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Ribbon-leaved water-plantain *Alisma gramineuem* Lejeune: A review of conservation work carried out under English Nature's Species Recovery Programme and the UK Biodiversity Action Plan, 1991-2005

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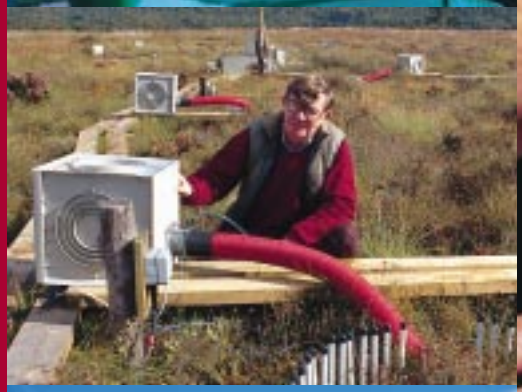

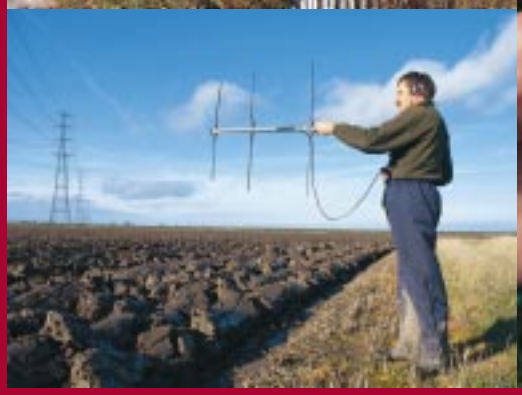

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Cover note

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Preface

Ribbon-leaved water-plantain *Alisma gramineum* is regarded as Critically Endangered in Britain (Cheffings & Farrell 2005). In 1991 English Nature launched its Species Recovery Programme, which included action to conserve *Alisma gramineum*. The objectives of the three-year programme on this species were to:

- maintain a strong population of at least 200 plants at the remaining site in Worcestershire;
- analyse water quality conditions at the Worcestershire site;
- plant out and provide the most suitable conditions possible for self-sustaining populations of at least 50 individuals at or as near as possible to two former sites in Cambridgeshire and Lincolnshire.

The Institute of Terrestrial Ecology (ITE), Monks Wood, was contracted by English Nature to undertake research on *Alisma gramineum*. Three annual reports on this work were submitted (Wells and others 1992, 1993, 1994).

Alisma gramineum is a priority species under the UK Biodiversity Action Plan (BAP). In 1995 a Species Action Plan for this plant was published (UK Biodiversity Steering Group 1995), with English Nature and the Environment Agency being joint Lead Partners. The Species Action Plan superseded English Nature's Species Recovery Programme, and from 1998 work on this species has been co-funded by the Environment Agency.

Further work on *Alisma gramineum* was carried out by Dr. Terry Wells from 1996 to 1999, as an independent contractor to English Nature (Wells 1997, 1998, 1999, 2000). The focus of investigations changed over the years, as understanding of the plant's ecology developed and experimental introduction to new sites was carried out. The objectives of the work in 1999 (Wells 2000) included:

- monitoring existing populations at the original site in Worcestershire and at introduction sites in Lincolnshire and Cambridgeshire;
- surveying a site in Lincolnshire where the species had been recorded;
- growing plants for introducing to new sites.

On Terry Wells' retirement from the project at the end of 1999, a contract was issued by English Nature to Tim Pankhurst and Richard Lansdown to continue the work under the banner of the UK BAP. The new set of objectives (Pankhurst & Lansdown 2000) were to:

- maintain and enhance known populations of *Alisma gramineum* in the UK;
- seek to locate more semi-natural populations of the plant in the UK;
- locate three suitable introduction sites with a view to establishing new populations;
- establish and maintain a reserve population in appropriate form for the purposes of introductions and for experimental study;
- facilitate the secure identification of the species by the botanical community;

- compile an ecological profile from at least thirty natural or semi-natural sites in Europe through correspondence followed by field survey in collaboration with local botanists.

These contractors produced annual progress reports covering the work from 2000 to 2004 (Pankhurst 2001, 2003, 2004, 2005), also a draft ecological profile of *Alisma gramineum* (Pankhurst & Lansdown 2004).

The current Species Action Plan for *Alisma gramineum* is given as Annex 1. The targets, adjusted following the 2001 BAP Targets Review, are to:

- maintain all known populations in a viable state;
- restore the species to three formerly occupied sites by the year 2005.

This review of the work on *Alisma gramineum* carried out under English Nature's Species Recovery Programme and the UK BAP, covers the period from 1991 to 2005. It is a collation and summary of information contained in contract reports produced by ITE, Terry Wells and Tim Pankhurst. In addition, it draws on the draft ecological profile of the species produced by Tim Pankhurst and Richard Lansdown. The review also includes information obtained from site managers in English Nature and the Welland and Nene Internal Drainage Board.

Acknowledgements

The information collated in this review was produced by the Monks Wood team (T.C.E. Wells, C.D. Preston, R. Cox, J.M. Croft, A. Frost and D. Barratt) who worked on the Species Recovery Programme and by subsequent contactors (Terry Wells, Tim Pankhurst and Richard Lansdown). I am particularly grateful to Terry Wells and Tim Pankhurst for providing copies of their reports and answering queries.

I would like to thank Hilary Ward, Jonathan Graham and Dawn Isaac, of English Nature, for answering queries about SSSIs, also Stan Pywell, of the Welland and Deepings Internal Drainage Board, for supplying me with information about the management of drainage channels. Henry Arnold provided me with records and a distribution map from the Biological Records Centre, Monks Wood. Janet Terry, Royal Botanic Gardens, Kew, kindly sent me a report produced from the Millennium Seed Bank database, giving details of the holding of *Alisma gramineum* seed. Chris Gerrard, Owen Mountford and Mark Tarttelin provided information on fen restoration projects in Cambridgeshire and Lincolnshire.

I am grateful to Jill Sutcliffe, of English Nature, for giving me the opportunity to produce this review and for supervising the contract.

Summary

Ribbon-leaved water-plantain *Alisma gramineum* is Critically Endangered in Britain and is threatened over much of its European range. It is a priority species under the UK Biodiversity Action Plan. Current targets for the species are to maintain all known UK populations in a viable state and to restore the species to three formerly occupied sites by 2005. This review summarises the work carried out on *Alisma gramineum* in the period 1991 to 2005, under English Nature's Species Recovery Programme and the UK Biodiversity Action Plan. The main sources of information were contract reports produced by the Institute of Terrestrial Ecology, Terry Wells, Tim Pankhurst and Richard Lansdown.

Alisma gramineum is sporadic in occurrence and its population size fluctuates widely. It has long been known at Westwood Great Pool, Worcestershire, and is still present there. After an absence of many years, it reappeared briefly in 1991 and 1992 in a newly-dredged drain that flows into the River Glen, Lincolnshire. *Alisma gramineum* has also been recorded from the River Glen itself and other associated drainage channels, a drain in Cambridgeshire and a mere in the Norfolk Breckland, but there have been no recent records from these sites. The species is believed to have declined as a result of competition from more vigorous plants, eutrophication of water bodies and unsuitable site management.

Previous locations in Britain for *Alisma gramineum* were searched to see if the plant had reappeared and were assessed for their suitability as translocation sites. Plants were introduced to two of these sites, but in each case they persisted for only two years. Reserve cultivated populations have been established and seed from the UK population is stored in the Millennium Seed Bank, Royal Botanic Gardens, Kew.

The following are key findings from the ecological research on *Alisma gramineum.*

- The species is a poor competitor and needs open areas in which to become established.
- Seed only germinates when the pericarp is removed or decays and the seed coat is punctured. Disturbance of the substrate by animals, flooding or human activity may trigger the germination of dormant seed.
- It is possible that long-lived submerged populations may act as sources, replenishing or replacing the more vulnerable emergent stands with germinands produced from cleistogamous flowers.
- When water bodies are drawn down, the plant adopts a marginal growth form, enabling cross-pollination and rejuvenation of populations to occur.
- On the European mainland, dynamic metapopulations occur where there are complexes of suitable sites linked by factors such as seasonal hydrological events, animal movement or common management practice, which facilitate dispersal of propagules.

In the absence of natural processes that create bare substrate, management of lakes and watercourses is required to provide suitable conditions for *Alisma gramineum.* Options include creating marginal scrapes, regularly de-silting drainage ditches, allowing poaching by stock and manipulating water levels. The long-term survival of metapopulations of *Alisma*

gramineum in the UK may depend on restoring mobile wetland systems such as those currently proposed for large areas of the Cambridgeshire fens.

Suggestions are made for the future direction of work on *Alisma gramineum*.

Contents

1 Morphology, identification, taxonomy and genetics

1.1 Morphology and identification

Alisma gramineum is a perennial aquatic herb with three morphologically distinct forms. Small, mainly submerged plants have translucent, narrow, linear leaves up to 25 centimetres in length, often partly floating on the surface of the water. Larger submerged specimens resemble the tops of pineapple plants because they have rosettes of thick leaves. Mature marginal and terrestrial plants have erect, aerial, lanceolate leaves, and those in shallow water may also have submerged ones. Flowers can be produced both under and above the water, on terminal inflorescences consisting of a series of whorled branches, each branchlet bearing a single, white to mauve, three-petalled flower.

Separation of *Alisma gramineum* from water-plantain *Alisma plantago-aquatica* and narrow-leaved water-plantain *Alisma lanceolatum*, can only be done with certainty through examination of the fruit. In *Alisma gramineum* the fruit is widest in the upper half and the strongly recurved style arises in its upper half (Stace 1991).

1.2 Taxonomic considerations

Alisma gramineum belongs to the family Alismataceae, of which the genera *Alisma*, *Damasonium, Baldellia* and *Sagittaria* occur in the UK. The only other members of the genus *Alisma* native to Britain are water-plantain *Alisma plantago-aquatica* and narrow-leaved water-plantain *Alisma lanceolatum*, both common species. There has been some confusion in the past over the taxonomy and identification of *Alisma gramineum.* Synonyms by which *Alisma gramineum* Lejeune 1811 has been known are:

A. gramineum Lej. ssp. *gramineum* Tournay *et* Lawalrée 1949
A. plantago γ *angustissima* DC 1815
A. gramineum Gmelin var. *angustissimum* Hendricks 1958
A. angustifolium J.Presl *ex* Opiz 1823
A. graminea Gmelin 1826
A. loeslii Gorski 1830
A. geyeri Torrey 1843
A. gramineum Gmelin var. *geyeri* Sam. 1932
A. longifolium J. Presl 1847
A. arcuatum Michalet 1854
A. validum Greene 1896
A. plantago-aquatica ssp. *arcuatum* Ascherson *et* Graebner f. *angustissimum* Ascherson *et* Graebner 1897
A. gramineum Gmelin ssp. *arcuatum* Hyl. 1945
A. plantago-aquatica ssp. *arcuatum* Ascherson *et* Graebner f. *aestuosum* Ascherson *et* Graebner 1897
A. submersum Adamov 1924

Records exist for two 'sub-species', *Alisma gramineum* ssp. *gramineum* and *Alisma gramineum* ssp. *wahlenbergii,* from Norfolk (Swann 1975). Neither taxon has been recorded there since 1972 and the record of *Alisma gramineum* ssp. *wahlenbergii* has not been substantiated. This taxon is now considered to be a separate species, *Alisma wahlenbergii*, which appears to be endemic to the northern Baltic (Björkvist 1968).

1.3 Genetic implications

The genus *Alisma* is isolated from other members of the Alismataceae by a sterility barrier. Hybrids between *Alisma gramineum* and other members of this genus are unknown in the wild, unlike *Alisma plantago-aquatica* and *Alisma lanceolatum*, which do hybridise (Preston & Croft 1997). *Alisma gramineum* is diploid (2n = 14). Pankhurst & Lansdown (2004) point out that submerged plants of *Alisma gramineum* can propagate vegetatively and are probably largely autogamous, so these stands may be clonal. Cross-pollination occurs frequently in plants in marginal situations that produce aerial inflorescences, so their seed will show genetic variation.

2 Distribution and current status

2.1 World

Alisma gramineum has a circumboreal distribution. The main range covers the cold temperate latitudes of Europe, Asia and North America (Björkqvist 1967). There are also records from warm temperate areas of the western USA and North Africa. The species is threatened in Russia but is common in some states of the USA and Canada.

2.2 Europe

The species is widespread in Europe but it is threatened over a large part of its range (Table 1).

Table 1 European countries in which *Alisma gramineum* occurs, with current status

Country	**Status** (Pankhurst & Lansdown 2004)
Austria	Critically Endangered
Belgium	Critically Endangered to Vulnerable
Czech Republic	declining
Denmark	Extinct in the Wild but rediscovered 2000
Estonia	no information
France	no IUCN status; protected by law
Germany	no IUCN status
Hungary	no information
Italy	no information
Latvia	Critically Endangered/Endangered
Lithuania	Critically Endangered/Endangered
Moldova	Vulnerable
Netherlands	common
Poland	rare
Slovakia	no information
Sweden	Extinct in the Wild but suspected still extant
Switzerland	Critically Endangered/Endangered
UK	Critically Endangered, protected by law

2.3 United Kingdom

Since 1990, *Alisma gramineum* has occurred as a native in only two 10 x 10 kilometre squares in Britain. In Westwood Great Pool, a shallow (maximum depth 5.5.metres) artificial lake in Worcestershire, it has been known since 1920 (Wigginton 1999) and has been recorded in many years up to the present time. Here, it grows both submerged in the open water and as an emergent in the reedswamp.

In 1955 the plant was found in a five kilometre stretch of the River Glen, south Lincolnshire, and in nearby drainage channels. It was recorded again in that vicinity in 1970. In 1991 it was rediscovered in Blue Gowt Drain, which is connected to the River Glen downstream of Spalding, during a search of the area by the ITE team (Wells and others 1992). *Alisma gramineum* was still present in Blue Gowt Drain in 1992, but has not been found there since.

Alisma gramineum was recorded in Vermuyden's Drain (Forty Foot Drain), near the Ouse Washes, Cambridgeshire, in 1972 (specimen in Norwich Museum) and the species was seen there again later in the 1970s, but has not been found since. In 1972 it was recorded from Langmere, in the Norfolk Breckland, but there are no subsequent records for this site. Because of difficulties in taxonomy and identification, information on historic distribution is likely to be incomplete.

Native records for *Alisma gramineum* held in the Biological Records Centre are given as Table 2. There is an additional record around 1987 for Northumberland, believed to be a planting into the wild. Under the Biodiversity Action Plan programme the plant has been introduced to two other sites (see Section 7.2.3).

Table 2 A summary of records for *Alisma gramineum* held in the Biological Records Centre, Monks Wood (native occurrences only)

County (and vice-county number)	Site and 10 km square	Years of records			
		Pre-1951	1951-1970	1971-1990	1991-2005
Cambridge-shire (vc. 29)	Welches Dam, Forty Foot Drain TL48			1972 1976	
Norfolk (vc. 28)	Langmere TL98			1972	
Lincolnshire (vc. 53)	Blue Gowt Drain, Surfleet TF22		1955		1991 1992
	Clink's Drain, Surfleet TF22		1955		
	River Glen, Surfleet TF22		1955		
	Vernatt's Drain, Surfleet TF22		1955 1970		
Worcestershire (vc. 37)	Westwood Great Pool SO86	1939 1949	1950+ 1953 1956 1970	1980 1985 1987+ 1989	1991 1992 1993
	Near Westwood Great Pool SO86			1990	

Figure 1 illustrates the distribution of the species in the UK. The map was produced by the Biological Records Centre, CEH Monks Wood, using Dr Alan Morton's DMAP software, from records compiled by the Botanical Society of the British Isles.

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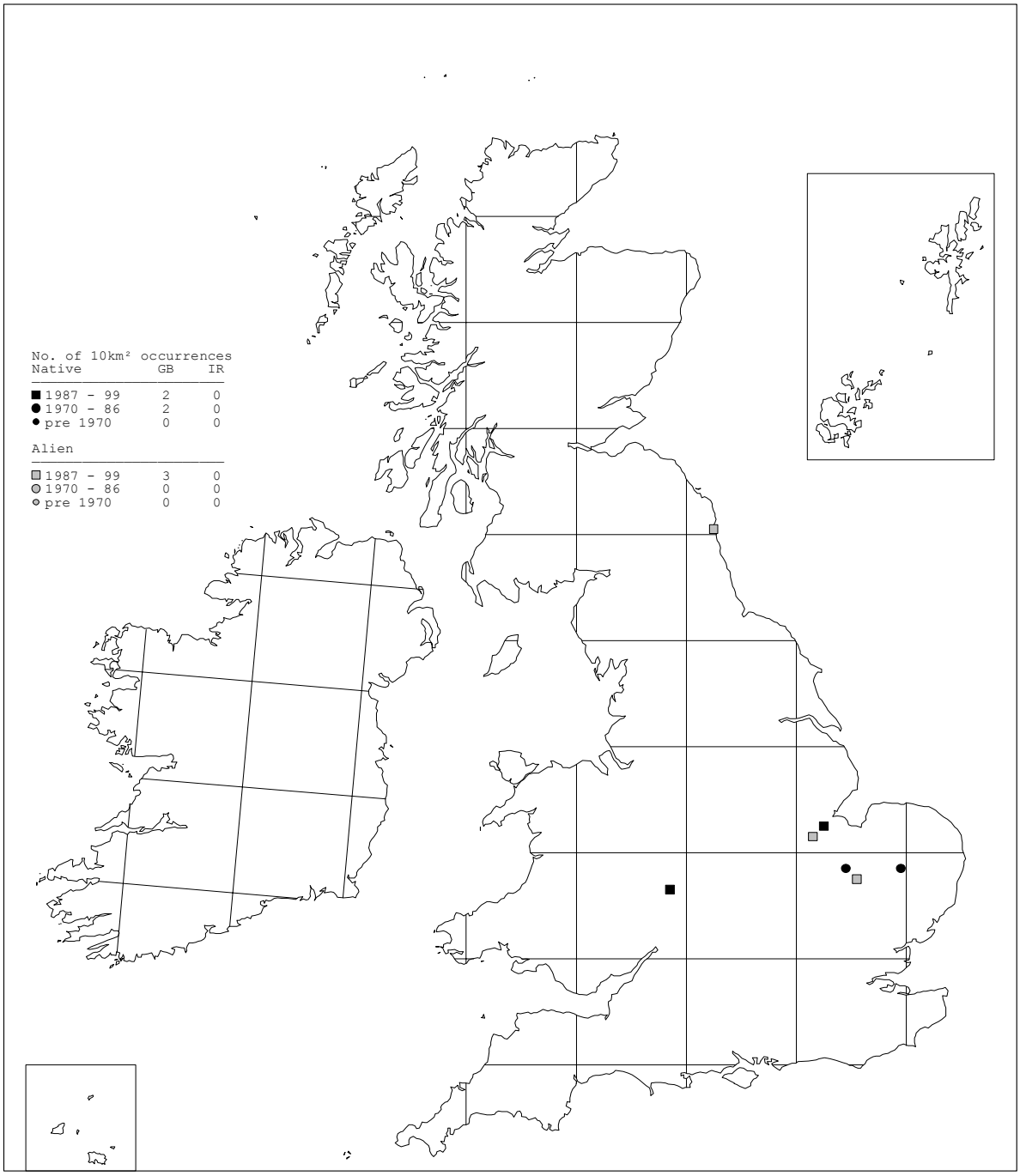

Figure 1 The UK distribution of *Alisma gramineum*

3 Ecology and life cycle

Alisma gramineum grows submerged in shallow or deep water, as an emergent, or as a terrestrial plant in muddy situations. In Britain it behaves as an annual or a perennial. It reproduces vegetatively and over-winters by producing basal turions. Its flowers are self-fertile, but the aerial inflorescences of marginal and terrestrial plants bear flowers that can be cross-pollinated by insects. Cleistogamous flowers develop under water and set seed (Preston & Croft 1997), but there is no definite evidence that seed produced in this way is fertile (Pankhurst pers. com.). Pankhurst and Lansdown (2004) observed that flowers sometimes open under water, so some cross-pollination may occur. It is thought that the seed is long-lived. *Alisma gramineum* produces very much less seed than *Alisma plantago-aquatica.* Pankhurst & Lansdown (2004) estimated that in the UK *Alisma gramineum* produces an average of 1,520 fruits per inflorescence, whereas *Alisma plantago-aquatica* produces an average of around 25,000.

Wells and others (1992) found that in cultivation seeds germinated when both the pericarp and testa were penetrated. Repeated wetting and drying of the seed may help to break down the pericarp and allow germination. Pankhurst & Lansdown (2004) observed germination in tanks outdoors from January to May. Earliest germination occurred immediately on thawing in frozen tanks, which is consistent with *Alisma gramineum* being a boreal species. Seeds may germinate while still attached to the parent plant. Germinands are buoyant and float on the surface of the water, to be dispersed by wind, currents or possibly by waterfowl and other animals. Wells and others (1992) postulated that the three morphologically distinct forms of the plant probably represent successive stages in development. However, the form of the plant may also reflect the depth of the water in which it is growing.

The species is notable for its sporadic appearance, and population size can fluctuate widely from one year to another. The plant has a number of reproductive strategies (Pankhurst & Lansdown 2004) defined as annual out-breeding, perennial out-breeding and perennial inbreeding. Pankhurst and Lansdown suggest that long-lived, deeply submerged populations may act as sources, which, if they produce fertile seed, replenish or replace the more vulnerable emergent stands within dispersal range with germinands.

4 Habitat requirements

4.1 The landscape perspective

The occurrence of *Alisma gramineum* at new sites in Britain has been attributed to dispersal by birds (Swann 1975). Its apparent re-appearance after long absence at some locations has led to the conclusion that the seed is long-lived and may form a persistent seed-bank (Wells and others 1992). However, such records may represent dispersal from an extant population. In mainland Europe, where processes allow dispersal of propagules in large, active river systems, the species occurs widely in suitable habitats connected to these river systems. In Germany (Sebald and others 1998) the Bodensee, a large sub-alpine lake, supports a substantial submerged population of *Alisma gramineum*. It seems likely that this population feeds the whole downstream Rhine system with propagules.

Pankhurst & Lansdown (2004) postulated that *Alisma gramineum* thrives on the Continent where there are dynamic metapopulations made up of discrete populations separated by unsuitable habitat, but between which there is reliable genetic exchange. Such metapopulation dynamics tend to occur in places where there are complexes of suitable sites linked by factors such as seasonal hydrological events, animal movement or common management practice. When water bodies are drawn down, the plant adopts a marginal growth form, enabling cross-pollination to occur. Draw-down zones are accessible to animals such as wild boar *Sus scrofa*, which may act as agents of dispersal. Disturbance of the substrate by animals, flooding or human activity may trigger the germination of dormant seed and facilitate further cross-pollination and rejuvenation of populations. Populations that are permanently submerged may be prone to inbreeding depression. These observations indicate the importance of active river processes for the conservation of *Alisma gramineum.*

4.2 Communities and vegetation

Alisma gramineum thrives best in open situations. The marginal form tends to succumb to competition by tall emergent vegetation, while young submerged plants often die as a result of smothering by filamentous algae or diatoms. Marginal plants quickly die if the mud dries out completely, so fluctuating water levels are beneficial.

Pankhurst & Lansdown (2004) collated and analysed (using TWINSPAN software) 100 vegetation samples containing *Alisma gramineum* from the UK and mainland Europe. The analysis showed that while *Alisma gramineum* occurs in association with a great many species, it has no faithful associates. It occupies in a wide range of freshwater and slightly saline habitats where an opportunity is provided by open areas and a lack of competition. The main habitats and National Vegetation Classification communities (Rodwell 1995, 2000) in which it occurs are listed below.

- Base-rich waters with some nutrient enrichment; mineral substrates; vegetation dominated by aquatic species; charophytes constant, generally *Chara contraria.* The aquatic element is closest to **A11a: *Potamogeton pectinatus-Myriophyllum spicatum*: *Potamogeton pusillus*** subcommunity. At Westwood Great Pool the emergent vegetation is closest to **S26: *Phragmites australis-Urtica dioica*** tall herb fen and **S12: *Typha latifolia*** swamp.
- Species-rich calcareous ditch vegetation with a mixture of aquatic, emergent and marginal species, plus some of open/disturbed terrestrial habitats; some nutrient enrichment; soils vary. *Spirodela polyrhiza* is constant, usually with *Elodea nuttallii, Lemna gibba/minor* and *Lemna trisulca.* The aquatic vegetation is closest to **A3: *Spirodela polyrhiza-Hydrocharis morsus-ranae***.
- Vegetation of periodically inundated, mineral or peaty soils affected by disturbance, particularly poaching by stock; few obligate aquatic species; *Agrostis stolonifera* constant, usually with *Plantago major.* Closest to **OV28a: *Agrostis stolonifera-Ranunculus repens*: *Polygonum hydropiper-Rorippa sylvestris*** sub-community.
- Seasonally inundated, low, marginal vegetation on exposed but undisturbed muds and fine sands; few obligate aquatic species; two of *Mentha aquatica, Myosotis scorpioides* or *Butomus umbellatus* dominant. Affinities with **OV31: *Rorippa palustris-Filaginella uliginosa*** community, with **OV28** and other more grassy vegetation types.

4.3 Summary of habitat requirements

The habitat requirements of *Alisma gramineum* are summarised in Table 3.

Table 3 Habitat features important to *Alisma gramineum*

Type	Description
Physical and topographical	Lowland (and sub-alpine in mainland Europe). Standing and flowing waters, including natural and artificial lakes, drainage ditches and rivers. Mineral (usually clay) or peaty soils.
Vegetational and structural	No constant associates; in the UK and in mainland Europe allied to various NVC communities. As a submergent in: A11a: *Potamogeton pectinatus-Myriophyllum spicatum*: *Potamogeton pusillus* or A3: *Spirodela polyrhiza-Hydrocharis morsus-ranae.* As an emergent: OV28a: *Agrostis stolonifera-Ranunculus repens*: *Polygonum hydropiper-Rorippa sylvestris* OV31: *Rorippa palustris-Filaginella uliginosa*. S26: *Phragnites australis-Urtica dioica* tall herb fen S12: *Typha latifolia* swamp. Open water, shallow water margins and wet soil are used by different morphological forms of the species. *Alisma gramineum* thrives best where there is bare substrate.
Processes	Seed may be long-lived. Young submerged plants are susceptible to algal blooms. Marginal plants are susceptible to competition from tall vegetation so thrive early in the hydrosere. Complete drying out of margins kills terrestrial plants, but the species thrives in waters with fluctuating levels. The species probably thrives best where there are dynamic metapopulations linked by seasonal hydrological events, animal movement or common management practice; active river processes create such conditions. Draw-down creates bare areas and encourages flowering and cross-pollination in marginal stands, leading to maintenance of genetic diversity.
Chemical	Base-rich waters. Some nutrient enrichment and salinity are tolerated, but young submerged plants are susceptible to eutrophication.

5 Threats / factors leading to loss or decline or limiting recovery

Shortage of appropriate habitat is not the main reason for the rarity of *Alisma gramineum* in the UK. A fundamental reason may be that populations are very isolated and dynamic meta-populations are seldom established. Other reasons for its decline and its loss from some sites are thought to be:

- competition from more vigorous emergent and submerged species;
- eutrophication of water bodies and associated algal growth;
- habitat destruction (eg reinforcement of banks of the River Glen).

6 Management implications

In the absence of natural processes that create bare substrate, active management of lakes and watercourses is needed in order to maintain existing populations of *Alisma gramineum* and to trigger germination of dormant seed. Options include making scrapes in reedswamp, frequent and extensive de-silting of drainage ditches, allowing poaching of water margins by stock, manipulating water levels to provide for occasional draw-down or flooding, and even rotavating the dry bed of drawn-down water bodies.

Although *Alisma gramineum* is moderately tolerant of enrichment, some deeply submerged plants in Westwood Great Pool appear to have been killed by the effects of algal blooms, probably through reduction in light levels. Improvement of water quality is therefore desirable.

Enhancing the connectivity of suitable habitats (e.g. through returning rivers to their natural hydrological regime) and coordinating management processes (e.g. routine drainage ditch clearance) would facilitate the spread of propagules and the formation of metapopulations.

7 Conservation measures

7.1 *In situ* measures

7.1.1 Legislation

Alisma gramineum has been listed under Schedule 8 of Part I of the Wildlife and Countryside Act 1981 (as amended) since 1981.

Westwood Great Pool, near Droitwich, Worcestershire, where the plant still survives, is scheduled as a Site of Special Scientific Interest (SSSI). A management agreement with the owner is currently in operation for the site. Langmere, in the Norfolk Breckland, where dormant seed of *Alisma gramineum* may remain, lies within an SSSI and a Special Area of Conservation (SAC) under the EC Habitats Directive. A section of the River Glen is included within Baston and Thurlby Fens SSSI (see Section 7.2.3), but Blue Gowt Drain, where there have been more recent records of *Alisma gramineum*, is not designated. Vermuyden's Drain is adjacent to the Ouse Washes SSSI, which is an SAC and a Special Protection Area (SPA)

under the EC Birds Directive. Some of the old records for the plant may be from ditches within the Ouse Washes site itself (Jonathan Graham pers com.).

7.1.2 Management of Westwood Great Pool

Westwood Great Pool is a dammed ornamental lake, about 24 hectares in extent and up to 5.5. metres deep, fringed by well developed reedswamp and woodland. It was constructed several hundred years ago and is now important for its wildfowl populations. In the past the Pool was drained and treated with rotenone. It is now used occasionally for water skiing (by one boat at a time) and fishing. It was stocked with rainbow trout in 2002.

There are regular, dense planktonic algal blooms towards the end of the summer, although the water is clear early in the season. Chemical analysis of water samples taken in October 1993 gave a total phosphorus concentration of 105 micrograms per litre (Carvalho & Moss 1998), which indicates artificial enrichment. Large colonies of the blue-green alga *Microcystis aeruginosa* were present in 1993. The source of the excessive nutrients was thought to be agricultural pollution, entering either as direct run-off from neighbouring fields or via groundwater. There has also been a suggestion that Westwood Great Pool may receive contamination from brine beds in the Droitwich area.

The dam, which leaked and allowed marked fluctuations in water level, was repaired in the late 1990s. The Environment Agency has installed a water level data logger. Owners of farmland bordering the SSSI agreed to FWAG preparing a nutrient budget for the land in 2004 and, although the land is still arable, high input sugar beet production has ceased.

In 1996 two scrapes were created in the reedswamp, to produce open areas for the benefit of *Alisma gramineum.* A floating boom was installed to catch flotsam produced by water skiing and to reduce wave action. Close mesh fences were erected in front of the scrapes in 1999, to exclude fish. In 2004 the boom and fencing were removed and vegetation in the area between and around the scrapes was taken out to extend the area of potential habitat for the plant.

7.1.3 Management of Blue Gowt Drain

Blue Gowt Drain, near Spalding, Lincolnshire, is a wide channel about 3500 metres long, outfalling to the River Glen just north of Spalding. It receives pumped runoff water at its head at Pinchbeck, but also backflow from the River Glen when water levels are low as a result of abstraction in the summer. The drain is about 2.5 metres deep from bank top to bed, with steep banks and a bed of clay and silt. The water level is maintained at a depth of 1 to 1.5 metres. The surrounding land is largely arable, but there is a golf course bordering one side of the drain near its confluence with the river. In places the drain is cut through the remains of Roman salterns (Stan Pywell, Welland and Deeping Internal Drainage Board, pers. com.). The River Glen in this vicinity has been reinforced with concrete blocks and stone and no longer provides a suitable habitat for *Alisma gramineum*.

Vegetation in the ditch is cut annually ('roding'). After an interval of ten years, the whole drain was desilted ('slubbed') in the winter of 1990/1991. 30 to 40 cm of sediment was removed, down to a firm substrate. *Alisma gramineum* appeared spontaneously later in 1991 and persisted into 1992. The drain was not slubbed again until March 2005, when 800 metres upstream of the River Glen were desilted, after consultation with English Nature. It is planned to clear the next 1200 metres upstream in 2006 and to tackle the remaining section

up to Pinchbeck in 2007 (Stan Pywell, pers. com.). The aim is to disturb the sediment, in the hope of triggering germination of any remaining dormant seed, and to provide the bare substrate that the plant requires in its subsequent development.

7.1.4 Management at Langmere

Langmere is a naturally fluctuating water body, fed from the chalk aquifer in the Norfolk Breckland. It is a Norfolk Wildlife Trust nature reserve. Although *Alisma gramineum* has not been recorded there since 1972, there is a possibility that dormant seed may remain in the bed of the mere. In an attempt to restore a population of the plant, a strip of the bed of Langmere was rotavated in 2001, during a dry phase, but no seedlings subsequently appeared.

7.2 *Ex-situ* measures

7.2.1 *Ex situ* cultivation and seed preservation

Plants were successfully cultivated in open-air tanks by the contractors, using seed from Westwood Great Pool and Blue Gowt Drain. Reserve populations were still flourishing in 2005 at Monks Wood, near Huntingdon, and in Tim Pankhurst's garden, at Leighton Bromswold, Cambridgeshire. In 1998 a commercial water lily grower in Skegness was provided with seedlings, to establish a further reserve population. This grower has since moved on and the fate of the plants is unknown.

In 1991, seed of *Alisma gramineum* from Westwood Great Pool was deposited in the seed bank held at Wakehurst Place by the Royal Botanic Gardens, Kew.

7.2.2 Germination experiments

Germination experiments were carried out at ITE Monks Wood between 1991 and 1993 on seed taken from plants at Westwood Great Pool. The main findings were that:

- removal of the pericarp and puncture of the testa are essential for germination;
- drying of germinating seeds for up to five days does not kill the seedlings.

7.2.3 Introductions to the wild

Extensive survey was carried out to decide on the most suitable places for introduction/re-introduction of *Alisma gramineum*. The following two introduction sites were finally chosen.

Baston Fen, south Lincolnshire

This site is a Lincolnshire Wildlife Trust Reserve adjacent to the River Glen, forming part of Baston and Thurlby Fens SSSI. The reserve consists of a series of 'washes' that are flooded in winter and grazed by cattle in summer. A shallow pond with a clay and peat bed, which had been cleaned out by a drag-line early in 1996, was chosen as a suitable area for the introduction. In July 1996 eleven two-year-old plants, grown from seed originating from Blue Gowt Drain, were planted in this pond in water about 30 centimetres deep (Wells 1997). The plants were in flower at the time.

Kingfisher Bridge, near Wicken, Cambridgeshire

This site is on private farmland in which an extensive wetland, including areas of open water, has been recreated beside the River Cam. In 1998 twelve two-year-old plants, grown from seed originating from Westwood Great Pool, were planted in 20 centimetres of water at the edge of a lake at Kingfisher Bridge (Wells 1999). Most of the plants were flowering when introduced.

7.3 Monitoring

7.3.1 Native sites

The presence of *Alisma gramineum* at Westwood Great Pool was noted by a number of observers between 1920 and 1950. Population size was assessed on numerous occasions between 1955 and 1990. Plants were counted by the contractors throughout the period of the Recovery Programme. The data given in Table 4 indicate marked fluctuations in the number of plants visible.

After the scrapes had been made in the reedswamp in 1996, some germination of *Alisma gramineum* seed occurred, but the overall population of the species at Westwood Great Pool increased very little. It was thought that most of the young plants that germinated were eaten by fish or geese.

Forty plants of *Alisma gramineum* were counted in Blue Gowt Drain in 1991, following slubbing. Six plants were found in 1992 but none has been seen since, despite a number of searches. Viable seed may still be present.

Between 2000 and 2005 *Alisma gramineum* was searched for in and near its former sites in the River Glen, Vermuyden's Drain and the Norfolk Breckland, without success.

Table 4 Summary of population size records of *Alisma gramineum* in Westwood Great Pool

Year	Population size (plants counted)	Comments
1920	Present	No quantitative data (source Wells, 2000)
1930	Present	No quantitative data (source Wells, 2000)
1932	Present	No quantitative data (source Wells, 2000)
1939	Present	No quantitative data. Recorder R.C.L. Burges (Wells 2000)
1948	Present	No quantitative data. Recorder F. Gibbons (source Wells 2000)
1950	Present	No quantitative data. Recorder J.J. Day (source Wells 2000)
1955	>100	Recorder R.C.L. Burges (source: Wells 2000)
1970	>20	Recorder F. Fincher (source: Wells 2000)
1982	0	Source: Wells (1997)
1983	0	Source: Wells (1997)
1984	0	Source: Wells (1997)
1985	44	35 plants were seedlings. Recorder P. Wilson (Wells 2000)
1988	4	Recorder J.J. Day (source: Wells 2000)
1989	59	Recorder J.J. Day (source: Wells 2000)
1990	0	Source Wells (1997)

Year	Population size (plants counted)	Comments
1991	216	Some young plants. Recorders ITE and J.J. Day (Wells and others 1992)
1992	13	Recorders ITE (Wells and others 1993). Water level low.
1993	21	Recorders ITE (Wells and others 1994). 1 plant tagged in 1991 had survived.
1994	-	No information
1995	0	Survey by ITE (Wells 1997)
1996	0	Site surveyed but no plants found (Wells 1997). Water level high.
1997	2	2 plants found in scrapes made in 1996. Water level low. (Wells 1998)
1998	1	Plant found in scrape had disappeared by July (Wells 1999)
1999	0	Site surveyed but no plants found (Wells 2000)
2000	c.140?	6 marginal and c.130 submerged *Alisma* plants; identification as *A. gramineum* unconfirmed (Tim Pankhurst).
2001	-	No visits because of foot and mouth disease
2002	0	Site surveyed but no plants found (Tim Pankhurst).
2003	0	Pool drawn down; much exposed mud (Tim Pankhurst)
2004	c.200	All plants submerged; many flowering (Tim Pankhurst).
2005	c.200	Some plants flowering; all plants submerged. Little regrowth of vegetation in scrape (Tim Pankhurst).

7.3.2 Introduction sites

After the 1996 introduction of 11 plants to Baston Fen, the population increased temporarily. In 1997, 16 plants were recorded, 12 of which had big inflorescences and produced a large quantity of seed. Disappointingly, no plants were found there in 1998 or in subsequent years.

Of the 12 plants introduced to Kingfisher Bridge in 1998, three survived until 1999 and at least two flowered. None has been seen there since. Plans to re-introduce *Alisma gramineum* to this site in 2004 were forestalled because the plants being cultivated for this purpose all died.

7.4 Investigations abroad

In 1992 members of the ITE team visited six sites in the Netherlands and two in Germany to investigate habitats for *Alisma gramineum.* The sites included lakes, ditches and a backwater of the Rhine. Their observations were as follows:

- the species is rare, appears sporadically and is probably declining in mainland Europe;
- it has been lost from many ditches in the Netherlands, probably as a result of eutrophication;
- some degree of disturbance is favourable;
- the plant establishes in open habitats and cannot grow where competition from other marginal or submerged species is strong;
- where pressure from competition is weak, plants are large, producing up to six inflorescences and 10,000 seeds per plant.

In 2001 Tim Pankhurst and Richard Lansdown visited France, Germany, the Netherlands, Austria and Switzerland, and met in the field with 28 local botanists familiar with *Alisma*

gramineum. The visitors examined a variety of aquatic habitats and even located a stand of about 2,000,000 *Alisma gramineum* plants in a field that had been cultivated for maize the previous year but which had subsequently been flooded, producing a large area of wet bare mud. In the Czech Republic and France some ponds supporting *Alisma gramineum* are known to be drawn down as part of traditional management cycles (Pankhurst and Lansdown 2004) and one of the former UK sites for the species, Langmere, in Norfolk, has been cultivated during dry periods.

The experience gained from the visit to Europe, together with a literature search covering the USA, Canada, Sweden, Finland, Poland, France, Germany and the Netherlands, was used in the production of an ecological profile of the plant (Pankhurst and Lansdown 2004).

Overall conclusions on habitat requirements are detailed in Section 4. As was pointed out in section 4.1, on the European mainland dynamic metapopulations of *Alisma gramineum* occur where there are complexes of standing and flowing water sites linked by factors such as seasonal hydrological events, animal movement or common management practice that allow dispersal of propagules. Pankhurst and Lansdown suggest that reservoirs of submerged populations may feed downstream areas with propagules. In draw-down zones the plant adopts a marginal form with aerial flowers that can be cross pollinated, thus rejuvenating the population through genetic exchange. Active river processes are therefore of great importance for the long-term survival of *Alisma gramineum* in mainland Europe.

8 Review of progress and suggestions for future work

Progress has been made towards the first target of the Species Action Plan, to maintain the known population in a viable state. At Westwood Great Pool the species continues to survive in the face of competition from algal blooms and reedswamp vegetation, but the population that reappeared spontaneously in Lincolnshire in the 1990s seems to have been ephemeral. The second target, to restore the species to three formerly occupied sites by the year 2005, was not met because the attempted translocations failed.

Suggestions for future work on *Alisma gramineum* are listed below.

- Continue to maintain, enhance and monitor the extant native population at Westwood Great Pool.
- Investigate the source of enrichment at Westwood Great Pool and find out whether the water is slightly saline.
- Install a water control structure at Westwood Great Pool and allow water levels to fluctuate seasonally, with the aim of revitalising the marginal population.
- Continue surveillance of former sites to see whether *Alisma gramineum* reappears.
- Where feasible, attempt reintroduction to historic sites with suitable habitat.
- Continue ecological research on reproduction and growth. In particular, determine whether seed produced by submerged flowers is viable and capable of producing floating germinands.
- Create an experimental area where the reproductive behaviour of an introduced population can be studied to elucidate the respective roles of submerged and marginal elements of the population. In particular, seek evidence to establish whether or not the presence of submerged plants is essential for the long-term survival of the marginal

element of the population. The experimental area could act as a source of material for any future introduction programmes.

Studies of *Alisma gramineum* in mainland European suggest that the long-term survival of the species in the UK may be dependent on restoring more mobile river systems, together with associated networks of floodplain water bodies. In the foreseeable future, climate change and sea level rise, together with a growing interest in wetland restoration schemes, could transform large parts of the East Anglian fens. This may provide the conditions needed for the long-term survival of *Alisma gramineum.* Two long-term projects in Cambridgeshire, the Great Fen Project (Anon 2005) and a proposed expansion of Wicken Fen (Colston & Friday 1999), aim to restore large wetland complexes with near-natural flooding regimes. The Great Fen Project is an ambitious plan to revert 3700 hectares of arable Cambridgeshire fenland to pre-drainage condition, thus linking Woodwalton Fen with Holme Fen and providing extensive fen habitat devoted to wildlife conservation. The National Trust has an equally ambitious plan to extend fen habitat at Wicken up to 4000 hectares. The Baston and Thurlby Fens Restoration Project, a smaller-scale initiative by the Lincolnshire Wildlife Trust, aims to provide 800 hectares of fen habitat, with the existing 57 hectare SSSI at its core (Mark Tarttelin, pers. com.). The potential for introducing and conserving *Alisma gramineum* should be borne in mind during the development of these projects.

Alisma gramineum will continue to be extremely vulnerable in this country if it is confined to a single site. The mystery remains as to why Westwood Great Pool, an apparently unsuitable site outside the main historic range, continues to be the only remaining UK stronghold of this species.

9 Links

Local Biodiversity Action Plans that include action plans for *Alisma gramineum* are those for Cambridgeshire, Lincolnshire and Norfolk.

Progress on UK Biodiversity Action Plan targets, as reported in the UK BAP 2002 reporting round, can be viewed online at: http://www.ukbap.org.uk/2002OnlineReport/mainframe.htm.

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Annex 1 Current UK Biodiversity Action Plan for ribbon-leaved water-plantain *Alisma gramineum*

Downloaded from http://www.ukbap.org.uk

Current status

This short-lived perennial aquatic is now confined to two sites in the UK: a shallow lake in Worcestershire, where it has been known for many years, and a drainage channel in Lincolnshire, where it was rediscovered in 1991 after a 20 year absence from the site. It was formerly recorded from two other sites in Norfolk and Cambridgeshire in the 1970s, but has disappeared from both sites. This aquatic plantain is rare and sporadic in mainland Europe, where it is probably declining. Populations fluctuate markedly from year to year, but the reasons are largely unknown.

The plant is currently protected by Schedule 8 of the WCA.

Current factors causing loss or decline

Eutrophication of water bodies and associated algal growth.

Competition from coarse marginal and aquatic species.

Current action

The Worcestershire site is an SSSI, with a management agreement currently in operation.

This species is the subject of an English Nature Species Recovery Programme project, which includes investigating the feasibility of re-introducing the plant to the former sites in Cambridgeshire and Norfolk.

Objectives and targets

Maintain all known populations in a viable state.

Restore to three formerly occupied sites by the year 2005.

Proposed actions with lead agencies

Policy and legislation

Identify water quality requirements which will maintain population levels at all known sites, and use these as a basis for setting standards. (ACTION: English Nature, JNCC, NRA).

Use identified water quality requirements for setting standards and monitoring.

Site safeguard and management

Ensure appropriate management of water bodies containing this species. (ACTION: English Nature).

Identify the habitat requirements of this species through research. (ACTION: English Nature).

Institute suitable management practices to ensure continued survival of existing and re-introduced populations.

Species management and protection

Collect and deposit seed in the National Seed Bank at Wakehurst Place. (ACTION: English Nature, JNCC, RBG Kew).

Encourage keeping plants in cultivation to provide plants for re-introduction and establish substantial seed production capacity. (ACTION: English Nature).

Encourage regeneration from the natural seed bank at former sites, if conditions still remain suitable. (ACTION: English Nature, JNCC).

Continue to investigate the feasibility of re-introducing plants to suitable sites, if natural regeneration falls, once they can be propagated.

Advisory

Ensure that relevant landowners and local authorities are aware of the presence of this species, the legal protection afforded it, and appropriate methods of management. (ACTION: English Nature).

Future research and monitoring

Investigate the source of enrichment at the Worcestershire site. (ACTION: English Nature, JNCC, NRA).

Survey former sites to see whether any suitable habitat remains and attempt natural regeneration or reintroduction where feasible. (ACTION: English Nature, JNCC).

Promote ecological research on this species to identify optimum conditions for growth and reproduction. (ACTION: English Nature, JNCC).

Encourage research on the ecology and conservation of this species on a international level, including the reasons for its decline and distribution, and use the information and expertise gained towards its conservation in the UK. (ACTION: English Nature, JNCC).

Pass information gathered during survey and monitoring of this species to JNCC or BRC so that it can be incorporated in national databases. (ACTION: English Nature).

Provide information annually to the World Conservation Monitoring Centre on the UK status of the species, to contribute to maintenance of an up-to-date global Red Data List. (ACTION: JNCC).

Communications and publicity

None proposed.

Links with other action plans

None given.

Lead partners

Environment Agency and English Nature.

ENGLISH NATURE

Research Information Note

English Nature Research Reports, No. 675

Ribbon-leaved water-plantain *Alisma gramineum* Lejeune: a review of conservation work carried out under English Nature's Species Recovery Programme and the UK Biodiversity Action Plan, 1991 to 2005

Report Authors: edited by Margaret A Palmer Date: November 2005
Keywords: ribbon-leaved water-plantain, SRP, review

Introduction

This review of the work on *Alisma gramineum* carried out under English Nature's Species Recovery Programme and the UK BAP, covers the period from 1991 to 2005. It is a collation and summary of information contained in contract reports produced by ITE, Terry Wells and Tim Pankhurst. In addition, it draws on the draft ecological profile of the species produced by Tim Pankhurst and Richard Lansdown. The review also includes information obtained from site managers in English Nature and the Welland and Nene Internal Drainage Board.

What was done

Ribbon-leaved water-plantain *Alisma gramineum* is Critically Endangered in Britain and is threatened over much of its European range. It is a priority species under the UK Biodiversity Action Plan. Current targets for the species are to maintain all known UK populations in a viable state and to restore the species to three formerly occupied sites by 2005. This review summarises the work carried out on *Alisma gramineum* in the period 1991 to 2005, under English Nature's Species Recovery Programme and the UK Biodiversity Action Plan. The main sources of information were contract reports produced by the Institute of Terrestrial Ecology, Terry Wells, Tim Pankhurst and Richard Lansdown.

Alisma gramineum is sporadic in occurrence and its population size fluctuates widely. It has long been known at Westwood Great Pool, Worcestershire, and is still present there. After an absence of many years, it reappeared briefly in 1991 and 1992 in a newly-dredged drain that flows into the River Glen, Lincolnshire. *Alisma gramineum* has also been recorded from the River Glen itself and other associated drainage channels, a drain in Cambridgeshire and a mere in the Norfolk Breckland, but there have been no recent records from these sites. The species is believed to have declined as a result of competition from more vigorous plants, eutrophication of water bodies and unsuitable site management.

Previous locations in Britain for *Alisma gramineum* were searched to see if the plant had reappeared and were assessed for their suitability as translocation sites. Plants were introduced to two of these sites, but in each case they persisted for only two years. Reserve cultivated populations have been established and seed from the UK population is stored in the Millennium Seed Bank, Royal Botanic Gardens, Kew.

Continued……

Results and conclusions

The following are key findings from the ecological research on *Alisma gramineum*.

- The species is a poor competitor and needs open areas in which to become established.
- Seed only germinates when the pericarp is removed or decays and the seed coat is punctured. Disturbance of the substrate by animals, flooding or human activity may trigger the germination of dormant seed.
- It is possible that long-lived submerged populations may act as sources, replenishing or replacing the more vulnerable emergent stands with germinands produced from cleistogamous flowers.
- When water bodies are drawn down, the plant adopts a marginal growth form, enabling cross-pollination and rejuvenation of populations to occur.
- On the European mainland, dynamic metapopulations occur where there are complexes of suitable sites linked by factors such as seasonal hydrological events, animal movement or common management practice, which facilitate dispersal of propagules.

In the absence of natural processes that create bare substrate, management of lakes and watercourses is required to provide suitable conditions for *Alisma gramineum*. Options include creating marginal scrapes, regularly de-silting drainage ditches, allowing poaching by stock and manipulating water levels. The long-term survival of metapopulations of Alisma gramineum in the UK may depend on restoring mobile wetland systems such as those currently proposed for large areas of the Cambridgeshire fens.

Suggestions are made for the future direction of work on *Alisma gramineum.*

English Nature's viewpoint

English Nature is committed to the conservation of this rare speceis which features among the top 5 English priorities but recognises that the conditions requried to retain this plant are moving water rather than the static conditions in which it occurs and and this needs to be investigated further. Excellent summary of work undertaken, results and directions for future work.

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Top left: Using a home-made moth trap.
Peter Wakely/English Nature 17,396
Middle left: Co_2 experiment at Roudsea Wood and Mosses NNR, Lancashire.
Peter Wakely/English Nature 21,792
Bottom left: Radio tracking a hare on Pawlett Hams, Somerset.
Paul Glendell/English Nature 23,020
Main: Identifying moths caught in a moth trap at Ham Wall NNR, Somerset.
Paul Glendell/English Nature 24,888