

These objectives will inform land managers’ decision-making throughout the wider conservation community.

The *Second Life for Ponds* Project was made possible through funding from SITA Trust through its Enriching Nature Programme.

### 3. Habitat Management Methodology

The project combined practical habitat management with research and therefore required multiple ponds, 15 in all. Despite the presence of over 300 ponds on the reserve, the topography of the ridge and furrow terrain meant that it was difficult to choose a single section of the reserve with the required number of ponds easily accessible for an excavator, so it was decided to conduct the experiment in three clusters. In each cluster four existing ponds were selected for study, plus a fifth which was newly dug. Ten ‘standardised’ new ponds were also created in a fourth cluster as preparation for future experiments.

Following baseline water quality and species surveys the following restoration methods were undertaken in each of the three main clusters, scraping the sediment and vegetation back to bare clay as described below:

1. Control pond - no management was applied.
2. Partial manual clearance with the assistance of volunteers (15 metres of the pond edge).
3. Partial mechanical clearance with an excavator (15 metres of the pond edge).
4. Complete mechanical clearance with an excavator.
5. New pond creation - a completely new pond was excavated. (Space restrictions limited the scope for excavating new ponds, and as a result two of the three new ponds failed, so two of the new ponds from Cluster 4 were used as surrogates in surveys of some of the taxa.)

### 4. Survey Methodology

All the selected ponds were monitored for water quality and surveyed for bearded stonewort and non-target taxa during Autumn 2008 to provide a baseline dataset prior to any management work. The project’s holistic approach to pond restoration required the involvement of specialists including an entomologist, botanist, vertebrate and freshwater ecologists. The following taxa were surveyed:

- Bearded stonewort *Chara canescens*
- Great crested newts *Triturus cristatus*
- Water voles *Arvicola terrestris*
- Other stoneworts
- Other aquatic plants
- Aquatic invertebrates
After restoration, monitoring continued with four follow-up surveys conducted at three-month intervals in Spring 2009, Summer 2009, Autumn 2009 and Spring 2010 for invertebrates, plants, and water and sediment quality; water vole surveys and great crested newt surveys were omitted in Summer and Autumn 2009 respectively, which represented a sub-optimal survey period for these species.

Some surveys were undertaken on the scale of managed area and others on whole pond. However, for standardisation all ponds had 15m sample stretches marked in the field to enable direct comparison with the partially restored ponds. Repeat surveys were carried out in the same stretch of pond. On partially restored ponds this area corresponded to the restored area whilst on all other ponds the selection of the 15m sample area was more arbitrary and determined in part by ease of access.

The 15m sample stretches were further divided into three 5-metre sections which were marked with stakes. However, due to the variability in data, records from the whole 15m sample stretch (water samples and quantitative invertebrates) or from the whole pond (invertebrate inventory survey, botany, newts and water voles) were pooled for analyses.

A Principal Components Factor Analysis (PCA) of charophyte, newt, water vole and water quality data was conducted using SPSS © statistical analysis program. (Invertebrate and non-stonewort plants were excluded from the analysis partly for technical reasons, and because the key focus of the project was to inform restoration for Chara canescens.)

## 5. Project Findings

### 5.1 Bearded Stonewort

Number of ponds with *Chara canescens* colonisation events:

<table>
<thead>
<tr>
<th>Habitat management technique</th>
<th>Ponds with <em>Chara canescens</em> colonisation events</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Control)</td>
<td>0 of 3</td>
</tr>
<tr>
<td>Partial manual restoration</td>
<td>1 of 3 - did not persist</td>
</tr>
<tr>
<td>Partial mechanical restoration</td>
<td>1 of 3 - did not persist</td>
</tr>
<tr>
<td>Complete restoration</td>
<td>3 of 3</td>
</tr>
<tr>
<td>New pond creation</td>
<td>1 of 3</td>
</tr>
</tbody>
</table>

Five out of nine (55%) restored ponds - six out of 12 (50%) if new ponds are included - led to colonisation; this was a successful result. However, initial results indicate that recolonisation following partial pond clearances does not persist for longer than a year, suggesting that if this restoration method is used a frequent management cycle would be required. *Chara canescens* has persisted for the full survey period in both newly created and completely restored ponds, so using these techniques a less frequent management cycle is feasible.

Monitoring of these ponds will continue until *Chara canescens* abundance declines or presence is lost; this will indicate with what frequency to maintain the management cycle to optimise *C. canescens* abundance and pond occupancy. It necessarily requires a longer timescale than the current project.

As Hampton Nature Reserve is very space-limited, and the terrestrial habitat is locally scarce and of relatively increased value, it is encouraging to know that not only is pond restoration a viable option for *Chara canescens* restoration but also, in the case of complete restoration, a better option than new pond creation. In conclusion, on Hampton Nature Reserve complete pond restoration is the optimum management strategy for *Chara canescens*.
5.2 AQUATIC PLANTS AND STONEWORTS

The pre-existing flora survived or recolonised remarkably well following management: only two species (both algae) were lost, neither of which were of conservation concern. Once seasonal variation is accounted for, species richness increased slightly following partial mechanical restoration and more notably following complete restoration and the creation of new ponds; the latter two techniques continued to show a positive trend at the end of the project’s survey period, which might be indicative of further increases in future.

Both complete and partial restoration techniques appeared to boost stonewort species richness, although this boost was only truly sustained in completely restored ponds. The relative dominance of stonewort species was also more variable following management; this was most apparent in completely restored ponds. All colonisation of new ponds represents a gain in aquatic species richness, but whilst the trend continued to increase with aquatics generally, stonewort persistence was not so high.

Traditional advice regarding pond restoration for plants recommends restricting management to partial clearances in order to balance the potential losses to perennial plants with the benefits to annual aquatic plant communities such as stoneworts. However, where these latter communities are the dominant interest and the majority of aquatic vascular plants are either unaffected by or even gain from greater intervention, as was the case in this study, then complete restoration should be favoured.

Complete restoration on Hampton Nature Reserve is especially viable due to the high number of ponds present. Although the site is not known to support any priority vascular aquatics an inventory should be made as a matter of routine prior to management; any species found which is disadvantaged by complete restoration can be served either by restricting the number of ponds managed in this way or by maintaining a long rotation of management across the site as a whole.

5.3 AQUATIC INVERTEBRATES

Habitat management led to considerable species loss, including substantial numbers of scarce species. Species richness is broadly highest for - in this order - control ponds, partially manually cleared ponds, partially mechanically cleared ponds, wholly cleared ponds and finally new ponds. Conservation interest scores follow a broadly similar pattern. The difference between manually and mechanically cleared ponds may be explicable by the less thorough clearance in manually cleared ponds, resulting in a less disturbed habitat. Alongside the losses habitat management has led to species turnover by creating opportunity for early succession and open structure species not found in more established ponds: this includes three which are Nationally Scarce and 20 not recorded from any of the ponds prior to management.

Even though early colonists arrive rapidly after pond management, colonisation is generally slow, with invertebrate succession slowest in completely cleared and new ponds, which suffer less with strays from unmanaged areas, which may compete with pioneer and early succession species. There is currently little evidence to suggest that completely cleared or new ponds support species which do not also colonise partially cleared ponds, and vice versa; in conjunction, this suggests that to maximize benefit to early succession species (albeit at the expense of existing interests) complete clearance would be the optimum management technique.

The benefits of complete clearance must be balanced against the losses of existing interest; in any isolated pond containing the level of invertebrate interest found here prior to management, or any pond in an old wetland or pond complex that might contain poorly mobile species, complete clearance would be unthinkable. Complete restoration is uniquely viable on Hampton Nature Reserve due to the vast reservoir of later succession ponds. New pond creation should provide similar opportunities, but to date new ponds have not performed as well as completely restored ones. This is probably because the timescale of the project was too short for a site with such slow succession. Once these new ponds become established there is no reason to believe that they will not develop a good invertebrate interest equivalent to that of existing ponds of similar size and profile on the site. However, the benefits of new pond creation must be balanced against loss of terrestrial habitats, which are locally scarce (especially considering the large number of ponds), so on this site complete restoration of existing ponds is more favourable than new pond creation.
If management is considered for invertebrates alone the default recommendation would remain, as usual, management for steady state conditions if possible. The ponds cleared for this study were probably close to their richest point, and with management of plant growth might have been kept there for a long time. Steady state management of early succession species could involve the partial clearance of ponds which are already at a quite early stage of succession, with a view to maintaining early succession stages indefinitely. These are valuable for many invertebrates whatever their history, but the best are ancient early succession stages, which have been present in one place for sufficient time to accumulate a rich assemblage.

If this is not possible, rotational partial clearance is the next preferred option. Given the high invertebrate value of the ponds selected for complete restoration the length of the rotation would need careful consideration. Many invertebrates benefit from a long rotation slowed as much as possible. However, much of this rotation would be wasted for early succession invertebrates, as well as for stoneworts, especially Chara canescens; given the profusion of ponds on Hampton Nature Reserve short rotations should also be included for these species.

5.4 Great Crested Newts

The general trend was to a decrease in great crested newt abundance. Against this background partial manual restoration had no noticeable effect, complete restoration gave mixed results but generally did not seem to be deleterious and partial mechanical restoration (the recommended option for great crested newts) was followed by an increase in abundance. Great crested newts were absent in several new ponds and generally only present in others in low numbers, despite the similarity in habitat to the control ponds, which had much higher abundances.

This suggests that habitat management for the benefit of newts should focus on partial mechanical restoration, but that contrary to expectations complete clearance does not seem to have a negative impact.

5.5 Water Voles

Water voles were present at all ponds prior to management and were only lost following complete restoration, which renders the habitat unsuitable. However, as their territories are on a larger scale than individual ponds they can withstand such losses, so long as the number and density of ponds completely restored in a single area is limited. Water voles were never present in the new ponds as neither the previous terrestrial habitat nor the freshly created pond edge habitat were suitable, although it is likely to develop into suitable habitat if left unmanaged.

5.6 Water and Sediment Quality

Baseline measures varied significantly between ponds but all were neutral to alkaline, and had low nitrate, phosphate and copper concentrations; restoration led to significant changes including increased pH, nitrate and phosphate levels, but in all cases remained below the threshold for limiting charophyte growth.

5.7 Multivariate Analysis

A multivariate analysis of the data showed clear associations and dissociations between the variables. Chara canescens was most closely associated with completely cleared ponds and ones which were newly dug, which in turn were associated with an increase in water and interstitial water pH and a re-oxidation of the interstitial water indicated by higher redox potential.
5.8 SUMMARY

The impact of different management techniques on taxa at Hampton Nature Reserve is summarised below.

<table>
<thead>
<tr>
<th></th>
<th>Control</th>
<th>Part manual restoration</th>
<th>Part mechanical restoration</th>
<th>Complete restoration</th>
<th>New pond</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chara canescens</td>
<td>A (+)</td>
<td>(+)</td>
<td>++</td>
<td>+</td>
<td></td>
</tr>
<tr>
<td>Stoneworts</td>
<td>P =</td>
<td>+</td>
<td>++ ↑</td>
<td>+</td>
<td></td>
</tr>
<tr>
<td>Aquatic plants</td>
<td>P =</td>
<td>+</td>
<td>++ ↑</td>
<td>++ ↑</td>
<td></td>
</tr>
<tr>
<td>Aquatic invertebrates</td>
<td>Species richness</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Conservation interest score*</td>
<td>1</td>
<td>2-3</td>
<td>2-3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Great crested newts</td>
<td>P =</td>
<td>++ ↑</td>
<td>?</td>
<td>+</td>
<td></td>
</tr>
<tr>
<td>Water voles</td>
<td>P =</td>
<td>=</td>
<td>=</td>
<td>=</td>
<td>A</td>
</tr>
</tbody>
</table>

*This trend is not as clear-cut as presented in this summary.

Key:
- - decrease relative to control ponds
= no difference to control ponds
+ increase relative to control ponds
++ increase relative to control ponds and most successful management regime
↑ trend still increasing at end of survey period relative to control ponds
? mixed results within treatment group
1-5 1=highest, 5 lowest

5.9 POND RESTORATION ON HAMPTON NATURE RESERVE: CONCLUSIONS

Complete clearance is best where pond restoration is primarily targeting Chara canescens. In this experiment it had the highest success rates (100%) and once present the species persisted throughout the two-year survey period. Furthermore, in general this technique did not appear to have negative side effects on the reserve’s other important taxa.

It also had the greatest effect in rejuvenating the stonewort community and aquatic plants generally.

Complete restoration led to a change in the invertebrate fauna, with reduced species richness and total conservation interest, but these species are widely represented on this site. The new community included otherwise under-represented early succession species, including species of conservation concern, so this management approach is judged to be of value to aquatic invertebrates. On smaller sites without such a reserve of suitable habitat for the later-succession species such changes should be weighed up with extreme care.

Contrary to expectations great crested newts did not appear to be adversely affected by this treatment.

The only taxon studied which was unequivocally negatively affected by complete restoration was the water vole, which was absent from completely restored ponds. However, on the larger habitat usage scale of water voles even complete restoration of a pond represents only a partial restoration of the available pond habitat.

On sites with many ponds such as Hampton Nature Reserve this is a good illustration of the principle of maintaining through management a mosaic of habitat structures, which in this case are levels of pond succession.

5.10 STONEWORT POND CREATION

Land managers at the nearby Whittlesey Brick Pits, Peterborough, created new ponds and scrapes for translocation of Chara canescens and investigated different translocation methodologies. A summary of this supplementary work has been included as a case study in the full report.
In this report the cost-effectiveness relationship is explored through two main choices: partial mechanical vs. complete mechanical restoration, and volunteer (manual) vs. mechanical (contractor) restoration. Whilst costs, split into two main categories (capital and running costs), are reasonably clear, cost-effectiveness is harder to define and measure.

Costs can be presented in two contrasting ways: absolute cost and cost-efficiency. Capital costs are relatively high but fixed, so while bigger projects accrue greater running costs they also become more cost efficient. This is also true when complete restoration is weighed against partial restoration.

Data from the project also showed that for Hampton Nature Reserve mechanical restoration was about 30% more costly than manual restoration, and complete mechanical restoration the most costly technique of all.

However, cost-efficiency per unit of labour-time is much lower with manual restoration because slubbing is both very labour and time intensive; from our experience we would recommend hiring excavators for larger restoration projects. This may not always be feasible financially, but equally it may be impracticable for a volunteer team to complete such work. There are also non-efficiency measures for consideration; for example, machines may be favoured on health and safety grounds for restoring deep ponds or volunteers may be preferable where access is poor or the surrounding terrestrial habitat is of value.

The real complications in defining and measuring cost-effectiveness relate to the second part of the formula: effectiveness. Effectiveness is linked not to efficiency but to the results of the restoration work, i.e. which technique offers the best balance between positive and negative effects on the pond flora and fauna. Gains and losses following pond works can be measured objectively, but the most appropriate technique, in terms of its effects on a range of taxa, remains necessarily a subjective decision.

Furthermore, the measure of this effectiveness cannot be reduced simply to cost. For example, there are risks to wildlife associated with pond restoration, and especially with complete clearance; these risks are amplified if multiple ponds are completely restored at the same time - the most cost-efficient option. By contrast, implementing restoration on multiple ponds on a long rotation creates the widest range of succession stages, and as succession is likely to be slowest following complete restoration, this would enable a slower cycle and therefore lower costs.

Effectiveness will always be site-specific, weighing different interests against each other. On Hampton Nature Reserve the most effective technique for *Chara canescens* restoration, even taking into account impact on other taxa, is complete restoration. It is also feasible and cost efficient due to the large scale of the project.

Cost, cost-efficiency and cost-effectiveness must therefore rely on principles and surveys rather than simple formulae.
7. Dissemination of Results

The full report and associated appendices are available, as separate documents, to download (for free) from www.froglife.org/hnr/secondlifeforponds.

The complete invertebrate report *The effectiveness of different pond restoration techniques for aquatic invertebrates*, is also available in its entirety as a separate document from www.froglife.org/hnr/secondlifeforponds.

We will work with the following bodies in order to disseminate the findings of this study to other conservationists, land managers, scientists and specialists, for example:

- University of East Anglia
- Plantlife
- Buglife - The Invertebrate Conservation Trust
- Local, regional and national BAPs
- Cambridgeshire Conservation Forum and Oxfordshire Nature Conservation Forum
- Amphibian and Reptile Groups of the UK

A report will be uploaded onto www.ConservationEvidence.com for dissemination through the evidence-based conservation community.

Additionally Froglife will promote the project online through its website, blog and social media outlets, as well as face-to-face at public events, talks and through contact with other conservationists.

8. Acknowledgements

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