Water Germander *Teucrium scordium* L. in Cambridgeshire: back from the brink of extinction

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ABSTRACT

The indigenous distribution of Water Germander *Teucrium scordium,* an endangered Red Data species in Britain, has contracted to just three sites: two in dune slacks in North Devon and one in a disused flooded limestone quarry in Cambridgeshire. In at least two of these, it has been suffering a decline. At Kingfishers Bridge near Wicken in Cambridgeshire what appears to be a highly successful attempt to boost an ailing indigenous population has been undertaken by transplanting plants propagated vegetatively from the original site onto a nearby wetland created since 1995 on what was intensively farmed arable. The population has increased explosively from 1522 shoots on plants introduced in 1997–2000 to over 180,000 shoots in September 2004. The spread appears to be largely by fragile stolon fragments, sometimes broken from the parent plants by grazing geese, being distributed by water in winter and early spring. Optimal conditions for establishment are sparsely vegetated water margins exposed by summer draw-down. The water at Kingfishers Bridge is base-rich and generally of good quality. Water Germander does not thrive in the shade of dense reed, scrub and other tall vegetation, but can tolerate inundation by water and ice cover in winter. Reintroduction also seems to have been successfully achieved at Bassenhally, an indigenous Cambridgeshire site from which Water Germander disappeared soon after its discovery in 1967. Nearly 1700 shoots were counted there in 2004.

INTRODUCTION

Water Germander *Teucrium scordium* is a British Red Data plant, classed as endangered in the recently revised Red Data List (Cheffings & Farrell 2005). It is currently restricted as an indigenous species to three sites, though it does occur in Western Ireland. The British populations have not been flourishing in recent years. This paper describes what appears to be a successful attempt to increase the Cambridgeshire population of Water Germander at a wetland recently created from intensive arable farmland at Kingfishers Bridge, close to the only remaining indigenous site in East Anglia and at another Cambridgeshire location from which the species had recently become extinct. This species recovery project is part of a wider ecological restoration campaign in the Fenland basin to rehabilitate degraded wetlands and to create new wetlands where they have been destroyed (Colston 2003; Hughes *et al*. 2005; Mountford & Wadsworth 2002). New and rehabilitated wetlands should support, in a sustainable way, as full a range of taxa as possible that were present in Fenland prior to the era of intensive drainage. In the 21st century context of climate change and fragmented landscapes, such restoration cannot hope to create individual perfect facsimiles of previous habitats and species assemblages. However, restoration programmes such as that at Kingfishers Bridge seek to restore natural ecological processes rather than make constructed copies of past habitats and are the antithesis of the “gardening” that has occurred in some nature management (Tomkins 1998). The programme at Kingfishers Bridge has also led to various observations on the ecology of *Teucrium scordium* which help to confirm the causes of the demise of the species in Britain and also offer ways of boosting existing populations by management and restoring this attractive plant to other sites.

PAST DISTRIBUTION – BRITAIN AND IRELAND

Teucrium scordium has never been known to have other than a very localised distribution in Britain. Pre-1970 it had been recorded from 24 10km squares extending from North Devon (v.c. 4), Berkshire (v.c. 22), Oxfordshire (v.c. 23) to South Lincolnshire (v.c. 53), North Lincolnshire (v.c. 54), Southwest Yorkshire (v.c. 63) and Northwest Yorkshire (v.c. 65). The centre of distribution was the East Anglian Fens: Cambridgeshire (v.c. 29) and Huntingdonshire (v.c. 31). By 1960 it had become extinct in all but North Devon, Cambridgeshire and West Suffolk (Perring & Walters 1962, Wigginton 1999, Preston *et al.* 2002). It was last recorded in South Lincolnshire in 1952 (Gibbons 1975). There is a record from Lakenheath, West Suffolk in 1860 (Hind 1889). It was 'rediscovered' in Stallode Wash (Botany Bay), Lakenheath in 1976 by M. G. and S. Rutterford (Rutterford 1977), but had disappeared by 1979 (Simpson 1982) – see Figure 1. In 2004, *T. scordium* was discovered on Anglesey (v.c. 52) by Richard Birch, where a small patch was found in 2004 in the draw-down zone of a balancing pond. The provenance and status of this population is unknown (Ian Bonner, pers. comm.), and there are no historical records from Anglesey or from Wales.

In Cambridgeshire, pre-1860, *T. scordium* was known from several sites in the fens, including from what is now within the northern boundary of Cambridge City (King's Hedges and Histon Road), 'abundantly on the road to Ely', Roswell Pits, Ely and at Mepal. There were earlier records from Waterbeach and Cottenham which could not be confirmed (Babington 1860). By the publication of the last full Cambridgeshire flora (Perring *et al*. 1964), it had long become extinct at all these sites, evidently due to its intolerance of competition from tall vegetation. A population does persist in the North Pit, (TL544733) 2·5 km north of Upware on the River Cam and the same distance northwest of Wicken Fen. Moreover, in 1967, Water Germander was discovered by Frank Perring and Ian Hepburn at Bassenhally Pit (TL286986) 1 km northeast of Whittlesey and close to the Nene Washes. By 1970, it had disappeared from this site (Langton 1970), though material from Bassenhally was grown on in the University Botanic Garden, Cambridge.

In North Devon, Water Germander has been known since the end of the 18th century from Braunton Burrows (Polwhele 1797). It was locally abundant in the winter-flooded dune slacks well into the 20th century (Martin & Fraser 1939, Palmer 1946). In 1982 a survey by J. Vause, J. Breeds, J. Hope-Simpson and M Tulloh recorded 18,874 shoots at six sites on the Burrows (Vause 1982). In 1998 only 3951 shoots at two of these sites were found. However, four 'new' sub-populations containing about 6881 shoots were located, including one of 6604 shoots previously unknown. Excluding the latter, but taking into account all colonies known up to 1997, the 1998 survey revealed 4228 shoots, a 78% decline on the 1982 count (Holyoak 1998). In an attempt to reverse this decline, from 1998 the site managers began to mechanically surface-scrape dune slacks that had formerly supported *T. scordium*, leading to a substantial population recovery by 2005 (J. Diamond, pers. comm.).

A second North Devon location was discovered by Mr W. Tucker in 1976 at Northam Burrows on the opposite side of the Taw Estuary from Braunton, growing in a similar habitat (Ivimey-Cook 1984; Tucker 1978). A survey of Northam made by one of the authors of the present paper (JOM) with Mr Tucker (then North Devon B.S.B.I. recorder) in 1997 showed a small population of <500 shoots, having declined from the few thousand stems of the 1970s, probably due to vegetation succession within the dune slack (W. Tucker, pers. comm.).

The North Pit near Upware, Cambridgeshire Braunton Burrows and Northam Burrows currently all have SSSI status. The plant in Devon differs from that in Cambridgeshire in being very hairy and has been described as var. *dunense* Druce (P. Sell in press).

Teucrium scordium has been recorded from twelve 10 km squares in western Ireland since 1970 and since 1987 is known from 10 of these (Preston *et al.* 2002). It extended along the Shannon from Roosky (Leitrim v.c. H29) to Doonass (Limerick v.c. H8). It is still locally abundant on the calcareous shores of Lough Derg (Clare v.c. H9; and SE Galway v.c. H15) and Lough Ree (southeast Galway). There are isolated stations in North Tipperary, v.c. H10 and elsewhere in Clare (Praeger 1934, Webb 1977).

Water Germander occurred on Guernsey in the Channel Islands where it was last seen in

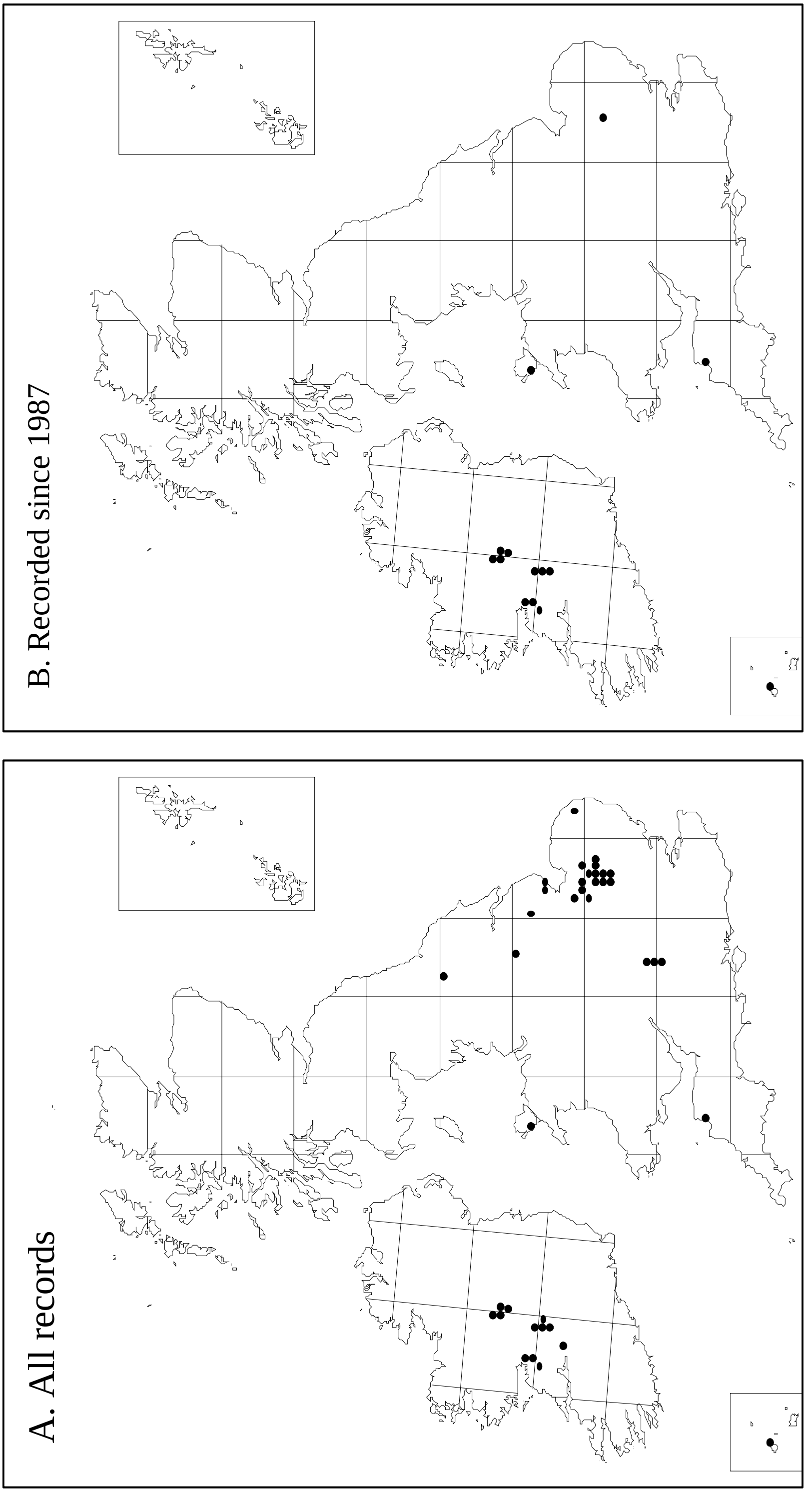

FIGURE 1. Distribution of *Teucrium scordium* L. in Britain and Ireland, showing:
A. All 10 km squares with which *T. scordium* has been recorded
B. 10 km squares where *T. scordium* has been recorded since 1987

TABLE 1. *TEUCRIUM SCORDIUM* SHOOT COUNTS CAMBRIDGESHIRE SITES 1997–2004

	1997	1998	1999	2000	2001	2002	2004	Total
North Pit (original, indigenous)	330	578	700	1200	558	600	214	
(introduced)		18*	2	8	4	3	0	
Cam Washes SSSI				599*	1294	156	0	
Wetland Creation Project (WCP) Kingfishers Bridge								
Fen (sites 1,2 & 10)		96*	72+110*	196+260*	1000	1500	338	
Reedbed (sites 3 & 4)		43*	72	69+800*	0+2330	2761	1125	
Lake (sites 7 & 8)		50*	86	423	520	3088	41,014	
Winter Flood (site 9)		24*	41+114*	165	1970	10,820	134,686	
Contour Ditch (site 5)		25*	39	119	130	2409	3595	
Big Ditch						323*	436	
Total shoots WCP			310	972	5950	20,578	181,194	
Total plants introduced		238*	224*	1060*	0	323*		1845
Bassenhally Pit (Whittlesey)			41*		96	30	1683	

(*Planted introductions)

TABLE 2. WATER GERMANDER *TEUCRIUM SCORDIUM* SHOOT DENSITY AND ASSOCIATED VEGETATION AT KINGFISHERS BRIDGE

	Teucrium shoot density	Associated vegetation height
	Mean/m^2	Mean cm
Kingfishers Bridge		
North Pit – indigenous (n = 2)	19	177·0 ± 30·9
Winter Flood N (n = 5)	457 ± 540	26·2 ± 13·3
(n = 4)	564 ± 557	21·9 ± 10·6
Winter Flood S (n = 5)	52 ± 95	24·1 ± 12·2
Lake shore draw down (n = 5)	45 ± 95	3·4 ± 3·3
Lake shore drift line (n = 5)	149 ± 99	30·8 ± 12·0
Reedbed/lagoon margin (n = 2)	368 ± 240	25·6 ± 12·5
Reedbed – tall & dense (n = 3)	192 ± 116	231·3 ± 26·7
Ditches (n = 6)	313 ± 230	37·5 ± 25·0
Bassenhally Pit		
Herb-rich fen		49·4 ± 29·2

1925 (McClintock 1975). The Guernsey plant was said to be referable to subsp. *scordioides* Rouy, which is the commonest form in coastal sites in southern Europe, including the Atlantic fringe and Mediterranean. A recent biometric study of *T. scordium* populations in northwest France and Brittany suggests that one population in dune slacks in Pas-de-Calais may be referable to subsp. *scordioides*, with other populations at the site appearing intermediate between subsp. *scordioides* and subsp. *scordium* (Toussaint *et al.* 2005).

BACKGROUND TO THE KINGFISHERS BRIDGE WETLAND CREATION PROJECT

Since 1970, attempts have been made to arrest the catastrophic decline of *T. scordium* through management of its remaining sites. By 1998, these attempts have met with some local success, but the area of remaining suitable habitat at North Pit (Upware) was tiny, both the Bassenhally and Stallode Wash populations had disappeared and in Devon, *T. scordium* was either declining (Northam Burrows) or with an uncertain future due to changes in the site's conservation status (Braunton Burrows). At a regional, national and international scale, it was becoming increasingly clear that nature conservation of small discrete sites through intensive management ("gardening") was becoming non-viable (Colston 2003) and that effective protection of nature had to not only conserve that which survived but pursue "creative conservation" i.e. ecological restoration (Sheail *et al.* 1997). The underlying philosophy behind the Kingfishers Bridge project is precisely this type of creative conservation and seeks to achieve a viable population of *T. scordium* in a large wetland site that itself forms part of a network of major restored wetlands around the southern margin of the Fenland basin.

The project is a private venture to restore a variety of semi-natural fenland habitats on land that was intensively farmed up to 1995. It lies close to the River Cam and is only 2·5 km from Wicken Fen, one of the oldest nature reserves, which is owned and managed by the National Trust. The project is the inspiration of Andrew Green who has dedicated 65 ha of his and his family's low-lying arable farmland to creating a nature reserve. Roger Beecroft (one of the authors of this paper) has provided major advisory and management input from the start of the project. The construction of the site has been described by Tomkins (1998).

Three types of soil are represented on the site: neutral fenland peat, Gault clay of marine origin and Corallian limestone. Most of the water originates as run-off from the land supplemented by some that is pumped from a neighbouring limestone quarry. It is both highly calcareous and of good quality. A small indigenous population of *Teucrium scordium* grows in a flooded long-abandoned limestone quarry close to the created wetland.

Five created habitats suitable for *T. scordium* at Kingfishers Bridge were well established by 2004:

- A 7·0 ha shallow lake of permanent water with eleven islands. In the summer there is considerable draw-down which exposes a sparsely vegetated shoreline;
- A 9·4 ha reed-swamp with pools of shallow water and stands of other marsh vegetation (the pools are subject to draw-down in summer);
- Seasonally flooded wet grassland in three areas which have shallow pools that remain well into the spring and which are grazed by sheep and wildfowl;
- Highly calcareous margins of two water-filled ditches;
- Two quarries specially excavated in Corallian limestone to provide nest-sites for Sand Martins (*Riparia riparia)* and Common Kingfishers (*Alcedo atthis*). Each quarry has a pool of clear water at the base of the excavated face.

RECORDING METHODS FOR *TEUCRIUM SCORDIUM*

As the species is a stoloniferous perennial, counting plants is impracticable, except for young ones occurring at a low density on bare ground. Following Holyoak (1998), counts of basal shoots made in late August or September were found to be a repeatable methodology allowing comparison of populations at different sites (Table 1). Mean shoot density per square metre was calculated by counting shoots in five 20 × 20 cm quadrats (sub-samples) nested within a 2 × 2 m quadrat. (Table 2). In all but the North Pit (indigenous population) and the Big Ditch (introduced) five 2 × 2 m quadrat samples were taken. The total shoot count was calculated either by counting shoots over the entire habitat (as in most instances) or where densities were particularly high over a sizeable area (as on the Winter Flood) by extrapolation from the mean density /m^2 × measured area.

The quadrat samples were also used to obtain cover/abundance estimates on a Domin scale for *Teucrium scordium* and associated plant species. Those species occurring in four or more of the sample quadrats in a habitat were treated as constants. One measurement of vegetation height was taken in each of the nested 20 × 20 cm sub-samples within the quadrats (Table 2). Distance from the nearest surface water was also measured as was the depth of 'soft' substrate (*i.e.* penetrable by a narrow pole). Each quadrat was located to a 10 figure grid reference by GPS.

POPULATION AND DISTRIBUTION OF WATER GERMANDER AT KINGFISHERS BRIDGE

A) INDIGENOUS POPULATION

T. scordium has long been known in the North Pit (often referred to as being at Upware though 2·5 km north of the village) at TL54367333. The population has been monitored irregularly in terms of percentage cover, but systematic recording (shoot counts) began in 1997 when R. Beecroft recorded 330 shoots. Cutting the Reed and other vegetation over all the area occupied by *T. scordium* resulted in an increase to 1200 shoots in 2000. Since then, vegetation cover has increased once more and water levels in the pit have risen. The shoot count diminished to 214 in 2004 and just 35 in 2006. The introduction in 1998 of a few propagated plants to a slightly different area within the pit had failed by 2004 (Table 1).

B) PROPAGATION

Cuttings from growing shoots were initially taken from the North Pit SSSI in 1997. Cuttings rooted easily with a success rate of almost 100%. The first batch of propagated plants was used as stock to provide more cuttings. Since there was no evident advantage from rooting in water first, subsequent cuttings were placed in compost from the outset. Propagation appeared to be a straightforward process and, once rooted, plants were kept in pots for about a year before being planted out.

C) PLANTING OUT

Initially 238 propagated plants were introduced to nine sites within the Kingfishers Bridge Wetland Creation Project area on 4th August 1998. Further introductions of propagated plants were made in 1999 (224 plants), 2000 (1060 plants) and 2003 (323 plants) – Table 1. The locations were chosen to give a range of hydrological conditions in an attempt to compare survival under different water regimes. Since it was difficult to identify individual plants once established, progress was measured by counting shoots in August and September.

D) INTRODUCTIONS

The propagated plants from North Pit stock were introduced to the Kingfishers Bridge Wetland Creation Project area as follows: the Fen, TL545738 (three sites); the Reedbed TL545739 (two sites); the south shore of the Lake TL540737 (two sites); the Winter Flood, TL541737 (one site) and two ditch banks, TL544736 and TL547733. A total of 1845 plants were introduced between 1998 and 2003. From 310 shoots on plants introduced in 1998, the count rose to 5950 by 2001, 20,578 by 2002 and in 2004 the number of shoots had soared to an estimated 181,000. The most marked increases were on the Winter Flood (from 165 shoots in 2000 to an estimated 135,000 in 2004) and the Lake, where plants had spread to all the shores and the seven islands (86 shoots in 2000 to 41,014 in 2004 including 11,060 on the islands). *T. scordium* has flourished and spread to a lesser degree on the banks of the two ditches (at one of them, 119 shoots in 2000 to 3595 in 2004). In the Fen and Reedbed, however, there was an increase up to 2002 but a subsequent marked decrease associated with development of a tall and dense reedbed that has invaded the Fen (Table 1).

An introduction was made in 2000 to the adjacent winter-flooded Dimmock's Cote Washes TL541727 (Cam Washes S.S.S.I.) following slubbing out of the channel and creation of open ground, in order to test establishment under a differing water-regime. The shoot count increased from 599 that year to 1294 in 2001, but by the following year few plants had survived and none was seen in 2004 (Table 1). It appears that the plants had failed to compete with robust Reed Sweet-grass *Glyceria maxima*. This site also lacks the summer draw-down present in Kingfishers Bridge.

HISTORY OF THE POPULATION AT BASSENHALLY PIT (WHITTLESEY)

In 1967 a small population (ca 20 plants) of *T. scordium* was found at Bassenhally Pit on bare mud by a path across a ditch (Crompton 2006). Following its disappearance by 1970, propagated plants from Bassenhally stock were reintroduced to the same location in 1973 by S. M. Walters, R. M. Payne and JOM. The population survived until at least 1975 but became increasingly etiolated and rarely if ever flowered (Crompton 2006; JOM records) it was not subsequently observed. This failure appeared to be due to the particular path having been abandoned and Hawthorn (*Crataegus monogyna*) scrub having grown up to shade the pit margin. By 1980 the original location appeared entirely unfavourable to Water Germander. A second introduction, this time from North Pit stock, was made in 1999 to a nearby herb-rich largely scrub-free fen, TL286987, known as the Central Depression (Langton 1970). Here where there are patches of relatively short vegetation, Water Germander had done well, and the count of 41 shoots introduced in 1999 had increased to 1683 by 2004 (Table 1).

HABITAT

I. KINGFISHERS BRIDGE AND UPWARE NORTH PIT

a) North Pit

The flooded North Pit, a long abandoned Corallian limestone quarry, supports the indigenous *T, scordium* population, which has been declining since 2000, possibly as a result of shading by taller vegetation and scrub that has invaded the pit, and variation in water quality and depth.

The vegetation of two 2 × 2 m quadrats in which *T. scordium* grows has been surveyed annually 1997–2004 with the exception of 2003. The *NVC* community of the site is Reed swamp (**S4**: Rodwell 1991–2000), and specifically the Marsh Bedstraw (*Galium palustre*) sub-community (**S4b**). Constants throughout the period have been *Phragmites australis, Galium palustre,* Great Pond Sedge (*Carex riparia*), Great Reedmace (*Typha latifolia*), Lesser Duckweed (*Lemna minor*) and the moss *Drepanocladus aduncus.* Lesser Water-parsnip (*Berula erecta*) and Great Water Dock (*Rumex hydrolapathum*) were constants in most years. Comparison with a survey made in 1989 (JOM and G. Crompton) suggests that Ivy-leaved Duckweed (*Lemna trisulca*) and Bittersweet (*Solanum dulcamara*) have both declined, the former markedly so. The overhanging scrub is composed mainly of Grey Sallow (*Salix cinerea*), Hawthorn (*Crataegus monogyna*) and Guelder-Rose (*Viburnum opulus*). In 2004 the reed stems were 'spindly' and growing at a rather low density, with a mean height of 177·0 ± 30·9 cm. The Reed swamp was floating and at the site where *T. scordium* was growing the water depth at the surface was 5–10cm with 30–40cm of silt below. *T. scordium* did not extend into the wetter and increasingly quaking swamp in the centre of the pit.

b) Reedbed and Fen

The Reedbed was established from what had been peaty arable land in 1997. *T. scordium* was introduced into the young reedbed first in 1998 and again in 2000. By 2004, a dense **S4** reed-swamp had developed with *Phragmites* of an average height (in September 2004) of 231·3 cm (n = 15). There was little other vegetation in the reedbed apart from *T. scordium*, which struggled to compete. Etiolated plants of *T. scordium* reached 180 cm in height, but had few if any flowers.

The Reedbed bordered a shallow lagoon, which by the end of the summer had an extensive draw-down zone of peaty mud colonised by Water Mint (*Mentha aquatica*), Amphibious Bistort (*Persicaria amphibia*), Creeping Bent (*Agrostis stolonifera*) and the moss *Drepanocladus aduncus* as well as sparse *Phragmites.* In 2004 *T. scordium* was flourishing in this open draw-down area between the reedbed and lagoon. The mean density there was 308 ± 240 shoots/m^2 compared with 192 ± 116 shoots/m^2 in the dense reedbed. Virtually all the Reedbed apart from embankments is submerged in shallow water over the winter. The Fen, on somewhat higher ground, had a vegetation community that was probably best described as **S26** tall herb fen *Phragmites australis–Urtica dioica* (Rodwell 1991–2000). Much of it has however converted to reed-swamp.

c) Winter Flood

This is an area of grassland bordering the Lake. Its depressions are shallowly flooded for much of the winter and spring. With a depth of only 5 cm of peat above the clay substrate, drainage was poor. In the northeast sector where *T. scordium* was particularly abundant, the constant plant species (forming over 50% cover in each sample) were *Persicaria amphibia, Mentha aquatica,* Whorled Mint (*Mentha x verticillata*), Gypsywort (*Lycopus europaeus*), Scentless Mayweed (*Tripleurospermum inodorum*), Great Plantain (*Plantago major*) and *Agrostis stolonifera.* Over an area of 0·13 ha *T. scordium* was one of the dominant species with an average density of 564 ± 557 shoots/m^2. However, where *Mentha aquatica* formed the predominant vegetation, *T. scordium* was sparse.

Further from the Lake, 150 m south of the main population, *T. scordium* was growing around depressions in the grassland that were permanently inundated between November and April/May, but only intermittently flooded by rain water at other times. Here the constants were *Agrostis stolonifera,* Common Spike-rush (*Eleocharis palustris*), Jointed Rush *(Juncus articulatus*) and *Plantago major.* The density of *T, scordium* was 52 ± 95 shoots/m^2, less than a tenth of that of the main population.

Such vegetation is not unequivocally classified in the *NVC*, but shows some allegiance to various kinds of regularly inundated grasslands within the alliance *Elymo-Rumicion crispi* e.g. **MG11** *Festuca rubra-Agrostis stolonifera-Potentilla anserina* grassland, **MG13** *Agrostis stolonifera-Alopecurus geniculatus* grassland and **OV28** *Agrostis stolonifera-Ranunculus repens* community (Rodwell 1991–2000).

d) The Lake

At its full extent there are 7 ha of water with eleven islands, some of which are submerged in winter. In summer a considerable area of peat and clay is exposed on the Lake shore and around the islands by draw-down. Such areas, including all the islands, have been extensively colonised by *T. scordium*. The main constants in the draw-down zone on the south shore were *Mentha aquatica*, Redshank (*Persicaria maculosa*), Hemp Agrimony (*Eupatorium cannabinum*), Brookweed *(Samolus valerandi*), Toad Rush (*Juncus bufonius*) and *Lycopus europaeus*. A number of annuals such as Red Goosefoot (*Chenopodium rubrum*) and Golden Dock (*Rumex maritimus*) were frequent. The average density of *T. scordium* was 45 ± 95 shoots/m^2 (n = 25), with 50–90% of the draw-down zone still bare peat. Many of the plants had only become established for a year or two.

At the winter/spring high water mark on the southern shore of the lake there was a 2 m wide drift line. This was totally vegetated, predominantly by *Lycopus europaeus, Mentha aquatica, Eupatorium cannabinum, Agrostis stolonifera, Persicaria amphibia, Samolus valerandi* and such annuals as *Persicaria maculosa* and Trifid Bur-marigold (*Bidens tripartita*). *T. scordium* here attained a mean density of 149 ± 99 shoots/m^2 (n = 25).

e) Ditches

T. scordium was introduced at two sites on the margins of ditches (Big Ditch and Contour Ditch). Here the substrate was highly calcareous clay. Where *Teucrium* was growing, the constants were *Agrostis stolonifera*, *Samolus valerandi*, *Plantago major* and *Eleocharis palustris*. The vegetation height in the sample plots varied between 11·4 cm and 78·.8 cm (n = 7). The *T. scordium* density was highly variable ranging from 35 to 520 shoots/ m^2 (n = 7).

II. BASSENHALLY PIT

Here the *T. scordium* occupied two distinct vegetation communities when surveyed in 2004. Where it had been reintroduced in 1999, *Agrostis stolonifera*, Brown Sedge (*Carex disticha*), Slender Spike-rush *(Eleocharis uniglumis*), *Galium palustre* and the moss *Drepanocladus aduncus* were dominant and the community was again best placed within the *Elymo-Rumicion crispi*. The presence in the site of *Eleocharis uniglumis, Juncus gerardii* and, in the second vegetation community, *Schoenoplectus tabernaemontani* suggested some brackish influence, and relationship to **SM20** *Eleocharis uniglumis* saltmarsh (Rodwell 1991–2000). The physiognomy of the vegetation has some resemblance to a dune-slack, and some areas resembled **SD17** *Potentilla anserina-Carex nigra* dune-slack, another component of the *Elymo-Rumicion crispi* alliance that is normally coastal in the UK (Rodwell 1991–2000). 329 shoots of *T. scordium* were counted in this zone.

T. scordium had also spread into taller vegetation in which Slender Tufted-sedge (*Carex acuta*) was predominant and included such species as Marsh Pennywort (*Hydrocotyle vulgaris*) and Grey Club-rush (*Schoenoplectus tabernaemontani*). Eighty percent of the population of *T. scordium* (1683 shoots) occupied this community which may prove to be a variant of **S6** *Carex riparia* swamp (Rodwell 1991–2000). The mean shoot height of *T. scordium* at Bassenhally was 38·7 ± 19·4 cm, while that of the surrounding vegetation was 49·4 ± 29·2 cm. The Central Depression at Bassenhally Pit is the most important part of a site with many species typical of herb-rich fen, including some locally scarce plants such as Great Water-parsnip (*Sium latifolium*), Marsh Speedwell (*Veronica scutellata*), Lesser Water-plantain (*Baldellia ranunculoides*), as well as *Eleocharis uniglumis*.

REPRODUCTION AND SPREAD: KINGFISHERS BRIDGE

T. scordium flowered prolifically in the more open areas at Kingfishers Bridge (Lake Shore, Winter Flood, the draw-down zone at the edge of the Reedbed and ditch margins). In the dense reedbed and in the North Pit where plants were shaded, flowering was largely suppressed. Many plants that had flowered on the Winter Flood were examined on 12 October 2004 – though abundant seed had been set with two to four nutlets per calyx, very few seeds had ripened by that date. At the time of the survey in mid-September 2004, there was little evidence of reproduction from seed, even on the bare peat of the Lake shore.

Most reproduction, at least at Kingfishers Bridge, appears to be vegetative from stolons that are produced in late summer and autumn. They differ from the erect flowering shoots in extending horizontally from the plant and are thickened, suggesting a storage function. In winter, stolon segments get detached from the parent plants *e.g.* by trampling and grazing by wildfowl – particularly Greylag Geese (*Anser anser*) and Canada Geese (*Branta canadensis*). Though sheep may trample and fragment *T. scordium* by trampling, they appear not to eat it, possibly because of its garlic-like odour[1].

[1]Both German vernacular names (Knoblauch-Gamaner and Lauch-Gamander) and the specific epithet *scordium* itself refer to garlic or leek.

Stolon fragments have been seen floating in flood water, even under ice. *T. scordium* had spread naturally from the original planting of 50 plants on the south central shore of the lake in 1998 right round the margin and to all eleven islands by 2004. In addition, a new colony appeared naturally on the east side of the Big Ditch opposite a planting on the west bank, 15 m across the water. On the Winter Flood even low raised banks 20–30 cm high have withheld the flow of winter flood water across the area and this has apparently limited the spread of *T. scordium* westward and southward. However, by 2005, plants had become established on a nearby, but discrete, winter-spring flooded area, in the Wader Meadow. This colonisation probably originated as a result of water being pumped onto the site from the Lake. By September 2006, there had been a further massive increase in the *T. scordium* cover, both around the Lake and on the sheep – and goose-grazed Winter Flood, where over an area of 0·58 ha it was dominant almost to the exclusion of other plants.

PRELIMINARY CONCLUSIONS ON THE ECOLOGY OF WATER GERMANDER IN CAMBRIDGESHIRE

The introduction of *T. scordium* has revealed or confirmed certain aspects in the ecology of the species (Hill *et al*. 1999):

- it flourishes in calcareous substrate – clays and peat (and calcareous sand in North Devon dunes) – the Ellenberg **R** indicator value is 8 i.e. moderately basic;
- it requires damp conditions and tolerates long periods of submergence in winter but quaking swamp conditions through the summer are detrimental – the Ellenberg **F** indicator value is 8 i.e. sites that are damp to seasonally wet;
- flowering is suppressed by shading, and though shoots become etiolated it appears that perennial plants are eventually out-competed by tall dense vegetation (such as Reed and scrub) and fail to reproduce vegetatively – the Ellenberg **L** indicator value is 7 i.e. preferring well-lit places, but will survive for a while in partial shade;
- the main form of reproduction in the studied sites is vegetative by stolons, which when detached can be dispersed widely by water;
- low banks that inhibit the flow of water can act as barriers to vegetative dispersal;
- optimal conditions for colonisation are the sparsely vegetated sites that are exposed on the margins of water bodies by summer draw-down.

ECOLOGY OF *TEUCRIUM SCORDIUM* IN NORTH DEVON

Most of the colonies of Water Germander in North Devon are in dune slacks that have, at least until recently, been regularly inundated by a water-table rise in winter. Inundation may continue well into the spring. Two of the sites were margins of artificial ponds. The large colonies were on predominantly level ground. The substrate on which *Teucrium* was growing was calcareous sand that was fairly humic (Holyoak 1998). Holyoak emphasised that Water Germander on the Burrows was associated with short vegetation, much of it less than 5 cm, and grew sparsely where vegetation exceeded 15 cm. It colonised temporarily disturbed ground after the excavation of ponds, and could tolerate some vehicle pressure leading to ruts. The short vegetation was being maintained by rabbit grazing and the poor nutrient status of the soil, together with winter flooding and near-drought conditions in summer.

A large number of plant species were associated with Water Germander in the Devon dune slacks. Most constant associates were *Agrostis stolonifera,* Bog Pimpernel (*Anagallis tenella*), Marsh Helleborine (*Epipactis palustris*)*, Hydrocotyle vulgaris,* Sharp Rush (*Juncus acutus*), Sea Rush (*Juncus maritimus*), *Mentha aquatica,* Silverweed (*Potentilla anserina*)*,* Common Fleabane (*Pulicaria dysenterica*) Creeping Willow (*Salix repens*) and the moss *Drepanocladus aduncus* (Holyoak 1998; unpublished data JOM). Such vegetation again approaches *NVC* communities of the *Elymo-Rumicion crispi* such as **MG11** and **SD17**, as well as other dune-slack types that are either more fenny *e.g.* **SD15** *Salix repens–Calliergon cuspidatum* or more scrub-dominated *e.g.* **SD16** *Salix repens-Holcus lanatus* (Rodwell 1991–2000).

Features similar to the Kingfishers Bridge site were:

- winter-spring flooding and tolerance of inundation;
- calcareous substrate with some shallow humic soil;
- short vegetation;

- colonisation of temporary disturbed ground; and
- frequent associated plants in all the Devon and Cambridgeshire sites were *Agrostis stolonifera, Mentha aquatica* and *Drepanocladus aduncus*. *Hydrocotyle vulgaris* occurred at Bassenhally and in the Devon slacks.

Major differences were:

- Braunton Burrows and, to a lesser extent, Northam Burrows are essentially natural; the Kingfishers Bridge wetland is recently created, even where the indigenous population of *T. scordium* still occurs is a disused quarry. Bassenhally Pit also is artificial, though like the North Pit, it has been abandoned for many decades;
- in Devon the main habitat is dune slack (to which the Bassenhally site bears some resemblance); at Kingfishers Bridge the species has flourished in the draw-down zone around a lake, reedbed lagoons and seasonally flooded grassland resulting from lowering water-table in summer;
- the substrate in Devon is humic sand; at the Fenland sites it is clay with some peat;
- on the Burrows species frequently associated with *T. scordium* included *Epipactis palustris, Potentilla anserina, Pulicaria dysenterica* and *Salix repens,* all of which were absent from sites where Water Germander occurred at Kingfishers Bridge. There *Persicaria amphibia, Lycopus europaeus, Plantago major* and *Samolus valerandi* were among the most frequent associates. A mixture of *Carex* species and submaritime *Cyperaceae* were especially common at Bassenhally;
- the areas where *T. scordium* still flourished at Braunton and Northam were heavily grazed by rabbits, which also browsed the margins of the Bassenhally site, while those at Kingfishers Bridge were grazed by sheep and feral geese.

REASONS FOR THE DECLINE IN THE UK

It should be acknowledged that, as a species of early successional habitats, *T. scordium* may always have been transient in individual sites, but able to maintain itself in a complex of sites within a region since, as one site became overgrown, suitable conditions developed elsewhere nearby. Insofar as the available literature can be used to reconstruct its distribution through the past 250 years, there is evidence that *T. scordium* indeed survived for many decades in particular regions, though "monitoring data" for particular populations were only gathered from the latter part of the 20th century onward.

The main reasons for the disappearance of Water Germander from most of its British sites were probably drainage and land claim. However, within those sites that survived into the modern era, it appears that competition and shading from tall wetland vegetation are the main factors in its decline (Perring *et al*. 1964). Thus at Stallode Wash at Lakenheath, its demise was almost certainly as a result of being unable to compete with tall vigorous *Phragmites australis* (Wigginton 1999). Indeed surveys made of the former Lakenheath site in the 1990s showed almost 100% cover of dense Reed, with canes reaching >2·5 m tall (JOM unpublished data). Its decline and lack of vigour at North Pit, Upware appears to be due to shading by scrub, though higher water levels may have contributed leading to extensive quaking swamp. Poorer water quality may also be a factor, with turbid water during winter floods preventing growth – witness the contemporary decline of *Lemna trisulca* at Upware. The fact that the indigenous population at Bassenhally Pit died out and that the first reintroduction was unsuccessful was almost certainly also due to scrub encroachment and the end of light trampling at that particular location within the pit. Both in Britain and Ireland, the most vigorous *T. scordium* populations have occurred where there is light disturbance, through trampling, peat cutting or regular draw-down. In the Reedbed at Kingfishers Bridge *T. scordium* still survives, but is unlikely to persist for long in the dense vegetation. The failure of the introduction at Dimmock's Cote is also linked to a highly competitive grass (*Glyceria maxima*).

At Braunton Burrows the decline is attributable to a falling water table and scrub encroachment in the dune slacks. Holyoak (1998) states that the vegetation had grown markedly taller between the 1982 and 1998 surveys. At a few sites where Water Germander was still flourishing the vegetation was kept short by rabbit grazing. Remedial conservation action at Braunton in 1998 has met with early success, and by 2004 *T. scordium* had re-appeared in seven of the eight dune-slacks where the surface has been mechanically scraped (J. Diamond, pers. comm.). This recovery appears to be due both to reduced competition from *Salix repens*, *Juncus acutus* etc., and also to bringing the sand surface where *T. scordium* is rooted closer to the underlying water-table.

Attention must also focus on the regeneration niche for *T. scordium*, and whether the species reproduces primarily from seed, or vegetatively. Data on seed productivity and viability come from collections of *T. scordium* held in the Royal Botanic Gardens Kew's Millennium Seed Bank at Wakehurst Place. From this source it is clear that *T. scordium* may produce very little viable seed in the wild, with collections from British populations varying from a maximum of 40 viable seeds per plant (i.e. 40 plants producing around 1600 seeds) to as little as 1 viable seed per plant (i.e. 12 plants producing an overall total of just 12 viable seeds). When wild material is grown on in horticultural conditions, productivity may be much higher, with the total seed-output of 40 plants varying from 1350 to ca 51000 seeds. A very small trail conducted within the present study is consistent with these results. Seeds collected from North Pit were sown to check viability, and only one seed germinated from twelve sown in March onto saturated compost and kept in a poly-tunnel. Taken together these observations strongly suggest that vegetative reproduction will be more important than establishment from seed in wild British populations; and may provide further explanation of why *T. scordium* has not re-established when previous sites have been subject to apparently suitable restoration management.

THE CAMBRIDGESHIRE SITES IN A EUROPEAN CONTEXT

According to Clapham *et al*. (1987), *T. scordium* is confined to a) Europe from Sweden, notably Öland and Gotland (Hultén 1950) and Estonia southwards and b) to West Siberia and the Aral-Caspian region. Hultén and Fries (1986) essentially confirm this distribution, showing it to be uncommon throughout its range but with concentrations locally in Germany, the Caucasus and former Yugoslavia. Hultén and Fries also suggest that *T. scordium* subsp. *scordioides* is largely confined to the Mediterranean zone, the Black Sea and Caucasus and the Aral-Caspian, although other sources (e.g. McClintock 1975) indicate that this subspecies is found as far north as the English Channel. The southern limits of its native distribution appear to be in Morocco (seemingly absent elsewhere in Africa), Malta (where it is endangered) Lebanon, Israel, northern Iran and Uzbekistan. Recent national distribution maps for countries in Central Europe indicate that *T. scordium* is most commonly associated with the floodplains of major rivers, and there is a suggestion that it has declined sharply in the former Federal Republic of Germany and Switzerland, whilst remaining locally frequent in the former Democratic Republic (Haeupler & Schönfelder 1989; Lauber & Wagner 2002; Benkert *et al.* 1998). Elsewhere in central and northern Europe, *T. scordium* is threatened in the Czech Republic, and endangered in both Latvia and Lithuania.

Though in Britain, *T. scordium* is at the edge of its distribution in Europe, some insight into its ecological requirements and causes of decline can be inferred from its behaviour elsewhere. In Ireland and the Netherlands, it is a typical species of the phytosociological alliance *Elymo-Rumicion crispi* (Nordhagen 1940), occurring in flooded swards (Westhoff & den Held 1969; White & Doyle 1982). Such vegetation is typical of seasonally inundated situations (including dune-slacks, lake banks and depressions where rain-water collects) with a marked summer to autumn draw-down leaving expanses of moist habitat with relatively low cover, and hence little competition. Although widespread in Europe, typically such vegetation occurs in more humid climates and where the site is liable to disturbance or intensive grazing, suppressing shade and maintaining open soil areas. The *Elymo-Rumicion* is classified by EUNIS/ CORINE as **37·24** Flood Swards and Related Communities. *Agrostis stolonifera* is the characteristic grass in such communities (Ellenberg 1988). Examination of the **SOPHY** data base shows that in France *T. scordium* is mostly lowland or coastal and that amongst its usual associates (or species with markedly similar ecological requirements) are: *Eleocharis palustris,* Purple Loosestrife (*Lythrum salicaria*), *Mentha aquatica*, *Persicaria amphibia*, *Potentilla anserina* and *Sium latifolium*. Several of these are important species in the Cambridgeshire sites for *T. scordium*. Interestingly, two other species cited by **SOPHY** as having a similar ecology to *T. scordium* are Ribbon-leaved Water-plantain (*Alisma gramineum*) and Fen Ragwort (*Senecio* *paludosus*), both extremely rare in Britain, typical of draw-down habitats, and with all or most of their recent sites within the Fenland basin.

Within central Europe, *T. scordium* apparently occurs in more closed fen habitats dominated by large sedges (*Magnocaricion*) or in fen-meadows of the *Molinietalia* (Oberdorfer 1977–1983). Both these vegetation groups are often associated with the *Elymo-Rumicion* at the same sites i.e. the large sedge communities occurring where disturbance/grazing is reduced and the fen-meadow where flooding is less prolonged and regular, and where mowing is often combined with grazing to suppress shrub-encroachment.

Further south in Europe, *T. s. scordium* is often replaced by *T. s. scordioides*, though both subspecies occur in România and France, for example. Within this region, Water Germander is still largely confined to seasonally wet habitats, often on somewhat calcareous sands in the coastal zone e.g. in Greece and România (JOM unpublished data). Many of the associated species in such habitats are once again draw-down specialists, including several that are extremely rare in the UK e.g. Brown Galingale (*Cyperus fuscus*) and Jersey Cudweed (*Gnaphalium luteo-album*), as well as widespread species like *Samolus valerandi* and dominant *Agrostis stolonifera*. In some sites near its southern limit of distribution, *T. s. scordioides* is found in more closed vegetation e.g. Mediterranean tall humid grasslands of the *Molinio-Holoschoenion*.

CONSERVATION OF *TEUCRIUM SCORDIUM* IN BRITAIN

When the success of the Kingfishers Bridge project is assessed in the context of what is known of the ecology of Water Germander, it is clear that the Fenland sites where *T. scordium* survived into the 20th century were in many respects becoming unsuitable. The evidence from the literature is that these habitats were suitable until possibly the middle of the century, when the reduced disturbance and grazing of wetlands, coupled to drainage and regulation of water-levels resulted in the relict sites becoming overgrown with shrubs and tall reeds (Crompton 2006; Perring *et al*. 1964). What evidence can be marshalled from the Devon sites suggests that falling water-tables and scrub encroachment were again major factors. Those healthy populations of this species observed by JOM in Ireland and mainland Europe are frequently in early successional habitats that share natural summer draw-down with low competition, often facilitated by grazing in lowland calcareous situations.

It is apparent that the managers at Kingfishers Bridge have produced precisely these conditions in the early years of the wetland creation project. The continued success of the *T. scordium* introduction scheme at Kingfishers Bridge requires that these conditions be maintained through periodically renewed disturbance. Changes in *T. scordium* abundance in the reed swamp at Kingfishers Bridge and recent history at Bassenhally and Braunton strongly suggests that intervention is necessary to prevent succession eliminating suitable conditions. So long as *T. scordium* and similar draw-down specialists are confined to a few British sites, some interventionist management may be the only way to assure their survival, though the Kingfishers Bridge project offers the possibility of engineering new sites and introduction of propagules as a practical means to widely disperse these plants through the landscape. However, creation of several large restored wetlands in proximity to one another offers a more sustainable future. Kingfishers Bridge forms part of a new network of wetlands in Fenland that should be sufficiently large and intrinsically diverse for natural ecosystem processes to ensure that early successional stages are always represented somewhere within a dynamic range of habitats.

There is evidence that *T. scordium* occurs in rather different habitats in different parts of its range, possibly reflecting genetic differences. Biometric studies of the British and Irish populations, similar to those conducted by Toussaint *et al.* (2005), might help tailor management prescriptions to the needs of the local populations. There is concern that both the re-introduced Cambridgeshire populations derived from vegetative propagation will have low genetic diversity. Further research is thus required on the relative contributions of sexual and vegetative reproduction (including seed dormancy) in British, Irish and Continental populations of *T. scordium*, and the precise conditions required for seed germination and seedling establishment. However, results from the Millennium Seed Bank (R.B.G. Kew at Wakehurst Place) suggest that establishment from seed is much less important that vegetative reproduction in Britain. Evidence from site management in the 1990s at both North Pit (Upware) and Bassenhally suggests that *T. scordium* does not reappear from dormant seed if suitable conditions for its growth are re-established. Our work with *T. scordium* together with the 6 wetland restoration schemes in Fenland offers realistic hope for building a sustainable mosaic of wetland habitats in Fenland, but still leaves some questions unanswered.

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