ENGLISH NATURE

The habitat and management requirements of spined loach *Cobitis taenia*

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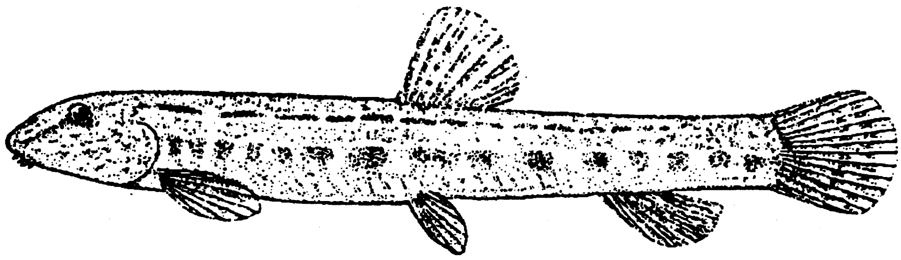

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Executive summary

Background information

Spined loach (*Cobitis taenia*) is listed under Annex II of the EC Directive on the conservation of natural habitats and flora and fauna. Member countries have the duty to ensure the favourable conservation status of the species through conservation of viable populations within Special Areas of Conservation (SAC's). However, this does not conserve the species in a wider context.

The conservation strategy for spined loach in the UK is therefore based on:

- Implementing the EC directive through the establishment of SAC's. Developing sufficient understanding to enable this process to occur is the principal target of English Nature, one of the partners of the current project.

- The conservation, and if possible, promotion spined loach in all waters in which it occurs. This to be achieved through production of a set of operational guidelines for those organisations undertaking management of waterways primarily for flood defence and drainage. This is the principal concern of the other project partner, the Environment Agency.

For these aims to be achieved, specific information on the distribution and habitat preferences and factors determining the size and viability of populations, particularly the role of habitat management are required. This to be placed within the context of a general understanding of the ecology (especially feeding and reproductive strategies) and population dynamics of the species.

Distribution

From the 180 records of spined loach gathered from a variety of sources during the project, it is clear that the species is naturally restricted to the Great Ouse and Trent (and connected Witham) catchments. This results from a combination of the patterns of colonisation from ancestral riverine connections prior to the severance of the land bridge at the end of the last ice age some 10 000 year ago, and the lack of subsequent dispersal through human means. Spined loach does, however, occur widely within its restricted range and is found in a number of different types of waterbody such as streams, rivers, drains and gravel pits.

Habitat preferences

From a review of available literature, analysis of routine Agency data and specific fieldwork, it appears that the optimal habitat of spined loach consists of a sandy substrate with patchy, dense macrophytes. Spined loach is restricted to fine sediments by its specialised feeding mechanism in which it pumps fine material through its buccal cavity, from which it extracts food particles with mucous. Although spined loach may tolerate silt or mud, a preference for sand may be linked to the presence of a wider range and abundance of its specific (0.2 - 0.75 mm in size), animal and plant food. It is also possible that sand is a more appropriate spawning substrate, perhaps leading to better egg survival. Both these factors may be linked to oxygen levels within the substrate.

Due to its small size, spined loach is thought to be vulnerable to predation from a variety of vertebrate (including piscivorous and omnivorous fish) and even invertebrate predators. Dense macrophytes (and other structures such as filamentous algae) may offer refuges against predation. This is offset against a need for unhindered access to the sediment to feed, probably at night. Consequently, a heterogeneous habitat comprised of dense patchy macrophytes interspersed with open sediment is required. This may be found in a variety of situations from streams to large lakes, which accounts for its occurrence within a range of different types of waterbody. However, on balance, the optimal habitat may be more abundant in natural streams and rivers, where spined loach evolved. This does however, require clarification.

Key issues of a conservation strategy

Spined loach displays a tendency to occur as morphologically and/or genetically distinct forms within the *Cobitis taenia* complex. The lengthy time scale of reproductive isolation both from the source stock in Continental Europe and also between stocks in different catchments within the UK, results in the possibility of endemic races, subspecies or even species being present. SAC selection must take this into account. However, in the absence of detailed information on genotypes, required to make a considered decision, the pragmatic option is to set up SAC's within at least the Great Ouse and Trent catchments. Moreover, as the connection between the Trent and Witham system is restricted to the Fossdyke, and thus mixing of populations may be limited, it may also be prudent to also establish at least one SAC within the Witham.

The conservation of viable populations both in protected areas and in all waterways it occurs, may be challenging. This is because spined loach is thought to be highly vulnerable to anthropogenic influences in any one season. This results from its dependence on annual recruitment, and the constraints of a specialised feeding mechanism and vulnerability to predation resulting in specific habitat requirements. Factors such as habitat changes resulting from management and perhaps stocking of other fish (potential competitors or predators), particularly where they impact upon larval/juvenile survival, may reduce the viability of the population, ultimately leading to local extinction.

Conservation within the Ouse Washes cSAC

Spined loach has been confirmed to be widely distributed in the Ouse Washes candidate SAC (cSAC), which incorporates 19 km of the Counterdrain/Old Bedford river (outer river) and Old Bedford/River Delph (inner river). The Ouse Washes cSAC is therefore likely to meet its objective of conserving a viable population of spined loach within one of its population centres. However, there are considerable differences in the current ability of outer and inner rivers to support spined loach, with the outer river supporting a denser population, with a high proportion of underyearlings. This is related to the presence of macrophytes and a suitable sediment.

Several issues that may compromise the ability of the site to support spined loach and ultimately jeopardise its conservation value are thought to include; nutrient loading and the resultant loss of macrophytes, loading of fine anoxic sediments, and the presence of large stocks of coarse fish. Future work to safeguard and if possible, improve the status of the cSAC and the site as a whole is recommended.

Preliminary management guidelines

Although sufficiently detailed information to determine a management prescription for spined loach is not yet available, a number of precautionary general and more specific guidelines are provided. In general, in any system containing important populations of spined loach, action should be taken to reduce eutrophication, excessive loading of fine sediments, excessive stocking of benthivorous fish and any wholesale management of river and stream channels (e.g. channelisation) that causes a significant reduction in habitat diversity.

Specific guidelines stem from the short-lived nature of spined loach and its reliance on annual recruitment to maintain populations. This suggests that the effects of various management practices used by the Environment Agency and other organisations, such as dredging, weed-cutting and channel profiling, may be considerable. Reduction in the frequency of management, leaving unmanaged refuge areas and alternatives to routine management are discussed.

Future monitoring and research requirements

It is recommended that the principal components of a future programme of research and monitoring include:

- Determining the taxonomic status of spined loach in the UK, through molecular studies.
- Determining the distribution and status of spined loach in the Trent & Witham and Great Ouse catchments with the view to establishing further SAC's.
- Undertaking a survey of spined loach in a number of habitats, particularly streams, in order to provide information on what constitutes a 'good and viable' population. This should also assess the value of the stream habitat and determine the likely impact of modification of streams upon spined loach populations.
- Conducting specific medium term (at least one year) research on the habitat requirements, especially of juveniles, and population dynamics of spined loach. This to be conducted in two study sites; one in a stream/river with sandy substrate and the other in a large drainage channels, with a more silty substrate.
- Determining the effects of different water quality criteria (e.g. salinity) upon spined loach, within a range likely to be encountered in natural habitats. Conducting laboratory eco-toxicological tests is considered to be the most cost-effective approach.
- Monitoring the impact of routine management practices such as channelization, dredging and weed-cutting. Study sites in both streams and large drainage channels are required. A scientifically rigorous experimental design, using replicates and a range of treatments incorporating controls, is recommended.

An assessment of sampling methods concluded that specific methods, including the use of the hand trawl (in large rivers and drainage channels) and point-abundance sampling by electrofishing (in streams) are required to sample spined loach effectively. These should be used in all aspects of future research on, and monitoring of, the species. It is also recommended that these methods, where appropriate, be incorporated into routine Agency sampling of waters within the known distribution of spined loach.

Contents

Background information

The spined loach (*Cobitis taenia*) has an extremely wide distribution across Europe and Asia as far as Japan. It is known from a wide variety of slow-flowing or still water bodies including rivers, streams, drains, canals, ditches and large and small lakes. Even with such a wide range and potentially broad ecological niche, it is generally regarded as threatened, if not rare in Europe (Lelek 1980), and is protected by law in Belgium and the Netherlands (Bervoets *et al.* 1990, OVB 1994). In accordance with its status, spined loach is listed under Appendix 3 of the Bern Convention and has recently been included under Annex II of the EC Directive on the conservation of natural habitats and flora and fauna. Member countries have the duty to ensure the favourable conservation status of the species through conservation of viable populations within Special Areas of Conservation (SAC's).

The current project is a collaborative effort between English Nature (EN) and the Environment Agency (Agency) (see *Project Management* below). Meeting the EC Directive forms the ultimate overall requirement of the project from an EN perspective, whilst the emphasis for the EA is focused on clarifying the distribution and status of the species and developing management guidelines that can be applied where it occurs. Until now, the assessment of the species' status had been constrained by the lack of commercial or obvious ecological/management value. Combined with its small size (<12 cm) and benthic habits (Fig. 1), which has generally precluded its sampling by standard fish stock assessment techniques, the spined loach has remained poorly studied.

Thus there is some uncertainty as to whether spined loach is a minor and/or rare component of the fish fauna, limited by specific habitat requirements, or is simply under-recorded. In the UK, it was thought to be patchily distributed within a range encompassing eastern England into the Midlands (Maitland 1972, Mann 1995). Within this range, one site, the Ouse Washes, is a candidate SAC (cSAC). Selection of this site was, however, hampered by the lack of detailed information on the distribution and habitat requirements of spined loach. Further, with a lack of comparable data from other sites, the value of the Ouse Washes as an SAC, in that it should conserve a good and viable population, remains uncertain. The selection of further SAC's hinges on more detailed knowledge of the limits of the distribution of spined loach and, at the very least, confirmation of its presence at previously identified locations. Maintenance of favourable conservation status within protected areas and in all waters in which it occurs, relies on detailed knowledge of the species' habitat requirements and adoption of best management practice. The latter is likely to be constrained by the needs of other functions such as land drainage or flood defence of property, as the distribution of the species is centred on a rather intensively managed landscape.

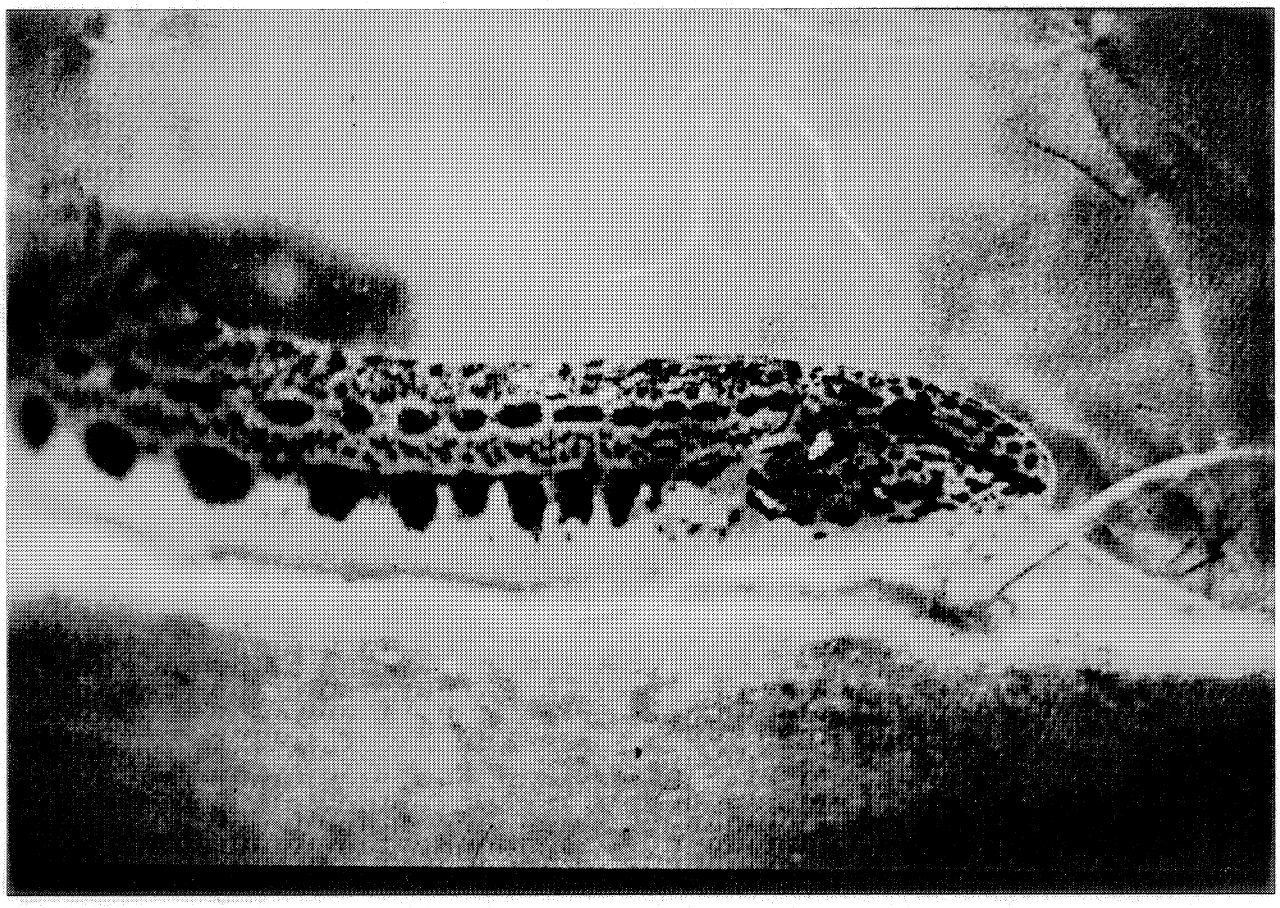


Figure 1. Profile of the spined loach. Note the distinctive body patterning, shape of the head and mouthparts and the indistinct barbels.

Project management

The managers of the project were Mary Gibson (freshwater ecologist) for EN and Andrew Heaton (Regional Conservation Officer for Severn-Trent) for the Environment Agency (hereafter known as the Agency). The Agency provided funds through R & D project 640, 'Species management in aquatic habitats, with EN managing the resulting contract.

Two meetings were held during the course of the project: one at its inception (23rd October 1996) and one to present the findings of the draft report (29th January 1997). A number of representatives from both organisations and from the Royal Society for the Protection of Birds (RSPB)(a major landowner at the Ouse Washes), were present at one or other meeting. These included Mike Evans (Agency), Richard Hall (Agency), Roger Handford (Agency), Neil Lambert (RSPB), and Matt Shardlow (RSPB).

Aims

The current project had five broad aims (see project brief-Appendix 1):

- To review and consolidate all existing information on the distribution of spined loach in England, so as to provide a clearer picture, than currently exists, of its distribution.
- To identify habitat requirements.
- To identify and where possible quantify the key factors/issues which will need to be addressed if favourable conservation of the spined loach is to be achieved across the range of habitats in which it is found.
- To produce management guidelines which will raise awareness relevant to conserving the spined loach and enable operational staff to ensure that management of those sites where spined loach occurs, is undertaken sympathetically. This refers especially to weed and silt control.
- To identify those aspects of ecology and distribution where further research or review is needed.

General information gathering

As it was known that spined loach has been poorly studied (Mann 1995), it was desirable to develop an understanding on all known aspects of its behaviour and ecology in order to fulfil the aims of the project. Consequently, during the search of the scientific literature using Bath Information Data Services (BIDS) at the University of East Anglia (UEA) and Aquatic Sciences and Fisheries Abstracts (ASFA) at the Ministry of Agriculture, Fisheries and Food (MAFF) laboratories at Lowestoft, general key words were used. These were '*Cobitis taenia*' in combination with 'ecology & biology', 'behaviour', 'spawning', 'feeding', 'food' and 'distribution' from 1978-1996. The current literature search extended a previous one using ASFA conducted by EN (M. Gibson, EN, *pers comm.*).

The literature search through ASFA provided 30 relevant references (Appendix 2) whereas BIDS supplied only 8. These are used where appropriate as background information or in the discussion of a particular point throughout the report.

Report structure

For ease of reference this report is divided into 5 sections, in accordance with the aims of the project:

- A. Distribution of spined loach in the UK.
- B. Habitat requirements of spined loach.
- C. Key issues of a conservation strategy for spined loach.
- D. The conservation of spined loach in the Ouse Washes cSAC
- E. Preliminary management guidelines.
- F. Further monitoring and research requirements.

Sections such as the habitat requirements used a combination of literature information supplemented by re-analysis of previously gathered data as well as original research. Within each section, where appropriate, the following is provided: brief background information, an outline of the methods used to gather information and presentation and discussion of the results.

A. Distribution of spined loach in the UK

Background information

As outlined earlier (see *Background information* above), spined loach was thought to occupy a range encompassing eastern England into the Midlands (Maitland 1972, Mann 1995). However, this required confirmation. The production of a distribution map showing all records of spined loach, to update and improve that produced by Maitland (1972) was thought to be a valuable output of the current project.

Methods

Records of spined loach were gathered from the following sources:

- Contact with all fisheries departments of the Agency both within the known range of spined loach (described by Maitland 1972) and in surrounding areas.
- Species Action Plan for spined loach by Mann (1995).
- Contact with a variety of organisations potentially holding records, recommended by the project board, including the Biological Records Centre (BRC), Natural History Museum and the RSPB.
- Consultation with Dr. Peter Maitland, author of the key to British Freshwater Fish (1972), which features a distribution map of spined loach.
- Contact with other individuals that have recorded the presence of spined loach. For example, Dr. Nick Giles, workers in the group of Dr. John Reynolds at the University of East Anglia (UEA) and Dr. Franklyn Perring.

A complete list of the names and addresses of all contacts is provided in Appendix 3. All records were entered into a database and a distribution map produced using the DMAP software package (A. Morton, Dept. Biology, Imperial College, London).

Results & Discussion

A total of 180 records were collected from 76 ten kilometre squares (Fig. 2). Spined loach is recorded from the counties of Bedfordshire, Buckinghamshire, Cambridgeshire, Derbyshire, Humberside, Leicestershire, Lincolnshire, Norfolk, Northamptonshire, Nottinghamshire, Staffordshire, Suffolk and Warwickshire (Appendix 4). A total of 75% of the records were recent (post 1990). The importance of recent records is also reflected by the range data, with only 30% of the 76 10k squares in which spined loach is now recorded, containing records prior to 1990. Overall it is suggested that these patterns indicate a increased tendency to record spined loach, particularly in standard fisheries surveys, rather than any increase in range, frequency of occurrence or abundance of the species. It is also thought that an increase in recording stems from a general increased awareness of so-called minor species (small species with no commercial interest), such as spined loach. An improvement in sampling techniques geared to smaller fish, may also have had a role.

It is clear that the distribution of the species is centred on three east-flowing river systems and their associated waterways; the Great Ouse, the Trent and the Witham (Fig. 2). The latter two river systems are connected through the Fossdyke, an artificial channel dating from Roman times. The fish fauna of east-flowing rivers is generally perceived to have originated from the continental Rhine system, prior to the separation of the land bridge between mainland Britain and continental Europe some 10 000 years ago at the end of the last ice age (see Wheeler. 1977).

Theories on the source of colonists, timing of colonisation and subsequent dispersal of fishes in relation to the land bridge are generally impaired by the lack of good fossil data, which itself is often restricted to bones of species exploited by humans and associated with sites of habitation. The lack of value of spined loach as a food fish and the simple fact that archaeologists use sieves with a mesh unlikely to retain the bones of small species (D. Brinkhuizen, Groningen University *pers comm.*) means that records of spined loach are scant (none known in the UK; none in the Netherlands - Brinkhuizen, 1979; and 1 in Belgium - van Neer & Ervynck 1994). Consequently, a working theory on the factors affecting the historical distribution of spined loach can only be derived from consideration of the evidence for the origin and development of, and likely prevailing ecological conditions within, the rivers in which it does or does not occur.

For example, the current presence of spined loach in the Rhine and its tributaries (e.g. the Ijssel) in the Netherlands (H. de Nie, Wageningen University, *pers comm.*) suggests that it should occur in the Thames (see above). Although there are some unconfirmed records (Maitland 1972, Phillips & Rix 1985), recent fisheries surveys (e.g. by statutory bodies such as the Environment Agency) do not substantiate them. Further, Wheeler (1977) considers a number of species indigenous to east-flowing rivers such as spined loach, silver bream (*Blicca bjoerkna*), burbot (*Lota lota*) (and maybe even barbel (*Barbus barbus*) -A. Wheeler, Natural History Museum, London, *pers comm.*) are also not native to the Thames (Wheeler 1977).

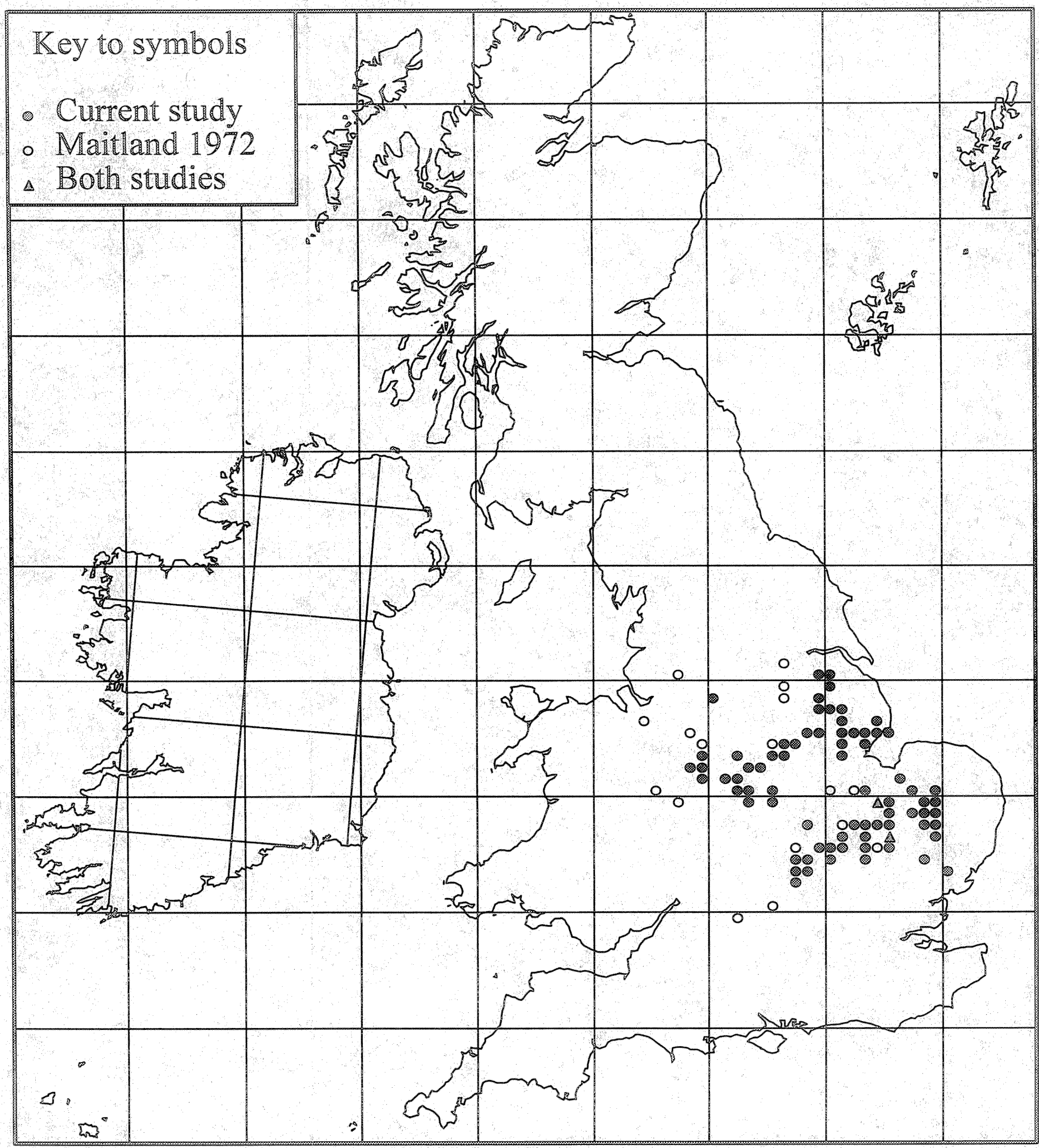
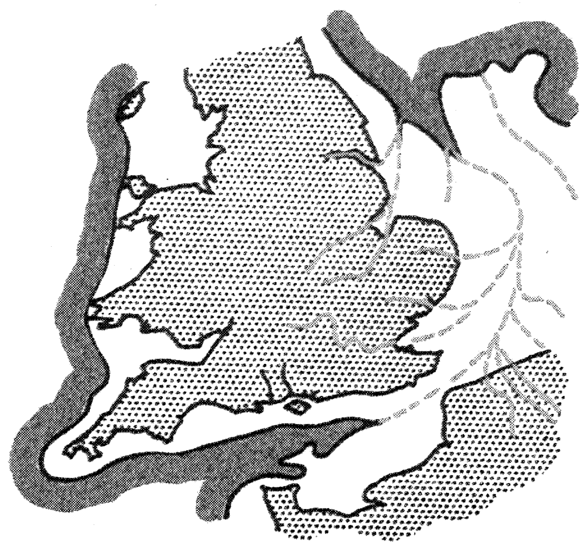


Figure 2. The distribution of spined loach (based on 10 km squares) in the UK, incorporating all records gathered in the current study and by Maitland (1972).

a)



b)

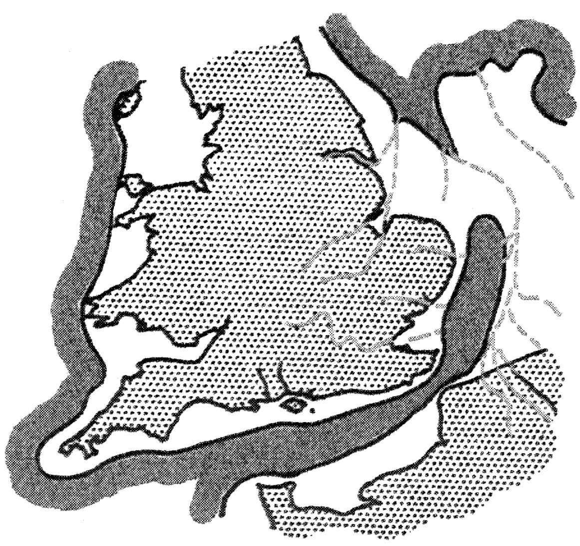


Figure 3. Sketch maps showing the probable position of the ancient rivers of 'dogger-land' immediately after the last ice age. The pattern of sea level rise from a) 9000 to b) 8700 years ago in relation to the current positions of Britain and mainland Europe is shown. Incorporating information from Varley (1967) and D.Brinkhuizen, Groningen University, *pers comm.*

The ultimate reason for the lack of spined loach in the Thames, may stem from the possibility that the principal east-flowing rivers were not confluent with each other but broadly divided into two groups; the Yorkshire Ouse, Trent and Great Ouse in one, and the Thames and southern East Anglian rivers (Yare, Stour etc.) in the other (Varley 1967, P. Gibbard, Cambridge University, *pers comm.*) (Fig. 3). Although there is good evidence that the latter group was confluent with the Rhine in the late Devensian (albeit through a different alignment through the Dover Strait), the former, Great Ouse group may not have been directly so (P. Gibbard, Cambridge University, *pers comm.*), although connection by overland flow cannot be ruled out. The two groups of rivers were therefore subject to different patterns of colonisation by fish, as both the ice receded northwards and the land bridge was eroded from the Dover Strait in the south. The more southerly rivers in the Thames group being isolated earlier than the northerly Great Ouse group (D. Brinkhuizen, Groningen University, *pers comm.*) (Fig. 3).

Spined loach (and the other species noted above) may thus have been in the process of colonising all rivers where ecological conditions were becoming more suitable after the retreat of ice and/or the amelioration of glacial floodwater conditions. It may be that there was insufficient time for the species to colonise the upper reaches of the Thames group (or perhaps these were still unsuitable e.g. too cold for effective recruitment in the case of barbel- Wheeler 1977) before the lower reaches were inundated by the rising sea level. Colonisation by spined loach may thus have been impeded by its generally sedentary nature (D. Brinkhuizen, Groningen University, *pers comm.*). A further several hundred years would have been available for spined loach to colonise the Great Ouse, Trent and Yorkshire Ouse systems. The (apparent) absence from the Yorkshire Ouse and connected rivers may be explained by the prevailing ecological conditions being unsuitable in this system, being the most northerly of catchments of the Great Ouse group and thus the most likely to retain an influence of receding ice and glacial meltwater.

The distribution of spined loach thus appears to have stayed virtually unchanged over the last 10 000 years. Some natural colonisation has occurred. For example, spined loach has been recorded from several gravel pits (e.g. Little Paxton and Great Linford) dug in the floodplain of the Great Ouse. A similar pattern has been observed in several large shallow lakes in the Netherlands with a riverine connection (Perrow & Jowitt 1996, Witteven & Bos unpubl. data). However, in contrast to many other species, spined loach are unlikely to be subject to accidental or deliberate introduction, one of the principal methods of dispersal for fishes (Wheeler 1977). This is primarily because they are of no commercial or angling interest and are unlikely to be used as livebait for larger predatory species. The latter has led to the introduction of other small species into a variety of water bodies (e.g. ruffe *Gymnocephalus cernuus* in Loch Lomond- Maitland & Campbell, 1992).

There is some possibility however of spined loach being transferred during fish rescue operations from polluted waterways, but as these are often conducted within or between neighbouring catchments this is unlikely to be a major supply of colonists to new areas. Indeed, the only outlying population recorded in the current study was that in the Essex Stour. This seems to have resulted from a water bypass scheme which draws water from the Cut-off channel, part of the Great Ouse system.

The outlying populations recorded by Maitland (1972) including one in the catchment of the Thames in Oxfordshire and one in the north-west near Manchester (Fig. 1), cannot now be verified (P. Maitland, consultant & BRC *pers comm.*). In the unlikely event of introduction (see above), we can only conclude that these records are a case of mistaken identity, perhaps resulting from confusion with stone loach (*Barbatula barbatulus*).

Conclusions

Spined loach is naturally restricted to the Great Ouse and Trent/Witham catchments. This results from a combination of the patterns of colonisation from ancestral riverine connections prior to the severance of the land bridge at the end of the last ice age, and the lack of subsequent dispersal through human means. It appears to be widely distributed within these river systems. An increase in the number of records in recent years, is reflective of an increased likelihood of recording the species, particularly in routine fisheries surveys conducted by the Agency and its predecessors. Consequently, there is no evidence of a change in range, frequency of occurrence or abundance in recent years. Several old records suggesting a wider distribution can no longer be verified and are suggested to be a case of mistaken identity.

B. Habitat preferences of spined loach

Background information

Spined loach has been recorded from a wide variety of water bodies including rivers, streams, drains, canals, ditches and large and small lakes. This suggests it has a broad ecological niche. However, it is also possible that the species has a narrow ecological niche which may be satisfied within a number of habitats. It is also possible that selection for different micro-habitats occurs within different types of waterbody. Unravelling these preferences is obviously critical if appropriate management is to be undertaken in different situations, to conserve or promote spined loach populations.

Methods

A four-pronged approach was adopted. First, any literature on habitat preferences was gathered. As this was limited to a few papers in a narrow range of habitats, it was thought that more insight could be gained into likely habitat relationships through an understanding of the general biology, in particular the feeding and reproductive strategies, of the species. Particular requirements in these critical aspects, may then indicate factors limiting the distribution and abundance of spined loach. This was achieved through a search of available literature in the manner described earlier (see *General information* above).

Second, the association between spined loach and other fish species was determined using a large data set derived from routine Agency fisheries surveys in Central area of Anglian region, in the catchment of the Great Ouse, at the heart of the known distribution of spined loach (see *Distribution of spined loach in the UK* above). Association of spined loach with any species/communities with known preferences (e.g. those associated with macrophytes - de Nie 1987), may have implied particular habitat preferences.

Third, the watercourses (or sections of large rivers where these change greatly in type along their course) within the catchment of the Great Ouse (see above), from which spined loach was recorded during routine fisheries surveys, were used in a simple analysis of the likelihood of spined loach occurring within each gross category of waterbody.

Fourth, a more direct approach to determining habitat preferences was undertaken by analysis of three data sets:

- Routine fisheries and river corridor surveys (RCS) from 24 watercourses (or sections of large rivers where these change greatly in type along their course) within Central area of Anglian region (see above).

- Recent surveys undertaken by ECON in the large Lake Veluwe, in the Netherlands as part of a larger study on the interactions between fish and macrophytes (Perrow & Jowitt 1996).

- Specific monitoring of the Ouse Washes candidate SAC (cSAC), as the fieldwork component of the current project.

Habitat implications of associations between spined loach and other fish species

Associations between different fish species were determined by hierarchical cluster analysis (Norusis/SPSS 1993) using presence or absence data from the 345 sites within 51 watercourses within the Great Ouse catchment. This mirrored the successful approach previously adopted by Penczak *et al.* (1991) at 233 sites in 13 drainage basins in Lincolnshire and South Humberside.

A potential caveat of the approach however, is that the techniques used - electrofishing and seine-netting - during routine surveys, were used to sample species important to the fishery. Therefore, spined loach is something of a by-catch. However, as considerable effort was expended at each site (e.g. several runs with electrofishing and several seine nets hauls), it was thought that if spined loach was present in any numbers, at least one individual would be captured.

Frequency of occurrence of spined loach within different types of watercourse

Spined loach has been recorded from 25 watercourses (or sections of large rivers where these change greatly in type along their course) within the catchment of the Great Ouse (see above), during routine fisheries surveys. These were divided into several categories: small rivers or streams, large rivers, drainage channels and canals. The frequency of occurrence of spined loach, within the variable number of sites sampled, during the most recent survey in which it occurred, was determined in each watercourse. A general comparison of the likelihood of sampling spined loach within different types of waterbody was made by determining the mean frequency of occurrence.

Habitat associations derived from routine fisheries and RCS surveys

From the data set outlined above (*Habitat implications of associations between spined loach and other fish species*), 24 watercourses, for which recent (1990-95) habitat data from river corridor surveys (RCS) was available, were selected. The basic approach was to test for differences in habitat variables between the 14 watercourses in which spined loach had been recently recorded (1990 onwards) and the 10 in which it had not. Although the same caveat of spined loach being unrecorded by the sampling techniques adopted (see above) still applies, the chances of sampling spined loach were further increased, by up to 19 sites being sampled within any one watercourse.

Eight habitat variables were determined from RCS data (Table 1). For variables that could be quantified, the mean values from 5 RCS sections, selected in a stratified random manner, were used. Other variables from the same RCS sections were expressed in a semi-quantitative way. For example, the number out of the 5 sites in which a particular substrate type was recorded, was used. Plant abundance, on the other hand, normally expressed as the DAFOR scale, was converted to a simple 1-5 scale and the average score used. The mean value (from all reference stations within each river or section) of three routinely taken water quality variables was also used (Table 1). Student-*t* tests were used to test for differences between watercourses with or without spined loach.

Table 1.
Habitat and water quality variables collected from RCS data, for comparison of sites in which spined loach was present or absent.

Type	*Variable*
Channel characteristics	width depth bank slope
Substrate	sand gravel silt
Macrophytes	submerged/floating littoral emergent
Water quality	BOD 90%ile ammonia 90%ile dissolved oxygen 90%ile

Habitat relationships in Lake Veluwe

Although spined loach is not typically associated with stillwaters in the UK, it is known to occur in several lake systems adjacent to rivers (e.g. Great Linford lakes-Giles 1992). Analysis of the data available from Lake Veluwe was thus potentially relevant to these populations. Moreover, it was plausible that spined loach could associate with the same or similar microhabitat in a number of apparently diverse habitats. As the study in Veluwe had the potential to provide specific detail on microhabitat distribution, with information on diurnal and seasonal patterns from a large number of fish, full analysis of the data set was justified.

Lake Veluwe, a large (3400 ha), shallow lake in the Netherlands is undergoing restoration at the present time and, in the year of study, 1996, was dominated by macrophytes, particularly *Chara* spp. The purpose of the study was to investigate the distribution patterns of fish in relation to macrophytes. Fish were sampled during June-October inclusive, by point-abundance sampling (PAS) (see Copp & Penáz 1988, Copp & Garner 1995), using high frequency (600 Hz) pulsed DC (rectangular wave at 300V with a variable duty cycle of 0-50%) electrofishing equipment, (Electracatch WFC11-12 volt powered by a 1.9 KVa generator) from a 3 m fibreglass dinghy. This was 'push' rowed by one operator, with a second operator electrofishing from the stern. For further details of the sampling technique see Perrow *et al.* (1996a).

During each monthly sampling occasion, samples were taken day (from 10-1100 hrs) and night (starting one hour after dusk) with an interval of approximately 30 hours. Fifty points were sampled along fixed transects (which were identified between occasions using GPS equipment) in each of five habitat zones:

- The littoral zone dominated by reed, *Phragmites australis.*
- The *Potamogeton* spp. and *Myriophyllum* spp. dominated zone, 75 m from the shore.
- Within the centre of *Chara* spp. meadows in the middle of the lake (around 200 m from the shore).
- Along the transition zone between *Chara* and open water, which also has a number of macrophyte species including *Potamogeton perfoliatus* and *Alisma* spp.
- In open water bordering the boat channel.

During PAS the boat was rowed along the transect and points were sampled at regular intervals, after the equivalent (depending on weather conditions) of 10 oar strokes. At each point, the anode was rapidly immersed, and any stunned fish seen were captured by a lightweight fibreglass hand net. Even where no fish were seen, the net was swept quickly through the stunned area to avoid sampling bias created by differences in visibility within habitats and between sampling occasions. The effective sampling radius of 1.3 m^2 was calculated by

)

determining the distance from the anode at which the voltage gradient was reduced to 0.12V, the level at which inhibited swimming occurs (Copp & Penáz 1988). Any spined loach captured were measured to the nearest mm before being returned unharmed. With a known sampling area, the density (n m^{-2}) of spined loach could be calculated. One-way ANOVA was used to test for differences in the density of spined loach between the various habitats on each sampling occasion (both day and night).

In addition, during June and July, a further transect across the width of the lake encompassing all habitats (see above), was explored. In this case, the electrofishing gear was kept on, whilst the boat was propelled forward. The position of capture for each loach was marked and several environmental measures taken. These were:

- The height of vegetation (cm).
- % cover of vegetation and hence bare sediment within a metre diameter of the capture.
- Estimated distance to the nearest bare patch (cm).

The same transect was then followed, recording only environmental variables, within a corresponding sample area, at intervals of 20 oar strokes. A similar number of samples were taken on all occasions. For example, 32 and 45 spined loach were captured and a corresponding number of habitat samples taken, on the first transect, in June and July, respectively. In comparison, 31 and 34 sets of habitat samples were taken on the second transect of each respective sampling occasion. Student-*t* tests were used to test for differences between variables at locations occupied by spined loach and those determined in a systematic manner.

Habitat preferences in the Ouse washes

The habitat preferences of spined loach within the Ouse washes cSAC were assessed during sampling to determine their status and distribution within the system (see *Key issues of a conservation strategy for spined loach* below). The cSAC is comprised of an approximately 19 km length of the Counterdrain/Old Bedford River and the Old Bedford/River Delph (Fig.'s 4 & 5). For ease of reference throughout this document, and following the nomenclature used by the RSPB, the Old Bedford/Delph will be referred to as the inner river and the Counterdrain/Old Bedford River as the outer river.

Within the sampling strategy adopted (see *Key issues of a conservation strategy for spined loach*), it was possible to evaluate the habitat preferences of spined loach at two levels:

- A comparison between populations of spined loach according to the gross habitat characteristics of the outer and inner rivers.

- Determination of the relationship between spined loach density and particular habitat variables within each river.

The basis for the comparison between outer and inner rivers came from RCS data held by the Agency. The outer river contains abundant submerged macrophytes (*Elodea canadensis*, *Myriophyllum spicatum*, *Potamogeton natans* & *P. lucens* as well as filamentous algae), over a silt/gravel substrate with imperceptible flow. The inner river on the other hand is wider (and therefore has a proportionally smaller littoral zone), has higher turbidity and consequently fewer macrophytes. The difference between these two adjacent systems separated by the Middle Level barrier bank stems from their different water supplies; the inner river being ultimately supplied by the Hundred Foot river as overspill through Earith sluice in winter, whilst the outer river is isolated from this water by Middle Level barrier bank, and principally drains water from arable land. At a critical level, the excess is pumped into the inner river via the pumping station at Welches Dam.

Following trials between different sampling methods (see *Further monitoring and research requirements*) the hand trawl was selected as the most appropriate technique (Fig. 6). This was originally designed to catch shrimps in shallow coastal waters by Dr. Bob James (UEA). It consists of a tubular aluminium D' frame of 75 cm x 25 cm height mounted on aluminium runners (0.7 m in length) which allow the trawl to be pulled or pushed (when a long metal handle is attached) across the sediment surface. A 'tickler' chain attached across the front of the runners is designed to disturb the fish (or shrimps) buried in the sediment, which leads to their capture within the 1.2 m long x 2.5 mm mesh tapering net attached to the frame.

Ten trawl samples were taken at each 6 sites in both outer and inner rivers within a five day period (17th-25th February 1997). Sites were spaced at approximately 3 km intervals along the length of the washes controlled by the RSPB from Earith in the south-west to Welney in the north-east (Fig. 4). Trawls were taken in the outer river, the equipment moved over the Middle Level barrier bank (Fig. 5) and then used in the inner river. During each haul, the trawl was dropped into to the water from a small (3 m) dinghy rowed to the opposite bank. Trawls were thus undertaken across the width of the channel or at a slight angle where the channel was narrow (c. 5 m). Mean trawl length was 8.17 m in the outer river and 9.17 m in the inner river. The density of loach (n m^{-2}) was determined simply by dividing the number captured by the area sampled (length of trawl in m x 0.75 m width). This was compared between the outer and inner rivers as well as between sites within a river, using a MANOVA nested design (Norusis/SPSS 1993).

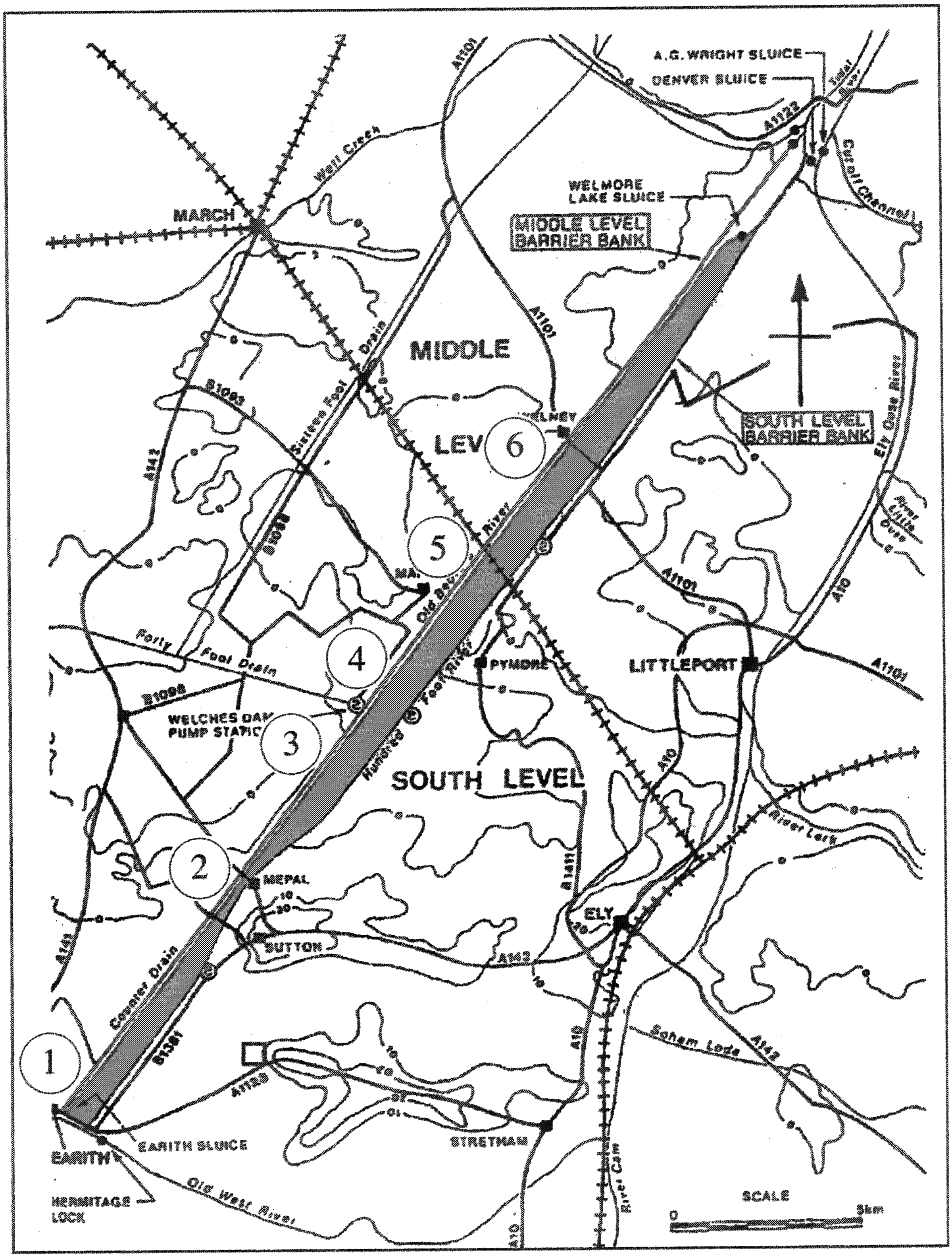


Figure 4. Map showing the extent of the cSAC incorporating the inner and outer river (red lines) and the current SSSI excluding the cSAC (green area). The sites sampled for spined loach during the current study are indicated (1-6).

Figure 5. View (looking north-east) along the Middle Level barrier bank near Welches dam on the Ouse washes. The outer river is on the left of the picture and the inner river and the partly flooded washes are on the right.

At the second level of comparison, the retention of material within a trawl also allowed certain gross habitat variables to be quantified, using simple rank scores (from 0-5). The variables included:

- Macrophyte cover and species richness.
- Cover of filamentous algae.
- Volume and type of mud.
- Biomass and species richness of other fish species.

A mean of each variable was determined for each of the six sites sampled in each river. The relationship between mean density (n m^{-2}) of spined loach recorded at the site and the mean of each variable was then explored using linear regression.

Results

Habitat implications of associations between spined loach and other fish species

Within the hierarchical cluster analysis (Fig. 7), spined loach was associated (at a cluster distance of 4) with fluvial species such as brown trout (*Salmo trutta*), stone loach and minnow (*Phoxinus phoxinus*). However, the closest association was with three-spined stickleback (*Gasterosteus aculeatus*) and carp (*Cyprinus carpio*), the latter of which is more typically associated with lakes and large rivers. The link with stickleback and carp bears a remarkable resemblance to the situation within *Chara* beds in Lake Veluwe (Perrow & Jowitt 1996). A similar result was obtained from analysis of 233 sites in 13 drainage basins in Lincolnshire and South Humberside by Penczak *et al.* (1991). Here, spined loach was broadly associated with a group of fluvial species including rainbow trout (*Oncorhynchus mykiss*), minnow, stone loach, brown trout and bullhead (*Cottus gobio*).

The implication that spined loach is associated with streams and rivers, needs to be treated with some caution, for two reasons. First, spined loach was only recorded from 30 of the 345 sites (i.e. 8.7%). The association with particular species may be a function of the analysis tending to group the rarer species (the 6 rarest, ranked from 17-22 are in the same cluster-Fig. 9), rather than be truly indicative of shared habitat preferences. This is reinforced by the data of Penczak *et al.* (1991), where spined loach was associated with the other species in its cluster at only 2.1% similarity. Second, the chances of spined loach being recorded may also be different within different types of waterbody, which are sampled by different techniques (see *Frequency of occurrence of spined loach within different types of watercourse* below). An increased tendency to sample spined loach in streams/rivers may cause an apparent association with fluvial species.

Figure 6. Using a hand trawl in the inner river at the Ouse washes

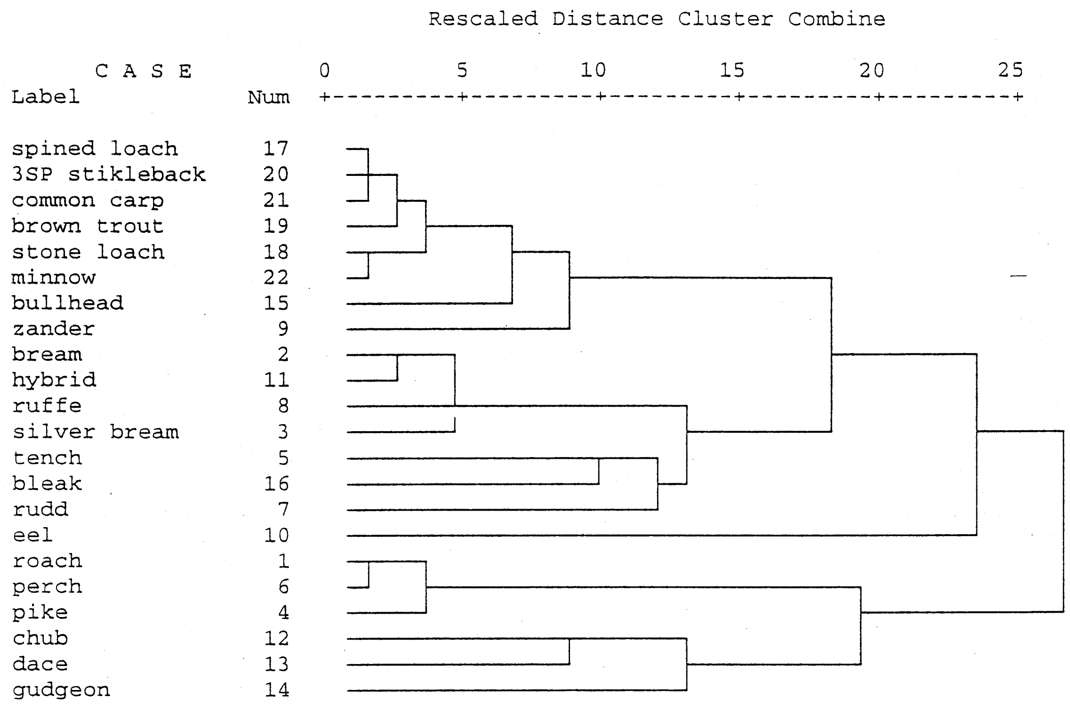


Figure 7. Dendrogram from hierarchical cluster analysis, illustrating the association (average linkage) between different fish species. Data are from surveys of 345 sites from 51 watercourses conducted by the fisheries team of the Central Area of the Anglian region of the Agency.

Table 2.

Frequency of occurrence of spined loach in watercourses from which it has been recorded, during routine fisheries surveys in Central Area of Anglian Region of the Agency. Details of the most recent survey in each watercourse are shown.

Type of watercourse	*Name of watercourse*	*Date*	*No. of sites*	*Sites with spined loach*	*%*
Small rivers/ streams	Ivel	1995	11	1	9
	Sapiston	1995	11	5	46
	Thet	1995	7	1	14
	Great Ouse-Brackley to N. Pagnell	1991	14	5	36
	Upper Little Ouse	1996	13	3	23
	Upper Wissey-u/s Whittlington	1993	8	1	13
	Nar	1996	13	2	15
	Claydon/Padbury	1994	9	1	11
	Ouzel	1987	13	1	8
	Tove	1995	10	3	30
	Watton Brook	1990	5	1	20
	Stringside Brook	1992	2	1	50
	Granta	1993	4	2	50
	Rhee	1993	8	2	25
Large rivers	Great Ouse-N. Pagnell to Bedford	1992	20	2	10
	Great Ouse-Brampton to St. Ives	1995	11	1	9
	Great Ouse-St. Ives to Earith	1989	6	1	16
	Lower Little Ouse	1993	8	1	13
	Lower Wissey-d/s Whittlington	1988	11	1	9
Drainage channels	Sixteen Foot Drain	1983	10	4	40
	Relief Channel	1979	8	1	13
	Cut-off Channel	1986	19	1	5
	Old Bedford River (counterdrain)	1993	9	1	11
	Soham Lode	1990	4	1	25
Canals	Grand Union	1990	15	1	7

Frequency of occurrence of spined loach within different types of watercourse

Within Central area of the Anglian region of the Agency, which represents something of a stronghold for the species (Fig. 2), spined loach is known from a wide variety of watercourses including, small streams, large rivers and small and large drainage channels (Table 2). There is the suggestion however, that spined loach tended to be encountered more frequently in small streams/rivers and the upper reaches of larger rivers (mean frequency 25%) than in the other habitats (mean frequency 11%). This may however result from the differences in methods employed in different types of watercourse. For example, seine netting is typically used in large channels whereas electrofishing is used in small channels. Electrofishing, with the ability of the technique to draw fish from cover (in sediments or amongst plants or debris) is likely to be more efficient, introducing a bias.

Habitat associations derived from routine fisheries and RCS surveys

From the data set, there were no significant differences between any habitat and water quality variables generated from watercourses with and without spined loach (Table 3), suggesting that spined loach is not restricted to particular habitats.

Table 3.
Mean (± 1 S.E.) values of the habitat and water quality variables in watercourses in which spined loach is known to be present or thought to be absent. Probabilities resulting from student t-tests are shown.

Variable	*spined loach present*	*spined loach absent*	*p*
width (m)	12.87 ± 2.16	12.75 ± 3.58	NS
depth (m)	0.79 ± 0.16	0.77 ± 0.14	NS
bank slope (°)	57.56 ± 2.17	66.33 ± 5.38	NS
sand (score/5)	0.78 ± 0.58	0.00 ± 0.00	NS
gravel (score/5)	3.22 ± 0.60	3.11 ± 0.74	NS
silt (score/5)	3.89 ± 0.31	3.33 ± 0.69	NS
submerged/floating macrophytes (rank DAFOR)	2.21 ± 0.24	2.74 ± 0.25	NS
littoral emergent macrophytes (rank DAFOR)	3.40 ± 0.20	3.22 ± 0.25	NS
BOD (90 percentile)	3.41 ± 0.35	3.93 ± 0.57	NS
ammonia (90 percentile)	0.35 ± 0.12	0.26 ± 0.04	NS
dissolved oxygen (90 percentile)	67.92 ± 2.51	63.70 ± 3.61	NS

However, this 'broad-brush' analysis was based on the derivation of mean values from an entire (or large section of a) watercourse and simply whether spined loach was present or absent. Comparison may have been confounded by high variability between and within sites. For example, a river may be channelized (overwidened and straightened) in one section and be almost natural (meandering with a variety of habitats) in another. In this analysis there was thus no scope to determine whether spined loach was associating with particular habitats within each system.

Habitat relationships in Lake Veluwe

Detailed sampling in Lake Veluwe, where a large population of the species was present (density reaching 0.36 m^{-2} in favoured habitats - Fig. 8), illustrated strong preferences of spined loach for particular habitats. Apart from the first sampling occasion, the density of spined loach was always significantly different between habitats during both day and night (Table 4). The pattern of selection for particular habitats also changed over the season and from day to night (Fig. 8). In early season, when spined loach numbers were at their lowest, although more were present in the *Chara*, this was not significantly different from the other habitats. At this time, there was also no evidence of selection for particular components of the habitat within the *Chara* beds (Table 5). In contrast, in July, fish were clearly selecting for areas with a greater proportion of bare sediment, within *Chara* beds (Table 5). This is reinforced on a larger scale, by the greatest numbers in the patchy *Chara* of the transition zone during the day, at this time (Fig. 8).

As *Chara* reached its peak cover in August, spined loach had become concentrated in the sparser *Chara* beds at the transition with open water, with significant differences between this and all other habitats. However, at night, spined loach were more abundant in the more open habitat of the *Potamogeton* zone, which at this point in time contained patches of filamentous algae but virtually no *Potamogeton* (*pers obs.*). This pattern of being found in patchy *Chara* during the day and more open habitats at night was reinforced in September, particularly as the extent of cover in the open water zone had increased through the abundance of *Alisma* spp. By October, the transition zone and the open water zone contained a similar density of fish during the day. At night, with the general decline of macrophytes in this period, spined loach was relatively evenly distributed throughout all habitats, apart from the littoral zone.

The pattern of distribution of 0+ fish was broadly similar to that of the entire population (Table 4). However, in July and August when 0+ fish were small (< 45 mm), no differences in density between habitats was observed, whereas when older fish were included in the analysis, strong significant differences, with the transition zone being favoured, were introduced. It is clear, however from Fig. 9, that the number of 0+ fish captured increased, rather than decreased as a result of mortality, during the season. This indicates that the 0+ were not captured efficiently at a smaller size, early in the season. The most likely reason for this is that these small fish were hidden within the sediments or the macrophytes, by day and easily missed.

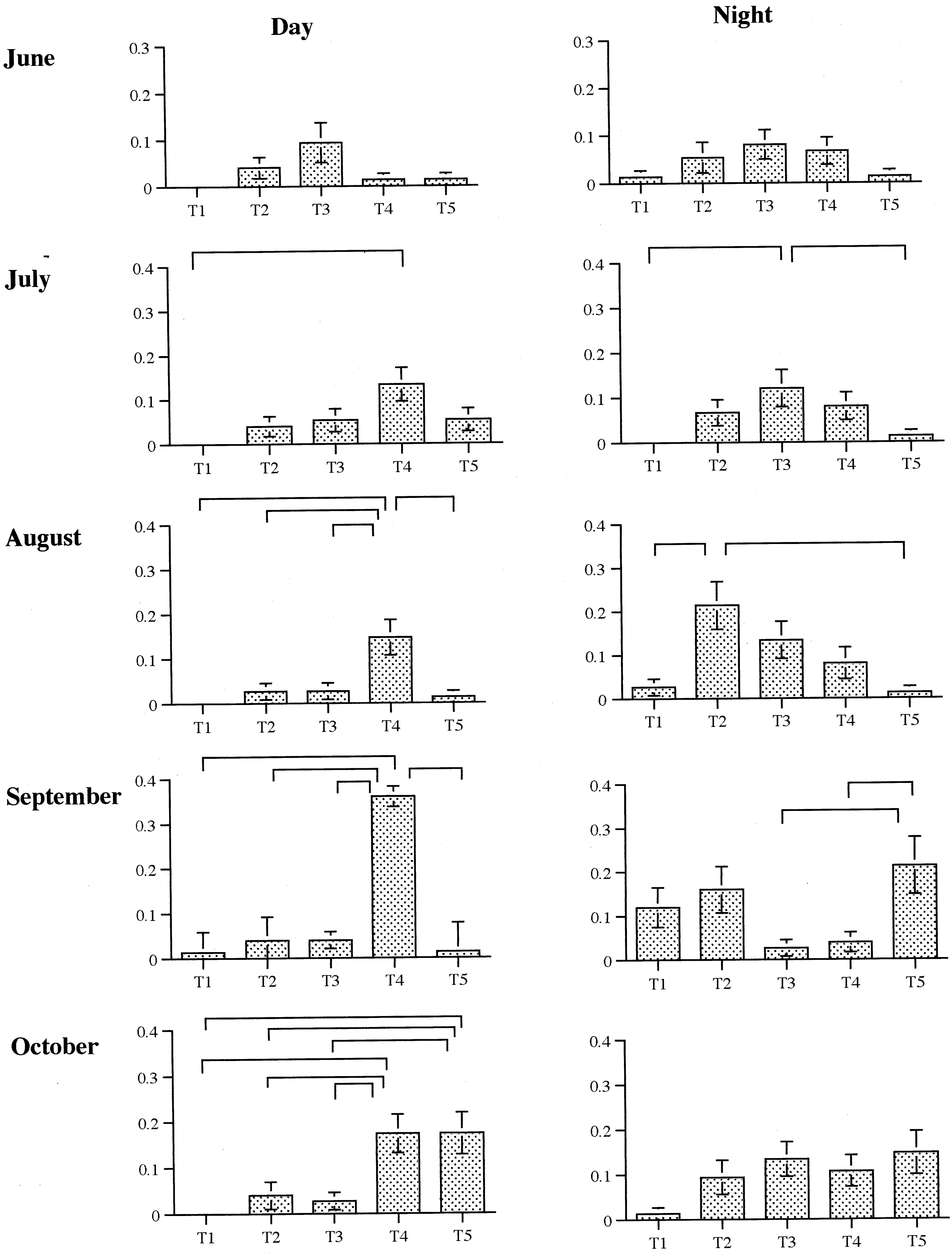
Table 4.
Results of ANOVA on the density (n m^{-2}) of spined loach of all age classes and 0+ alone (in parentheses) , in the range of habitats (littoral, *Potamogeton*, *Chara*, *Chara*-open water transition and open water zones) in Lake Veluwe from June-October 1996. F values and associated probability (NS, * p<0.05, ** p<0.01, *** p<0.001), are shown.

Date	*Sample*	*F value*	*p*
June	day	2.6	NS
	night	1.5	NS
July	day	3.8 (1.0)	**(NS)
	night	3.5 (5.3)	**(***)
August	day	7.1 (1.5)	***(NS)
	night	5.3 (4.4)	***(**)
September	day	15.1 (15.1)	*** (***)
	night	3.3 (11.1)	** (***)
October	day	9.3 (7.2)	*** (***)
	night	2.7 (2.2)	* (NS)

Table 5.
Comparison between characteristics of *Chara* beds (mean ± 1 S.E.) at systematically sampled locations, and at those occupied by spined loach, from transects conducted in Lake Veluwe in June and July 1996. Significant differences, as revealed by t-test, are shown (* p<0.05, ** p<0.01, *** p<0.001).

Variable	*June*			*July*		
	occupied	*systematic*	*p*	*occupied*	*systematic*	*p*
height of *Chara* (cm)	9.75 ± 0.29	10.3 ± 0.54	NS	14.8 ± 1.13	19.0 ± 1.27	*
% bare sediment	26.3 ± 3.55	24.2 ± 4.09	NS	33.8 ± 3.45	14.6 ± 3.96	***
distance to bare sediment (cm)	13.9 ± 39.7	45.4 ± 202.1	NS	9.8 ± 2.91	127.3 ± 40.7	***

Figure 8. Mean (±1 S.E.) density (n/m2) of spined loach in PAS transects during day and night from June to October in Lake Veluwe.
Where T1 = *Phragmites* zone, T2 = *Potamogeton* zone, T3 = *Chara* zone, T4 = *Chara* transition zone, T5 = open water. Significant differences between habitats according to one-way ANOVA are marked.



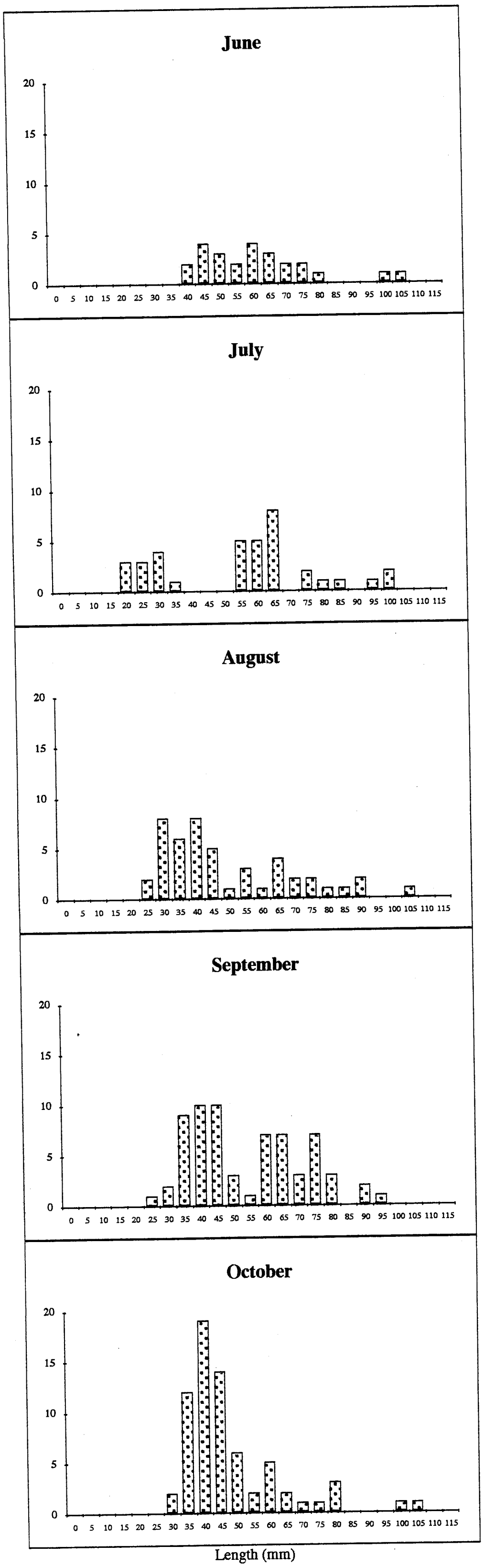


Figure 9. Length frequency histograms of all spined loach captured in Lake Veluwe from June to October 1996

Habitat preferences in the Ouse washes

There were clear differences in a number of ecological variables between the two rivers as predicted from Agency RCS data (Table 6). A greater abundance (0.92 ± 0.26 to 0.15 ± 0.08) and species richness of macrophytes (0.48 ± 0.25 to 0.12 ± 0.06) and algae (3.04 ± 0.77 to 0) was recorded in the outer river. The inner river, in contrast, had a greater quantity of mud (2.42 ± 0.88 to 0.34 ± 0.22), which was typically black and anoxic.

Table 6.
Mean (± 1 S.E.) scores (on a scale of 0-5) for a number of ecological variables in both inner and outer rivers at the 6 sites sampled.

Ecological variable	*River*	*Site 1*	*Site 2*	*Site 3*	*Site 4*	*Site 5*	*Site 6*
mud	outer	0	0.2 ± 0.1	1.2 ± 0.5	-		
	inner	0	0.3 ± 0.2	4.7 ± 0.3	3.5 ± 0.4		
macrophyte abundance	outer	0.2 ± 0.2	0.7 ± 0.3	0.7 ± 0.3	-	1.6 ± 0.4	1.4 ± 0.3
	inner	0.3 ± 0.2	0.5 ± 0.2	0.1 ± 0.1	0	0	0
number of species	outer	0.2 ± 0.2	0.8 ± 0.3	0	-	0.1 ± 0.1	1.3 ± 0.3
	inner	0.3 ± 0.2	0.3 ± 0.2	0.1 ± 0.1	0	0	0
algal abundance	outer	5.0 ± 0.0	2.3 ± 0.7	0.7 ± 0.5	-	4.4 ± 0.5	2.8 ± 0.4
	inner	0	0	0	0	0	0

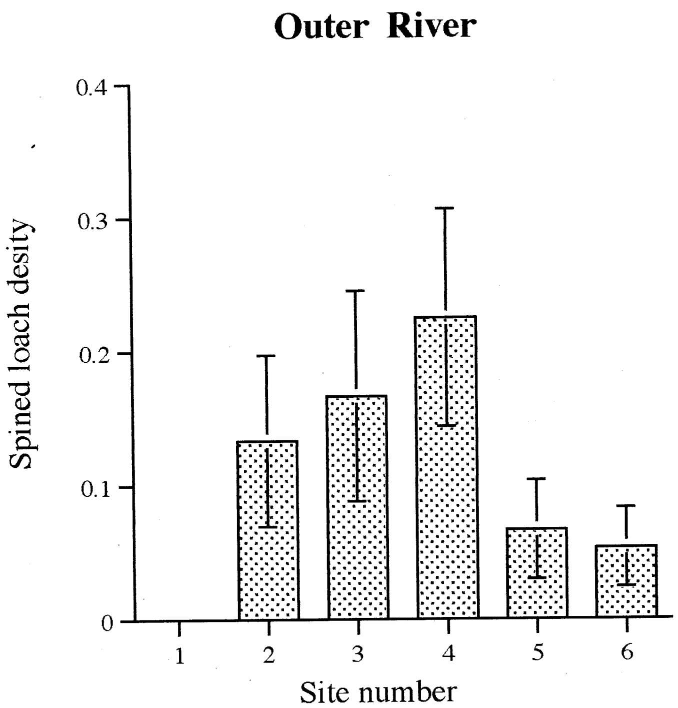
The gross habitat differences are borne out by the fish community in each river. Species typically associated with macrophytes, including rudd (*Scardinius erythrophthalmus*) tench (*Tinca tinca*) and pike (*Esox lucius*) (de Nie 1987, Perrow & Jowitt 1997), were only recorded in the outer river (Table 7). In contrast, bream, typically a fish of unstructured turbid waters, was only recorded in the inner river. Ten-spined stickleback (*Pungitius pungitius*) was also only present in the inner river, although this may be a result of the direct link with the dyke system of the washes themselves, where this species dominated the community (see *Key issues of a conservation strategy for spined loach* below). Overall, the species richness was typically higher in the outer river (4.33 ± 0.56 to 3.67 ± 0.21) (Table 7), as was the overall density of fish (0.40 m^{-2} compared to 0.19 m^{-2}).

In accordance with the overall results for the fish community, MANOVA showed there was a significantly greater density of spined loach in the outer compared to the inner river (Table 8, Fig. 10). Moreover, although there was a considerable variation in density between sites within each river (Fig. 10), there were no significant differences (Table 8).

Table 7. Mean (± 1 S.E.) density (n/m2) of all fish species captured by hand trawl at each survey site in both outer and inner rivers in February 1997. Species richness, diversity (derived from Simpson's diversity index) and equitability are also shown.

Site			Roach	Bream	Rudd	Tench	Spined loach	Perch	Pike	Ruffe	Stickleback	Total	Richness	Diversity	Equitability
Outer river	1	Mean	0.000	0.000	0.067	0.150	0.000	0.117	0.017	0.000	0.000	0.350	4	3.00	0.75
		se	*0.000*	*0.000*	*0.027*	*0.052*	*0.000*	*0.043*	*0.017*	*0.000*	*0.000*	*0.088*			
	2	Mean	0.000	0.000	0.019	0.038	0.133	0.210	0.019	0.000	0.000	0.419	5	2.75	0.55
		se	*0.000*	*0.000*	*0.019*	*0.025*	*0.064*	*0.078*	*0.019*	*0.000*	*0.000*	*0.079*			
	3	Mean	0.000	0.000	0.000	0.000	0.167	0.250	0.000	0.067	0.000	0.483	3	2.47	0.82
		se	*0.000*	*0.000*	*0.000*	*0.000*	*0.079*	*0.094*	*0.000*	*0.027*	*0.000*	*0.135*			
	4	Mean	0.017	0.000	0.017	0.017	0.233	0.233	0.017	0.017	0.000	0.550	7	2.74	0.39
		se	*0.017*	*0.000*	*0.017*	*0.017*	*0.145*	*0.067*	*0.017*	*0.017*	*0.000*	*0.183*			
	5	Mean	0.000	0.000	0.000	0.117	0.067	0.067	0.000	0.050	0.000	0.300	4	3.60	0.90
		se	*0.000*	*0.000*	*0.000*	*0.050*	*0.037*	*0.051*	*0.000*	*0.025*	*0.000*	*0.111*			
	6	Mean	0.107	0.000	0.000	0.040	0.053	0.067	0.000	0.000	0.000	0.267	4	3.51	0.88
		se	*0.056*	*0.000*	*0.000*	*0.020*	*0.029*	*0.022*	*0.000*	*0.000*	*0.000*	*0.066*			
Inner river	1	Mean	0.000	0.000	0.000	0.000	0.015	0.015	0.000	0.015	0.015	0.059	4	4.00	1.00
		se	*0.000*	*0.000*	*0.000*	*0.000*	*0.015*	*0.015*	*0.000*	*0.015*	*0.015*	*0.033*			
	2	Mean	0.000	0.000	0.000	0.000	0.015	0.104	0.000	0.044	0.000	0.163	3	2.05	0.68
		se	*0.000*	*0.000*	*0.000*	*0.000*	*0.015*	*0.039*	*0.000*	*0.023*	*0.000*	*0.047*			
	3	Mean	0.000	0.000	0.000	0.000	0.119	0.074	0.000	0.030	0.015	0.237	4	2.72	0.68
		se	*0.000*	*0.000*	*0.000*	*0.000*	*0.048*	*0.025*	*0.000*	*0.020*	*0.015*	*0.071*			
	4	Mean	0.013	0.067	0.000	0.000	0.000	0.253	0.000	0.027	0.000	0.360	4	1.86	0.47
		se	*0.013*	*0.054*	*0.000*	*0.000*	*0.000*	*0.115*	*0.000*	*0.018*	*0.000*	*0.168*			
	5	Mean	0.000	0.000	0.000	0.000	0.044	0.015	0.000	0.000	0.000	0.059	2	1.60	0.80
		se	*0.000*	*0.000*	*0.000*	*0.000*	*0.023*	*0.015*	*0.000*	*0.000*	*0.000*	*0.033*			
	6	Mean	0.044	0.000	0.000	0.000	0.000	0.193	0.000	0.015	0.000	0.252	3	1.61	0.54
		se	*0.023*	*0.000*	*0.000*	*0.000*	*0.000*	*0.088*	*0.000*	*0.015*	*0.000*	*0.088*			

Figure 10. Mean (± 1 S.E.) density (n/m2) of spined loach captured by hand trawl, at each survey site in both outer and inner rivers of the Ouse washes, in February 1997.



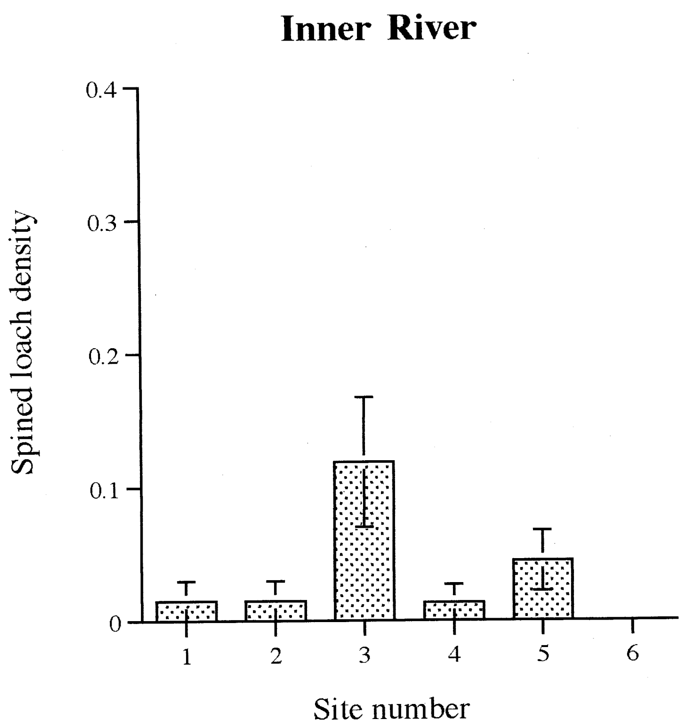
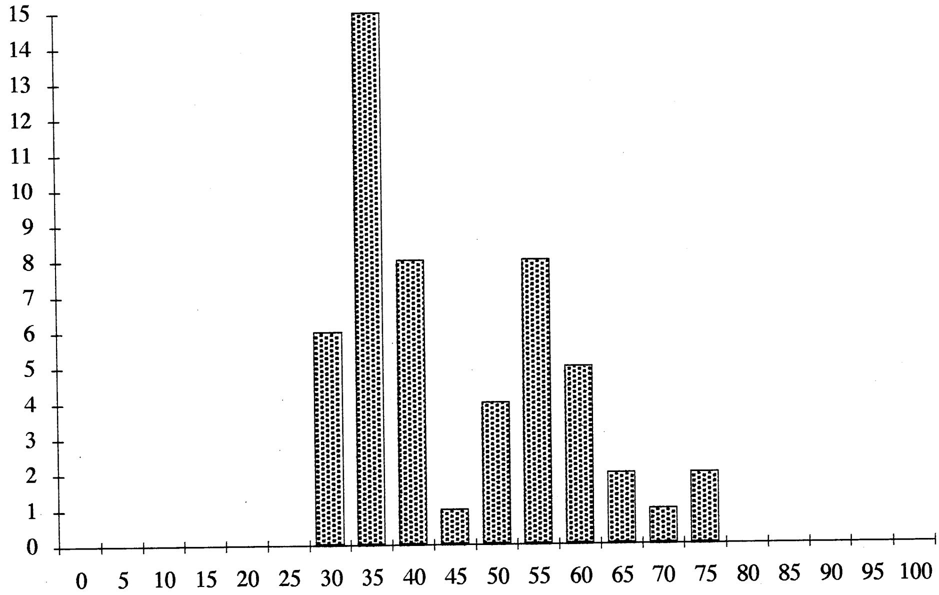
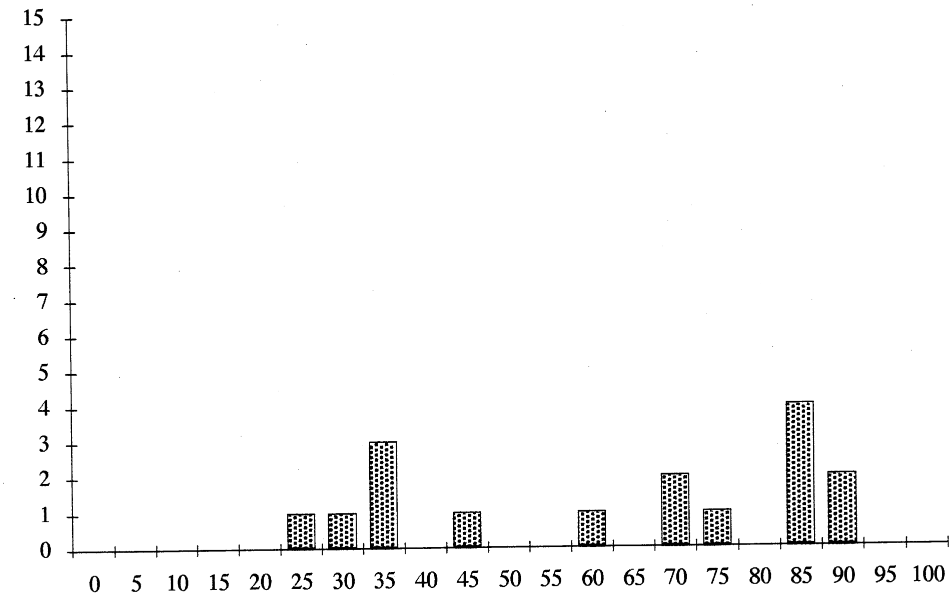


Figure 11. Length frequency histograms of all spined loach captured in the outer and inner rivers of the Ouse washes, in February 1997.

Outer River



Inner River



Mean length inner river = 61.3 mm
Mean length outer river = 43.7

$t = 3.832$, $df = 66$, $p = 0.0003$

Table 8.
Results of MANOVA on the density (n m^{-2}) of spined loach between the inner and outer rivers and between sites within a river, at the Ouse Washes.

Source of variation	*Sum of squares*	*Degrees of freedom*	*Mean squares*	*F value*	*p*
within & residual	4.00	128	0.03		
between rivers	0.18	1	0.18	5.61	0.019
sites within a river	0.56	10	0.06	1.79	0.069
model	0.86	11	0.08	2.51	0.007
total	4.86	139	0.03		

The age structure of the populations in the outer and inner rivers are quite different (Fig. 11). In the outer river, a number of size classes were represented, corresponding perhaps to three age classes; 0+ (born in 1996), 1+ (born in 1995) and 2+ (born in 1994). Underyearlings (0+) were numerically dominant. In contrast, few 0+ were present in the inner river, although a number of age classes including perhaps a 3+ age class (larger than any recorded in the outer river), were represented. Size differences in the populations were significant, with the mean size of spined loach in the outer river being smaller than that in the inner (t-test: mean outer river, 43.7 mm; mean inner river, 61.3 mm; df=66, t=3.83, $p<0.001$).

Combining all age classes there were no significant relationships between any environmental variable and spined loach density in the inner river (Fig. 12). This was probably due to the low number of spined loach present. However, in the outer river, the abundance of spined loach was significantly negatively correlated with filamentous algal cover (n=5, $r^2= 0.76$, $p<0.05$) (Fig. 12). There were no significant relationships between the density of 0+ spined loach in the outer river and any environmental variable, although there was a tendency for 0+ to be associated with macrophytes ($r^2= 0.43$) (Fig. 13).

Figure 12. Relationships between mean density of all spined loach and mean score of each environmental variable, at each site in both outer and inner rivers of the Ouse washes.

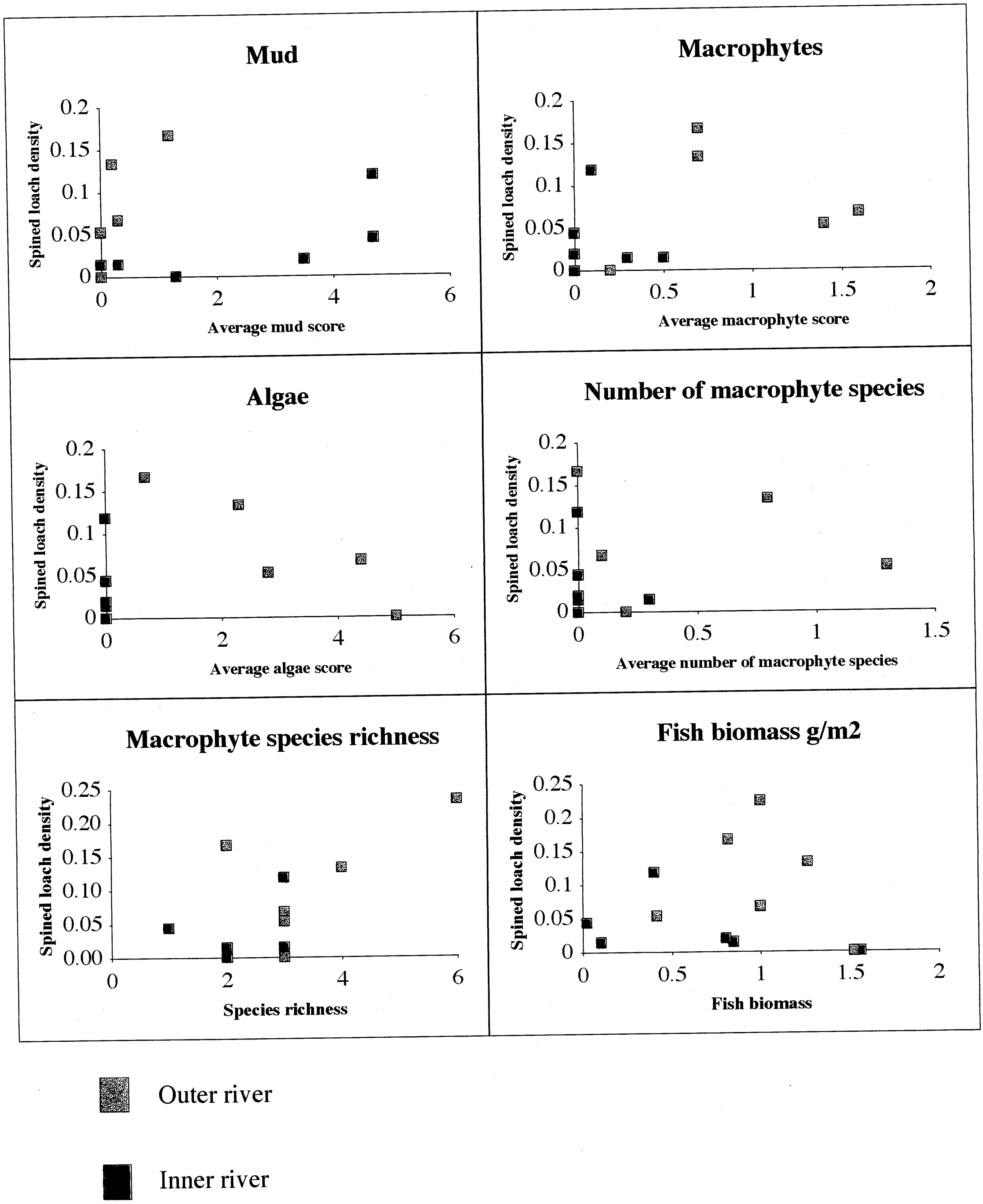
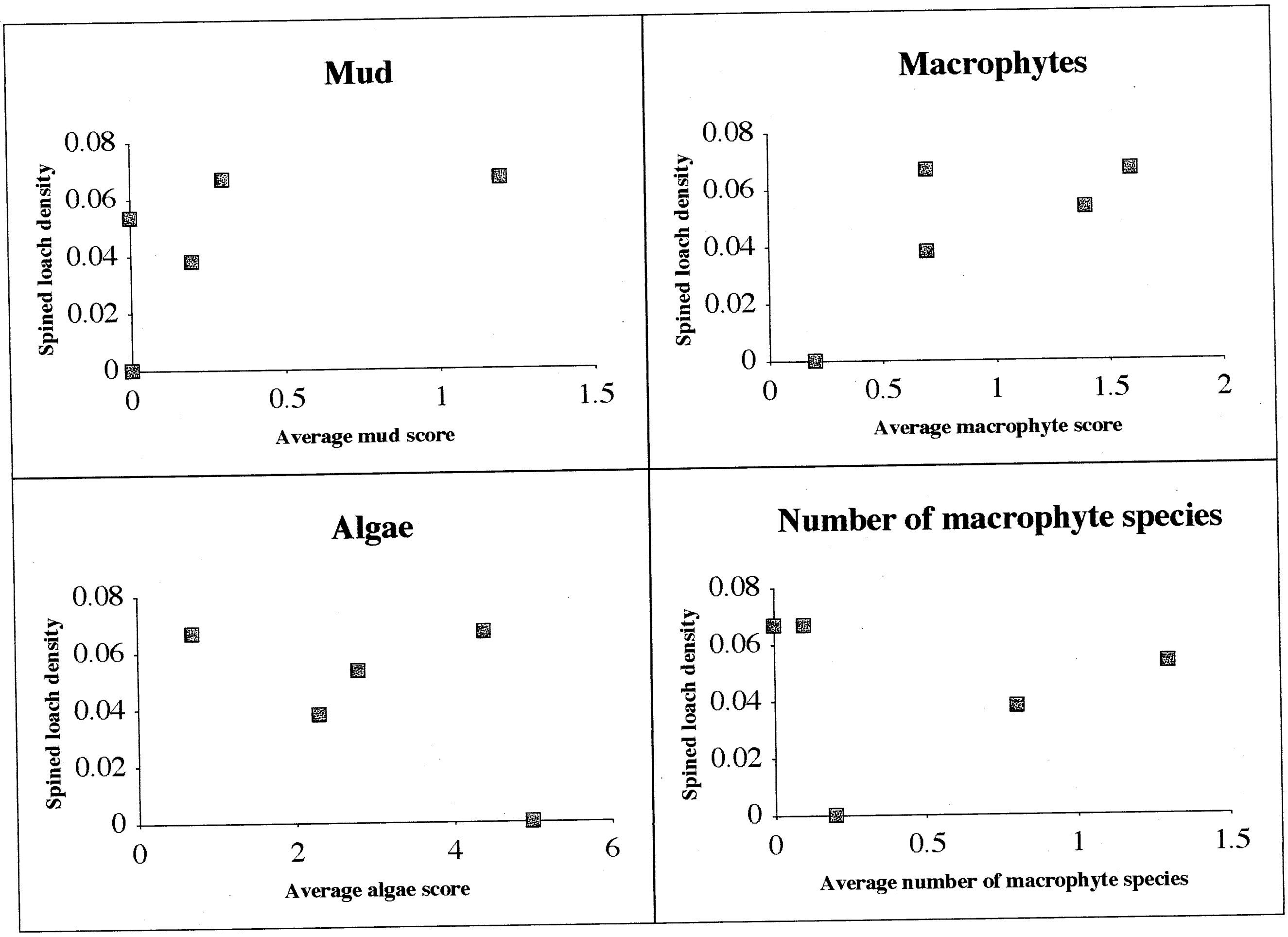


Figure 13. Relationships between mean density of all 0+ spined loach and mean score of each environmental variable, at each site in the outer river of the Ouse washes.



Discussion

Spined loach has two distinctive morphological/physiological features which give a clue to its habitat preferences. First, it has a relatively high gill surface area through the presence of large numbers of secondary lamellae, for the absorption of oxygen (Robotham 1978b). Like other species of loach, it probably can also take in atmospheric oxygen at the water surface for absorption through the gut. This suggests the species can tolerate relatively productive waters. By implication, this also suggests that it can tolerate enhanced levels of other potentially limiting factors such as ammonia (as opposed to non-toxic ammonium), typical of productive waters. Further, unpublished data (Habitat Geschiktheid Index model: Kleine modderkruiper (Habitat suitability index model for spined loach-Witteveen & Bos *unpubl. data*) suggests spined loach can also tolerate a wide range of pH (5-10) albeit with an optimum around 7. Overall, it is suggested that water quality criteria typically limiting fish populations (apart from salinity for which there is no information) do not appear to limit spined loach. This is supported by the observation of Agency fisheries staff that spined loach often survive conditions that lead to the mass mortality of other species (fish-kills). However, like stone loach (which is known to be able to take in atmospheric oxygen), this does not restrict it from occupying or even preferring waters of higher quality (see below).

The second feature is the specialised feeding mechanism, in which it pumps fine material through its buccal cavity and extracts food particles from it with mucous (Robotham 1982). The diet of spined loach is accordingly dominated by small items (0.2-0.75 mm), both animal; particularly chydorids, copepods (especially copepodites and nauplii) rhizopods, ostracods, rotifers; and plants principally desmids and filamentous algae (Robotham 1977). All of the important food items are associated with the surface of the substrate. The diet and feeding mechanism intuitively restricts spined loach to fine, presumably food-rich sediments, which can be directly ingested. Indeed, the field sampling and laboratory choice experiments of Robotham (1978a) (the only published reference on factors affecting the distribution of spined loach) confirmed the preference of the fish for sediments of particle size of 0.15-0.34 mm containing organic material.

However, Robotham then argued that the major factor limiting the distribution of spined loach in his study site in the Great Ouse was the presence of fine sediment. Such a sediment is typically abundant in many if not all, rivers, lakes and artificial channels within the known, effectively lowland, area of distribution of spined loach. Much heavy loading of fine sediments results from drainage and wash-out from arable land and is generally seen as undesirable and is frequently the target of river rehabilitation schemes (e.g. Perrow *et al.* 1996b). The abundance of muddy or silty sediments in many large rivers and drainage channels is also clearly at odds with its rather (apparently) patchy distribution and its rarity in such habitats (Table 2).

Experiences from the Netherlands from sampling in the Kleine beek (stream), Nordieep lake (4.5 ha), the Botshol wetland area (see Simons *et al.* 1994) and the very large lakes Wolderwijd (2700 ha) and Veluwe (3400 ha) (Witteveen & Bos *unpubl. data*), throw more light on the optimal sediment composition of spined loach. Results from all these situations suggest the species prefers a sandy substrate. Indeed, the habitat suitability index model developed for the spined loach (Habitat Geschiktheid Index model: Kleine modderkruiper-Witteveen & Bos unpubl. data) is based on this premise. Further support for this substrate preference is present in the general document on the status of the species by Lelek (1980), who also suggests that sand is preferred. It may also be no coincidence that in the data set from the Agency's Central Area of Anglian region, analysed above (although there was no significant relationship), spined loach was absent from those watercourses that did not contain any sandy substrate (Table 3).

The presence of spined loach in good numbers in the outer river of the Ouse washes and in Wicken and Burwell Lodes (Peacock 1997), does however, show that spined loach can tolerate other substrates such as silt or mud. Perhaps the key is that the sediment surface contains a good food supply, which is probably more likely if it is rich in organic material, but is still oxic. Heavy loading of organic material, with accompanying increase in BOD, ultimately produces anoxic sediments. These require specialised adaptations (e.g. many sediment-dwelling worms and fly larvae have enhanced levels of haemoglobin) and support a lower faunal and floral diversity and biomass. This is likely to disfavour spined loach and the comment of Lelek (1980) that the layer of mud should not be 'thick or coherent' seems particularly pertinent. Peacock (1997) provides some field evidence that dense accumulations of silt were avoided. However, in laboratory experiments, a thin layer of silt, was actively selected. Silt may also be unsuitable for reproduction. Spined loach appear to broadcast eggs which then sink onto whatever substrate is available (Lodi & Malacarne 1990 - see below). It is conceivable egg survival is reduced on anoxic silty sediments. This may be a further explanation of the absence of 0+ spined loach on the inner river at the Ouse washes (Fig. 13).

Workers in the Netherlands also perceive spined loach to be strongly associated with vegetation. In the waters outlined above, this included the moss (*Fontinalis antipyrecta*), the submerged macrophytes, *Chara* spp. and *Ceratophyllum demersum* and also emergent vegetation including reed (*Phragmites australis*) and reed sweet-grass (*Glyceria maxima*). The habitat suitability index model (Witteveen & Bos *unpubl. data*) also suggests that spined loach prefers, perhaps a 50-80% coverage of macrophytes with 100% cover being less suitable. This is in close agreement with the results from the study in Lake Veluwe and indicates that spined loach prefers a heterogeneous environment with macrophytes and open sediment. The creation of a such a habitat within Veluwe appeared to be linked to depth, and consequent availability of light for macrophytes. In addition, grazing by mute swans (*Cygnus olor*) appeared to create open patches within the *Chara* itself.

Spined loach may require direct access to the sediment surface to feed efficiently, and is therefore likely to avoid total macrophyte cover. Where macrophytes are patchy, it must move in open water to feed. In Lake Veluwe this occurred at night, in keeping with the general feeling that spined loach is a crepuscular feeder (Maitland & Campbell 1992). The laboratory experiments of Peacock (1997) also showed the active selection for filamentous algae or *Phragmites* stems during the day, was relaxed at night, with fish spacing themselves randomly between vegetation and open water. Robotham (1977) has however, recorded foraging activity in some populations after dawn and even up until midday. Clearly, feeding is likely to be at least as efficient during the night as it is in the day. However, spined loach is a very small species that could readily be consumed by a variety of vertebrate and even invertebrate (large beetles, dragonflies etc.) predators. These may include facultative piscivores but also omnivorous species. The fact that a small carp (< 20 cm) was observed to predate spined loach in the laboratory (*pers obs.*), illustrates that even benthivorous fish may present a considerable threat to spined loach. What may be perceived to be a general anti-predator strategy of spined loach, to bury itself in the sediment when inactive or as a direct response to disturbance (Lodi & Malacarne 1990, Maitland & Campbell 1992, Peacock 1997) is probably of little defence against such species.

Overall, it is suggested that the risk of predation is a major force in determining the pattern of distribution of spined loach. This has frequently been demonstrated for a number of other small, albeit zooplanktivorous species, whose typical response is to undertake diel migrations from cover during the day to feed in open water under the cover of darkness (e.g. Naud & Magnan, 1988, Werner & Hall 1988, Turner & Mittelbach 1990, Gliwicz & Jachner 1992). In Lake Veluwe, one would predict this to be a profitable strategy. First, the dominant piscivore in open water, the perch (*Perca fluviatilis*), is generally thought to be diurnal (Perrow & Jowitt 1996). Second, eel (*Anguilla anguilla*) although efficient at night was generally associated with the littoral vegetation and not the open water. Third, the large benthivorous fish typically avoided the *Chara* beds (Perrow & Jowitt 1996), when feeding during the day, as they allowed little or no direct access to the sediments. Although there would have been some risk from these fish in open water at night, this would, nevertheless, have been significantly lower than that experienced from a suite of potential predators during the day.

Macrophytes, with structural complexity increasing the chances of remaining hidden and increasing the possibility of escape, even if attacked (Gotceitas & Colgan 1987), may thus be particularly important as refuges against predation. Intuitively, smaller 0+ fish may be at a greater risk from a greater range of predators and this may explain the tendency for these to be associated with macrophytes both in Lake Veluwe (Table 4) and in the outer river in the Ouse washes (Fig. 15). Annual recruitment is likely to be critical to maintain populations of this short-lived species (see *Key issues of a conservation strategy for spined loach* below), and a healthy population is thus likely to be numerically dominated by 0+ (Fig. 9). The availability of suitable habitat for juvenile fish may be the critical factor for the maintenance of viable populations (Mann 1995). The presence of good populations in the outer river in the Ouse washes and the relative lack of fish in the inner river, stemming from the poor recruitment of 0+, may be directly attributable to the presence of macrophytes.

A further function of macrophytes could be that they act as a spawning substrate for spined loach (see Mann 1995). However, there is no clear evidence to support this claim. Observations of the spawning behaviour of the species in aquaria by Lodi & Malacarne (1990) suggests the eggs are laid upon whatever substrate is available.

It is also plausible that macrophytes may support an important food source for spined loach in the form of epiphytic plants, animals and organic material (aufwuchs). Whether adult or particularly juvenile spined loach are capable of browsing on this material on the living plant is unknown. However, decaying plant material on the sediment surface is likely to contribute significantly to the potential food supply, which may be exploited in the conventional way (see above).

It appears that the principal role of macrophytes, most likely to be a refuge against predation, may be fulfilled by filamentous algae under certain conditions. For example, Peacock (1997) showed that the number of spined loach captured in a slow-flowing drainage channel, Reach Lode, by using a push-net (hand trawl equipped with a handle) was positively correlated with the volume of algae recorded in the net ($r_s = 0.40$, $n=92$, $p<0.001$). Furthermore, Robotham (1978a) suggested that the filamentous alga, *Cladophora,* was a major 'summer habitat and probable breeding site' in the Great Ouse. However, filamentous algae was also correlated with fine sediments in the slow flowing depositional zones of the river. Which factor was the most important determinant of spined loach distribution is unclear (see below). Both these results contradict the findings in the outer river of the Ouse washes where filamentous algae was avoided (Fig. 12). Consequently, it may be that the relationship with filamentous algae depends on the availability of other habitats. Where macrophytes are available, these are preferred and where they are absent, filamentous algae may be selected. Further, whether fish associate with algae or not may be a function of its density. If it is too dense, as it was in many places on the outer river of the Ouse washes, this may deny access to the sediment and render the habitat unsuitable for spined loach.

It must also be noted that there is also a likely interaction between filamentous algae and macrophytes, with dense coverage of filamentous algae disfavouring macrophyte growth and development (Philips *et al.* 1978). Some macrophytes also produce algal-inhibiting allelopathic substances (e.g. *Chara* spp., Wium-Anderson *et al.* 1982). Macrophytes and algae may therefore be mutually exclusive to some extent. The factors favouring the development of filamentous algae relative to macrophytes are unclear. Experiences in the Norfolk Broads, suggests that development of filamentous algae is linked to the presence of reducing nutrient-rich sediments. This is just one expression of an increase in the rate of supply of nutrients, typically termed eutrophication.

As eutrophication typically leads to the loss of macrophytes, often through increases in algal production which subsequently shade out submerged plants, eutrophication is likely to be detrimental to spined loach. Other effects may include the tendency for sediments to become black and anoxic. This will influence the food supply available to spined loach (see above) and as in the inner river and the dykes at the Ouse washes (see above and *The conservation of spined loach in the Ouse Washes cSAC* below) populations are likely to be affected.

High stocks of zooplanktivorous/ benthivorous fish are also known to reduce submerged macrophytes and promote the effects of eutrophication through various mechanisms:

- Selective predation on large-bodied Cladocera which may in turn reduce grazing pressure on phytoplankton populations causing turbid water and shading out of submerged macrophytes (Phillips *et al.* 1996).
- The indirect increase in phosphorus available to phytoplankton through enhanced release from the sediments as a result of disturbance from foraging fish (Tatrai *et al.* 1990).
- The direct increase in phosphorus available to phytoplankton through egestion (Tatrai & Istvánovics 1986).

As well as presenting a direct threat to spined loach (see above), the vigorous feeding action of benthivorous fish, digging deep into the sediment may disturb resting loach and also change the nature of the substrate and thus the benthic community (Breukelaar *et al.* 1994, Tatrai *et al.* 1994). This may adversely affect the density and biomass of the small animals and plants associated with the surface layers of the mud and vegetation. Any impact will increase in accordance with the biomass of the benthivore population. This may be artificially enhanced by stocking for angling purposes. Some supportive evidence of this hypothesis is provided by the Central area data set. Here, sites with spined loach had a significantly lower density of the numerically dominant roach, than those without (t-test, $n=315$ & 30, $t=2.01$, $p<0.05$). Moreover, within this data set, spined loach was also associated with more diverse fish communities (t-test, $n=315$ & 30, $t=2.44$, $p<0.05$). A similar result was also found in the Ouse washes. This is generally indicative of an association with higher quality water and structurally diverse habitat. This may result from the constraints imposed upon spined loach by a specialised diet and mode of foraging and vulnerability to predation, being more likely to be overcome by the broad and diverse resource base in a good quality habitat. However, provided the major requirements of fine sediment, food supply and refuge from predation or disturbance are satisfied, there are few other restrictions on its distribution, such as water quality. Therefore it appears that spined loach has a potentially wide distribution but actually a rather narrow ecological niche. Therefore within community analyses, although it may appear to associate with a variety of riverine or lacustrine assemblages, it generally has a low level of similarity with any of them, as it is not responding to the same driving variables as the other species.

Conclusions

Although spined loach may tolerate silt or mud, sand seems to be preferred. This may be linked to greater food resources and better egg survival within and on, sandy as opposed to silty, substrates. This in turn may be linked to the oxygen levels within the substrate. A combination of sand with patchy, dense macrophytes, as refuges against predation, is likely to constitute the optimal habitat for spined loach. This may be found in a variety of situations from streams to large lakes, but on balance may be more abundant in natural streams and rivers. Rivers are after all, the ancestral habitat of spined loach, through which they colonised the UK (see *Distribution of spined loach* above). The potential of these habitats is illustrated by the study of Marconato & Rasoto (1989) in a small (12-15 m wide and < 30 cm deep), stream in Northern Italy. Here, the density of 0+ spined loach reached a massive 73.8 m^{-2} just after hatching. Although, the density subsequently declined rapidly to 0.6 m^{-2}, the mean density over the season (May-November) was still 2.28 ± 1.6 m^{-2}, higher than any other recorded during this study (e.g. 0.36 m^{-2} in Lake Veluwe and 0.2 m^{-2} in the Ouse washes).

More work is clearly needed on the distribution and abundance of spined loach in streams and rivers in the UK. A focus for this work may be the relative suitability of natural and modified (e.g. channelized) channels. The latter tend to have higher silt levels with little instream structure as a result of poor flow diversity (Perrow *et al.* 1996b), implying they may be generally unsuitable for spined loach. Spined loach may also be limited by flow velocity. For example, Robotham (1978a) in his study on the Great Ouse, showed spined loach selected for lower (mean of 15 cm sec^{-1}) and avoided higher (mean of 29 cm sec^{-1}) flow. However, the presence of fine sediment and filamentous algae were also negatively correlated with flow (see above), and it is unclear which was the important variable in this association. Whether or not spined loach, can tolerate higher flows, like its relative the stone loach, therefore also requires clarification.

C. Key issues of a conservation strategy for spined loach

Background information & methods

Specific information on the distribution of spined loach within the UK (see *Distribution of spined loach in the UK* above), within the framework of a general understanding of its ecology- including habitat preferences (see *Habitat preferences of spined loach* above), population dynamics and genetics allows the key issues of any conservation strategy to be determined. Material used in the section was gathered during the general search for information (see *General information gathering* above).

Results & Discussion

Implications of the taxonomic status of spined loach in the UK

Spined loach is known to occur in a number of races or subspecies, typically referred to as the *Cobitis taenia* complex (Saitoh 1990). In Japan, there is good evidence through sarcoplasmic protein banding that one such subspecies *C. taenia taenia* originates from a hybrid of *C. taenia striata* and a related species *C. biwae* (Sezaki *et al.* 1994). There is also sound evidence that differently-sized sympatric races or forms of spined loach are reproductively isolated, with different spawning sites and general habitat preferences i.e. small irrigation creeks for the small form and the main stream and tributaries for the middle form (Saitoh 1990). Further, Saitoh & Aizawa (1987) showed seven races tended to occupy specific geographic ranges and where sympatric, hybridisation was not effective.

Within Europe, Lelek (1980) recognised eight subspecies (Table 9). There is some debate, however, as to whether such differentiation is valid. For example, Marconato & Rasotto (1989), working in a small river in northern Italy, illustrated that males within a population may exhibit great differences in colour pattern within a season with *puta*, *intermedia* and *bilineata* forms being recognised (Marconato & Rasotto 1989). *Bilineata* appears to be the livery adopted by mature males during the breeding season. Lodi & Malacarne (1990) showed that both forms may exist within the reproductive season and that some males maintain *puta* colouration even when sexually active, although *puta* males show considerably less reproductive activity and potentially less reproductive success than *bilineata*.

Table 9.
Possible subspecies of the spined loach in Europe
(after Lelek 1980).

Subspecies	*Distribution*	*Authority*
C.t. bilineata	northern Italy	Canestrini 1866
C.t. dalmatina	River Cetina, Dalmatia	Karaman 1928
C.t. haasi	eastern Spain	Klausewitz 1952
C.t. meridionalis	Lake Prespa	Karaman 1924
C.t. paludicola	Tejo basin and northern Africa	F. de Beun 1930
C.t. puta	Po, Brenta & Dese basins	Cantoni 1882
C.t. strumicae	Struma basin	Karaman 1955
C.t. zanandreai	Campania, Italy	Caricchioli 1965

In the UK, populations of spined loach have been isolated from those in continental Europe for around 10 000 years, since the end of the last ice age and the severing of the land bridge. Further, although there is potential for mixing of populations between the Trent & Witham, neither catchment is connected to the Great Ouse system. Mixing of these populations is not likely to have occurred through typical agents such as stocking by anglers (see *Distribution of spined loach in the UK* above). Thus, it is plausible that the UK contains a number of endemic forms (with characteristic morphological differences analogous to the races of brown trout-see Maitland & Campbell 1992), subspecies or even full species of 'spined loach' (see Robotham 1981). Any of these may exhibit different habitat requirements (Saitoh 1990). Indeed, this may explain some of the disparities in habitat preferences shown by the 'species' in different types of waterbody (see *Habitat preferences of spined loach* above).

Without detailed research on different populations, including molecular work such as chromosome banding, their taxonomic status will remain unclear. This will demand further resources including finances and time. The pragmatic approach may thus be to establish SAC's in each of the Trent and Great Ouse catchments to safeguard potentially different spined loach populations. Even if subsequent work shows the fish in these populations to be of the same taxonomic status, the setting up of at least two SAC's in each is likely to meet the principal objective of Annex II of the EC Directive, to ensure the conservation status of the species through conservation of viable populations.

Conservation implications of life history traits

The lifespan of spined loach rarely exceeds three or four years (Robotham 1981, Marconato & Rasotto 1989). Females tend to live longer and grow faster than males, reaching around 130 mm considerably larger than males, which barely reach 70 mm. Both males and females tend to mature in their 1+ year (Robotham 1981, Marconato & Rasotto 1989). For males this may occur at only 40 mm in length. The short lifespan of spined loach, means that populations are typically dominated by young fish (see Fig. 9 & Fig. 11 for examples from Lake Veluwe and the outer river at the Ouse washes, respectively). Recruitment in any one year is thus essential to maintain the population. Factors limiting recruitment typically include:

- A limited adult stock or inappropriate sex ratio.
- Poor spawning conditions (water temperature, various aspects of water quality, lack of suitable substrate).
- Poor egg survival.
- Poor larval and juvenile survival (through predation, food limitation etc.).

The spawning behaviour of spined loach is described by Lodi & Malacarne (1990). There is some evidence that spined loach undergo a simple courtship as a prelude to mating. This may involve just one male and one female, as opposed to the group spawning observed in many other fish species. Unequal sex ratios with a female bias may thus limit recruitment to some extent. This could occur through selective predation upon the smaller male fish. During courtship, the pair participate in synchronous swimming, with the male using his sub-ocular spine as a tactile stimulant . The organ of Canestrini, a blade-like bony appendage issuing from the base of the second ray of the pectoral fin, found only on males, may also have a role in courtship, but this is unclear as yet. During the final stages of courtship, the male coils laterally around the females body and squeezes. A batch of around 50 eggs is extruded and fertilised as the females swims or wriggles along the bottom. This sequence may be repeated 4 or 5 times a day. The total number of eggs laid during the observations of Lodi & Malacarne (1990), was around 100-400. In contrast, Marconato & Rasotto (1989) estimated a 90 mm female could produce around 1000 or so eggs. As the pattern of gonad development mirrors that of other fractional spawners, it is likely that during the course of spawning season, a female may produce far more eggs than first appears. The ability to mate several times during the course of an extended mating season (May to July with a peak in June in Italy - Marconato & Rasotto 1989), probably with different partners, decreases the chances of failure due to adverse conditions. It also allows individual females to maximise their reproductive output within a short lifespan.

The reproductive strategy adopted by spined loach gives the impression that the factors affecting breeding up to the point of laying eggs are unlikely to limit the potential for recruitment. It is considered to be more likely that the bottleneck for recruitment is related to egg or larval survival (see Mann 1995). Unfortunately, there is no information available on the factors affecting either at the current time. It is clear, however, from the study of Marconato & Rasotto (1989) that losses following hatching may be massive. Predation is suggested to be a major influence (see *Habitat preferences of spined loach* above) and the abundance of refuges such as macrophytes may be critical in determining the strength of recruitment and thus the viability of the population in the long term.

Conclusions

The taxonomic status of the spined loach in the UK is unclear. The lengthy timescale of reproductive isolation both from the source stock in Continental Europe and also between stocks in different catchments within the UK, results in the possibility of endemic races, subspecies or even species. SAC selection must take this into account. However, in the absence of detailed information on genotypes, required to make a considered decision, the pragmatic option is to set up SAC's within at least the Great Ouse and Trent catchments. Moreover, as the connection between the Trent and Witham system is limited (though the artificial channel the Fossdyke) and thus mixing of populations may be limited, it may also be prudent to also establish at least one SAC within the Witham.

The conservation of viable populations both in protected areas and in all waterways it occurs, appears challenging at first sight. This is because spined loach is thought to be highly vulnerable to anthropogenic influences in any one season. This results from its dependence on annual recruitment and the constraints of a specialised feeding mechanism, specific habitat requirements and vulnerability to predation (see *Habitat preferences of spined loach* above). Factors such as habitat changes resulting from management (see *Preliminary management guidelines* below) and perhaps stocking of other fish (potential competitors or predators), particularly where they impact upon larval/juvenile survival (see above), may reduce the viability of the population, ultimately leading to local extinction. Spined loach may thus be something of an indicator species of habitat change (like other 'minor' fish species), being among the first to decline as the quality of the habitat changes.

Whether or not spined loach is capable of quickly colonising areas where any formerly limiting factor has been removed, is open to question. However, the fact that spined loach has successfully colonised several gravel pits associated with rivers and also crossed catchments via a water transfer scheme (see *Distribution of spined loach* above) suggests it may be.

With more detail on the specific habitat requirements of spined loach, especially juvenile/larval fish, it is possible that aquatic systems may be managed to favour spined loach (see *Preliminary management guidelines* below). Moreover, ecological improvement through more general restoration/rehabilitation schemes, especially in streams and rivers, may also have considerable direct benefit. Where spined loach are able to colonise and conditions are favourable, the r-type reproductive strategy of spined loach may lead to rapid population expansion. This should be exploited wherever possible, within the current range of spined loach. Where there are restrictions to natural colonisation, (as a result of physical barriers such as weirs or ecological barriers such as a lack of suitable habitat between the source and area to be colonised) introduction of individuals of the specific genotype may be considered.

D. The conservation of spined loach in the Ouse Washes cSAC

Background information

The Ouse washes comprise a 1914 ha area of lowland wet grassland (the largest example in the UK). These are sandwiched between the Hundred Foot river to the east, and the Old Bedford River/River Delph and the Counterdrain/Old Bedford River, separated from each other by the Middle Level Barrier Bank, to the west. As stated earlier (see *Habitat preferences of spined loach* above), for ease of reference and following the nomenclature used by the RSPB, the Old Bedford/Delph will be referred to the inner river and the Counterdrain/Old Bedford River, the outer river, throughout this document. The washes are of huge conservation importance, as recognised under SSSI, Ramsar site and SPA status. The site is noted for wintering wildfowl and breeding waders, although several nationally rare/uncommon plants are also represented. The area is drained by 140 km of ditches which form an important habitat for aquatic plants and animals. Floral and invertebrate diversity is high in places, partly dependent on substrate type and more importantly, nutrient loading (Cadbury *et al.* 1993-see below). The dykes also act as wet fences to control the movement of livestock. The latter maintain the grass dominance of the site, which would otherwise quickly become dominated by *Glyceria maxima* and willows (N. Lambert, RSPB, *pers comm.*).

The current Ouse washes cSAC incorporates an approximately 19 km length of the outer and inner rivers (Fig.'s 4 & 5). The likely effectiveness of the SAC was however, compromised by the lack of knowledge of the species in this area and of the effects of the intensive management regime in this largely artificial system. Records of spined loach were limited to a report of a large (but undetermined) number of spined loach encountered in the outer river during a fish rescue operation (R. Handford, Agency, *pers comm.*), a single site record (density of <0.001 n m^{-2} -Agency *unpubl. data*) from the same (Old Bedford River at that point) and a single individual accidentally captured by site wardens during collection of material for a demonstration of animal and plant life in the washes. There is a further unconfirmed sighting of what may have been a spined loach by a RSPB researcher (G. Tyler, RSPB, *pers comm.*) from the inner river near Sutton Gault (the Old Bedford River). There are no known records from the main, Hundred Foot (New Bedford) River or the system of ditches, both of which are currently outside the SAC. As the latter particularly are an integral component of the freshwater resource on the washes, it was also desirable to ascertain whether the ditch habitat is important and if there was a case to incorporate the ditches into the SAC (see Mann 1995). The ditches are however subject to dredging ('slubbing') work on a regular basis in order to increase the efficiency of water management across the washes. Information on whether this limited their value for spined loach, or not, was also desirable.

The principal question to be answered is whether the Ouse washes justified its proposed designation as a SAC for spined loach. Further, key issues affecting the conservation of viable populations of spined loach at the site needed to be identified. This also needed to be set in the more general context of conserving and promoting populations of spined loach in the UK.

Methods

Distribution of spined loach within the Ouse washes

Prior to sampling the efficacy of a number of sampling methods was assessed (see *Further monitoring and research requirements* below). Following this, PAS by electrofishing (see *Habitat relationships in Lake Veluwe* above) was selected to sample the dykes and the hand trawl (see *Habitat preferences in the Ouse Washes* above) was selected to sample the inner and outer rivers. Sampling was conducted from 17th - 25th February 1997.

To cover as large an area as possible, whilst providing sufficient replication within a site to have confidence in the resulting estimate, ten trawl samples were taken at each 6 sites in both outer and inner rivers. Sites were spaced at approximately 3 km intervals along the length of the washes, controlled by the RSPB from Earith in the south-west to Welney in the north-east (Fig. 4) (TL405773, TL433807, TL447828, TL465853, TL49887 and TL525933 respectively). Trawls were taken in the outer river, the equipment moved over the Middle Level barrier bank (Fig. 3) and then used in the inner river. The use of the hand trawl is outlined above (see *Habitat preferences in the Ouse Washes*).

The presence of abundant vegetation and the narrow (2-3 m), shallow (around 1m) nature of the dykes prevented the use of the trawl and PAS by electrofishing was used instead (Fig. 14). The strategy was to sample sections of a number of dykes, over approximately a 1 km area. Of the 10 dykes selected: 3 had been dredged the previous year (1996), 4 dredged 2/3 years ago (2 each in 1994 and 1995) and 3 dredged more than 10 years ago (1 in 1985 and 2 in 1983). This also allowed the impact of the frequency of dredging to be investigated. Twenty points were sampled at 5 m intervals within a 100 m section by either sampling from the bank with a 100 m cable attached to bank/boat mounted gear (Fig. 5), or, where the channel was too wide or deep, fishing directly from the boat (3m dinghy) (for full details of methodology see *Habitat relationships in Lake Veluwe*). The boat was also used to move equipment and personnel between dykes.

Figure 14. Point-abundance sampling (PAS) by electrofishing in the dykes at the Ouse washes

Factors affecting the conservation value of the Ouse Washes cSAC

To provide general information, a site visit to the Ouse Washes RSPB reserve, which form a large proportion (c. 800 ha) of the washes area associated with the cSAC, was undertaken on 21st January 1997. This involved in depth discussions with Neil Lambert (warden) and Cliff Carson (senior warden) on the management of the system and the factors affecting its conservation value. Additional background information was provided by the in-depth report by Cadbury *et al.* (1993) on the dyke flora.

Results

Distribution of spined loach within the Ouse washes

Spined loach was recorded at all but one site in each river (TL405773 in the outer river and TL525933 in the inner river) (Fig. 4) along the length of the Washes from Earith in the south-west to Welney in the north-east, indicating it is has a wide distribution. However, it occurred at significantly higher density in the outer compared to the inner river (Table 8), principally as a result of the abundance of young (0+ and perhaps 1+) in one and not the other (Fig. 11). Although MANOVA indicated no significant difference between the densities between sites in either river (Table 8), it does appear that in the more suitable, outer river (apart from at site 1), a higher density (i.e. the 'best' populations) of spined loach was present above Welches Dam (sites 1-4) than below it.

In contrast to the two major drainage channels, no spined loach were captured in the dykes. Consequently, any impact of the frequency of dredging upon spined loach populations within the dyke system could not be determined as no spined loach were captured. The fish community was dominated by ten-spined stickleback which had a rather patchy distribution, with no obvious relationship to the frequency of management (Table 10). A total of only 5 species were captured, and no more than 2 fish species were captured in any one section of dyke.

Table 10.
Mean (± 1 S.E.) density (n m^{-2}) of individual fish species in dykes subject to different frequencies of dredging.

Category	*Year dredged*	*Roach*	*Dace*	*Pike*	*Ten-spined stickleback*	*Eel*
Annual	1996	0.03 ± 0.03	0.03 ± 0.03			
	1996			0.03 ± 0.03		
	1996				0.07 ± 0.05	
2/3 years	1994				0.47 ± 0.15	
	1994					
	1995					
	1995				0.03 ± 0.03	
>10 years	1983				0.27 ± 0.11	
	1983				0.13 ± 0.08	0.03 ± 0.03
	1985					

Discussion

Although spined loach was widely distributed within the two rivers comprising the cSAC, it was more abundant in the outer river compared to the inner. In the outer river, there is evidence to suggest that the population density is broadly comparable with that recorded in the few other known studies. To illustrate, the maximum density recorded in the outer river in February, after winter mortality and thus at a potential low point, was > 0.2 m^{-2}. This is higher than that recorded in June in Lake Veluwe, and similar to the maximum value of 0.36 m^{-2} recorded in one habitat in September (Fig. 8). Even in the study of Marconato & Rasotto (1989) in a small river in northern Italy, after the spring recruitment of 0+ with a massive density of 73.8 m^{-2}, the population was only 0.6 m^{-2} at the end of the growing season.

In contrast, the density in the inner river only exceeded 0.1 m^{-2} at one site. Moreover, only in the outer river, does the relatively high abundance of 0+, suggest that the population is self-sustaining (see *Key issues of a conservation strategy for spined loach*) Overall, it is suggested that the Ouse Washes cSAC would be likely to meet the objective of conserving a viable population of spined loach within one of its population centres (see *Distribution of spined loach in the UK* above). However, the low density in the inner river as a whole and at some sites in the outer river are causes for concern. The apparent absence of spined loach in the dykes, a major part of the freshwater resource at the site, which considerably limits the scope for their inclusion in the cSAC, is also disturbing. Clearly steps must be taken to ensure that the cSAC continues to meet its objective through the maintenance and if possible, improvement, of the current situation. To begin to identify the critical issues affecting the suitability of the system for spined loach, it is necessary to understand the water control of this relatively complex entirely regulated system.

In simple terms (see Cadbury *et al.* 1993), the Hundred Foot river takes the flow of the system from the Bedford Ouse, past the washes, to Denver Sluice and ultimately to the Wash. When it reaches a particular level, water is diverted via the sluice at Earith. As this overtops, the washes begin to fill. As the levels vary considerably within the washes, this movement of water is relatively complex, but in general terms the washes in the Welney area (site of the RSPB and Wildfowl and Wetlands Trust (WWT) flood last and drain first, and all washes fill from the bottom third first. Moreover, the outer river (counterdrain) receives water from adjacent arable land. When the levels within this are high, water is pumped into the inner river by the pumping station at Welches Dam. A sluice gate on the inner river downstream at Welney is closed prior to pumping and is reopened as the levels rise. Water is then allowed downstream to Denver Sluice. This sequence of events usually occurs in winter. However, the incidence of flooding in spring and summer has increased since 1974 and in the last few years has increased to such an extent as to create problems for nesting waders (C. Carson, RSPB, *pers comm.*). The reasons for this increase are largely unknown but may be linked to changes in operational procedure and channel capacity (through silting) of the river below Denver sluice. All of this water level control is undertaken by the Environment Agency flood defence engineers. There is some current concern that with changes in water level control, the levels of salinity will increase (R. Hall, EN, *pers comm.*), although in the absence of any available information (see *Habitat preferences of spined loach* above) it is not possible to predict if any detrimental impact is likely should this occur.

The outer river is thus virtually isolated from the inner river and its water supply which in turn is related to the Hundred Foot river and the dykes within the washes. Water largely originates from run-off from arable land, during the winter months. Therefore, in the summer the outer river is effectively a 'linear lake' (C. Carson, RSPB, *pers comm.*). In contrast, inner river is ultimately connected, although sporadically, via the dykes to the Hundred Foot river. The movements of any fish, particularly small species such as spined loach are therefore unrestricted. This is indicated by the presence of dace (*Leuciscus leuciscus*), a riverine species, within the dyke system thought to have most likely originated (as may have the roach, *Rutilus rutilus*, captured in the same dyke) from the Hundred Foot river. Moreover, as the systems are connected, it is plausible that the same factors are responsible for the apparent absence of spined loach in the dykes and the low density in the inner river.

Samples taken on site (N. Lambert, RSPB, *pers comm.*) indicate that the nutrient levels within the Hundred Foot river place it into the hypertrophic category. Evidence that the nutrient loading, to the system has increased in recent years is provided by the detailed surveys of the dyke flora conducted in 1978 and 1992 by Cadbury *et al.* (1993). During that period, the botanical richness of the site declined dramatically with a notable increase in nutrient tolerant species such as *Ceratophyllum demersum* and *Lemna* spp. These aggressive species may be responsible for the poor species richness in many dykes. Six species have declined (including *Chara vulgaris*) and four (including the pondweeds *Potamogeton berchtoldii* & *P. compressus* and *Zannichellia palustris*) are thought to have become extinct (Cadbury *et al.* 1993). A heavy loading of fine sediments is also likely to have accompanied the increase in nutrient levels. The presence of peat or even marl based sediments in many dykes in the past has now been replaced by a thick layer of black, anoxic silt, which covers the bed of both the dykes and the inner river. In the shallower dykes, poor water quality with low oxygen and high ammonia, is likely to be the principal cause of the low diversity and biomass of the fish community. Circumstantial evidence that water quality may drop below the levels required to support fish was illustrated by the presence of a dead stickleback and a dead pike in two of the dykes sampled.

The loss of macrophytes and changes to the nature of the sediment compromising its ability to support a suitable food resource, through eutrophication, is argued to be ultimately responsible for the dearth of spined loach in the waters of the Ouse washes, excepting the outer river. The isolation of the outer river from the general sources of nutrients to the washes, through the Hundred Foot river and the inner river once water is diverted to it via the Earith sluice (see above) appears to have allowed the maintenance of a peaty sediment and macrophytes and thus a good population of spined loach. Run-off from agricultural land (see above) is however, by its very nature, nutrient-rich. Although this does not appear to have reduced the macrophyte population to any significant degree through eutrophication as yet, this process is insidious and once nutrient levels reach a critical threshold the system may 'switch' and become dominated by planktonic algae. Further, for a given level of nutrient loading shallow water bodies like the outer river may exist as alternative stable states, either dominated by submerged macrophytes or planktonic algae (Irvine *et al.* 1989, Scheffer *et al.* 1993). The switch from one state to the other may be instigated by changes in fish community structure (Bronmark & Weisner 1992).

Winter or summer kill of zooplanktivorous or benthivorous species may cause or perpetuate a clear water state dominated by macrophytes through the mechanisms outlined earlier (see *Habitat preferences of spined loach* above). There is evidence of a least one major fish kill in the outer river in the recent past as a result of a pollution incident (R. Handford, Agency, *pers comm.*). Regular events of this type may thus help maintain clear water even in the face of continued nutrient loading in the outer river and ultimately help conserve spined loach populations.

Conclusions

Spined loach is widely distributed in the cSAC (outer and inner rivers). Although more work is clearly needed to establish what constitutes a 'good and viable' or 'representative' population (see *Further monitoring and research requirements* below), through sampling other populations in a range of waterbodies in the UK, it appears that the Ouse Washes cSAC would meet its objective of conserving a viable population of spined loach within one of its population centres (see *Distribution of spined loach* above). There are however considerable differences in the current ability of outer and inner rivers to support spined loach, with the outer river supporting a more age-structured and dense population. This is related to the presence of macrophytes and a suitable sediment. There is concern that continued nutrient loading and the resultant loss of macrophytes and the loading of fine anoxic sediments will further compromise the ability of the site to support spined loach and ultimately jeopardise its conservation value. Future work to safeguard and if possible, improve the status of the cSAC and the site as a whole should include:

- Monitoring of water quality; particularly in the outer river, but also in the inner river, dykes and Hundred Foot river.

- If the nutrient levels are either increasing or are currently at a high enough level to mean there is risk of reversion to a turbid, algal dominated state in the outer river, the source should be identified and appropriate action taken. This may involve reduction of run-off of nutrient rich water, perhaps through changes in catchment land use with reversion to grassland rather than arable crops.

- If nutrient levels are currently unacceptably high in the wider system, including the inner river, ditches and Hundred Foot river, long term action to reduce nutrient loading (e.g. installation of phosphate strippers at source in sewage works upstream) should be instigated.

Management of the outer river during routine maintenance operation is another major issue. There is some evidence from the dykes in the washes that dredging tends to favour the development of more speciose macrophyte communities after 2/3 years (Cadbury *et al.* 1993). Whether or not this applies to larger, less silty channels such as the outer river is unknown. If it does, dredging may favour spined loach in the medium term.

In the short term, however, dredging may be detrimental through:

- Potential removal of spined loach buried in the sediments
- Changes to the nature of the sediment and its associated microfauna and flora (Pearson & Jones 1975)
- Promotion of dense filamentous algal mats denying spined loach access to the sediment;

As the presence of high numbers of benthivorous/zooplanktivorous fish may directly and indirectly impact the ability of shallow systems to support macrophytes and thus spined loach, any stocking of fish into the outer river, even after fish-kill, should be carefully considered. Given the statutory duties of the Agency to both angling and conservation interests, perhaps a pragmatic solution is to only undertake the introduction of coarse fish, where absolutely necessary, below Welches Dam. This would protect the greater population of spined loach in the river upstream of this point (Fig. 4).

E. Preliminary management guidelines

Background information

The dependence of spined loach populations upon annual recruitment combined with specific habitat requirements makes them vulnerable to habitat change (see *Key issues of a conservation strategy for spined loach* above). The multi-functional aspect of many waterbodies, within the range of spined loach (see *Distribution of spined loach in the UK* above) such as flood control, water supply etc., necessitates a programme of routine maintenance such as dredging and control of both submerged and emergent plants, which in turn, may impact upon spined loach populations.

There is some circumstantial evidence to support this contention. For example, of the 24 generally intensively managed waterways, in which spined loach was recorded from Central Area of Anglian region, only 3 (Upper Great Ouse, River Nar and the River Wissey) contained spined loach in more than one (and never more than 2) surveys (between 2-7 were conducted on each waterway between 1979 and 1996). This suggests spined loach populations may wax and wane, colonising new areas as they become suitable, and then disappearing as they change for the worse, perhaps following intensive management.

Unfortunately, an attempt to gather more specific information on one form of management, dredging, was confounded by the absence of spined loach in the samples taken from the dyke system in the Ouse washes (see *Distribution of spined loach within the Ouse washes* above). In the outer river however, there was some evidence that dredging may have a indirect impact on spined loach. Many sections which had been recently dredged (with vegetation and substrate piled on the bank) had become dominated by filamentous algae, with a consequent impact on the density of spined loach (see *Habitat preferences in the Ouse washes* above).

Consequently, at this stage, any management guidelines can only be preliminary. These are based on rather general information on the ecology and life history traits of spined loach. Moreover, a precautionary, inclusive, approach has been adopted to reduce the possibility of potential areas of relevance being excluded. Both general and more specific guidelines are provided below.

Results & Discussion

General management guidelines

The following guidelines stem from the optimal habitat for spined loach being a sandy substrate with patchy, although dense, macrophytes. Silt or muddy substrates are tolerated although these should not be thick or coherent. Favourable habitat may be found in a variety of waterbodies, although it may be commonplace in natural streams and rivers. Spined loach are therefore representative of diverse habitats, where they are part of a diverse fish fauna. Spined loach are thus not typically associated with fish assemblages dominated by a few species, generally omnivorous coarse fish.

All of the following apply to any system containing important populations of spined loach, as well as SAC's:

- Eutrophication leading to the loss of submerged macrophytes in any water body in which spined loach is present is likely to adversely affect the population. Action should therefore be taken to significantly reduce nutrient loading.

- Excessive loading of fine sediments is likely to be detrimental to populations of submerged macrophytes and benthic flora and fauna and ultimately spined loach Action should therefore be taken to significantly reduce any sediment loading.

- Management causing a significant reduction in habitat diversity e.g. channelization (widening, straightening, deepening, removal of woody debris and other channel features), of river and stream channels is likely to impact upon spined loach. Action should therefore be taken to limit or even cease such intensive management either in capital schemes or during routine maintenance programmes.

- A high biomass of omnivorous fish may change the nature of the sediment and deplete its invertebrate resources, disfavour populations of submerged macrophytes (through a variety of mechanisms- see *Habitat preferences of spined loach* above) and may even present a direct predation risk to spined loach. Action should therefore be taken to a) regulate excess stocking of species such as roach and bream (*Abramis brama*) b) prevent any introductions of further species not native to the catchment (e.g. carp) and limit any unregulated manipulations (e.g. removal of pike, which may help suppress the development of high biomasses of coarse fish and indirectly promote the domination of macrophytes-see above).

Any of the actions recommended above may also be used to promote the suitability of a waterbody for spined loach. Furthermore, tackling any of the broad issues cited may form the focus of more general enhancement/rehabilitation/restoration schemes currently adopted by a variety of organisations. Of direct relevance to the Agency, the rehabilitation of streams and rivers, currently gathering pace in the UK (see Perrow & Wightman 1993, Driver 1997) may have the spin-off benefit of promoting spined loach populations even where these do not form the target of the scheme in question.

Specific management guidelines

Specific information on the effects of various management practices used by the Environment Agency and other organisations, such as dredging, weed-cutting and channel profiling, on populations of spined loach will be required before concise operational guidelines can be developed. This will be critical for those organisations involved in routine maintenance work. For example, the flood defence function of the Agency. Such information is likely to be an essential component of the strategy to conserve and promote spined loach populations (see *Further research and monitoring requirements* below).

The following constitutes a preliminary attempt to construct specific operational guidelines:

- Adopt sensitive weed-cutting. For example, cutting down just the centre, or perhaps one side, of the channel, to create a heterogeneous habitat suitable for spined loach.

- Consider longer term management of macrophytes, through tree planting where appropriate, to create shade along one bank.

- Although some dredging may also promote a heterogeneous habitat, this should not be undertaken across the whole width of the channel as the short term consequences are likely to be considerable. Dredging in the centre of the channel, leaving undisturbed refuge areas, may be acceptable.

- The frequency of dredging should not be more than once every 4 years to enable populations of spined loach to recover and achieve maximum lifespan. The frequency of dredging may however be increased to every 2/3 years where a rotational regime is adopted, again always leaving suitable refuge areas.

F. Further monitoring and research requirements

Background information

The distribution of spined loach is centred on the Great Ouse and Trent catchments, the latter of which includes the Witham and connected waterways (see *Distribution of spined loach in the UK* above). However, records within each system are generally rather patchy. But is the result of inefficient sampling methods or that spined loach have specific habitat requirements? To clarify the distribution and status of spined loach, in order to ensure populations are conserved and promoted, there is a clear need to assess the efficiency of standard and more specific sampling methods. The most appropriate methods may then be used to facilitate the selection of further SAC's within each of these catchments, which forms the basis of the conservation strategy for spined loach (see *Key issues of the conservation strategy for spined loach* above).

Caveats in the knowledge of spined loach include the habitat requirements of the species, but especially juveniles and also a greater understanding of population dynamics. Combined with information on the impact of habitat management upon populations, management prescriptions for spined loach may be developed. This will be a critical aspect of the conservation and management of spined loach populations.

Methods

Assessment of sampling methods

A preliminary assessment of the efficiency of different sampling methods was conducted in the outer river on 17th-18th February 1997, prior to the survey of the distribution of the species within the system (see *The conservation of spined loach in the Ouse Washes cSAC* above).

The methods used were:

- Standard seine netting as typically used by the Agency fisheries teams. Two nets were used: a) a 50 m long x 5 m deep net with 25 mm mesh in the wings and 5 mm mesh in the bag b) a 50 m long x 2.5 m deep with 5 mm mesh throughout.

- PAS by electrofishing which had previously been used to great effect in sampling spined loach in Lake Veluwe (see *Habitat preferences of spined loach* above).

- A modified push net (designed for catching shrimps) used in the manner of a hand trawl. (see *Habitat preferences in the Ouse Washes* , above).
- Bottle traps, which had successfully caught spined loach during sampling for bitterling (*Rhodeus sericeus*) used at Wicken Fen by Dr John Reynolds *et al.* at UEA.

A total of 8 seine net hauls (5 with the shallower fine mesh net and 3 with the deep net), 100 point samples and 20 trawls were taken. Twenty bottle traps (standard 1.5 litre plastic bottles cut in half with the neck inverted and pushed inside the lower half, creating a funnel) were set at intervals of about 20 m at various distances from the bank. These were marked with floats and left for 24 hours before being collected. Density estimates of all fish species, as well as spined loach were calculated in the standard way for each quantitative method (see *Habitat relationships in Lake Veluwe* above for PAS & *Habitat preferences in the Ouse washes* for the hand trawl). For seine nets this was derived by sampling a known area with a net of known length set in a circular fashion. Catches for the qualitative bottle traps were expressed as CPUE.

Results & Discussion

Assessment of sampling methods

No fish were captured by the bottle traps, probably as a result of the low water temperature inhibiting fish movement and the possibility of fish encountering and entering traps. The different quantitative sampling methods generated very different estimates of virtually all fish species.

Seine netting was clearly adept at sampling the species important to the fishery such as roach, bream , perch, rudd and pike. By far the highest estimate of density was obtained by this method (Table 11). A large size range of fish from roach of 30 mm to pike of >500 mm was also captured. However, even though a proportionally large area was sampled by this method (nearly 1600 m^{-2}), no spined loach were captured. It is thought that even a 5 mm mesh may be too large to sample spined loach effectively and their capture by nets relies on them becoming entangled in macrophytes, algae or the substrate retained by the net. Few macrophytes were actually retained by the net during the current sampling, although they were present. Macrophytes appeared to become flattened against the rather hard peaty substrate with the net riding over the top. It is thought spined loach are only likely to be sampled in softer substrates where the lead line sinks in to some extent, disturbing buried spined loach and at least providing a chance of them being captured.

Table 11.
Mean (± 1 S.E.) density (n m^{-2}) of all fish species captured by the different quantitative methods used in the outer river of the Ouse washes , in February 1997.

Species	*Seine net*	*Hand trawl*	*PAS electrofishing*
Pike	0.005 ± 0.001	0.008 ± 0.008	0.023 ± 0.013
Eel	-	-	0.015 ± 0.011
Roach	1.003 ± 0.342	0.033 ± 0.020	-
Rudd	0.021 ± 0.012	0.008 ± 0.008	0.015 ± 0.011
Bream	0.030 ± 0.008	-	-
Tench	-	0.016 ± 0.035	-
Spined loach	-	0.220 ± 0.082	0.015 ± 0.011
Perch	0.050 ± 0.024	0.179 ± 0.044	0.062 ± 0.024
Ruffe	0.006 ± 0.004	0.016 ± 0.012	-
Total	1.266 ± 0.351	0.481 ± 0.014	0.131 ± 0.031

Overall it is suggested that the somewhat low efficiency of seine netting will also be variable according to the nature of the substrate and the presence of macrophytes. This means that routine Agency surveys using these methods may only provide records of spined loach. Spined loach may be present where it is suggested to be absent and the density is always likely to be a considerable underestimate.

The disappointing performance of point-sample electrofishing during the current assessment was related to the excessive maximum depth (>2 m) in the centre of the channel. Captures of fish, including spined loach, were thus limited to the shallower water close to, and within, the littoral margin. In general, point abundance sampling (PAS) by electrofishing (Copp & Penáz 1988, Perrow *et al.* 1996a) has several advantages over the standard techniques employed by the Agency (depletion fishing between stop-nets), as it involves taking a large number of samples leading to a low variance to mean ratio (Perrow *et al.* 1996a). Electrofishing may draw the fish from cover (including the sediment) and point sampling provides a means of generating quantitative estimates of fish density. Quantification of environmental variables at each point, is also a powerful way of assessing the factors determining the distribution and abundance of the fish.

Experience has shown that even where water clarity precludes seeing small fish near the bottom, netting through the area sampled by the anode results in the capture of any stunned fish. Point sampling may thus be undertaken successfully in relatively turbid water. However, point sampling by virtue of sampling only a small area at each point and even with considerable numbers of points, the area sampled may not be large (200 points would only be 300 m^{-2}), may mean rare species are ineffectively sampled. This is particularly relevant in the case of spined loach which appears to show an aggregated distribution (*pers obs*).

Therefore, in sites which have few spined loach, a more qualitative technique, sampling a larger area may prove to be more effective. Conventional electrofishing, exploring the habitat, may be used. The choice of gear will however be critical. For example, pulsed DC and DC forms may draw fish from cover, whereas AC does not. Routine electrofishing using AC may therefore be less likely to sample spined loach effectively. Moreover, high frequency gear will minimise possible injury to fish (see Perrow *et al.* 1996a). Even with appropriate gear, the efficiency of electrofishing will be different in relation to depth, width and the relative size of the anodes (Zalewski & Cowx 1990). Further modifications such as the use of oversize anodes (> 45 cm diameter), a slow sampling speed with careful exploration of any macrophytes etc. and fine-meshed (c. 2 mm) lightweight nets may be required. Even then, catch-per-unit-effort (CPUE) measures may be more appropriate and 'free' electrofishing over a known time period or perhaps known length of littoral margin undertaken.

During routine surveys, where species of importance to the fishery are the target, minor species such as spined loach are likely to be missed. Modifications to the standard techniques such as those recommended above, may also detract from sampling the major species of interest. Therefore, any modifications may be inappropriate. Consequently, without modification and even in small streams where conventional electrofishing is likely to be at its most efficient, the density of spined loach will not be effectively sampled by routine surveys. Further presence/absence is only likely to be reliably recorded in small streams.

Of the quantitative techniques used, the hand trawl was the most effective at capturing spined loach. It also has several distinct advantages over the other more standard techniques :

- Readily quantifiable through sampling of a known area.
- A reasonably large area may be sampled leading to sampling of rare or aggregated species such as spined loach (see discussion below).
- Relatively inexpensive of time and effort.
- Little operator bias.

The actual efficiency of the hand trawl in sampling spined loach is unknown at the present time. It is likely that the efficiency will also change according to the nature of the substrate and the abundance of any macrophytes and especially filamentous algae. Without trials on known populations under different circumstances, this cannot be addressed. At this stage, the hand trawl is likely to be effective in still or slowly flowing water of almost any depth. It cannot be effectively used where there is emergent vegetation or macrophytes or algae dominate the water column. The hand trawl may typically be used in range of large rivers and drainage channels.

Establishing further SAC's

Detailed molecular work (e.g. chromosome banding) is required to establish the taxonomic relationships between the different populations in the UK and also the ancestral stock in Continental Europe. This will also shed further light on the origin of spined loach in the UK. (see *Distribution of spined loach in the UK* above). In the absence of this information, the strategy of establishing SAC's within the Great Ouse and Trent/Witham catchments is a pragmatic one, based on the possibility that the spined loach present in each, are genetically different from each other (see *Key issues of a conservation strategy for spined loach* above).

The SAC designation generally overlays previous designation, at least SSSI status, at a particular site. For many SAC species, included within the SSSI framework, designation of SAC's may be relatively straightforward. However, spined loach has only recently been recognised as being worthy of conservation interest and had therefore not been included in the established legislative framework. Consequently, many good sites for spined loach (once these are determined - see below) are not likely to be SSSI's. However, as spined loach may often be associated with high quality, diverse habitats (see *Habitat preferences of spined loach* above), at least some riverine or lacustrine SSSI's are likely to contain good populations of spined loach. It may thus be pragmatic to exploit the latter, whilst alternative mechanisms of designating SAC's are sought.

Establishing further SAC's within the Great Ouse and Trent/Witham catchments relies on determining the status of populations and identifying key areas.

The following 'rules of thumb' may be used to target areas of potential value:

- Determine the distribution of any riverine SSSI's.
- Determine the distribution of other sites of lesser status, such as County Wildlife sites.
- Determine the distribution of non-designated areas of generally good habitat quality and a low level of anthropogenic disturbance. This may use the knowledge of staff of relevant organisations including Agency, EN and Trusts as well as specialist individuals. Agency RCS data may also be exploited.
- Using any available records from the catchment, check for any clustering or repeat records of spined loach, that may indicate good areas.
- Begin preliminary surveys in the small tributaries off the main channel as these will often have relatively high quality habitats, lower fish biomasses and a preponderance of smaller species with which spined loach tends to be associated.

The Great Ouse and associated waterways, already contains a candidate SAC, the Ouse washes (see *Key issues of a conservation strategy for spined loach* above). Preliminary surveys revealed good numbers of spined loach in the outer river at least, indicating that the site is worthy of its status. However, there are a number of issues associated with the system that are of concern (e.g. nutrient enrichment). At this stage, without further information the long-term value of the site cannot be assured (see *Conservation of spined loach in the Ouse washes cSAC* above). Therefore, it is desirable to establish at least one further SAC within the Great Ouse catchment.

Wicken Fen appears to be a most suitable candidate, with its current status as an National Nature Reserve (NNR), SSSI and cSAC for fen meadow communities (R. Hall, EN, *pers comm.*). The wide distribution of spined loach in the channels (lodes) of the fen has been confirmed during sampling undertaken as part of the research on bitterling, led by Dr. John Reynolds and his team at UEA. Bottle traps, electrofishing (some of which has been undertaken by ECON) and the 'push-net'(see above) have all successfully captured the species. Good numbers are also known to be present, with Peacock (1997) capturing >100 individuals using the push-net.

A further site of interest is the ARC Wildfowl refuge at Great Linford. Spined loach has colonised from the Great Ouse and is reputed to be very common, frequently being encountered in invertebrate samples (N. Giles, consultant, *pers comm.*). There is thus merit in establishing the size of the population on the site and if it is freely distributed between the different lake types, varying from macrophyte- to phytoplankton dominated (Giles 1992).

It is thought that there are few sites of conservation value within the Trent and Witham catchments. Attenborough gravel pits SSSI alongside the Trent is the only obvious site. This means that designation of SAC's within the Trent & Witham will have to rely on the use of alternative mechanisms to establish SAC's (see above).

During any sampling for spined loach, habitat and water quality variables should be quantified to provide additional data on the habitat preferences of spined loach, particularly juvenile fish, in different situations (see below). Of the water quality variables, determining any impact of salinity is of high priority due to the lack of knowledge of its influence and it's particular relevance to the Ouse Washes cSAC (see *Habitat preferences of spined loach* above).

Clarifying the habitat use of different age classes of spined loach

The habitat use of spined loach, especially that of juveniles, requires further clarification. In particular, the details of the potential refuge effect of macrophytes needs to quantified. For example, what plant species and coverage is important? From a population perspective, the ultimate question that needs answering is - What is the role of refuges in determining recruitment strength? Some useful information may be provided by habitat association determined during sampling of cSAC's (see *Establishing further SAC's* above) or streams (see *Determining the effects of routine management practices* below). However, a more targeted programme of research is clearly needed, along the lines of that adopted in Lake Veluwe (see *Habitat relationships in Lake Veluwe* above).

It would be beneficial to sample two distinct habitat types such as a stream/river and a larger drainage channel, with for example, a sandy and a more silty substrate respectively. Sampling should be conducted in all available habitats using transects or perhaps random sampling. Electrofishing (PAS and/or free sampling-see above) within the stream and the hand trawl in the drainage channel are the most appropriate techniques (see *Assessment of sampling methods* above) The sampling period should be at least one year. Additional information on sex ratios, fecundity, spawning periods, mortality rates and perhaps even diet should also be taken. An attempt to sample the diet of potential predators of spined loach including eel, perch, chub (in the stream) should also be made in an attempt to account for changes in population density. In the fluvial study site, an attempt should also be made to determine the effect of flow on different size (age) classes of spined loach.

Determining water quality criteria

The effect of different water quality criteria on spined loach is as yet unknown, although there is a suggestion that spined loach is adapted to low oxygen conditions and thus may tolerate other factors likely to be encountered in such circumstances (e.g. ammonia) (see *Habitat preferences of spined loach* above). High nutrient levels through changes to habitat structure are predicted to impact spined loach populations (see *Conservation of spined loach in the Ouse washes cSAC* above). Other variables such as heavy metals, salinity etc. may also have a direct effect. The best approach in determining any impact upon spined loach may be to look for relationships between the occurrence of spined loach in any particular waterbody and any particular variable. Routine Agency water quality monitoring may be utilised. An obvious problem is that the standard Agency fisheries surveys are relatively ineffective at sampling spined loach, particularly on a site basis. However, in a watercourse in which a large sampling effort has been undertaken, at least the presence of spined loach is likely to have been recorded (see *Habitat associations derived from routine fisheries and RCS surveys*). This may, however, be of insufficient detail to be useful. Consequently, laboratory eco-toxicological tests of the effects of particular variables on spined loach in the laboratory, may be the most effective approach. Such tests should only use the range likely to be encountered in natural habitats, of any particular variable.

Determining the effects of routine management practices

Several types of routine management practice undertaken particularly by the flood defence function of the Agency, may directly impact populations of spined loach (see *Preliminary management guidelines* above). In perceived order of importance these are:

- Channelisation (widening, deepening, straightening) of small streams.
- Dredging.
- Weed cutting.
- Channel profiling and littoral margin management .

During sampling to determine distribution of spined loach within the Trent and Witham catchments (see above), a comparison of spined loach populations between channelized and more natural streams is recommended. This could be achieved by sampling a minimum of 5 streams of each type. PAS by electrofishing is thought to be the most suitable sampling method (see below). At each point, the density of spined loach and the abundance of particular habitat variables may be determined with the aim of adding to the information on habitat relationships. The impact of littoral margin management may be investigated in the same way, perhaps within the same date set.

In the case of dredging and weed-cutting, monitoring of replicate (n>5) stretches at an experimental site, where controlled dredging and weed-cutting could be applied is deemed to be the most scientifically rigorous approach. Monitoring should be conducted pre- and post-management for at least one year to investigate short and longer term effects on habitat use, population structure and recruitment patterns. If effects prove to be significant, monitoring may be extended over a longer time period. Waterbodies subject to routine dredging such as the drainage channels of the lower Great Ouse and Witham system, are the most applicable to this type of approach. Weed-cutting may be investigated in these channels and also perhaps in streams in the Trent catchment which are also subject to an annual weed-cut in late summer/autumn to increase drainage efficiency in periods of increased flow.

Conclusions

The current conservation strategy for spined loach is to a) implement the EC directive through the establishment of SAC's and b) to conserve, and if possible, promote spined loach in all waters in which it occurs.

The strategy of establishing SAC's within each of the catchments in which spined loach occurs is a pragmatic solution to the possibility that different populations are genetically distinct from each other. Detailed knowledge of the taxonomic relationships between the different populations in the UK and the ancestral stock in Continental Europe, through detailed molecular work, should be sought at the earliest opportunity. This is likely to require a high level of expertise (such as that found in a number of University's in the UK) and considerable financial and time resources. Such a project is thought most likely to funded through the EC, with a number of partners in different member countries.

The conservation (and promotion) of spined loach in all waters in which it occurs requires further detailed knowledge of its habitat preferences, population dynamics and response to routine management practice. Knowledge on these three aspects will allow management prescriptions to be generated for different types of waterbody.

The principal components of a future programme of research and monitoring should therefore include:

- Determining the distribution and status of spined loach in the Trent & Witham and Great Ouse catchments with the view to establishing further SAC's. Useful information to add to the base of knowledge on the habitat preferences of spined loach may also be gathered.

- Specific medium term (at least one-year) research on the habitat requirements, especially of juveniles, and population dynamics of spined loach. This to be conducted in two study sites; one in a stream/river and the other in a large drainage channels. These to have different substrates, preferably sand and silt, respectively. Such a detailed programme of research may be most appropriately undertaken during a PhD.

- Monitoring the impact of routine management practices such as channelization, dredging and weed-cutting. Study sites in both streams and large drainage channels are required. A scientifically rigorous experimental design using replicates and a range of treatments incorporating controls, is recommended. This is because a high level of confidence in the results is required, as these have the potential to shape future management policy, with considerable financial implications.

From an assessment of sampling methods, it is clear that specific methods including the use of the hand trawl and point-abundance sampling by electrofishing, are required to sample spined loach effectively. These should be used in all aspects of future research on, and monitoring of, the species (see above).

Conversely, there is evidence to suggest that standard fish sampling methods such as seine netting and electrofishing between stop-nets are inefficient at sampling spined loach. The recording of spined loach in routine fisheries surveys conducted by the Agency, although adding to the base of knowledge on spined loach, is therefore of limited value in determining the distribution and status of spined loach. Although populations in small rivers and streams may be monitored after some modification to the standard electrofishing techniques, more specific methods are generally required. The incorporation of hand trawl sampling and point-abundance sampling by electrofishing, where appropriate, into routine Agency sampling of waters within the distribution of spined loach, is recommended.

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Appendix 1. Terms of Reference.

Spined Loach (*Cobitis taenia*): A review of habitat and management requirements

BACKGROUND

The Spined Loach is a small bottom dwelling fish which is confined to the rivers and drainage channels in the Midlands and eastern England. It is generally considered to be widely distributed within these areas, but since it is often overlooked in fish surveys, detailed information is lacking. Apart from selected studies its ecology appears to have been little studied in England.

The spined loach is considered to be threatened within Europe and is therefore listed on Appendix 3 of the Bern Convention and Annex II of the EC Directive on the conservation of natural habitats and wild flora and fauna. The latter places a duty on member states to ensure the long term conservation of this species, and specifically requires that special areas of conservation (SACs) should be designated for it and that appropriate actions should be defined and undertaken which will enable them to ensure its long term favourable conservation status (fcs) to be ensured. Following a review of available information, one site in the UK, the Ouse Washes, has been proposed for designation as a SAC. It is likely that it will be confirmed. However, it is clear from the review that the lack of detailed information on either the distribution of the spined loach or its habitat requirements coupled with the lack of general awareness about the species had not only restricted the ability to identify key sites but could potentially also hinder the development of best management practice to protect this and other sites where it occurs.

In view of this, there is now an urgent need to more fully review the existing knowledge and information on the distribution and habitat requirements of the Spined Loach and to define where possible preferred habitat and best practice for those operations and functions for which bodies such as the Environment Agency and the Internal Drainage Boards are responsible. In addition it will be equally important to identify those aspects of ecology and distribution which will need further research if the requirements of the Directive are to be fully met.

Overall Objective

The overall objective of the project is to ensure that the requirements of the EC Directive on the conservation of natural habitats and wild flora and fauna can be met.

It should be noted that the overriding requirement of the project is to inform management decisions which need to be taken now. As such the emphasis is to draw together the best available advice, testing this where appropriate, rather than seeking to set up and undertake a detailed research programme.

Project Aims

There are five broad aims.

1. To review and consolidate all existing information on the distribution of the Spined Loach in England, so as to provide a clearer picture than currently exists of its distribution.

2. to identify habitat requirements;

3. To identify and where possible quantify the key factors/issues which will need to be addressed if favourable conservation of the Spined loach is to be achieved across the range of habitats in which it is found;

4. to produce management guidelines which will raise awareness of the issues relevant to conserving the spined loach and also enable operational staff to ensure that sympathetic management of those sites where Spined loach occurs can be undertaken with particular reference to weed and silt control; and

5. to identify those aspects of ecology and distribution where further research or review is needed.

Methodology

The main aims of the project will be met through the following approaches.

1. A review of the published literature and any information held by regional EA staff and other interested bodies ie IDBS, NT, RSPB to identify all known records of Spined loach, in its area of distribution.

2. A review of habitat requirements in both the published and grey literature to produce clear guidelines of physical and chemical and biological characteristics of its preferred habitats.

3. Analysis of the information held on the Ouse Washes to confirm the habitat characteristics of those sites where Spined Loach occurs, and to identify other possible sites where they may occur.

4. Limited survey, using appropriate techniques such as `point electric fishing', to confirm the presence and if possible the population characteristics of Spined Loach from a selection of sites known to support the species and a selection of sites, which from an analysis of their attributes should support Spined Loach.

5. The synthesis of the results from 1 to 4 to produce draft management guidelines covering those operational functions, particularly weed and silt control, undertaken by the EA, IDBs and others. As part of these guidelines it will be important for the contractor to identify existing management practices and to indicate clearly whether or not these need to be modified. Where there are clear gaps in knowledge, advice should reflect the precautionary principle. Raising awareness of the likelyhood of finding and recording the presence of spined loach is an important part of this and a section of the guidelines should be devoted to this.

6. Recommendations for future research.

7. Recommendations for monitoring whether favourable conservation status is being maintained, including details of any actual survey techniques.

Results

The results of this project will be presented in the form of a written report, produced to the satisfaction of the project board. If appropriate a distinction should be drawn between different channel types ie river, ditch or dyke. Management guidelines should be produced in the format adopted by the EA and illustrated to the example included in Appendix 1.

Project Management

The project will be overseen by a project board comprising officers from EN and the EA.

Timescale

A draft report will be produced by December 1996.

A final report by April 1997.

Appendix 2.

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Appendix 3.

List of Consultees

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Dr. Nick Giles, 50 Lake Road, Verwood, Dorset, BH31 6BX

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Dr. Franklyn Perring, Green Acre, Wood Lane, Peterborough, Cambridgeshire, PE8 5TP

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Environment Agency Offices:

Thames Region:

West Area Office: Isis House, Howbery Park, Wallingford, Oxon, OX10 8BD

Waltham Cross: The Grange, 97 Crossbrook St, Waltham Cross, Hartfordshire, EN8 8HE

South East Area Office: Riverside Works, Fordbridge Road, Sunbury, Middlesex, TW16 6AP<B

Guildford Office: Ladymead, Bypass Road, Guildford, Surrey, GU1 1BZ

Midlands Region

Upper Trent Area Office: Sentinel House, 9 Wellington Crescent, Fradley Park, Lichfield, Staffs, SW13 8RR

Lower Trent Area Office: Trentside Offices, Scarrington Road, West Bridgford, Nottingham

Upper Severn Area Office: Hafren House, Welshpool Road, Shrewsbury, SY3 8BB

Lower Severn Area Office: Riversmeet House, Northway Lane, Tewkesbury, GL20 8JG

Anglian Region:

Central Area Office: Broomholme Lane, Brampton, Huntingdon, PE18 8NE, Norwich Office: 79 Thorpe Road, Norwich, NR1 1EW

North West Region:

Regional Office, Richard Fairclough House, Knutsford Road, Warrington, WA4 1HG

Appendix 4. List of all confirmed spined loach records

Grid references in brackets were worked out by AJ from discriptions

River	Site Name	NGR	Year	Source
Ouse	Whitings stretch	(SP805714)	1990	Mann 1995 (Copp 1990b)
Ouzel	Stoke Hammond	(SP885364)	1990	Mann 1995 (Copp 1990b)
Ouzel	Caldecote: channels	(SP885424)	1990	Mann 1995 (Copp 1990b)
Ouse	Kempstone: side channel	(TL021476)	1990	Mann 1995 (Copp 1990b)
Elstowe Brook		(TL051474)	1990	Mann 1995 (Copp 1990b)
Kym	Hail Weston	(TL170623)	1990	Mann 1995 (Copp 1990b)
Ouse	Hall Green Brook	(TL303680)	1990	Mann 1995 (Copp 1990b)
16 Foot Drain	Sparrow Hall	(TL465943)	1983	Mann 1995 (NRA Anglian))
Swaffham Bulbeck Lode		(TL550640)	1990	Mann 1995 (Copp 1990b)
Delph	DS Earith - fish resuce	(TL576856)	1993	Brampton EA
16 Foot Drain	Poplar Farm Bridge	?	1983	Mann 1995 (NRA Anglian))
16 Foot Drain	Crown Drove Road	?	1983	Mann 1995 (NRA Anglian))
Rippingdale Running Dyke	Dunsby Fen	?	1984	Mann 1995 (NRA Anglian))
Sincil Dyke	d/s 5 Mile House	?	1982	Mann 1995 (NRA Anglian))
Witham	Cherry Willingham	?	1978	Mann 1995 (NRA Anglian))
Ancholme	Brigg Sports Centre	SE993069	1979	Mann 1995 (NRA Anglian))
Sow	Eccleshall	SJ831296	1992	Lichfield (EA)
Sow	Yoxhall Bridge	SJ831296	1993	Lichfield (EA)
Sow	Eccleshall	SJ831296	1993	Mann 1995 (NRA Seven Trent)
Trent	U/S Scotch Brook	SJ901334	1995	Lichfield (EA)
Penk	Atherstone Rattcliffe Bridge	SJ915137	1993	Lichfield (EA)
Penk	Penkridge-Cuttlestone Bridge	SJ915137	1993	Mann 1995 (NRA Seven Trent)
Sow	Eccleshall	SJ918233	1993	Lichfield (EA)
Sow	Broad Eye Bridge	SJ918233	1993	Mann 1995 (NRA Seven Trent)
Penk	Stafford Radford Bridge	SJ938216	1995	Lichfield (EA)
Penk	Stafford-Radford Bridge	SJ938216	1995	Mann 1995 (NRA Seven Trent)
Sow	St. Thomas Bridge	SJ946228	1992	Lichfield (EA)
Sow	Penkridge-Cuttlestone Bridge	SJ946228	1995	Lichfield (EA)
Sow	St Thomas Bridge	SJ946228	1995	Mann 1995 (NRA Seven Trent)
Penk		SJ949221	1993	Lichfield (EA)
Penk		SJ949221	1994	Lichfield (EA)
Penk		SJ949221	1996	Lichfield (EA)
Trent	Hilton	SK131177	1992	Lichfield (EA)
Trent	Yoxall Bridge	SK131177	1992	Mann 1995 (NRA Seven Trent)
Mease		SK235113	1994	Lichfield (EA)
Anker	R.Sence to R.Tame	SK237048	1996	Lichfield (EA)
Hilton Brook	Hilton	SK242306	1992	Mann 1995 (NRA Seven Trent)
Derwent	Wilne	SK242314	1994	Mann 1995 (NRA Seven Trent)
Sibson Brook		SK334004	1996	Lichfield (EA)
Grantham Cannal		SK350290	since 1990	Nottingham (EA)
Trent & Mersey Cannal	Twyford	SK350290	since 1990	Nottingham (EA)
Trent	Swarkestone	SK375283	since 93	Lichfield (EA)
Trent	Swarkestone	SK375283	1993	Mann 1995 (NRA Seven Trent)
Trent	Kings Mills	SK417274	1994	Mann 1995 (NRA Seven Trent)
Trent	Shardlow	SK447299	1994	Mann 1995 (NRA Seven Trent)
Trent	Thrumpton	SK510315	since 93	Lichfield (EA)
Trent	Thrumpton	SK513317	1994	Mann 1995 (NRA Seven Trent)
Soar	Aylestone	SK570001	1995	Mann 1995 (NRA Seven Trent)
Trent	Ladybay Bridge	SK585387	1993	Mann 1995 (NRA Seven Trent)
Trent	Stoke Bardolph	SK650405	1995	Mann 1995 (NRA Seven Trent)
Trent	Stoke Bardolph	SK651407	since 93	Lichfield (EA)
Devon	Cotham	SK780470	since 1990	Nottingham (EA)
Trent	South Muskham	SK803565	since 93	Lichfield (EA)
Trent	South Muskham	SK803565	1994	Mann 1995 (NRA Seven Trent)
Trent	Winthorpe Bridge	SK805567	1995	Mann 1995 (NRA Seven Trent)
Till	Broxholme	SK903768	1978	Mann 1995 (NRA Anglian))
Till	Squires Bridge	SK903824	1994	Mann 1995 (NRA Anglian))
Till	Till Bridge	SK907797	1994	Mann 1995 (NRA Anglian))
River Brant	Navenby Road Bridge	SK940580	1994	Mann 1995 (NRA Anglian))
Skellingthorpe Main Drain	Kews Holt	SK945740	1994	Mann 1995 (NRA Anglian))
Fossdyke	Pyewipe Inn	SK949723	1978	Mann 1995 (NRA Anglian))
Burton Catchwater Drain	Bishops Bridge	SK950733	1982	Mann 1995 (NRA Anglian))
Witham	Lincoln Power Station	SK993714	1981	Mann 1995 (NRA Anglian))
Anker	Broad Eye Bridge	SP317985	1993	Lichfield (EA)
Anker	Atherstone Ratcliffe Bridge	SP317985	1993	Mann 1995 (NRA Seven Trent)
Anker		SP318986	1996	Lichfield (EA)

Sence		SP320996	1996	Lichfield (EA)
Soar	Narborough	SP541973	1994	Mann 1995 (NRA Seven Trent)
Soar	Whetstone	SP552985	1993	Mann 1995 (NRA Seven Trent)
Padbury or Claydon Brook	Hillfarm	SP728285	1994	Brampton (EA)
Padbury	Thornborough	SP729332	1990	Mann 1995 (Copp 1990b)
Great Ouse	Mounthill farm	SP763376	1991	Brampton (EA)
Tove	Bozenham	SP776483	1990	Mann 1995 (Copp 1990b)
Great Ouse	Passenham	SP782393	1989	Mann 1995 (Copp 1990a)
Great Ouse	Passenham	SP782393	1990	Mann 1995 (Copp 1990b)
Great Ouse	d/s Passenham Weir	SP785401	1991	Brampton (EA)
Great Ouse	Manor Farm	SP808425	1991	Brampton (EA)
Great Ouse	ARC Wildfowl reserve	SP840430	1990 on	Giles pers com
Great Ouse	Backwater	SP853448	1997	Brampton (EA)
Great Ouse	Ravenstone: mill stream	SP854486	1989	Mann 1995 (Copp 1990a)
Great Ouse	Ravenstone: side channel	SP855485	1989	Mann 1995 (Copp 1990a)
Grand Union	Woolstone	SP872390	1990	Brampton (EA)
Great Ouse	Newport Pagnell	SP877440	1974	Robotham 1977
Great Ouse	Newport Pagnell	SP882441	1992	Brampton (EA)
Great Ouse	Sherington: side channel	SP883455	1989	Mann 1995 (Copp 1990a)
Great Ouse	Sherrington: side channel	SP883455	1990	Mann 1995 (Copp 1990b)
Great Ouse	Sherington Bridge	SP884454	1989	Mann 1995 (Copp 1990a)
Great Ouse	Sharnbrook	SP990579	1984	Mann 1995 (Unpublished IFE data)
Ancholme	North Kelsey Carrs	TA006006	1979	Mann 1995 (NRA Anglian))
Witham	Greetwell Hall	TF015711	1978	Mann 1995 (NRA Anglian))
Ancholme	TF015970	TF015970	1979	Mann 1995 (NRA Anglian))
Ancholme	Snitterby Carrs	TF018948	1989	EA Anglian (Northern)
Ancholme	Pease Holme	TF023936	1993	Mann 1995 (NRA Anglian))
Ancholme	Pilford Bridge	TF036886	1989	EA Anglian (Northern)
Witham	5 Mile House	TF059715	1978	Mann 1995 (NRA Anglian))
Barling's Eau	Newballwood	TF082758	1982	Mann 1995 (NRA Anglian))
Sincil Dyke	Bardney Locks	TF105702	1982	Mann 1995 (NRA Anglian))
Witham	u/s Bardney Bridge	TF110614	1994	Mann 1995 (NRA Anglian))
Witham	Bardney	TF112691	1981	Mann 1995 (NRA Anglian))
Farroway Drain	Praie Grounds	TF136523	1994	Mann 1995 (NRA Anglian))
Witham	Southrey	TF139663	1981	Mann 1995 (NRA Anglian))
Witham	Stixwold station	TF155655	1981	Mann 1995 (NRA Anglian))
South 40 Foot Drain	Dowsby Road	TF167324	1990	Mann 1995 (NRA Anglian))
Witham	Kirkstead Bridge	TF175621	1981	Mann 1995 (NRA Anglian))
South 40 Foot Drain	Bicker Fen	TF185395	1995	Mann 1995 (NRA Anglian))
Head Dyke	Pump Station	TF186467	1995	Mann 1995 (NRA Anglian))
Witham	Thorpe Tilney	TF189589	1981	Mann 1995 (NRA Anglian))
Witham	Tattershall Bridge	TF196563	1981	Mann 1995 (NRA Anglian))
Witham	Dogdyke	TF208554	1981	Mann 1995 (NRA Anglian))
West French Drain	Dovecote	TF281528	1990	Mann 1995 (NRA Anglian))
West French Drain	Newham drain	TF292500	1993	Mann 1995 (NRA Anglian))
Witham	Anton's Gowt	TF301474	1981	Mann 1995 (NRA Anglian))
West French Drain	Medlam drain	TF322539	1993	Mann 1995 (NRA Anglian))
French Drove		TF331089	1995	Mann 1995 (NRA Anglian))
Sibsey Trader System		TF339597	1990	Mann 1995 (NRA Anglian))
Cowbridge Drain	d/s Kelsey Bridge	TF346465	1995	Mann 1995 (NRA Anglian))
Hobhole Drain	Kelsey Bridge	TF346465	1993	Mann 1995 (NRA Anglian))
East Fen Catchwater	Holmes Road, Stickney	TF350566	1993	Mann 1995 (NRA Anglian))
Hobhole Drain	Hemholme Bridge	TF403586	1993	Mann 1995 (NRA Anglian))
Bellwater Drain	Bellwater Farm	TF423592	1993	Mann 1995 (NRA Anglian))
Lym	Mill Bridge	TF430641	1993	Mann 1995 (NRA Anglian))
Steeping	Firsby	TF457621	1993	Mann 1995 (NRA Anglian))
Steeping	Relief channel	TF488602	1993	Mann 1995 (NRA Anglian))
Steeping	Tasco's Bridge	TF508599	1993	Mann 1995 (NRA Anglian))
Nar	d/s Setchey	TF635135	1996	Brampton (EA)
Nar	Wormegay High Bridge	TF671135	1996	Brampton (EA)
Stringside stream	Barton Bendish	TF703039	1993	Brampton (EA)
Watton Brook	d/s Carbrooke	TF938020	1990	Brampton (EA)
Great Ouse	Radwell Bridge	TL005573	1989	Mann 1995 (Copp 1990a)
Great Ouse	Radwell Bridge	TL005573	1990	Mann 1995 (Copp 1990b)
Great Ouse	Bromham Hall	TL012510	1989	Mann 1995 (Copp 1990a)
Great Ouse	Hillgrounds Park: side channel	TL021476	1989	Mann 1995 (Copp 1990a)
Great Ouse	Kempston	TL023476	1992	Brampton (EA)
Great Ouse	Bedford: Barns Drain	TL072486	1989	Mann 1995 (Copp 1990a)
Great Ouse	Mill Farm: side channel	TL080480	1989	Mann 1995 (Copp 1990a)
Great Ouse	Great Barford mill stream	TL134517	1989	Mann 1995 (Copp 1990a)

Ivel		362	TL154526	1995	Brampton (EA)
Great Ouse	Little Paxton gravel pit		TL197628	1985	Richard Hall - English Nature
Great Ouse	Godmanchester (u/s Cookes backwater)		TL243710	1989	Mann 1995 (Copp 1990a)
Great Ouse	Dolphin Meadow		TL309714	1995	Brampton (EA)
Rhee	Wimpole		TL333485	1993	Brampton (EA)
Rhee	Malton Farm		TL374483	1993	Brampton (EA)
Old West		225	TL396744	1996	Brampton (EA)
Inner River/Ouse Washes			TL405773	1997	ECON survey
Old West		227	TL418728	1996	Brampton (EA)
Inner River/Ouse Washes			TL433807	1997	ECON survey
Outer River/Ouse Washes			TL433807	1997	ECON survey
Old West		228	TL435724	1996	Brampton (EA)
16 Foot Drain	Boots Bridge		TL446912	1983	Mann 1995 (NRA Anglian))
Inner River/Ouse Washes			TL447828	1997	ECON survey
Outer River/Ouse Washes			TL447828	1997	ECON survey
16 Foot Drain		724	TL447914	1994	Brampton (EA)
16 Foot Drain		726	TL464943	1994	Brampton (EA)
Inner River/Ouse Washes			TL465853	1997	ECON survey
Outer River/Ouse Washes			TL465853	1997	ECON survey
16 Foot Drain		727	TL474959	1994	Brampton (EA)
16 Foot Drain		728	TL485977	1994	Brampton (EA)
Inner River/Ouse Washes			TL493887	1997	ECON survey
Outer River/Ouse Washes			TL493887	1997	ECON survey
Granta	Babraham		TL496514	1993	Brampton (EA)
Granta	Babraham (I.A.P.)		TL507508	1993	Brampton (EA)
Counter Drain	Vandervells		TL512917	1993	Brampton (EA)
Bottisham Lode			TL517652	1997	Brampton (EA)
Outer River/Ouse Washes			TL525933	1997	ECON survey
Reach Lode			TL545697	1996	Reynolds, UEA pers com
Wicken Lode			TL565705	1996	Reynolds, UEA pers com
Soham Lode	Soham Cotes		TL576745	1990	Brampton (EA)
IDB drain near Little Port	Paddinal Fen - Fish resuce		TL576856	recent?	Brampton EA
Cut off Channel	u/s Hockwold Bridge		TL727875	1986	Brampton (EA)
Little Ouse	Hockwold Common		TL736873	1993	Brampton (EA)
Wissey	Bodney Meadows		TL831983	1993	Brampton (EA)
Stour			TL866413	94	Essex EA
Little Ouse	Nunnery Golf Course		TL873815	1996	Brampton (EA)
Little Ouse	Barnham Village		TL878800	1996	Brampton (EA)
Sapiston	Euston		TL889798	1995	Brampton (EA)
Sapiston	u/s Second Riffle		TL914753	1995	Brampton (EA)
Sapiston	d/s Third Riffle		TL914758	1995	Brampton (EA)
Sapiston	d/s Bardwell Mill		TL933742	1995	Brampton (EA)
Sapiston	Micklemere		TL937699	1995	Brampton (EA)
Little Ouse	Knettishall Heath		TL951809	1996	Brampton (EA)
Thet	Snetterton		TL994918	1995	Brampton (EA)
Stour			TM045334	1995	Essex EA