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Distribution and habitat occurrence of water shrews in Great Britain

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Executive Summary

Of all riparian mammals in Britain, least is known about the Eurasian water shrew (*Neomys fodiens*). Its small size, elusive nature and sporadic occurrence have resulted in it being relatively overlooked compared to the larger riparian species - the water vole, otter and mink.

Although there has been no documented evidence of an overall population decline, localised studies suggest that water shrews have decreased in number and occurrence in areas where they were once abundant. The loss and degradation of riparian habitat and increases in pollution and pesticides may be responsible for this speculated decline. The Environment Agency commissioned a Species Action Plan and Species Management Guidelines for the water shrew (Churchfield, 1997a,b) to clarify its status.

In response to the recommendations proposed in the Species Action Plan, The Mammal Society implemented a volunteer-based survey to determine the nationwide distribution and habitat occurrence of the water shrew. Fieldwork for the survey was carried out over four seasons between April 2004 and September 2005, with volunteers using the bait tube method to detect the presence of water shrews in riparian habitats of their choice. Small mammals are attracted to the baited tubes and whilst feeding on the bait, deposit scats (faecal pellets). These are collected and their content examined. Water shrews are the only small mammal species to regularly feed on aquatic invertebrates and the remains of these prey in scats confirms the presence of water shrews at a site. At each survey site, volunteers recorded information on the habitat type, the characteristics of the water body such as water depth and width, features of the bank, including height and incline, the presence of aquatic and bankside vegetation, the level of bankside management, the type of human use at a site and the adjacent land use.

Over the four survey seasons a total of 506 volunteers surveyed 2159 sites across Britain finding evidence of water shrews at 387 sites (17.4%). Water shrews were widely distributed across the country from northern Scotland to the southern most tip of England, with a concentration in central and eastern England. More water shrews were recorded during the summer survey seasons (July-September) than the winter/spring survey seasons (December-April).

Analysis of the habitat information revealed water shrews to be ubiquitous and adaptable. Previous work on water shrews suggested they have a preference for fast-flowing rivers and streams. Records from this 2004-5 survey found evidence of water shrews in these lotic habitats but also in lentic habitats such as ditches, canals, ponds and lakes. Previous records from such habitats are scarce.

Water shrews are ecologically flexible. They occurred in sites with a variety of substrate types, water depths and water widths. They were little influenced by bank height and incline and were apparently unperturbed by human activity, being found in sites where angling, walking and boating were common pursuits. There was no statistical evidence to suggest that either bankside management or the land use

adjacent to a site influenced water shrew occurrence. The presence of aquatic vegetation favoured water shrew occurrence, although they were also found in sites where this was absent.

Of the habitat variables investigated, herb cover and the interaction between trees and shrubs showed a statistically significant association with water shrew occurrence. Water shrews were recorded more frequently in sites with a dense cover of herbs and less frequently in sites where both tree and shrub cover were dense. Of the structural variables analysed (location, year, season, bait type, number of tubes used/site), the ‘easting’ element of location was found to be statistically significant with a greater proportion of water shrews found in more easterly locations.

Using data provided by the Environment Agency National Data Unit, the effect of water quality on water shrew distribution was investigated. Biochemical Oxygen Demand (BOD), nitrate, phosphate and pH data from all Environment Agency monitoring sites within 1km of those surveyed during the Water Shrew Survey were provided. Average water quality was calculated for 10km grid squares and related to the proportion of water shrew positive sites in each square. Low BOD and nitrate levels and a pH in the range 7.0-8.0 were significantly associated with a higher proportion of water shrews.

Although interesting, it is suggested that the findings of these statistical analyses should be interpreted with caution. The predictive ability of these models was poor, implying that, while these variables have some impact on water shrew occurrence, there are other factors, as yet unidentified, which may be more important in predicting their occurrence.

This first national survey of water shrew distribution highlights the value of using volunteers for a large-scale survey. A large quantity of baseline information has been collected, against which the results of future studies can be compared. The widespread distribution of the species is encouraging. However, until the population size of water shrews in Britain can be determined it is not possible to fully assess their conservation needs. For now, it is recommended that riparian habitats be managed sensitively to maintain existing water shrew populations and encourage the establishment of new populations. Particular attention should be given to encouraging the growth of bankside herb cover, ensuring that both shrub and tree cover are not dense and maintaining low BOD and nitrate levels in water. The Mammal Society recognises the importance of building on the work presented in this report and plans to continue monitoring water shrews as part of a nationwide Small Mammal Monitoring Scheme to be implemented in the near future.

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1 Introduction

1.1 Background

The Eurasian water shrew (*Neomys fodiens*) is one of Britain's least known mammals. It has a sporadic and localised occurrence and remarkably little is known about its habitat requirements and population dynamics in Britain and continental Europe. It has never been the subject of a nationwide survey in Britain, and evidence of its occurrence is patchy. Its current conservation status in Britain is uncertain but it has been identified as a species of conservation concern to the Environment Agency (Churchfield, 1997a,b) and is on the Conservation Action Priority list of English Nature.

While there is no documented evidence of population decline, there is concern that the water shrew may be undergoing a decline in numbers and occurrence as a result of habitat loss, pollution and pesticide use. Changes in land-use and habitat management have resulted in the loss and degradation of much riparian habitat which is known to have contributed to the dramatic decline in water vole numbers and may, similarly, have had an adverse effect on the water shrew. Anecdotal reports, coupled with live-trapping studies, suggest that water shrews have declined in abundance and occurrence in sites previously well-populated by these shrews.

Accordingly, the Environment Agency commissioned the production of a Species Action Plan and Species Management Guidelines (Churchfield, 1997a,b). One of the recommendations of the Species Action Plan was that the national status of the water shrew should be investigated.

The Mammal Society's Water Shrew Survey 2004-5 was the first survey designed exclusively to determine the distribution and habitat occurrence of the water shrew on a national scale. The survey used volunteers to survey Britain for water shrews, employing the bait tube method (Churchfield, Barber and Quinn, 2000). This method was used successfully in an extensive pilot study in south east England (Greenwood, Churchfield and Hickey, 2002). Prey remains in scats deposited in the tubes provide evidence of water shrew presence.

1.1.1 Aims

1. To determine the distribution of water shrews in Great Britain and produce an up-to-date distribution map for this species.
2. To determine the habitat occurrence of water shrews and examine habitat predictors that might assist management and conservation.
3. To assess the effect of water quality on water shrew distribution.
4. To produce a Conservation Handbook for water shrews.

1.2 Water shrew ecology

The water shrew is the largest of the three species of shrew inhabiting mainland Britain. Unlike its smaller counterparts, the common shrew (*Sorex araneus*) and the pygmy shrew (*S. minutus*), the water shrew is not restricted to foraging on land. Being able to swim and dive, water shrews can exploit both terrestrial and aquatic environments in search of food (Churchfield, 1984a, 1990, 1998; Hutterer, 1985). Although their feet are not webbed, fringes of stiff hairs on the fore and hind feet increase their surface area when swimming and aid propulsion. There is also a keel of long, stiff hairs on the underside of the tail which acts as a rudder, providing additional propulsion.

The water shrew is able to dive to over one metre in depth in search of aquatic prey (Vogel, Bodmer, Spreng and Aeschimann, 1998). To combat low water temperatures it has a particularly dense pelage in which a layer of air is trapped, repelling water and insulating the shrew. However, this results in the shrews being very buoyant and thus dives are mostly short and frequent as hard paddling is required to remain underwater (Churchfield, 1998).

Touch-sensitive vibrissae (whiskers) on the snout are used to detect prey underwater and, once caught, these items are usually brought to the bank where they are killed and eaten. As well as consuming small aquatic invertebrates, water shrews are capable of catching larger prey such as amphibians and fish, rendering them immobile with a narcotising secretion found in the saliva. Experimental studies on mice have shown that this is a neurotoxin, causing limb paralysis and blood and respiratory disorders (Pucek, 1959). The toxin is not lethal to humans but can cause skin irritation and discomfort.

All shrews eat terrestrial invertebrates but water shrews are the only soricid to also forage underwater for aquatic invertebrates. The presence of aquatic prey remains in water shrew scats (faecal pellets) makes it possible to distinguish them from the scats of the other shrew species. The aquatic invertebrates most frequently eaten by water shrews are the crustaceans *Gammarus pulex* and *Asellus aquaticus* and Trichoptera (caddis) larvae, which are commonly found in a variety of freshwater habitats (Table 1). When living close to water, an average of 50% of the prey consumed by water shrews is aquatic (Churchfield, 1985). Only 11% of water shrew scats examined by Churchfield (1998) were found to lack aquatic prey. On rare occasions, common and pygmy shrews will consume aquatic prey captured close to the shore without the need for diving. However, Churchfield *et al.* (2000) found that only 2% of scat samples from common and pygmy shrews contained aquatic prey and the scats were easily distinguishable from those of water shrews based on their size and the small volume of aquatic prey they contained.

Table 1 The major prey types found in the diets of water, common and pygmy shrews (adapted from Churchfield, 1984a).

	Prey type	Water shrew	Common shrew	Pygmy shrew
Terrestrial	Araneae and Opiliones (spiders and harvestmen)	●	●	●
	Adult Coleoptera (beetles)	●	●	●
	Isopoda (woodlice)	●	●	●
	Hemiptera (bugs)	●	●	●
	Myriapoda (centipedes)	●	●	●
	Insect larvae	●	●	●
	Gastropoda (slugs and snails)	●	●	●
	Lumbricidae (earthworms)	●	●	
Aquatic	Diptera larvae (flies)	●		
	Trichoptera larvae (caddis)	●		
	Other insect larvae	●		
	Crustacea	●		

Water shrews are usually associated with freshwater habitats but they occasionally frequent coastal areas and can often be found far from water when dispersing. Like most shrews they are essentially solitary. They tend to have linear territories of some 106-276m^2 along stream-sides, encompassing an area of water plus adjacent banks in which they make their nests (van Bemmel & Voesenek, 1984; Lardet, 1988).

They have an annual lifecycle and short life span. The breeding season for water shrews is between April and September, during which time they can produce 2-3 litters of young. In each litter, 5-7 young are produced of which only 3-4 will survive. Shrews born in summer pass the winter in an immature state but quickly grow to maturity the following spring when the breeding season commences. After breeding, the adults die, leaving their young to carry the population through the winter. Accordingly the population follows a seasonal cycle with a peak in summer, a decline in autumn and low numbers in winter. Individuals rarely live more than 12 months (Churchfield, 1984b). Water shrews do not hibernate, remaining active throughout the year and foraging in water in all seasons.

Water shrews are believed to exist in small, localised populations (<3/hectare), which, coupled with their elusive nature, has made them a difficult species to study. By contrast, common and pygmy shrews are much more abundant. Pygmy shrews have populations of 5-30/ha in grassland while common shrews reach 17-69/ha in deciduous woodland (Churchfield, 1990).

Figure 1 **Water shrew feeding on earthworm** (photo by Martin Smith).

2 Methods

The Mammal Society's Water Shrew Survey was carried out by volunteers from across Great Britain. Some were experienced mammalogists and field workers, but for most this was their first opportunity to contribute to a national mammal survey. The ease of the survey method may have contributed to large numbers of volunteers signing up for the survey.

2.1 Bait tube method

The chosen sampling method was the bait tube method (Churchfield *et al.*, 2000). This exploits the attraction of water shrews and other small mammals to short lengths of plastic tubing with bait in. The tubes are placed in a chosen habitat for two weeks to allow small mammals to visit them. While feeding on the bait, mammals deposit faecal pellets in the tubes, which can be collected and stored. The scats of water shrews can be distinguished by their size, shape and colour and, in aquatic habitats, by the presence of aquatic prey remains. In comparison to live-trapping, bait tubes are cheap to produce, easy to carry and have a minimal risk of mortality, because small mammals are free to enter and leave the tubes at will. The results of the bait tube technique compare favourably with those of live-trapping in recording water shrew presence (Churchfield *et al.,* 2000).

2.1.1 Bait tubes

Figure 2 Bait tube in bankside vegetation (photo by Phoebe Carter).

Bait tubes were made from short lengths of white, plastic waste pipe (20cm long, 4cm diameter). To prevent the bait from spilling out of the tubes while they were being placed at a site, one end of the tube was covered by a piece of muslin and secured in place by an elastic band. The suggested bait was blowfly pupae *(Calliphora* sp.), commonly known as casters. These can be obtained from most fishing tackle shops in England, although they are harder to obtain in Wales and Scotland where coarse fishing (for which they are commonly used as bait) is limited. Before use, the casters were frozen to prevent them from hatching into adult flies. A small handful of casters (20-30) were placed in each tube. For those volunteers who were unable to obtain casters, we recommended using dried mealworms (larvae of the beetle *Tenebrio molitor*). These are available by mail order from several companies.

2.1.2 Placing bait tubes at a site

Because of the importance of aquatic prey in identifying water shrew scats, surveys were only carried out in riparian habitats where shrews had access to freshwater invertebrates. Volunteers chose their own survey sites. Sites had to be at least 1km apart to minimise the chance of detecting the same individual at two locations. To enable a distribution map to be generated, all volunteers were asked to supply a six-figure grid reference for each of their sites. As the survey progressed, volunteers could call The Mammal Society with the grid references for the sites they wished to survey and the database could be searched to verify that these sites had not been surveyed previously by another volunteer.

We suggested that volunteers used a minimum of four tubes at each site and, if possible, surveyed four sites in each survey season. Along linear watercourses such as rivers, streams, canals and ditches, the tubes were placed at 10m intervals. Around non-linear water bodies such as ponds, lakes, fens and bogs the tubes were also placed at 10m intervals. However, if this was not possible they were placed with equal distances between them. To increase the likelihood of water shrews encountering the tubes, we recommended that tubes were placed in bankside vegetation within 2-3m of the water's edge. To ensure that scats were not lost as a result of flooding, we advised that tubes were placed well above water level.

We recommended that bait tubes were left in place for two weeks, during which they did not need to be revisited. However, provided that volunteers recorded how many days the tubes were set for, they could leave them for a time period that suited them. After this time, the tubes were collected and dried and any scats found were returned to The Mammal Society for identification. We advised posting them in disused film canisters, to prevent the scats from being crushed. The contents of all the tubes from one site were placed in a single film canister labelled with the volunteer name, site name and site number. Scats from each site were kept separate.

2.1.3 Survey packs supplied to volunteers

Each volunteer was given a survey pack containing eight bait tubes, muslin and elastic bands, four field forms (see p16) and one information booklet detailing how to take part in the survey. Volunteers had to supply their own bait, as it was not feasible for The Mammal Society to send live bait through the post.

2.1.4 Survey seasons

The fieldwork for the Water Shrew Survey ran from April 2004 until the end of September 2005. There were two survey seasons in each year, one in winter/spring (1 December-30 April) and the other in the summer (1July-30 September). In this way, surveying took place at two key points in the annual population cycle of water shrews: summer when the shrews are most active and their populations are at a maximum and winter/spring when populations are lower but relatively stable. Due to a series of unavoidable delays the first survey season was only a month long and was run in April 2004. The short running time of this survey season did not affect volunteer involvement with a similar number of volunteers taking part in this survey season compared to later survey seasons. The seasons were as follows:

Table 2 Dates of the four Water Shrew Survey seasons.

	Dates
Season 1	1-30 April 2004
Season 2	1 July–30 September 2004
Season 3	1 December 2004–30April 2005
Season 4	1July–30 September 2005

2.1.5 Scat identification

On arrival at The Mammal Society, scat samples were labelled with the details of the volunteer that returned them and the site name and number. Each sample was then sorted to separate shrew scats from rodent scats and detritus. Dr Phoebe Carter at The Mammal Society identified the water shrew scats, with subsequent verification by Dr Sara Churchfield, King's College, London. Scat identification was based on their size, colour and contents: water shrew scats are larger and more rounded than those of the smaller terrestrial *Sorex* shrews, and typically have a light brown grey/brownish colour when dry due to the pale chitinous remains of freshwater crustaceans. By contrast, scats of the *Sorex* shrews are nearly black, due to the dark chitin of beetles and, in the case of the common shrew, the remains of earthworms (Figure 3).

Figure 3 **Examples of water shrew and common shrew scats showing the difference in size between the two species.** Paler prey fragments can be seen in the water shrew scats (photo by Sara Churchfield)

Scats were fragmented in a small droplet of water and were then examined under a binocular microscope for the presence of aquatic invertebrate prey remains. Examples of the commonly consumed prey are shown in Figure 4 and some readily identified parts of these prey are shown in Figures 4, 5 and 6.

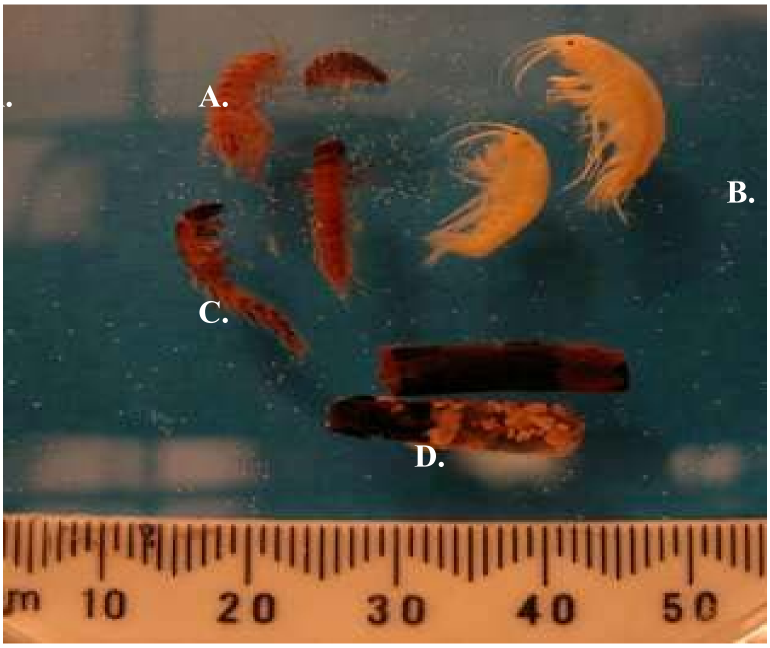


Figure 4 **Examples of the aquatic invertebrates commonly eaten by water shrews.** A. *Asellus,* B. *Gammarus,* C. Trichoptera larvae and D. Trichoptera larva cases. The colour of these invertebrates is an artefact of the photography (photo by Sara Churchfield).

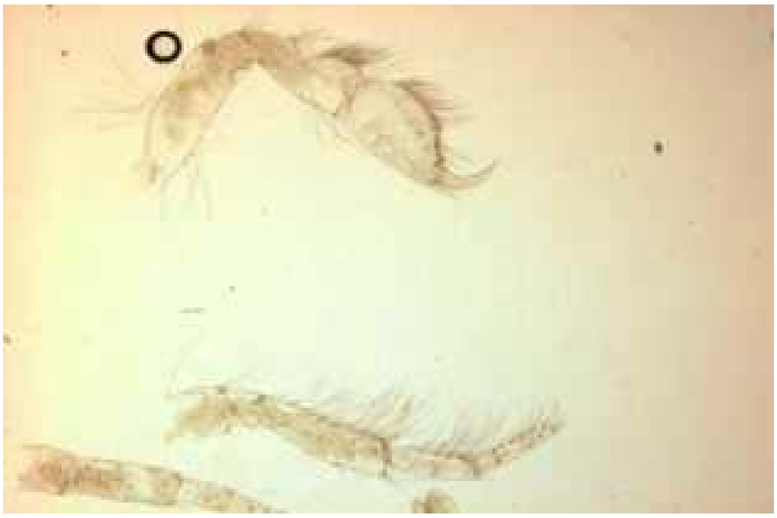


Figure 5 **Freshwater shrimp (*Gammarus)* remains.** Distinctive legs covered in long, hair-like setae. Particularly abundant in the water shrew diet in the summer and autumn (×10 magnification).

Figure 6 **Caddis larva (Trichoptera) remains.** Legs are heavily chitinised with long black hairs. Common in the diet throughout the year (×20 magnification).

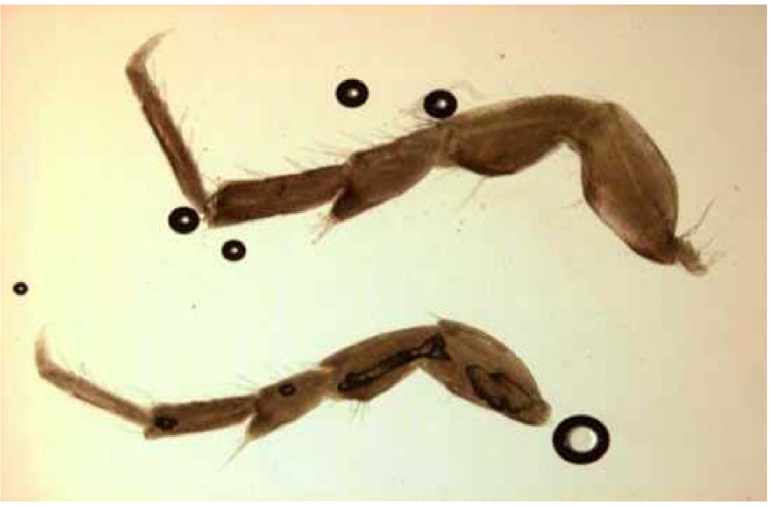
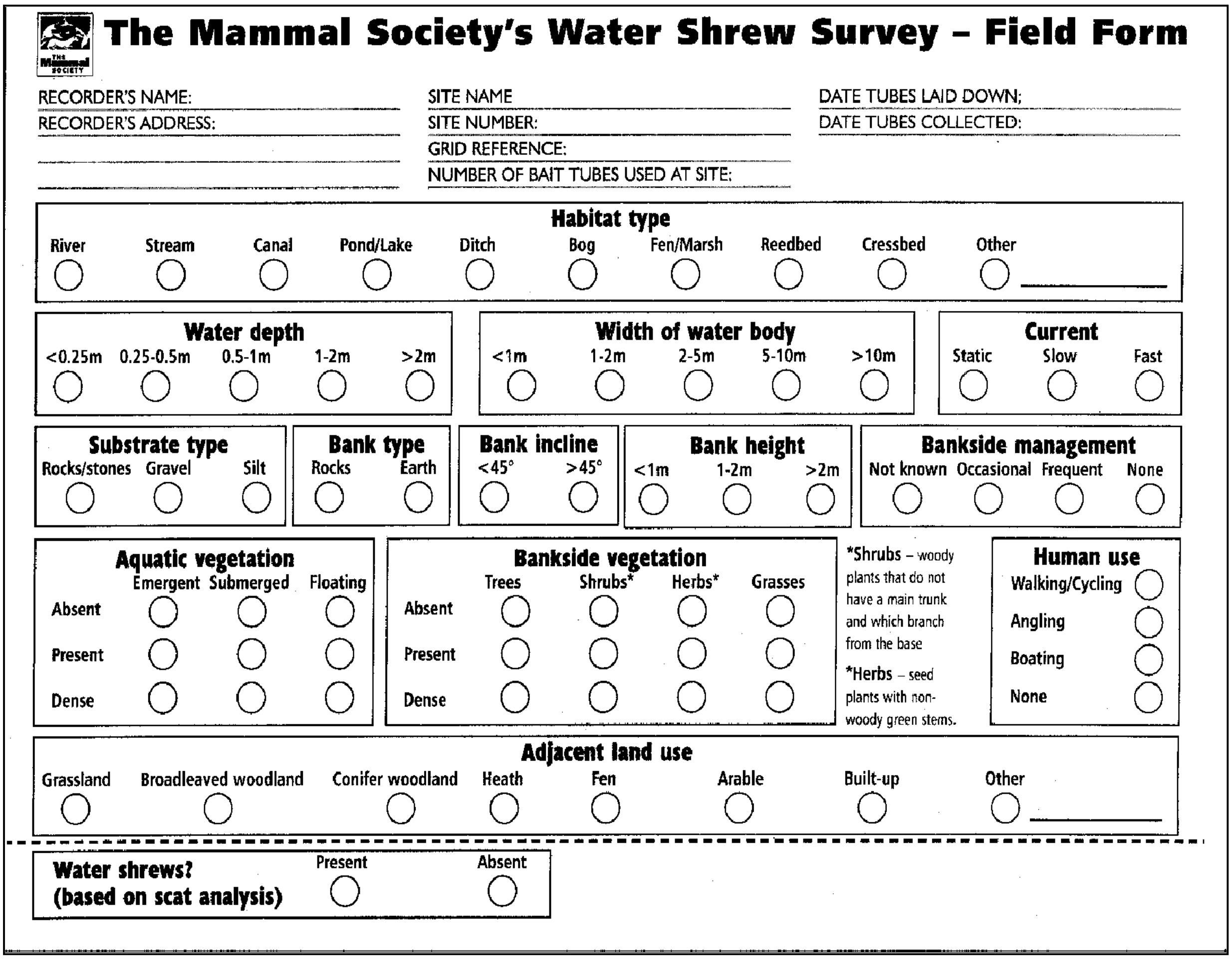


Figure 7 **Water slater (*Asellus*) remains.** Distinctive legs. They are the dominant prey item in the water shrew diet throughout the year (×35 magnification) (photos by Sara Churchfield).

2.1.6 Habitat information

To determine the habitat occurrence of water shrews, volunteers were asked to fill in habitat forms (field forms) at each of their sites (see below). The forms were designed to provide maximum information about the characteristics of a site with minimal effort from volunteers.


The Mammal Society's Water Shrew Survey – Field Form

RECORDER'S NAME:
RECORDER'S ADDRESS:
SITE NAME
SITE NUMBER:
GRID REFERENCE:
NUMBER OF BAIT TUBES USED AT SITE:
DATE TUBES LAID DOWN;
DATE TUBES COLLECTED:

Habitat type
River Stream Canal Pond/Lake Ditch Bog Fen/Marsh Reedbed Cressbed Other

Water depth
<0.25m 0.25-0.5m 0.5-1m 1-2m >2m

Width of water body
<1m 1-2m 2-5m 5-10m >10m

Current
Static Slow Fast

Substrate type
Rocks/stones Gravel Silt

Bank type
Rocks Earth

Bank incline
<45° >45°

Bank height
<1m 1-2m >2m

Bankside management
Not known Occasional Frequent None

Aquatic vegetation

	Emergent	Submerged	Floating
Absent			
Present			
Dense			

Bankside vegetation

	Trees	Shrubs*	Herbs*	Grasses
Absent				
Present				
Dense				

*Shrubs – woody plants that do not have a main trunk and which branch from the base

*Herbs – seed plants with non-woody green stems.

Human use
Walking/Cycling
Angling
Boating
None

Adjacent land use
Grassland Broadleaved woodland Conifer woodland Heath Fen Arable Built-up Other

Water shrews? (based on scat analysis) Present Absent

A variety of habitat details were collected, including the habitat type, water depth and flow, substrate type, the presence of aquatic and bankside terrestrial vegetation, bankside management, human use of the site and the adjacent land use. No measures of prey diversity and abundance were made, as it was not logistically possible for volunteers to provide comparable quantitative data for aquatic invertebrates. Although prey abundance may be an important factor in habitat selection by water shrews, we decided that its assessment was beyond the scope of this study.

All habitat information was recorded on the Water Shrew Database designed by BioEcoSS Ltd. and held on computer at The Mammal Society offices. In all communications to volunteers the importance of negative results was emphasised and they were continually reminded to return habitat forms from all sites, even from those where no scats of any sort were recorded.

2.1.7 Water quality

Water quality can exert both direct and indirect effects on water shrews. Pollutants can be ingested during grooming, while factors such as BOD (Biochemical Oxygen Demand), nitrates, phosphates and pH may have indirect effects, through impacts on their invertebrate prey.

Water quality data were provided by the Environment Agency National Data Unit at Twerton. We acquired chemical data from all Environment Agency monitoring sites within 1km of each of the grid references surveyed in the Water Shrew Survey, for both survey years. In most cases the grid references surveyed by volunteers and those used by the Environment Agency for monitoring were not the same, so it was not possible to exactly match the water quality data to the Water Shrew Survey sites. We calculated an average water quality value for each chemical, for each 10km square in which data were available. We also determined the proportion of water shrew positive sites for each 10km square. Only 10km squares that contained Water Shrew Survey sites and had water quality data were included in the analysis (n=591).

The water quality factors that were investigated were BOD, nitrates, pH, phosphates and orthophosphates. More information on the Environment Agency's water quality monitoring programme can be found on www.environment-agency.gov.uk.

Water quality for Scotland is monitored by the Scottish Environmental Protection Agency (SEPA). However, there were too few positive water shrew sites in Scotland to carry out a worthwhile assessment of the influence of water quality on their distribution.

2.2 Recruiting and training the volunteers

2.2.1 Numbers of volunteers

The Water Shrew Survey was regularly advertised in The Mammal Society's magazine, *Mammal News,* in BBC Wildlife Magazine and other more local publications. Flyers were distributed at conferences, symposia, training courses and other public events. Volunteers were invited to register their interest to take part in the survey and each person who signed up to the survey was sent a pack with all the equipment and instructions needed to take part.

A total of 1382 people registered their interest, with only 506 undertaking the survey and returning results. Unfortunately, the start of the survey was delayed. We had planned to start in 2003 and it is possible that some of those who had expressed an interested were no longer able to take part, or had changed address, when the survey began in April 2004.

2.2.2 Training for volunteers

To accompany the survey, a special, subsidised course was created by The Mammal Society's Training Officer, Angela Gall (and subsequently Gayle Dower), with information and advice provided by Dr Sara Churchfield. The training objectives of these one-day courses were that participants would:

- understand the aims of The Mammal Society's Water Shrew Survey;
- increase their knowledge of shrews, particularly water shrew identification and ecology;
- understand the methods used in The Mammal Society's Water Shrew Survey, know the reasons behind them and how the results would be used;
- be able to carry out stage 1 scat analysis (distinguish between rodent and shrew scats);
- have attempted stage 2 scat analysis (identify water shrew scats from the scats of other shrew species) and be able to recognise some body parts of the main aquatic prey species;
- understand how to submit their results;
- have had a chance to ask any questions about the survey or other work of The Mammal Society.

Nine courses were run across Great Britain between July and September 2004:

- Mabie Forest, Dumfries and Galloway 10 July 2004
- Hallsannery Field Centre, Devon 11 July 2004
- Newcastle upon Tyne, Tyne and Wear 24 July 2004
- Wildwood, Herne Bay, Kent 24 July 2004
- Bridgend, Wales 24 July 2004
- Mold, Flintshire 7 August 2004
- Wildwood, Herne Bay, Kent 9 August 2004
- Nantwich, Cheshire 14 August 2004
- Snowdonia, Wales 13 September 2004

Each of these nine courses was fully booked, with the maximum number of 15 participants attending.

A further 5 courses were run between February and March 2005:

- Arlington Reservoir, Brighton, East Sussex 12 February 2005
- Wildwood, Herne Bay, Kent 12 February 2005
- The Nature Centre, Tondu, Bridgend 19 February 2005
- Edinburgh Zoo, Edinburgh 26 February 2005
- Exminster, South Devon 19 March 2005

Each of these five courses had 6 or more people attending. All courses were run by 6 trainers who had attended an intensive training day organised by Angela Gall and taught by Dr Churchfield.

All participants were asked to fill in an evaluation form about the course they attended. Overall, all courses were graded ‘good’ to ‘very good’. Most comments were aimed at the stage 2 scat analysis, which involves identifying water shrew scats. It is a difficult task that takes practice and cannot be perfected in one afternoon. However, the course did provide the volunteers with the chance to analyse scats they had collected during their surveys and taught them how to easily identify shrew from rodent scats. For the first suite of courses there was limited reference material (scat samples) and this may have compounded the difficulties associated with scat analysis. Due to a good response from volunteers during the first summer survey season we had a large collection of water shrew scats plus those from other shrews and rodents, for use in the 2005 training courses.

Because it is difficult to correctly identify water shrew scats, The Mammal Society asked volunteers to return all scats they collected to the office for verification, after they had identified them. This ensured that all the results were validated and no ‘false positives’ were recorded. In some rare instances, people that had been trained in scat analysis by Dr Churchfield and in whose identification skills she was confident were not required to send in samples for verification.

2.2.3 Feedback to volunteers

An important factor in retaining volunteer enthusiasm is ensuring that volunteers are kept up-to-date with the progress of a survey and can see the value of their input. The Mammal Society produced a newsletter, *Shrew News* (see below). It was sent out after each survey season to everybody who had registered an interest in taking part, irrespective of whether they had returned results. The newsletters addressed any problems that volunteers had encountered with the survey method and displayed maps of all the sites surveyed and the sites where water shrews were recorded. The newsletters were a good way to encourage people to survey areas of the country that had not been well covered in the survey thus far. Three newsletters were sent out during the course of the survey. A fourth and final newsletter, summarising the findings of the survey, will be sent out to volunteers on submission of this technical report.


The Mammal Society

Shrew News

The Summer Survey Season

Summary

Conference Presentation

Distribution and habitat occurrence of water shrews in Great Britain

3 Results and observations

Data collected by volunteers were used to look for associations between the methodological and habitat variables and water shrew presence. Many different habitat options were provided on the field forms, to encourage volunteers to provide as much site information as possible. However, there were not enough data for several of the categorical variables to be statistically analysed separately. We combined some of the categories to create larger sample sizes, as described in Table 3.

Table 3 Recording of method and habitat variables.

Variable	Original categories	New categories
Number of tubes	Actual number used by volunteers	<4; =4; <=8; >8
Habitat type	Canal and ditch	Canal/ditch
Habitat type	Bog, fen/marsh, reedbed, cressbed, other	Other
Bank management	Occasional and frequent	Yes
Human use	Walking/cycling, angling and boating	Yes
Adjacent land use	Conifer woodland, heath, fen, built-up and other	Other
Water depth	<1; 1-2; 2-5; 5-10 and >10m	<1; 1-2; >2m

3.1 Volunteers

The majority of volunteers that took part in the Water Shrew Survey came from England (82.4%) with only 9.6% and 8.0% coming from Scotland and Wales, respectively. One volunteer took part on Alderney in the Channel Islands.

In each season of the survey an average of 175 volunteers took part and returned information. More people took part in the summer survey seasons, particularly in the first summer season (season 2).

Table 4 Number of volunteers taking part in each survey season.

Survey season	Number of volunteers
1	149
2	248
3	143
4	161

The number of sites surveyed in each season is shown in Table 5. It is not surprising that the greatest number of sites (791) was surveyed during season 2, when the most volunteers took part. However, it is interesting that the survey season with the least number of volunteers taking part (season 3) did not have the least number of sites surveyed.

Table 5 Number of sites surveyed in each season.

Survey season	Number of sites surveyed
1	299
2	791
3	541
4	528

As with most volunteer based surveys (for example, Winter Mammal Monitoring, see Noble *et al*., 2005), volunteer turnover was relatively high during the Water Shrew Survey. Only 2.7% of volunteers took part in all four survey seasons, compared to 72.1% who took part in only one survey season (Table 6).

Table 6 Percentage of volunteers taking part in one or more survey seasons.

Number of survey seasons taken part in	Per cent of volunteers taking part
1	72.1%
2	20.3%
3	4.8%
4	2.7%

3.2 Scat samples and success rate of volunteers

All volunteers were asked to return any scats they found to The Mammal Society for identification..

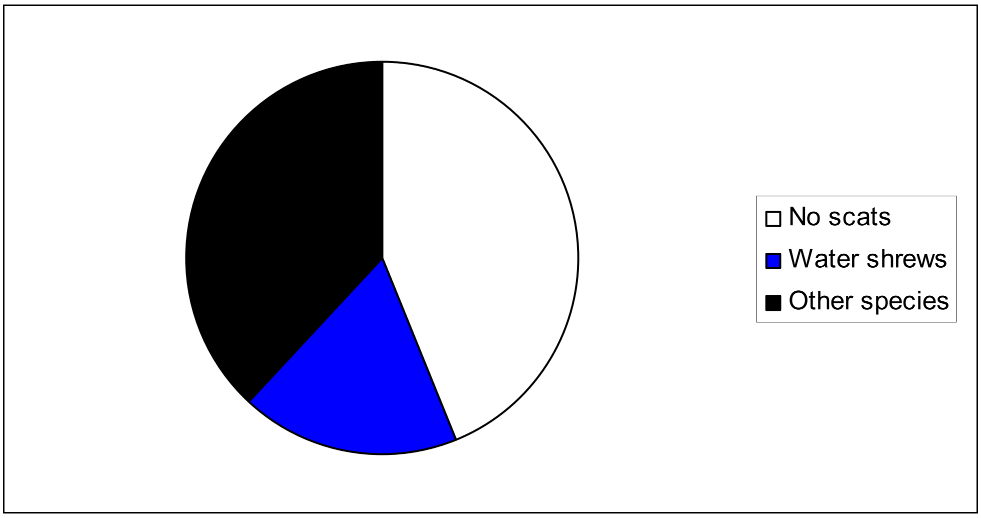


Figure 8 Proportion of various types of scat returned by volunteers.

Despite a good return of water shrew scats and scats from ‘other’ small mammal species, a relatively large percentage of sites produced no scats of any sort. Snail casts and debris were frequently mistaken for small mammal scats by volunteers. Scats from ‘other’ species included common and pygmy shrews and rodents. It is generally not

possible to identify rodent scats to species level and thus volunteers could only be told that rodents had visited their tubes. Scats of common and pygmy shrews were identified where possible (on the basis of size and prey contents) but they were often fragmented and mixed in the bait tubes and so could not be distinguished reliably.
The term ‘terrestrial shrew’ was used as a generic term for the scats of these two species. With the exception of the final survey season, a record was kept of all the species that were found at each site. Table 7 shows the results from the first three survey seasons.

Table 7 Percentage of sites where different shrew species were recorded (first 3 survey seasons only).

Species	% of sites with scats
Water shrew	19.0%
Terrestrial shrew	66.3%
Water shrew & terrestrial shrew scats at the same site	14.7%

Water shrews and terrestrial shrews were only found together at a relatively low proportion of sites (14.7%).

In each survey season, more than 20% (mean 31.3%) of volunteers found water shrews, with consistently higher success in the summer seasons compared to the winter seasons (Table 8).

Table 8 Percentage of volunteers finding evidence of water shrews at one or more sites.

Survey season	Per cent of volunteers with one or more positive sites
1	22.8%
2	36.3%
3	25.9%
4	36.0%
Mean over all survey seasons	31.3%

3.3 Variations in survey effort and bait used

Although we recommended that volunteers used four bait tubes at each site, they could use as many as they liked provided the number used was recorded on the field form. From this information, we have assessed the effect of volunteer effort on the chance of detecting water shrews. Figure 9 shows that the greater the number of tubes used, the greater the proportion of sites where water shrews were detected. This was particularly evident when more than eight tubes were used at each site.

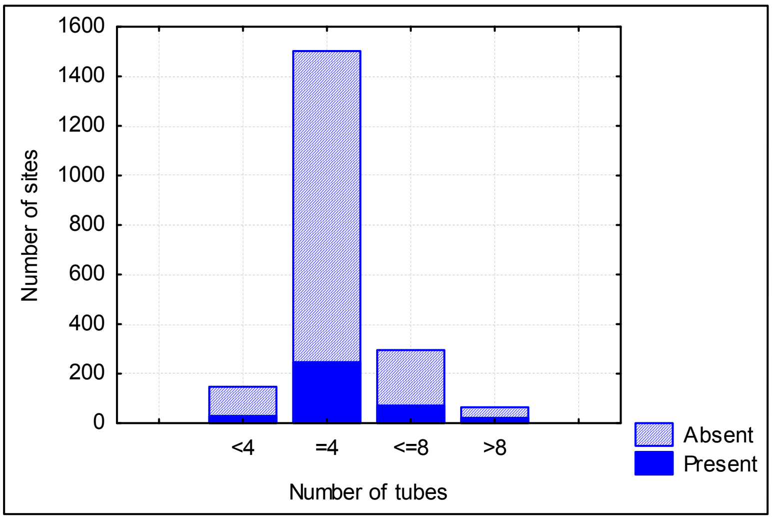


Figure 9 The frequency of occurrence of water shrews (solid) when using different numbers of bait tubes.

The recommended bait for use in the survey was casters, which the majority of volunteers were able to obtain and use. Mealworms were only used at 7.3% of all sites.

Table 9 Percentage of sites using each of the recommended baits.

Bait	Per cent of sites	Per cent of sites positive for water shrews
Casters	92.7	18.9
Mealworms	7.3	9.6

Table 9 shows that both types of bait were effective at attracting water shrews. A greater percentage of sites was recorded as positive when casters were used.

3.4 Seasonal and annual differences in the occurrence of water shrews

Over the four survey seasons, a total of 2159 sites were surveyed. 2008 of them were visited once, 151 were visited more than once. Evidence of water shrews was found at an average of 17.4% of these sites (Table 10).

Table 10 Percentage of sites positive for water shrews in each survey season.

Survey season	Number of sites surveyed	Number of positive sites	Per cent of sites positive
1	299	38	12.7%
2	791	142	18.0%
3	541	70	12.9%
4	528	137	25.9%
Mean over all survey seasons	539.8 ± 89.9	96.8 ± 22.9	17.4%

The percentage of sites found to be positive for water shrews was consistently greater in the summer survey seasons compared to the winter seasons and was particularly high in survey season 4 (Table10).

To try and explain the particularly high percentage of positive sites found in survey season 4, data from the small sample of volunteers who surveyed sites in all four seasons (n=14) were examined to determine if there was an increase with time and experience in their ability to select water shrew positive sites for surveying. The results of this analysis are presented in Figure 10.

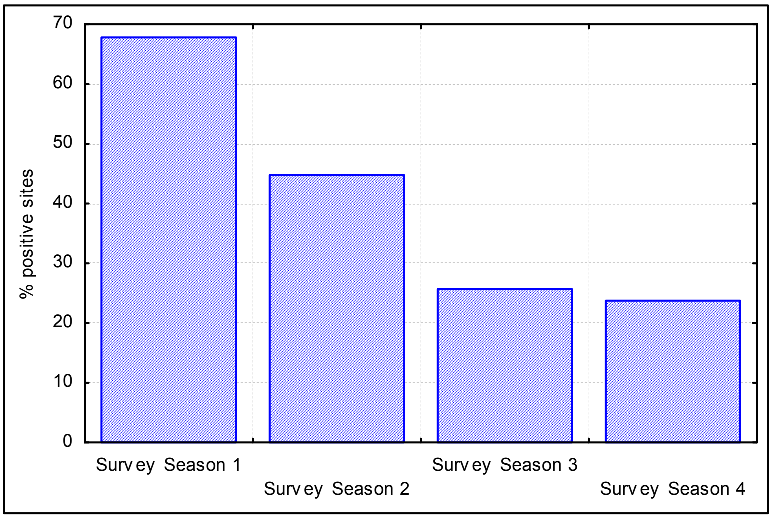


Figure 10 Percentage of positive sites in each season found by volunteers (n=14) that surveyed sites in all four survey seasons.

As can be seen, there was a decrease in the percentage of positive sites found by this select group of people in each successive survey season, suggesting that it was not their ability to select suitable sites but characteristics of the water shrew population that contributed to large numbers of positive sites in survey season 4.

3.5 Distribution of water shrews

Prior to this survey, the most current water shrew distribution map was that generated by Arnold (1993) for the *Atlas of Mammals in Britain*. The map was produced from 117 records collected up until 1959 and from 654 records collected from 1960 until publication in 1993. The majority of these records were made from sightings of live or dead water shrews. While it is likely that most of these would have been accurate identifications, there is always an element of error when identification is based on sightings alone. Likewise, although very useful, water shrew records from owl pellet analysis can only place the individual at the roost or nest site of the owl. As barn owls have a foraging range of 1km in summer and 4.5km in winter (Taylor, 1994), the location of the water shrew cannot be pinpointed using this method. The distribution map generated by our survey is unique in that all records are based on the analysis of scat samples. As water shrews are the only species to regularly feed on aquatic invertebrates, the generation of 'false positive' records is highly unlikely.

The Water Shrew Survey was very successful with a wide coverage of the country, as shown in Figure 11. Although the majority of sites surveyed were in southern and central England, there were many in northern England and Wales and some in Scotland (including the Isle of Skye). Few counties in England and Wales were not surveyed. The country-wide distribution of sites in the current survey reflects the success of The Mammal Society's advertising campaign and the wide geographical distribution of the associated training courses.

Figure 12 shows all the sites where evidence of water shrews was found in the current survey. Although the presence of water shrews largely reflects the distribution of surveyors it is encouraging that records were collected from the very north of Scotland to the southern-most tip of England. There is no way of knowing whether sites where no water shrews were recorded were actually devoid of the species or whether the species was merely not recorded within the time frame of the survey. The terms 'absent' or 'negative' used to describe these sites are descriptive, rather than absolute and should be interpreted with caution.

There was a concentration of positive sites in central and eastern England (Figure 12). This effect is further highlighted when the proportion of positive sites in each 100km grid square are plotted on a colour-graded map of Great Britain (Figure 13). With the exception of an anomalous square in Pembrokeshire, a greater number of dark squares are situated in the east of the country. In Pembrokeshire only one site was surveyed in total and was positive for water shrews.

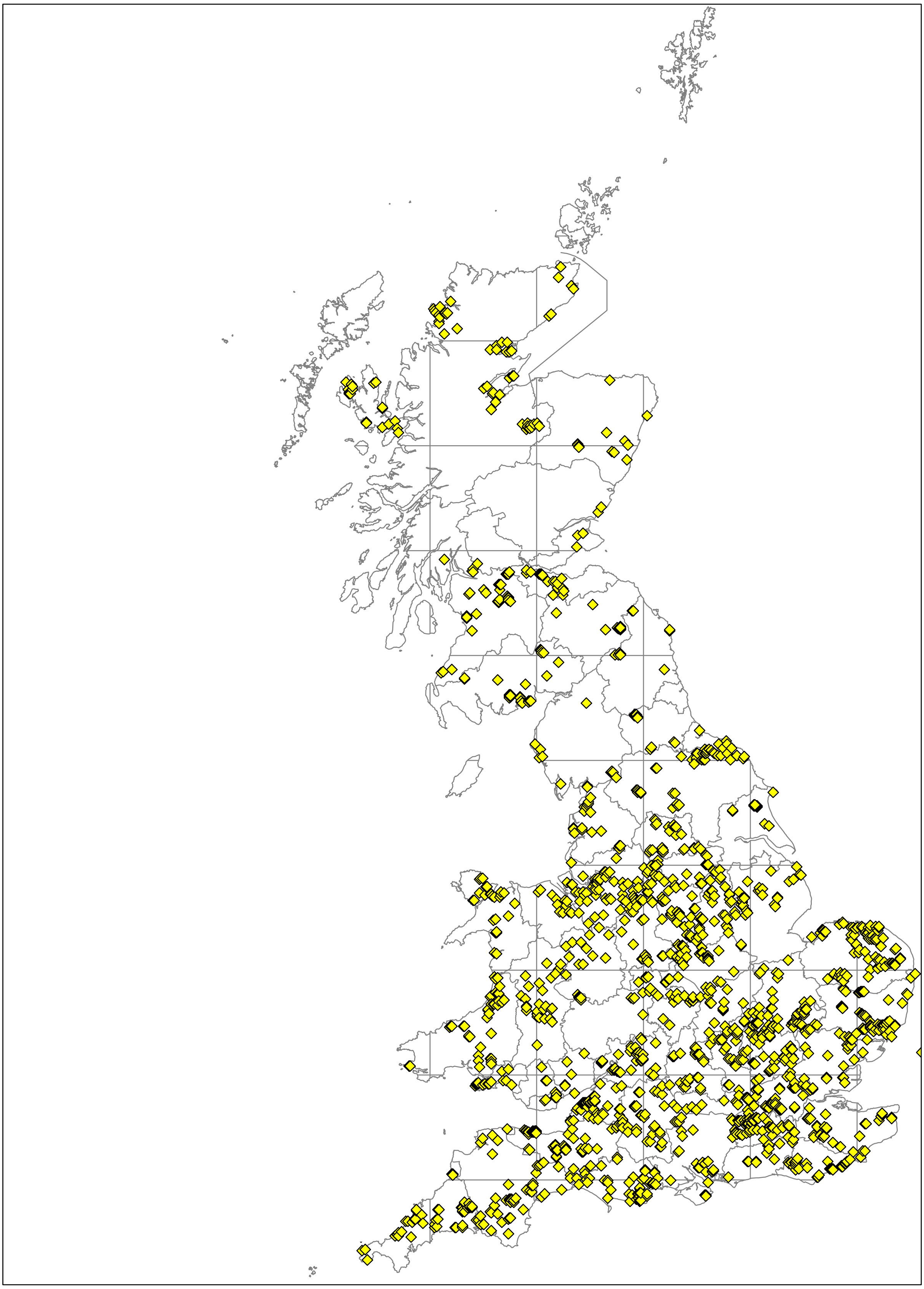


Figure 11 Map of all sites surveyed during the Water Shrew Survey.

Neomys fodiens

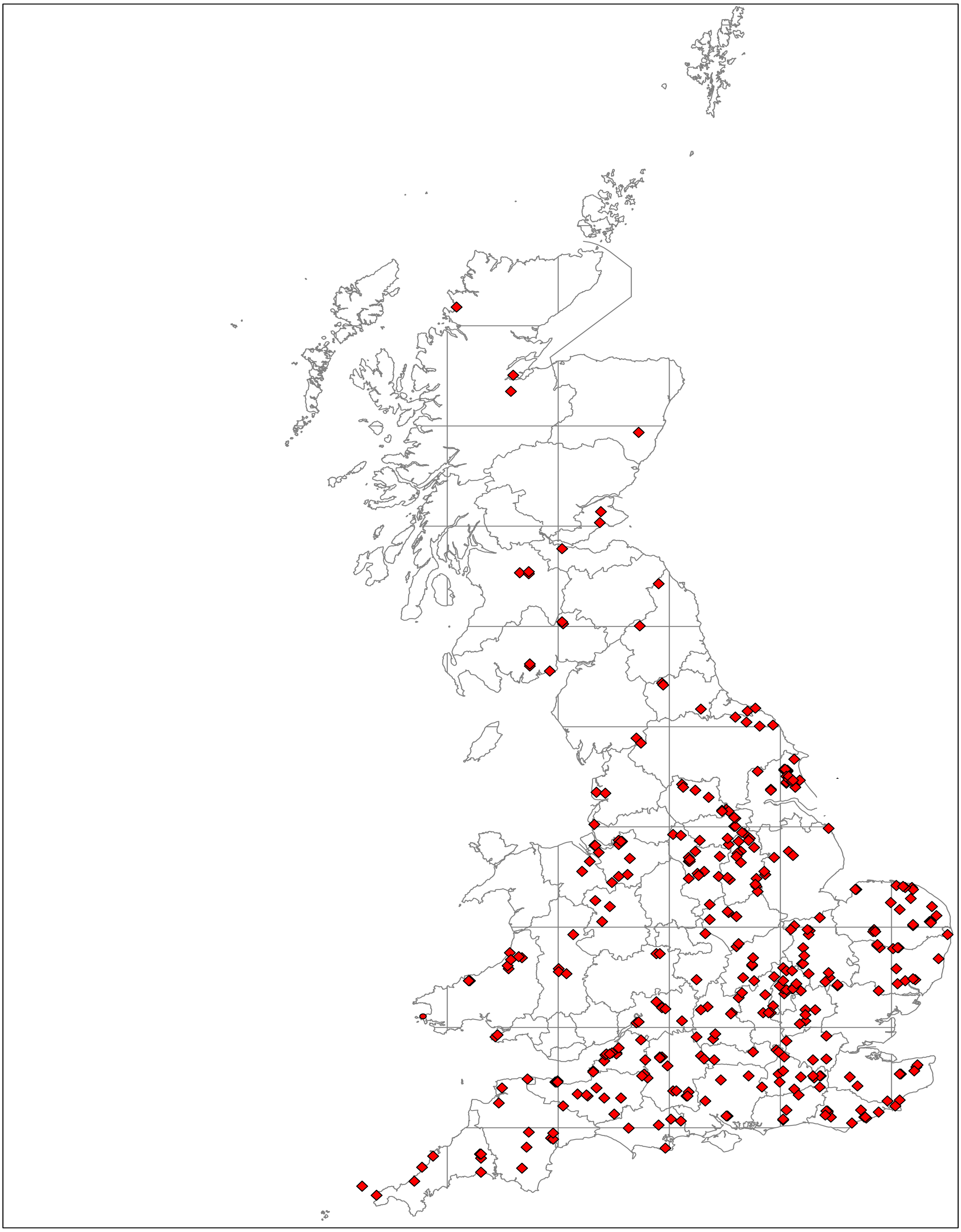


Figure 12 Map of all positive sites generated during the Water Shrew Survey.

Neomys fodiens

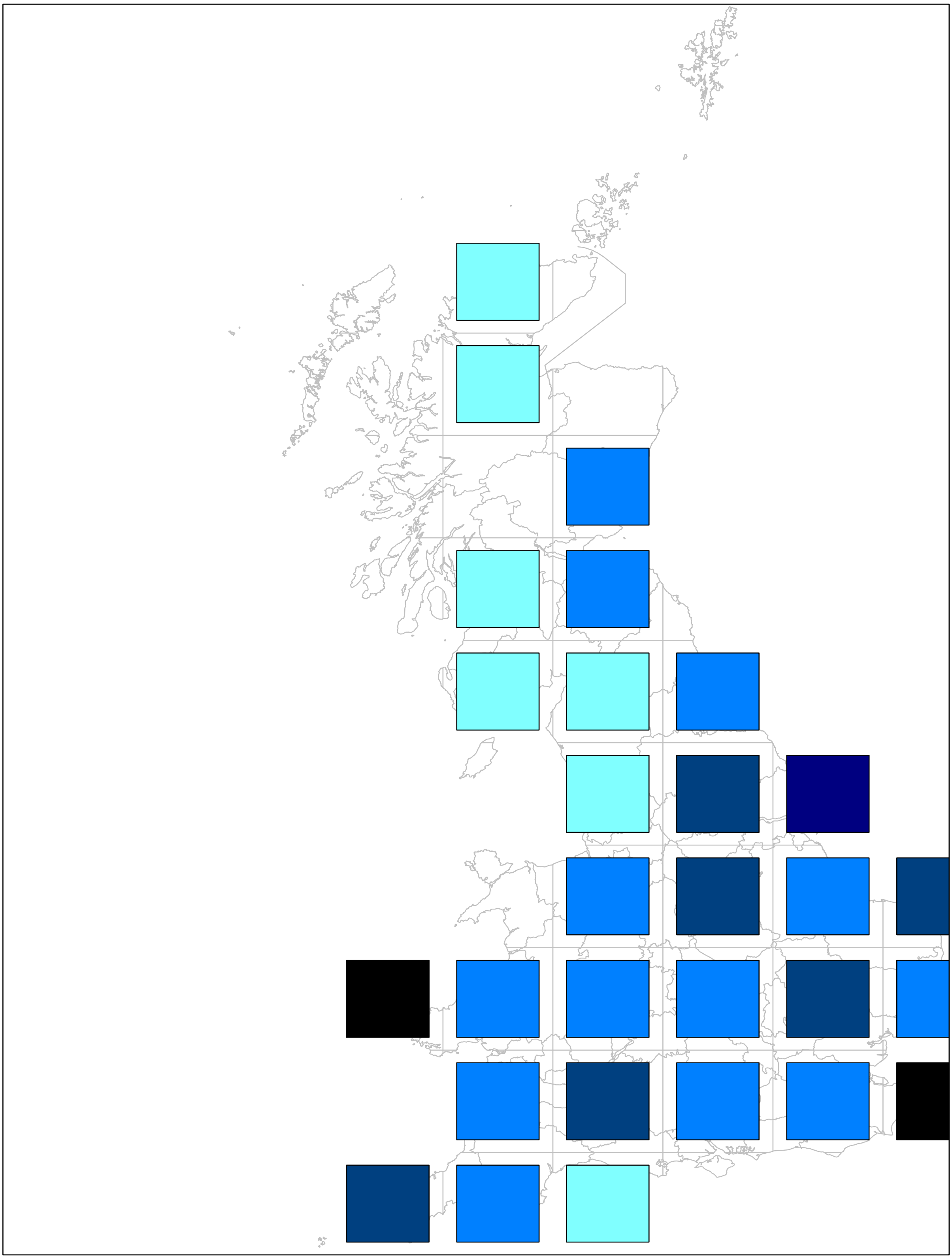


Figure 13 Proportions of positive sites across the country. Darker shades represent greater proportions of positive sites. Blank areas represent areas where no water shrews were recorded during the survey.

3.5.1 Historical water shrew records

From the beginning of the Water Shrew Survey, volunteers and interested members of the general public began contacting The Mammal Society with historical records of water shrews or current records collected outside the survey. The Mammal Society collected and maintained a database of these records. As the records for the *Atlas of Mammals in Britain* were collected up to 1993, The Mammal Society only collected records from 1993 onwards. They came from a variety of sources including bait tubes, Longworth trapping, cat kills and owl pellet analysis. Only a few of these records were accompanied by field forms and we decided that, to standardise the data, habitat information collected outside the survey would not be included in statistical analyses. Grid references were used, however, and the data are presented in Figure 14. All County Mammal Recorders were contacted during the survey and asked to submit any water shrew records they held. In return they were provided with all new records for their county, collected during the survey. While many Mammal Recorders responded, there were several who did not, and thus the results in Figure 14 should not be considered to be complete. However, it is the first time since 1993 that such a large number of water shrew records have been collated.

Neomys fodiens - From 1993 to present day

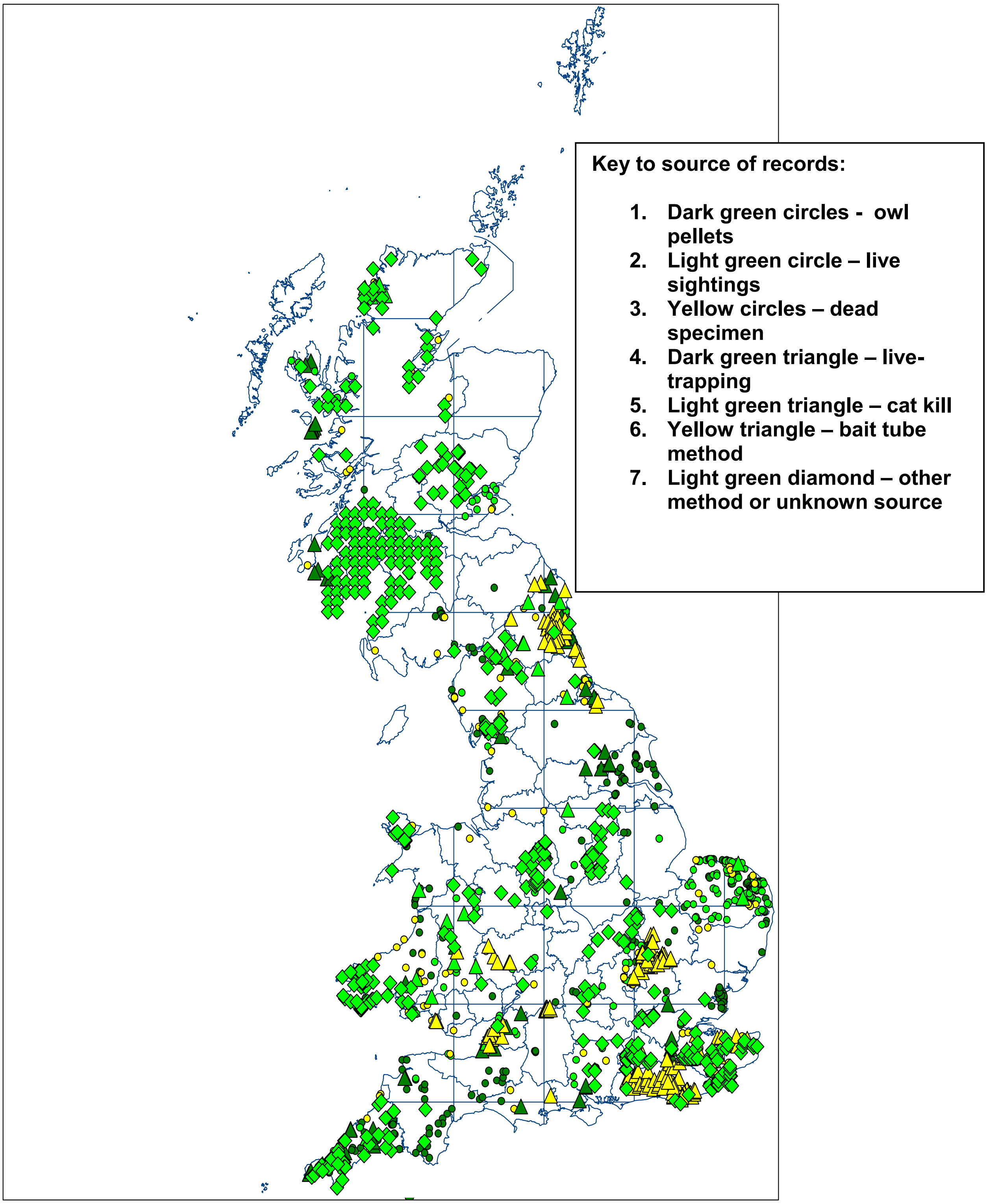


Figure 14 Historical records of water shrews from 1993 to present day - not including records collected during the Water Shrew Survey.

3.6 Habitat occurrence of water shrews

Many different types of aquatic habitat were investigated during the survey (Table 11), although the majority of survey sites comprised rivers, streams, ponds/lakes and ditches. Water shrews were found in most habitat types with the exception of bogs and cressbeds. As well as being found in rivers and streams, with which they have commonly been associated, water shrews were found in slow flowing or static water bodies such as ponds and lakes, ditches and canals (Table 11). In fact, water shrews were found in a greater proportion of lentic sites than lotic ones.

Table 11 The frequency of positive sites in each habitat type.

Habitat type	Total sites	Positive sites	Per cent sites positive
River	410	65	15.6
Stream	666	114	17.2
Canal	78	24	30.8
Pond/Lake	420	77	18.3
Ditch	245	49	20.0
Bog	15	0	0
Fen / Marsh	35	9	25.7
Reedbed	41	7	17.1
Cressbed	2	0	0
Other	89	21	23.6

3.6.1 Current speed and substrate type

Water shrews were found in sites with fast-flowing water and in those where the water current was slow or even static (Figure 15). Approximately equal proportions of sites with static and slow-flowing water were found to support water shrews (19.7 and 18.9%, respectively), while only 14.6% of fast-flowing sites supported the species.

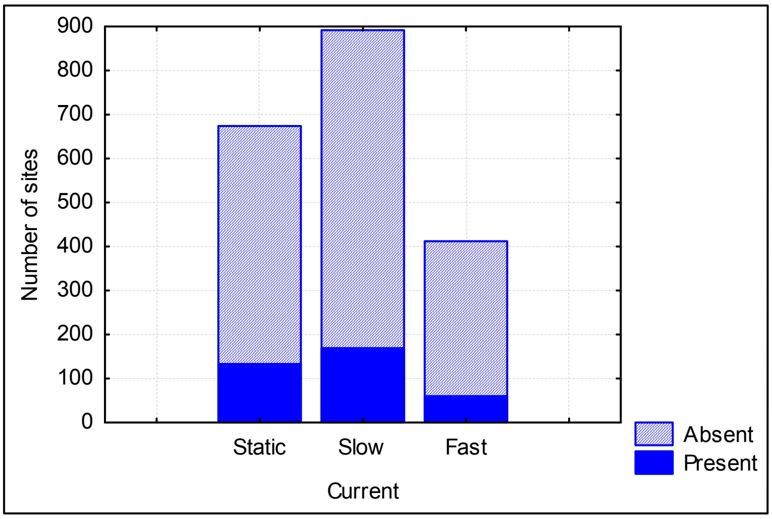


Figure 15 The frequency of occurrence of water shrews in sites with different water currents.

The substrate in the majority of the water bodies surveyed by volunteers was silt, as shown in Figure 16. The occurrence of water shrews was greatest in sites where the substrate was gravel (22.7% of sites), although they were also found in sites with silt-based substrates (18.4% of sites) and in sites with substrates of rocks and stones (13.2% of sites).

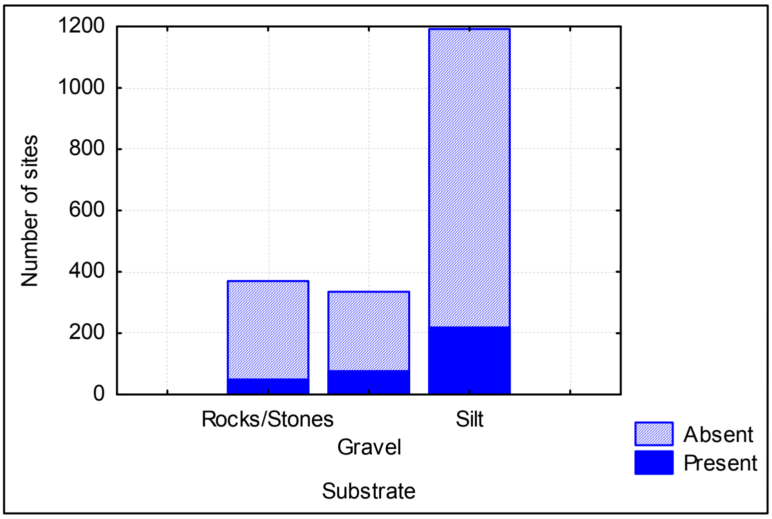


Figure 16 The frequency of occurrence of water shrews in sites with different substrate types.

3.6.2 Depth and width of water body

Water shrews were found to occur in sites with a range of different water depths (Figure 17). However, sites with a water depth over 0.5m were favoured. 20.1%, 21.9% and 20.4% of sites with depths of 0.5-1.0m, 1.0-2.0m and >2.0m, respectively, were positive for water shrews. In contrast, 16.1% and 15.3% of sites with depths of <0.25m and 0.25-0.5m, respectively, had water shrews.

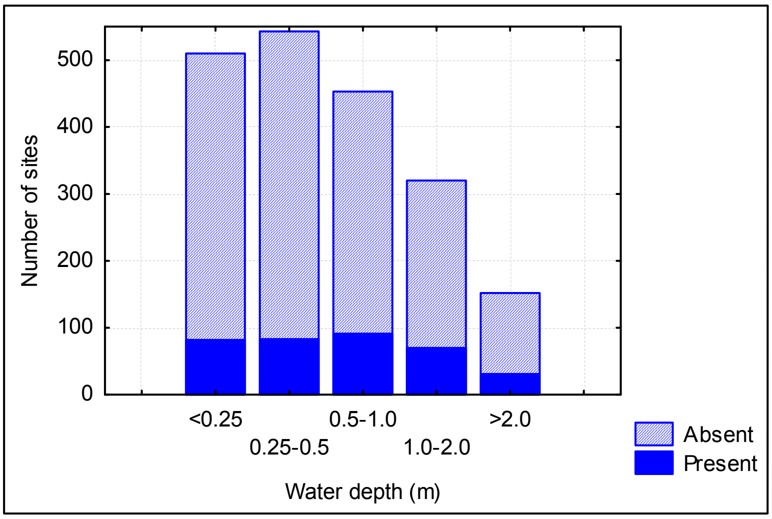


Figure 17 The frequency of occurrence of water shrews in sites with different water depths.

The width of the water body seemed to have little influence on the occurrence of water shrews as they were recorded in sites with water widths ranging from <1m to >10m (Table).

Table 12 The percentage of water shrew sites in water bodies of different widths.

Water width	Total number of sites	Per cent sites positive
<1m	284	17.3
1-2m	484	16.1
2-5m	515	20.6
5-10m	319	19.4
>10m	383	17.8

3.6.3 Bank characteristics

Volunteers were asked to record if the banks of their chosen water-course were predominantly earth or rocky. The large majority of sites surveyed had earth banks (81.7%) with only 18.3% of sites having rocky banks. Water shrews were recorded at 18.6% of sites with earth banks and at 11.4% of sites with rocky banks.

The incline of the bank also appeared to have little impact on the occurrence of water shrews with 17.3% of sites with bank inclines of >45º and 19.1% of sites with inclines of <45º having water shrews present. The versatility and agility of the water shrew can be seen in Figure 18 where an individual is using a nearly vertical rock bank to descend into the water.

Figure 18 Wild water shrew using steep rock bank (photo by Dr S. Furness).

Water shrews were found to occur at sites with bank heights of <1m, 1-2m and >2m. 21.2% of sites with bank heights of >2.0m had positive records of water shrews while only 18.2% and 18.0% of sites with heights of 1.0-2.0m and <1m, respectively, were found to be positive (Figure 19).

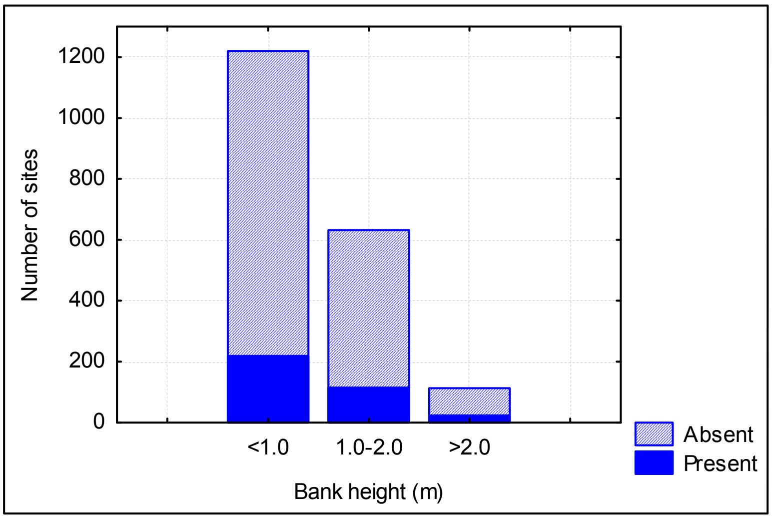


Figure 19 The frequency of occurrence of water shrews in sites with different bank heights.

3.6.4 Aquatic and terrestrial vegetation

From the data collected by volunteers it appears that the presence and amount of aquatic vegetation may influence the presence of water shrews. Fewer sites were occupied by water shrews if aquatic vegetation was absent compared to sites where it was present or dense (Table 13).

Table 13 Percentage of water shrew positive sites with each type and relative quantity of aquatic vegetation.

Aquatic vegetation	Absent	Present	Dense
Emergent	13.6	19.2	25.7
Submerged	14.8	20.6	21.0
Floating	16.1	22.3	21.3

By contrast, the pattern of occurrence in relation to terrestrial vegetation on the banks of the water-course was less clearly defined (14). More water shrews were found at sites where there were no trees but where shrubs were present and herbs and grasses were dense.

Table 14 Percentage of water shrew positive sites with each type and relative quantity of terrestrial vegetation.

Terrestrial vegetation	Absent	Present	Dense
Trees	22.9	17.4	14.5
Shrubs	15.1	19.6	17.2
Herbs	9.3	16.3	23.3
Grasses	12.7	17.5	20.5

3.6.5 Habitat management

For most sites, volunteers provided information about the amount of bank management. The level of management was unknown for a small proportion of sites (Figure 20). A greater proportion of sites that were subject to bank management were found to be positive for water shrews (21.9%) compared to those where no management was in evidence (14.0%).

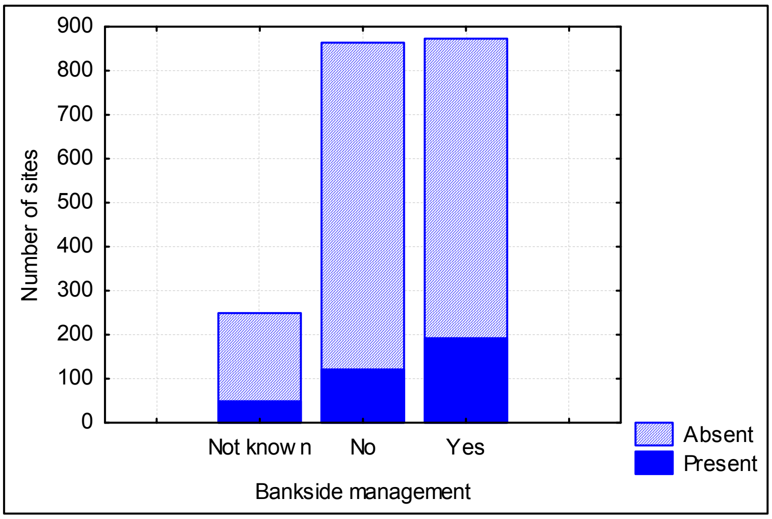


Figure 20 Frequency of occurrence of water shrews in sites with different levels of bankside management.

3.6.6 Human activity and adjacent land use

Just over half of the sites surveyed were used by humans for walking, cycling, boating or angling (Figure 21). Water shrews were found at 19.2% of sites where human activity was in evidence and 17.3% of sites where there was no human activity.

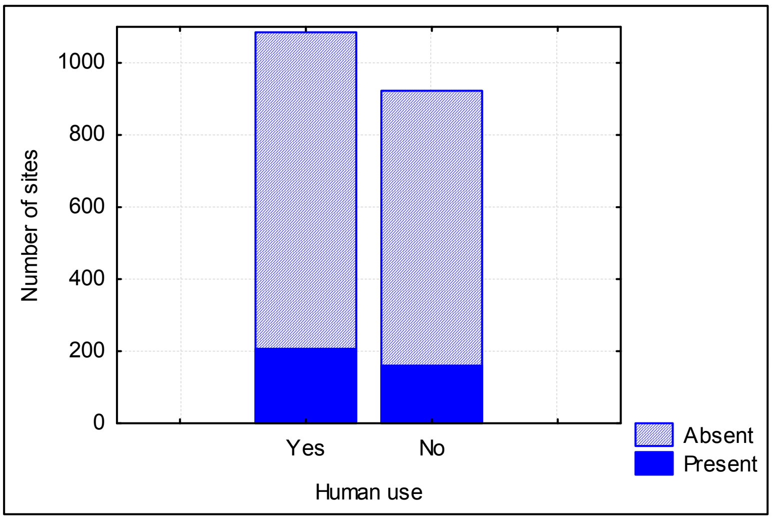


Figure 21 Frequency of occurrence of water shrews at sites with and without human use.

This finding suggests that human activity has little impact on the presence of water shrews. Indeed, several records came from sites where the adjacent land use was urban or gardens, implying frequent recreational use by humans and possibly their pets (Table 15).

Table 15 Records of water shrews from unexpected locations

Adjacent land use to the site	Number of records of water shrews
Urban	3
Garden	7
Sports/amenity ground	3
Fish farm	2
Saltmarsh	1
M5 motorway (within 150m)	1
Scrapyard	1

Figure 22 shows the occurrence of water shrews at sites with different adjacent land uses. The most common sites to find water shrews were those adjacent to arable land (25.3% of such sites were positive). Broadleaved woodland and grassland had approximately equal occupation rates by water shrews (19.6 and 17.3% respectively).

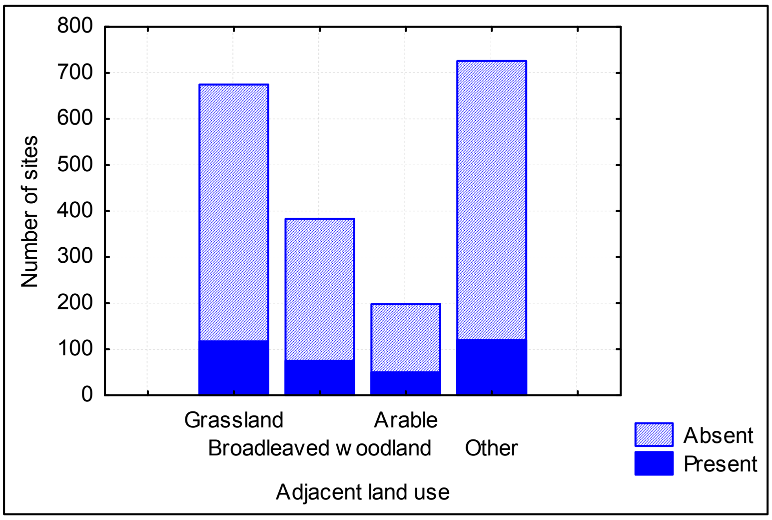


Figure 22 Frequency of occurrence of water shrews at sites with different types of adjacent land use.

3.7 Statistical analysis

Logistic regression was used to explore if there were any relationships between the suite of predictor variables and the presence of water shrews. Logistic regression analysis was selected because the data comprised multiple categorical variables (habitat characteristics, bait type, season, year), several continuous variables (easting, northing, number of tubes used, days set) and a binary response variable (presence or absence of water shrews). This statistical model not only looks at the effect of individual factors on the response variable but also allows interactions between the various factors to be investigated and is a robust and widely used statistical test (see Olsson *et al.*, 1992; Fisher and van Belle, 1993). A series of stepwise binomial models, with logit link-function, were built to ascertain which of the variables accounted for the greatest level of variance in water shrew presence. For all analyses, $p<0.005$ was the chosen level of significance.

The analysis was undertaken using Statistica 6 (StatSoft Inc., Tulsa, USA) and was carried out on data from the 2008 independent sites that had only been visited once. The only exception was one site that had coincidentally been visited by two different volunteers, within 200m of each other. As the visits were made by different people at different times, the data were considered to be independent and included in the analyses.

Results from 151 sites were not included in the analyses because they were not considered to be independent. They were either deliberate re-visits to the same site or artificial subdivisions of a single site (individual habitat forms completed for each tube within one site).

3.7.1 Structural, methodological and habitat variables

The structural variables in the study were season, year, and easting and northing components of the grid reference. The methodological variables were the number of tubes used, number of days the tubes were left and the bait type. The habitat variables were those recoded from the field form (see Table 3).

A series of statistical models were built using a range of different structural, methodological and habitat variables, to determine which accounted for the greatest amount of variance in water shrew occurrence and which correctly classified the largest number of positive sites. The factors responsible for the greatest amount of variance and for correctly classifying the largest number of sites can be considered to have the most influence on water shrew occurrence.

The first two models investigated the methodological and the habitat variables separately. Each model accounted for approximately 4% of the variance and correctly classified less than 1% of positive sites. Even when just the significant factors from each of these two models were factored into a third model, only 8.3% of the variance and 3.7% of positive sites were accounted for. A fourth model was built using all of the methodological and all of the habitat variables at once. With all the variables and all the interactions between the variables included, the model failed to converge and had to be re-run several times, each time removing interactions until convergence was achieved. However, only 6% of the variance with respect to water shrew occurrence was accounted for by this model and it only accurately classified 2% of positive sites.

In each of these models, all available data were used – even from sites where no scats were found. We felt that the data from these 'no scat' sites contributed little to the analysis and may have been masking some of the true effects present in the data. So we built a further model using only data from the sites where scats of some sort had been found (water shrew, terrestrial shrew or rodent).

This model was first run using all variables. The model was re-run using only the significant main effects and the significant two-way interactions between categorical factors. The model failed to converge and, as before, had to be re-run several times, removing interactions each time until the model converged. This model showed that two factors and two interactions between factors had significant ($p<0.005$) effects on water shrew occurrence. The significant factors were easting (the east-west component of the grid reference) and herbs (the presence of herbaceous terrestrial vegetation). The significant interactions were between survey season and shrubs, and trees and shrubs.

As suggested by the geographical distribution of water shrews presented in Figures 12 and Figure 13, easting is a significant factor in determining water shrew occurrence (Figure 23).

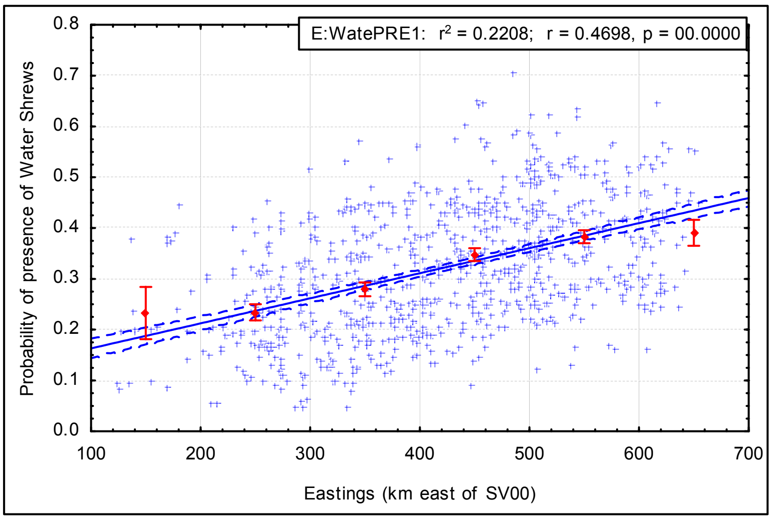


Figure 23 Presence of water shrews in relation to easting.

The interaction between the effects of shrubs and season is shown in Figure 24. More water shrews were found in sites with dense shrub coverage in winter than in similar sites in the summer.

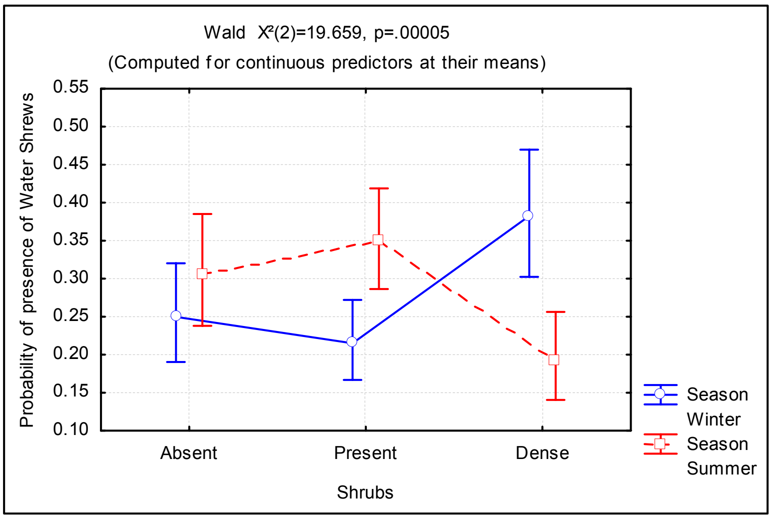


Figure 24 Interaction between season and shrubs.

The level of coverage by herbs was a significant determinant of the presence of water shrews. The likelihood of finding water shrews increased as the level of herb cover increased.

Finally, the model showed a significant interaction between trees and shrubs (p=0.003). When trees were present, but not dense, and shrubs were dense, there was a greater likelihood of finding water shrews (see Figure 25).

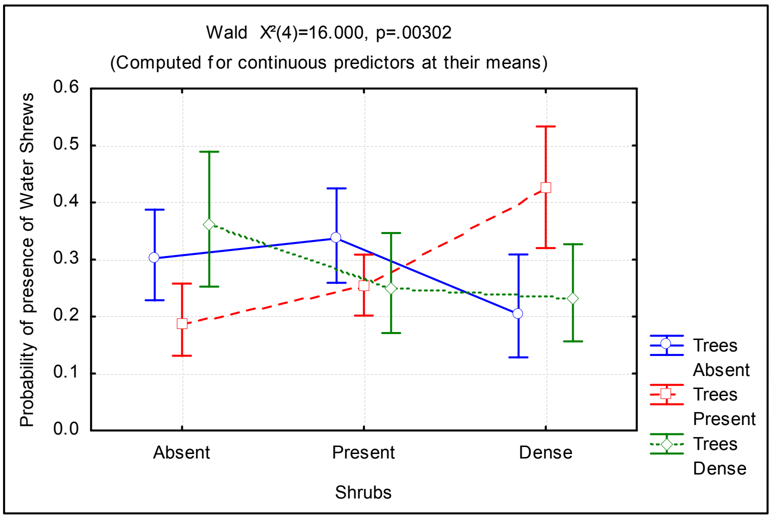


Figure 25 Interaction between trees and shrubs.

Without the data from sites where no scats were found, this model accurately predicted 13.95% of positive sites. While this is a more impressive percentage of accurately predicted positive sites compared to the other models, it is still very low. The model only accounts for 6.7% of the total variance in water shrew presence implying that other factors are more important or that water shrews are ubiquitous and capable of exploiting any aquatic habitat.

3.7.2 Water quality

Logistic regression was also used to look for relationships between water shrew occurrence and water quality. BOD, nitrates, pH and phosphates were investigated. There were too few data for orthophosphates to be incorporated into the analyses. We only used water quality data obtained in the same time frame as the Water Shrew Survey (2004 and 2005). Water quality data from before the survey may not be relevant, because water shrews are nomadic. We cannot tell whether those recorded in the survey occupied the same sites in previous years.

An average value was calculated for each chemical determinand within each 10km square of Great Britain. Nitrate and BOD variables were mathematically transformed to make their distributions more normal, as required by the model. The categorical variables used to build the initial model were thus LogBOD, pH, phosphates, SqrtN, and year. The continuous variables were easting (E10km) and northing (N10km). The response variable was the proportion of water shrew positive sites in each 10km square. The model was run several times, each time factoring in the significant main effects and their interactions from the previous model and removing non-significant interactions until the model converged. The results of the final model showed three interactions to be significant at $p<0.005$ (Table 16). They were the interactions between northing and BOD, between pH and nitrate and between BOD and nitrate.

Table 16 Results of logistic regression of chemical water quality data (values in red are significant P<0.005).

Present - Test of all effects: BINOMIAL Link function: LOGIT

	D.f.	Wald stat.	p
Intercept	1	119.8419	0.000000
"N10km"*LogBOD	1	24.0172	0.000001
pH*SqrtN	1	35.8184	0.000000
LogBOD*SqrtN	1	23.2082	0.000001

The interaction between northing and BOD was highly significant. When presented graphically the interaction can be clearly seen (Figure 26). A greater proportion of water shrews were found in more southerly sites where the BOD was low.

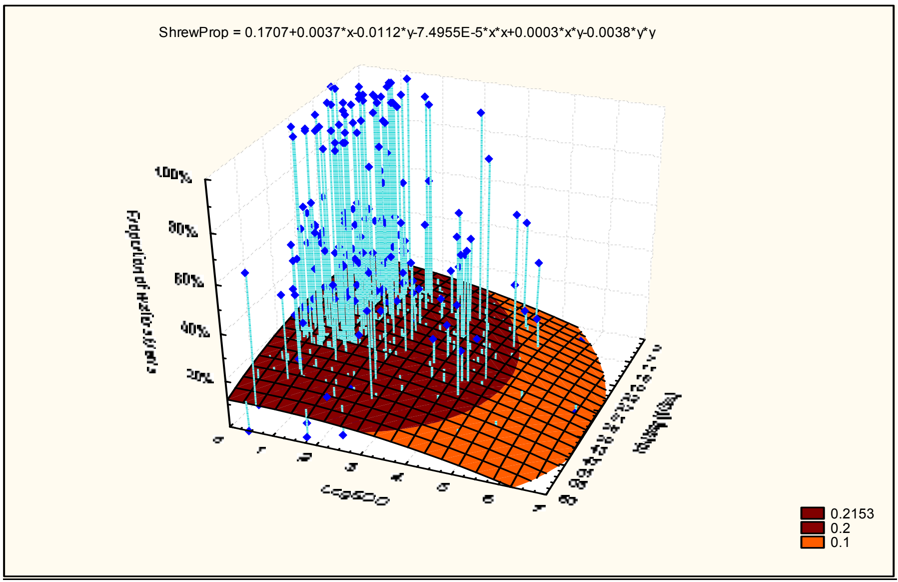


Figure 26 The effect of BOD (LogBOD) and northing (Northing 10km) on water shrew occurrence

There was also a highly significant interaction between pH and nitrates (Fig. 27). Water shrew occurrence was greatest when the pH of the water was neutral or slightly alkaline (7.0-8.0) and where nitrate levels were low (Fig 27).

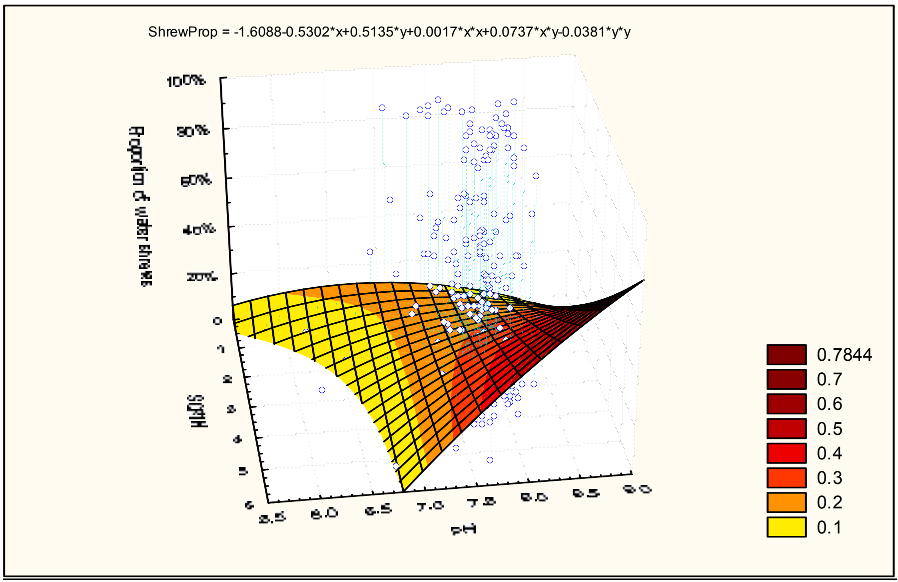


Figure 27 The effect of pH and nitrates on water shrew occurrence

The interaction between BOD and nitrates was also significant (p=0.000001) with the greatest occurrence of water shrews occurring where levels of both were low (Fig. 28).

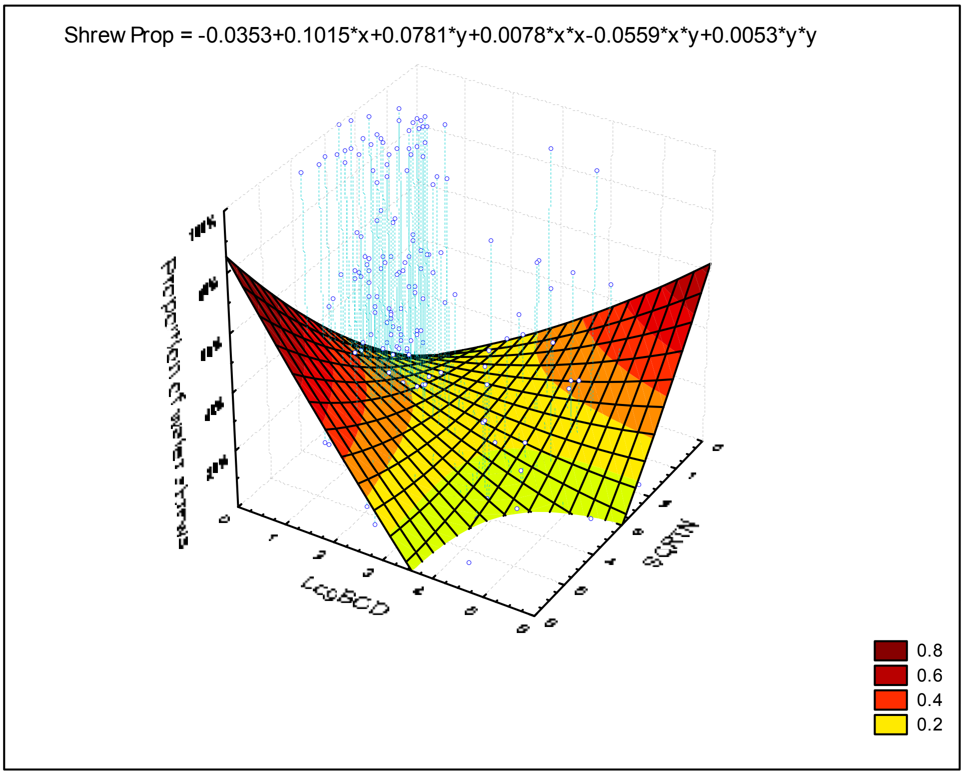


Figure 28 The effect of BOD and nitrates on water shrew occurrence

Despite these significant findings it is unlikely that the water quality variables investigated here are the factors of greatest importance in determining water shrew occurrence. This is reflected in the fact that the model was unable to correctly classify any of the positive sites (Table 17.).

Table 17 Classification of cases in final water quality model

Odds ratio: 0.000000 Log odds ratio: infinity

	Predicted present	**Predicted absent**	**Percent correct**
Water shrews present	0	249	0.00000
Water shrews absent	1	1099	99.90909

4 Analysis and discussion

4.1 Volunteer involvement

Most national mammal surveys rely on volunteer networks for the collection of data. The majority of volunteers for the Water Shrew Survey and other mammal surveys (for example Noble *et al*., 2005) are based in England. This bias is principally the result of the greater population density in England compared to Scotland or Wales. As water shrews are not found in Ireland, the lack of Irish volunteers taking part in the survey was not surprising. Despite water shrews being considered absent from the Channel Islands, one volunteer undertook the survey on Alderney and recorded the presence of the greater white-toothed shrew (*Crocidura russula*).

The fact that more volunteers took part in the summer survey seasons compared with the winter survey seasons can probably be attributed to the better weather at this time of year, making conditions more conducive to surveying. The particularly large number of volunteers taking part in the first summer survey season is due to the amount of publicity that surrounded the survey in its early stages.

The number of volunteers who carried out the survey in all four seasons was low. Despite having a relatively simple methodology, considerable commitment and dedication is required by volunteers. The recent Tracking Mammals Partnership report, '*UK Mammals – Species Status and Population Trends*' (Battersby, 2005), estimated that volunteer time across all mammal surveys would equate to a cost of £4.5 million if professionals were paid to do the same work. Volunteers of the Water Shrew Survey gave an estimated 8,200 hours per annum, which may explain why the majority only took part in one survey season. Volunteers who failed to find any evidence of water shrews, or indeed scats of any species, in their first survey season may have become disheartened and not continued with the survey in subsequent seasons. Although the importance of 'negative' results was highlighted continually throughout the survey there was still an assumption by volunteers that we would not be interested in results from sites where nothing was found. There is a high probability that many of the people that originally signed up for the survey actually undertook field work but did not return any results as they did not find any scats. Unfortunately, the number of people to which this applies is unknown.

A large number of sites (2159) was surveyed during the two years of the Water Shrew Survey (1090 in the first year, 1069 in the second). This number is particularly impressive when compared to other national surveys. For instance, the more methodologically-complex Winter Mammal Monitoring survey run by The Mammal Society and the British Trust for Ornithology covered 1,121 sites over 3 years (Noble *et al*., 2005), while the simple questionnaire survey, Living with Mammals, run by Mammals Trust UK covered only 790 sites in one year. We believe that informing volunteers of the findings from each of their sites and sending them a newsletter charting the progress of the survey provided strong encouragement and contributed to a large number of sites being surveyed. Many volunteers individually surveyed a large number of sites (30 sites, for example).

Despite such good coverage of the country there were still a few areas that were sparsely surveyed. In England, the most obvious gap in the records was Herefordshire (see Figure 11). Prior to The Mammal Society survey, Sara Churchfield ran two courses for members of the Herefordshire Wildlife Trust and Herefordshire Action for Mammals. Following these courses, the group surveyed 25 sites across the county and found evidence of water shrews at four of these. These results have subsequently been submitted to The Mammal Society and feature on the map of historical records. This previous involvement in surveying for water shrews may have resulted in the lack of involvement with the current survey. The lack of sites surveyed in large areas of Scotland is not surprising given that the population density in Scotland is much lower than in England and that much of the landscape is not easily accessible. However, in those areas that were surveyed, evidence of water shrews was found and a more concentrated survey effort in Scotland would probably find a greater incidence of water shrews.

4.2 Methodological considerations

One the of the features of water shrew biology that contributes to their elusive nature is that they are considerably more nomadic than either the common or pygmy shrew, appearing to spend a short time in one area (a few months) before moving on. They may then recolonise the same area after an absence of several months or even years (Churchfield, 1984b, 1990). This nomadic mode of life exacerbates the problems associated with monitoring the water shrew. A survey of this species needs a sampling method that is easy to use and can be widely applied, to ensure that volunteer involvement is high, survey coverage maximal and running costs minimal.

The bait tube method was successful in generating positive records of water shrews during the survey, with 17% of sites recorded positive for this species. However, at just under half of all the sites surveyed no scats of any sort were found. Several volunteers were concerned about this, particularly in instances where the bait was removed from the tubes, but still no scats were found. Casters are a popular food item for all small mammals (particularly wood mice) and it is not uncommon for them to be removed and hoarded in a nearby nest and no scats to be deposited in the tube. The smooth inner surface of the tubes may have made it difficult for small mammals to enter the tubes unless they had been securely placed, flush with the ground. It is also possible that scats were overlooked by volunteers when searching through the contents of the tubes: fresh scats are easily flattened and can resemble soil samples, while dried scats are easily fragmented by the activities of the small mammals visiting the tubes, potentially making them unrecognisable. During the survey, several volunteers reported flooding at their survey sites. The flooding of tubes may have washed them clean or filled them with silt making it hard to distinguish scats from mud. Many volunteers did, however, return the entire contents of the tubes. When these were examined the only items present were often snail casts and debris, implying that the tubes had not been used by small mammals.

Several volunteers suggested that using Longworth traps would have avoided these problems. However, as mentioned previously, live trapping is time-consuming, labour intensive and requires all trappers to hold a shrew licence. Live trapping is also reliant on trappers being able to accurately identify the species caught. Traps must be checked frequently to prevent shrews dying, even when appropriate bedding and food have been provided. By contrast, the bait tube method does not trap small mammals at any point, which has obvious benefits for animal welfare.

Comparing the efficacy of bait tubes and Longworth traps for recording water shrew presence in a variety of riparian habitats, Churchfield *et al.* (2000) found that bait tubes compared favourably with Longworth traps. Bait tubes are considerably cheaper to produce than live traps and have proved to be an effective method for use in a nationwide volunteer-based study.

The current survey showed that there was a greater likelihood of detecting water shrews when more bait tubes were used at a site. With more tubes a greater area of each site could be surveyed, thus increasing the chances of water shrews (if present) locating the tubes. However, due to the expense of posting bait tubes to volunteers it was only possible for a total of eight tubes to be sent to each. Thus, two sites could be monitored at the same time, with four tubes used at each. This was considered sufficient, given that in their study of the Weald, Greenwood *et al.* (2002) used five bait tubes at each site and found that 81% of tubes were positive for small mammal scats and that 42% were positive for water shrews. However, in future surveys we would recommend that volunteers use all eight tubes at one site. While this may reduce the number of sites surveyed, it may increase the number of water shrew records that we collect.

The majority of volunteers were able to use casters as bait, but those that could not used dried mealworms. The difficulty in obtaining casters in some areas of the country was not fully appreciated until the survey was underway. While both baits were effective, it is interesting to note that water shrews were more likely to be found when casters were used. This may be attributed to the difference in attractiveness of the two baits. However, as the difference in effectiveness of the two baits was non-significant, we recommend that either be used in future surveys.

4.3 Seasonal and annual differences in survey findings

The percentage of volunteers who found evidence of water shrews at one or more of their sites was consistently greater in the summer survey seasons. This can be attributed to seasonal cycles in the population numbers of the species and to seasonal patterns in activity. As with common and pygmy shrews, water shrews breed between April and September. By the end of May, 90% or more of female shrews are either pregnant or lactating. Weaned young emerge from nests between May and September resulting in shrew populations reaching a peak in mid-late summer. In autumn, there is a natural decline of the population as old individuals die and the young disperse (Churchfield, 1984b, 1990). Shrews are generally less active in winter, with smaller territories and more time spent in their nests. Consequently, there is a greater chance of finding water shrews in summer than in winter.

The relatively high percentage of positive sites recorded in the second summer season (season 4) is interesting. Analysis suggests that this was not an artefact (volunteers getting better at selectively choosing likely sites for water shrews). Although annual population fluctuations are not uncommon in shrews, they do not seem to undergo the same peaks and troughs displayed by some rodent species (Churchfield, 1990). An alternative contributory factor may be rainfall. During the summer of 2005, the mean monthly rainfall across England, Wales and Scotland (averaged from monthly records from the Meteorological Office) was 85.9mm. By comparison, mean monthly rainfall in survey seasons one, two and three was 100.7mm, 95.7mm and 181.8mm, respectively. Rather than a biological phenomenon accounting for the greater incidence of water shrews, it is possible that, with less rainfall, the contents of fewer tubes were washed out by heavy rain and spating rivers. As a result, more water shrew scats were retained.

4.4 Geographical occurrence

The distribution map of the water shrew produced during the current survey is unique in that the records come from detailed analysis of scat samples and there is very little chance of any of the results being falsely positive. This is the first time that a nationwide survey has been carried out for the water shrew and the findings have produced a wealth of baseline information against which future changes to the geographical and habitat occurrence of the species can be monitored.

The findings from the current survey are in accordance with previous reports and records that water shrews are found throughout mainland Britain but are scarcer in northern Scotland (Churchfield, 1991). Of particular note is their predominance in central and eastern England. This survey has produced the first evidence that easting is a significant factor in determining the presence of water shrews. The reasons for this may be related to climate, altitude, topography and the type of habitat available (mostly lowland riparian) but further research is needed to elucidate this novel finding.

4.5 Coexistence of shrew species

The presence of terrestrial shrews (*S. araneus* and *S. minutus*) as well as water shrews was recorded as the scat samples were analysed. Results showed that terrestrial shrews regularly visited bait tubes but only 14.7% of sites in which water shrews were found showed evidence of terrestrial shrews too. This suggests there may be differences in habitat preferences between *Neomys* and *Sorex* leading to some segregation between these species. It could also imply some form of competitive interaction, with the larger water shrews excluding other shrews from many of the sites.

4.6 Habitat occurrence

4.6.1 Habitat type

Water shrews have commonly been associated with fast-flowing rivers and streams with a substratum of rocks and stones where the greatest quantities of invertebrate prey are supported (Churchfield, 1998). The results of this national survey have shown that water shrews are ubiquitous and do not have clearly defined habitat preferences. This was highlighted by the lack of statistically significant association with any habitat type. Individuals were recorded in a range of habitats including static and slow-flowing waters such as ponds, lakes and, interestingly, canals. Water shrews have rarely been recorded in such sites and these findings suggest that canals provide valuable habitat for water shrews and should not be overlooked in future surveys or in the drafting of habitat management guidelines.

In Britain the greatest population densities of water shrews have been recorded in water-cress beds and reed beds (Churchfield 1984a, b; Perrow, *pers comm*) where they can be found in relatively high numbers for the species (>3/hectare). Watercress beds are considered to be one of the favoured habitats for the species. In the current survey only two of the sites surveyed were water-cress beds and water shrews were not found at either site. Obviously, the sample size is too small to be representative of the habitat type as a whole and too small for statistical comparisons with other habitat types to be made. Appeals for water shrew records were made to several large commercial cress farms during this survey but went unacknowledged.

As well as being found in sites next to arable land, water shrews were found in almost equal proportions in sites adjacent to grassland, broadleaved woodland and a range of other types of habitat, showing their versatility and adaptability. Although the ‘other’ category provided to volunteers on the field form produced some interesting anecdotal evidence for unusual locations of water shrews, including gardens, amenity sites and a scrap yard, it did not provide much useful information for statistical analysis. Careful consideration would be given to the value of including this category in future surveys.

4.6.2 Current speed and substrate type

Because the majority of sites that were surveyed were classified as slow flowing or static, it is unsurprising that the predominant substrate type was silt. Several of the aquatic prey items commonly consumed by water shrews can be found in silt-based substrates. For example, several species of caddis fly larvae (for example *Glyphotaelius pellucidus*, *Limnephilus rhombicus*) and the freshwater hoglouse (*Asellus aquaticus*) are associated with slow flowing or standing waters (Sterry, 1997) where the substrate is silt-based. Caddis fly larvae and *Asellus* are the main aquatic components of the water shrew diet and the presence of both in silt substrates explains why water shrews were recorded in these sites. Freshwater shrimps, *Gammarus pulex,* are another important aquatic prey item for water shrews. Being intolerant of low oxygen content, gammarids tend to be found in faster-flowing waters where the substrate contains little silt due to the flow of the water. As all substrate types support one or more prey species on which water shrews feed, it is not surprising that these shrews were found in all substrate types and were not significantly associated with any type in particular. This supports the findings of Greenwood *et al.* (2002).

4.6.3 Water depth and width

In the wild, water shrews have been recorded foraging in streams generally to depths of less than 30cm, but occasionally up to 200cm (Schloeth, 1980). However, captive water shrews are capable of diving to depths in excess of 2m in standing water (Vogel *et al.*, 1998). Water shrews were recorded in sites with water deeper than 2m in the current study. In these sites it is likely that water shrews forage only at the shallower edges rather than exploiting prey in the depths. It is unlikely that they can swim against the strong currents that are found in deep, swiftly flowing water. The energetic demands associated with swimming in deep water may also constrain water shrews to the shallow edges. Indeed, this tendency to forage in the shallow water at the edges of a watercourse may explain the lack of correlation between water shrew occurrence and the width of a water body.

4.6.4 Bank substrate, height and incline

Water shrews live either in burrows that they dig themselves, or they use the disused burrows of other species such as bank voles. The easiest substrate in which to create burrows is earth and in, the current survey, the majority of sites where water shrews were found had earth banks. Although a predominantly rock-based substrate seems less conducive to burrowing, 11% of sites with rock banks had water shrews. Being both agile and good climbers, water shrews are able to utilise even vertical rocks to gain access to the water. They may also use gaps between the rock for shelter and nesting. Bank type was not a significant predictor of water shrew occurrence in our survey.

Greenwood *et al.* (2002) found that low bank inclines (<45°) and shallow banks (<1.5m) had a negative effect on water shrew presence. They attributed this to the fact that the burrow systems of water shrews usually have entrances above water and that steeper bank inclines minimise the risk of these systems becoming waterlogged. The results from the national survey show, however, that bank incline and bank height have little effect on the occurrence of water shrews, with relatively equal proportions being found at sites with low and steep inclines. Due to the extensive nature of the data in a national study, it is possible that true effects that are apparent in localised, intensive studies are masked. Greenwood *et al.* (2002) made their study in the Weald of south-east England where the majority of sites were rivers and streams (lotic) and where water levels are liable to rapid changes in level, thus intensifying the need for water shrews to create burrow systems in steep banks, well above the water level. In the national survey approximately half of the positive sites were lentic (canals, ponds, lakes, ditches). In lentic habitats, spating is much less of an issue and bank height and incline may be less critical for water shrews. The data from these lentic sites may have masked any associations between water shrew occurrence and bank incline and bank height like those observed in the 2002 study.

4.6.5 Aquatic and terrestrial vegetation

Aquatic vegetation supports a host of aquatic invertebrates, shades the water column (preventing algal blooms), produces a well-oxygenated environment and offers protection from predators. Being so buoyant, water shrews will often hold on to submerged plants while foraging. While aquatic vegetation holds obvious benefits for water shrews, too much may restrict water flow and lead to excessive silting of a water body, making it hard for water shrews to locate prey. However, these advantages and disadvantages appear to be of little consequence to water shrews as shown by the lack of statistically significant association with any type or density of aquatic vegetation.

Terrestrial vegetation plays an important role in riparian habitats. It provides cover for small mammals on the banks of watercourses and the root systems provide stability to banks and prevent erosion. Leaves from bankside trees and waterside plants add to the leaf litter both in the water and on land and this helps to sustain a range of invertebrates. However, trees shade the waterway and while this has the advantage of helping to maintain constant water temperatures in the summer, it can prevent the growth of periphyton algae on which many aquatic invertebrates feed. Trees also restrict the growth of ground cover. In their study, Greenwood *et al*. (2002) found that trees were present at every site where water shrews were found but sites with dense tree cover had relatively few records of these mammals. However, in the current study water shrews were found at tree-less sites but there was no statistically significant association between trees and water shrew occurrence. The interaction between trees and shrubs was statistically significant, however. When both types of vegetation are dense, ground cover is shaded and its growth is restricted, resulting in poorer habitat conditions for water shrews.

Herb cover was found to affect water shrew occurrence significantly in both the national survey and that of the Weald. However, the effects were in direct contrast to each other. In the study of the Weald, there was a statistically greater chance of finding water shrews when herbs were scarce (Greenwood *et al*., 2002) while in the national survey the chance of finding water shrews rose significantly when herb cover was dense. The difference in findings probably reflects the greater diversity of habitat types that were surveyed in the national study.

4.6.6 Habitat management, human activity and land use

Careful bankside management and habitat enhancement have been very effective in helping in the conservation of the water vole (see Strachan, 1998) and we were interested in the effect of bank management on the presence of water shrews. The most common forms of management in riparian habitats involve annual weed-cutting, strimming and mowing, tree-trimming and pollarding. Preventing overgrazing and poaching of banks by livestock is also commonly undertaken as this can compact the soil making the site unsuitable for burrowing by water voles and other riparian mammals. These types of management tend to remove overgrown vegetation that shade the waterways and result in a shorter, thicker, unshaded vegetation layer which may encourage water shrews. As the level of bankside management may not be known by all volunteers we offered a ‘not known’ category on the field form. While this category did not provide us with any useful information it did ensure that volunteers who were unsure of the scale of management did not guess and bias the results. Despite a greater proportion of water shrews being found in sites that were managed, there was no statistically significant association between bank management and water shrew presence.

Perhaps one of the most interesting findings from the survey is that water shrew occurrence was not restricted by human use of a site (angling, walking and cycling, for example). This will be of particular interest to wildlife workers who need to resolve the conflicts between human use of a site and its conservation and enhancement. Human activity tends not to coincide with the most intensive periods of foraging by water shrews at dawn and dusk. Also, the types of human use mentioned above are relatively quiet, low impact pursuits. It may be that higher impact activities would have more effect on water shrew occurrence. However, several water shrew records in the survey came from sites where the adjacent land use was urban, several were from sports grounds and amenity land and one site was within 150m of the M5 motorway. This suggests that water shrews are relatively resilient to human activity. Greenwood *et al.* (2002) found a similar resilience, and there are many reports (Churchfield, 1991, 1998)of water shrews occurring in other man-made habitats such as garden ponds, gravel pits and fish hatcheries. The fact that water shrews were recorded in sites near urban areas might encourage more people to get involved in future surveys and may show that they are more widely distributed than previously thought.

There has been speculation that numbers of water shrews were in decline due to habitat loss, pesticide use and pollution. A large contributor to all these factors was the intensification of farming during and after World War II, when marginal land was farmed and the use of fertilisers, herbicides and insecticides was increased. In an attempt to redress the loss to biodiversity, farming practices are now being changed. Perhaps most relevant to the water shrew is the Defra Code of Good Agricultural Practice for the Protection of Water. This aims to minimise the risk of polluting water while allowing economic agriculture to continue.

The Code advises that spreading of fertilisers should not occur within 10m of a ditch or a watercourse and within 50m of springs, wells or boreholes and that the spraying of pesticides should not drift off-target. In addition, a 10m strip of set-aside must be left adjacent to all watercourses. Implementing all these schemes has probably substantially reduced the run-off into water from agricultural land and it is likely that water quality has significantly improved in the last decade. The set-aside also provides a better habitat for small mammals and birds as it is managed to develop a range of sward heights and habitats. These two factors probably contribute to the fact that in the current survey water shrews were found in many sites adjacent to arable land. It would be interesting to have historical habitat data with which to compare the results of this survey to determine if, prior to these changes in farming practices, water shrews were less common in arable areas. One of the most important outcomes from this survey is that we now have the baseline data against which to assess future changes to the distribution and habitat occurrence of water shrews.

4.6.7 Water quality and water shrew occurrence

Poor water quality can have a deleterious effect on both water shrews and their aquatic invertebrate prey. Determining the extent to which water shrew occurrence is affected by water quality is essential to furthering our knowledge of their biology and ecology.

Biochemical Oxygen Demand (BOD) is used as a measure of the level of organic pollution. The greater the BOD, the more rapidly oxygen is depleted from water and the poorer the diversity of oxygen-dependent plants and animals. Nitrates can equally increase the level of eutrophication in a water body. The results from this survey suggest that water shrews are more commonly associated with low levels of BOD and nitrates where the invertebrate and plant communities are probably more conducive to their survival. Our findings also show that low BOD is associated with a greater proportion of water shrews in southerly sites compared with more northerly sites. There is obviously scope for further work to investigate the reasons for the suggested east/west and north/south division of water shrew occurrence that has been highlighted by the current survey.

Most aquatic life cannot tolerate extremes in pH and so it was not unexpected that water shrews were found in greater proportions in sites with a pH range of 7.0 to 8.0 where conditions are conducive to the survival of their aquatic invertebrate prey.

The assessment of the effect of water quality on water shrew occurrence has provided us with some interesting findings. Our results suggest that water quality is sufficiently high nationwide to support water shrews in a great diversity of sites and habitats. However, in using the average water quality per $10km^2$ we may have missed any subtle associations that might have been detected had water quality data been available for each of the survey sites. Further, intensive, localised surveys may highlight more water quality associations than have been revealed by the current study.

4.6.8 Interpreting the results of logistic regression analysis

Using the habitat data collected by volunteers and the water quality data provided by the Environment Agency, we had hoped to be able to identify variables that might be important predictors of water shrew occurrence. Such information could be useful in producing habitat management guidelines for those interested in conserving water shrews. Greenwood *et al.* (2002) found that a logistic regression model built with the habitat features they investigated predicted 58.3% of the variance in relation to water shrew presence. However, the logistic regression models built from data collected in the current survey were poor predictors of water shrew occurrence. Although they suggested that many of the habitat variables and several of the water quality variables have some influence on the occurrence of water shrews, they only predicted a maximum 6.7% of the variance in water shrew presence. This suggests that there are other, more important factors determining water shrew occurrence that were overlooked or not feasible to investigate in this study. For example, we recommend that future studies assess the effect of the aquatic food supply on water shrews as well as collecting water quality information from each survey site. The field forms were designed to collect useful data without asking for too much input from volunteers. However, the options provided may not have been sufficiently detailed to discriminate between microhabitat variables. At a localised scale it may be easier to elucidate predictors of water shrew presence than at a national level where the wide range and large geographical spread of different habitats being investigated may dilute the effect of specific habitat and water quality features. Spatial factors may influence the population dynamics and dispersal of water shrews and these may be more important to the distribution of the species (Greenwood *et al.,* 2002). The low predictive ability of our models suggests that water shrews are flexible with respect to habitat type and microhabitat variables and are capable of exploiting any aquatic habitat provided it has food and cover.

5 Conclusions

The 2004-2005 Mammal Society Water Shrew Survey found that water shrews are widely distributed across mainland Britain. They were found at 387 (17.4%) of the 2159 sites surveyed. The survey was the first of its kind on a national scale and has collected a wealth of baseline information against which future changes in the distribution and occurrence of the species can be compared. As the first nationwide survey the results cannot address the question of whether water shrews are declining or increasing in the British Isles.

The survey has shown that water shrews are ubiquitous and capable of exploiting many varied habitat types. They were found in slow-flowing and static water bodies such as ponds and canals, as well as fast-flowing rivers and streams. They were found in sites with a range of substrate types and were little influenced by either the depth or width of a water body. Their versatility has enabled them to exploit watercourses with earth banks and those with rocky banks and their agility has resulted in them being unrestricted by either bank height or incline.

More water shrews were found in sites where aquatic vegetation was present but they were also found in sites where it was lacking. Water shrew occurrence was significantly affected by herb cover. A greater proportion of sites with dense herb cover were positive for water shrews. The presence of dense trees and shrubs had a negative impact on water shrew occurrence, probably by restricting growth of the understorey on which the shrews are reliant for cover.

Water shrews were found in sites where management of bankside vegetation was in evidence and in sites where none occurred. They seemed unperturbed by human activity and were found in gardens and in some unusual locations such as within 150m of the M5 motorway. Although more commonly found where the adjacent land use was arable farmland they were also regularly found in sites next to broadleaved woodland and in sites next to grassland.

Although water shrews were widely distributed across the country, the survey showed a statistically significant association between water shrew occurrence and the easting component of grid reference, with more water shrews occurring in the east of Britain. There is some statistically significant evidence to suggest that water quality can influence water shrew distribution, with low BOD, low nitrate levels and a pH of 7.0-8.0 resulting in a higher incidence of water shrews.

The results of these statistical analyses should be interpreted with caution, as none of the variables investigated were particularly strong predictors of water shrew occurrence. Other factors not measured in the survey, such as prey availability, may have a greater influence over the occurrence of this species.

The survey was a great success. A large quantity of high quality data was generated. We were able to map the occurrence of water shrews on both a national and a regional scale and gain a significant insight into the broad habitat range of this elusive and little known species. Volunteers from all over the country were extensively involved. A national Small Mammal Monitoring Scheme, to be implemented by The Mammal Society in the near future, will continue to collect information on the water shrew, building on the large dataset accrued during this pioneering survey.

6 Recommendations

6.1 Conservation

Our survey has shown that water shrews are widely distributed around mainland Britain. They are ecologically flexible and utilise many different freshwater habitats with a wide range of conditions with respect to water depth and width, substrate type, bank type, and abundance of aquatic and terrestrial vegetation. They also tolerate a range of different water qualities, human activities and levels of bankside management.

The wide geographical distribution and broad habitat range of water shrews is encouraging. However, only 17.4% of the sites investigated showed signs of water shrews and poor water quality and loss or degradation of riparian habitat may affect their occurrence on a local scale. There is also the possibility that the spread of predatory American mink may adversely affect their distribution. To fully assess their conservation needs we must determine and monitor the population size of water shrews in Britain.

In light of our findings, we urge sensitive management of riparian sites to encourage water shrew populations. This should include the encouragement of bankside ground cover, the management of bankside trees and shrubs and the maintenance of low BOD and nitrate levels in water courses.

6.2 Future research

The results from the survey have highlighted several areas for future research:

1. **Population size.** Future plans involve continued monitoring of water shrews as part of a nationwide Small Mammal Monitoring scheme. The sampling protocol using bait tubes will be modified to produce an index of water shrew abundance that can be used to determine their population size.

2. **Geographical occurrence.**
    a) The survey has shown an association between easting and water shrew occurrence. We recommend future research to investigate this trend more fully. This will require more detailed assessment of habitats than was possible during our survey.
    b) We recommend that a more extensive water shrew survey of Scotland be carried out. This may show water shrews to be more widely distributed in Scotland than previously thought.

3. **Prey availability.** We were unable to investigate the diversity and abundance of aquatic invertebrates at different sites in this survey. This could be an important factor in determining the occurrence of the water shrew and should be subject to further investigation.

4. **Water quality.** The findings suggest there may be an association between water quality and water shrew occurrence. Further work should be carried out to elucidate these associations.

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