Ecology of the Bullhead

Cottus gobio

Conserving Natura 2000 Rivers

Ecology Series No. 4

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This document was produced with the support of the European Commission's LIFE Nature programme. It was published by **Life in UK Rivers**, a joint venture involving English Nature (EN), the Countryside Council for Wales (CCW), the Environment Agency (EA), the Scottish Environment Protection Agency (SEPA), Scottish Natural Heritage (SNH), and the Scotland and Northern Ireland Forum for Environmental Research (SNIFFER).

ISBN 185716 704 X

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This document should be cited as: Tomlinson ML & Perrow MR (2003). *Ecology of the Bullhead*. Conserving Natura 2000 Rivers Ecology Series No. 4. English Nature, Peterborough.

Technical Editor: Lynn Parr
Series Ecological Coordinator: Ann Skinner

Cover design: Coral Design Management, Peterborough.
Printed by Astron Document Services, Norwich, on Revive, 75% recycled post-consumer waste paper, Elemental Chlorine Free. 1M.

Cover: Adult bullhead. Photo by Sue Scott

Conserving Natura 2000 Rivers

This account of the ecology of the bullhead (*Cottus gobio*) has been produced as part of **Life in UK Rivers** – a project to develop methods for conserving the wildlife and habitats of rivers within the Natura 2000 network of protected European sites. The project's focus has been the conservation of rivers identified as Special Areas of Conservation (SACs) and of relevant habitats and species listed in annexes I and II of the European Union Directive on the Conservation of Natural Habitats and of Wild Fauna and Flora (92/43/EEC) (the Habitats Directive).

One of the main products is a set of reports collating the best available information on the ecological requirements of each species and habitat, while a complementary series contains advice on monitoring and assessment techniques. Each report has been compiled by ecologists who are studying these species and habitats in the UK, and has been subject to peer review, including scrutiny by a Technical Advisory Group established by the project partners. In the case of the monitoring techniques, further refinement has been accomplished by field-testing and by workshops involving experts and conservation practitioners.

Life in UK Rivers is very much a demonstration project, and although the reports have no official status in the implementation of the directive, they are intended as a helpful source of information for organisations trying to set 'conservation objectives' and to monitor for 'favourable conservation status' for these habitats and species. They can also be used to help assess plans and projects affecting Natura 2000 sites, as required by Article 6.3 of the directive.

As part of the project, conservation strategies have been produced for seven different SAC rivers in the UK. In these, you can see how the statutory conservation and environment agencies have developed objectives for the conservation of the habitats and species, and drawn up action plans with their local partners for achieving favourable conservation status.

Understanding the ecological requirements of river plants and animals is a prerequisite for setting conservation objectives, and for generating conservation strategies for SAC rivers under Article 6.1 of the Habitats Directive. Thus, the questions these ecology reports try to answer include:

- What water quality does the species need to survive and reproduce successfully?
- Are there other physical conditions, such as substrate or flow, that favour these species or cause them to decline?
- What is the extent of interdependence with other species for food or breeding success?

For each of the 13 riverine species and for the *Ranunculus* habitat, the project has also published tables setting out what can be considered as 'favourable condition' for attributes such as water quality and nutrient levels, flow conditions, river channel and riparian habitat, substrate, access for migratory fish, and level of disturbance. 'Favourable condition' is taken to be the status required of Annex I habitats and Annex II species on each Natura 2000 site to contribute adequately to 'favourable conservation status' across their natural range.

Titles in the Conserving Natura 2000 Rivers ecology and monitoring series are listed inside the back cover of this report, and copies of these, together with other project publications, are available on the project website: www.riverlife.org.uk.

Introduction

The bullhead, *Cottus gobio* L. (also known as Miller's Thumb or Tommy Logge), is the only freshwater cottid found in the UK. The Cottidae (sculpins) are mostly marine fish, with around 300 species worldwide. A small species, the bullhead rarely exceeds 15 cm in length and a weight of 28 g (Maitland & Campbell 1992). It is easily identified by its large head (which can account for 25% of body length), with eyes on the top and a dorso-ventrally flattened tapering body adapted to life on the bottom of flowing waters.

Martin Perrow

The bullhead is a small species, with a large head and eyes. It is well adapted to its benthic habits, with a flattened body and a mottled skin that camouflages it among weeds and stones.

A further adaptation to a benthic habit is the lack of a swim bladder, conferring negative buoyancy. The eyes are unusual in that they have a double cornea with a fluid-filled space in-between. This may help protect the eyes from damage from moving particles or as the fish seeks shelter under stones.

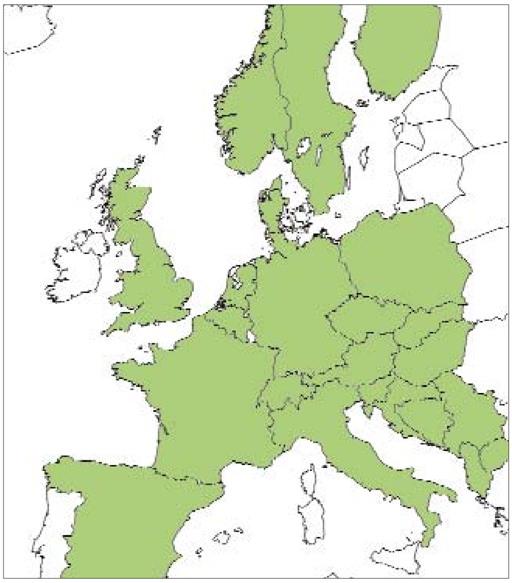
The bullhead also has a strong rear-pointing spine issuing from the operculum, extremely large pectoral fins, well-developed outward-curving pelvic fins that lie flush with the bottom as the fish rests, and two dorsal fins. The first dorsal fin has six to nine spines, while the second is longer, with 15 to 18 soft rays.

The mottled skin, which varies in shade according to background, offers good camouflage among stones and leaf litter. There are no scales on the skin, apart from 30–35 scale-like structures on the complete lateral line, which is slimy to the touch. The mouth has an extremely wide gape, and villiform teeth are present on both jaws, as well as on the front of the vomer bone.

Status and distribution

The bullhead is widely distributed throughout Europe. It occurs from Greenland and Scandinavia in the north to Italy in the south (Smyly 1957, Mills & Mann 1983). In the British Isles it is common in England and Wales, excluding northwest Wales. The bullhead is absent from Ireland and present in only a handful of catchments in Scotland (Maitland & Campbell 1992).

Bullhead probably colonised England and Wales from the southeast when Britain was connected to mainland Europe during the last Ice Age, 10,000 years ago (Wheeler 1977). Explanations for its current distribution include natural headwater capture and possibly human introduction. The latter is likely to be linked to the fact that bullheads were once eaten for their flavour (Maitland & Campbell 1992), and also to their use as live-bait for larger fish species.



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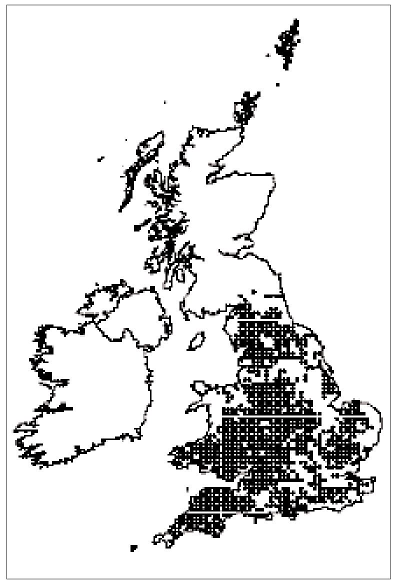
The bullhead is found throughout Europe, but not always in large numbers.



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Bullhead are widely distributed throughout England and Wales.

Bullheads predominantly occur in stony streams and rivers where the flow is moderate and the water is cool and oxygen-rich. These range from high-altitude streams to the chalk rivers of southern England (Smyly 1957), and the headwaters of many types of upland and lowland river between these two extremes. However, they may also be found in lakes (for example, Lake Windermere), where they not only occur in stony margins, but also in the profundal zone in depths of >20 m (Crisp & Mann 1991). Wanzenböck *et al*. (2000) also document the pelagic early life history of the bullhead in a deep Austrian lake, in accordance with the pattern displayed by related sculpin species in North America.

Life history

Reproduction

Unusually among freshwater fishes in the UK, bullheads exhibit parental care within a protected environment (a 'nest'). They are also unusual in that the semen biology is intermediate between the usual patterns for internal or external fertilisation. The structure, physiology and metabolism of the sperm are typical of an internal mechanism, but the mode of fertilisation is external. Slow currents within the nest may thus aid the sperm in reaching its target.

Bullheads spawn from February to June: typically once for females in upland streams, and up to four times in warmer, more productive lowland streams (Fox 1978a). Females adopt fractional reproduction in the latter, with successive batches of secondary oocytes developing into eggs, which the female then lays, perhaps with different partners. The fact that males are territorial and tied to their nest suggests females may exert considerable mate choice. Males are readily distinguished at spawning time by their dark colouration, a creamy dorsal edge to the first dorsal fin, and protruding genital papillae.

The male excavates a nest under a suitable large stone to attract a female. Part of this may be achieved by emission of acoustic 'knocking' sounds by the males (Ladich 1989), a further highly unusual feature of the species – although this may primarily have a territorial function. The female lays a batch of up to 400 eggs (2–2.5 mm in diameter), which adhere to the underside of the stone. Some males may attract more than one female (Smyly 1957, Pecl 1990). In situations without suitable stones, bullheads may use other media, perhaps amongst woody debris or tree roots.

The male then defends the brood against egg predators such as caddis larvae (Fox 1978a, see below) and manages the nest by fanning the eggs with his pectoral fins. In the absence of the water circulation

Derek Lippett/Environment Agency

Male bullheads assume breeding colouration when seeking a mate. After excavating a nest and attracting a female by making knocking sounds, a male bullhead will defend its nest and fan its eggs with its pectoral fins.

provided by the male, fungi rapidly invade the eggs. It is thought the male fasts at this time, although he may consume some eggs to survive, especially if stressed (T Hatton-Ellis, pers. comm.).

The eggs hatch after 20 to 30 days, depending on water temperature. The newly hatched larvae (6–7 mm in length) are supplied by a large yolk sac, which is absorbed after 10 days (Maitland & Campbell 1992). There is some debate as to whether the male continues to guard the larvae or not. In either case, the young absorb their yolk sac after which, as fry (9 mm in length), they are ready to disperse. Wanzenböck *et al.* (2000) suggest the occurrence of larval and juvenile bullheads in the drift in rivers could imply a planktonic dispersal phase in running water as well as deep stillwaters. This may allow young bullheads to readily colonise newly available habitat downstream of their birthplace, including temporary channels, winterbournes and floodplain lakes connected at times of flood.

Growth and longevity

As with the number of spawning attempts, the growth rate, age of sexual maturity and longevity of bullheads vary in response to their environment. Generally, bullheads attain a length of 40–50 mm after their first year, 60 mm after their second and 70–90 mm after their third (Maitland & Campbell, 1992). They do not generally live for more than three or four years, although fish of over 10 years old have been recorded.

Behaviour and activity

Bullheads are retiring fish, actively hiding from light under stones or any other available objects. This may be linked to their vulnerability to predation. For this reason, shade and cover are important components of their preferred habitat.

Adults are territorial, using sound as well as visual threat displays (spreading gill covers and darkening) to repel invaders. Calling is accompanied by nodding head movements during which the pectoral girdle and skull are rapidly moved against each other (Ladich 1989). While males and females both produce sounds, males do so far more frequently, with more calling at night. A dominant individual will also approach the calls from another to chase it away. Bullheads rarely resort to fighting, and larger individuals readily oust smaller ones from their shelters. Where not evicted by another, Pecl (1990) suggests that fish are faithful to a permanent shelter for many years. In laboratory experiments, Smyly (1957) showed that bullheads developed a fixation for their 'home' stone, selecting it above others even when it was moved, although for a short time the fish occasionally returned to its stone's original location.

This suggests bullheads may home effectively; a finding that was supported by a field experiment in which 87% of fish were found under the same stone six days after initial capture. Bullheads may thus be particularly sedentary. In the eight-month study of Downhower *et al*. (1990), bullheads in one population only moved between 4 and 10 m on average between captures. This was directly related to density, as at a lower density (<0.5 compared to 1 individual m^{-2}), fish moved between 12 and 48 m on average between captures. Both Smyly (1957) and Perrow *et al*. (1997) suggest intra-specific competition for space causes spatial segregation between individuals, including those of different age groups.

Food and feeding

Benthic invertebrates comprise the bulk of the diet. In experiments in aquaria, Welton *et al*. (1991) concluded that bullheads select for their preferred habitat rather than for particular prey. Diet therefore changes with the seasons and the availability of different food items. Generally, crustaceans (particularly *Gammarus* spp. and *Asellus* spp.) are taken in the winter months, and a wide range of insect larvae in the summer. Bullheads are visual predators with large eyes, and respond to movement, although their main feeding activity takes place at dusk (and presumably dawn) and perhaps also at night (Welton *et al*. 1991). The crepuscular feeding habit of the bullhead seems to be related to predator avoidance, although aquatic invertebrate activity also increases at dusk. It is plausible that the large eyes and special arrangement of the cornea enable bullheads to forage effectively in low light.

Sue Scott

The bullhead's large eyes and special corneal arrangement may help it to forage effectively in low light.

Predators and competitors

Being small, bullheads are vulnerable to a wide range of predators. Brown trout are the principal threat, and a medium-sized fish (75 g) can take a bullhead of up to 8 cm (Crisp 1963). However, bullhead and brown trout often co-exist (Crisp 1963, Prenda *et al*. 1997), and provided that suitable refuges are available, good densities of bullhead can be maintained (Perrow *et al*. 1997). Other species of fish, including pike (*Esox lucius*) eel (*Anguilla anguilla)*, chub (*Leuciscus cephalus*), and perch (*Perca fluviatilis)*, are also likely to take bullheads.

Bullheads fall prey to piscivorous birds, particularly the grey heron (*Ardea cinerea)*, kingfisher (*Alcedo atthis)*, as well as the dipper (*Cinclus cinclus)*. Ormerod & Tyler (1991) showed the latter may take a relatively high proportion of bullhead in Welsh streams.

The introduced North American signal crayfish (*Pacifastacus leniusculus)*, has been proven to have a detrimental effect on bullhead populations, unlike the native white-clawed crayfish (*Austropotamobius pallipes)*. Guan & Wiles (1997) showed that there is an inverse correlation between the number of signal crayfish and benthic fish species, including bullhead. Signal crayfish affect bullhead density through competition for shelter and food, in addition to predation of bullhead eggs and direct predation of adults by larger individuals.

GH Higginbotham/English Nature

Bullhead are vulnerable to predation by a range of species, including piscivorous birds such as the kingfisher.

Invertebrate predators may take a toll of bullhead eggs. Fox (1978b) identified the caddis larvae *Halesus digitatus* and *Potamophylax cingulatus* as the most prolific.

Genetics

A 'flock' of some 29 species of Cottids is recognised in Lake Baikal in East Siberia (Slobodyanyuk *et al*. 1995). This contrasts with the situation in Europe, with only three freshwater species: common bullhead (*Cottus gobio*); Alpine bullhead (*Cottus poecilopus)* and fourhorn sculpin (*Triglopsis quadricornis)* (Maitland 2000). Others have been described, including *C. ferrugineus* from Italy and *C. petiti* from a small part (3 km) of the Lez in the South of France. *C. petiti* is considered to be endangered, particularly as a result of competition with *C. gobio* (Billard 1997).

However, Maitland (2000) documents *C. petiti* as a subspecies of *C. gobio*, a view supported by a recent phylogeographic study (Englbrecht *et al*. 2000). This recognised six haplotypes of *C. gobio*, with *C. petiti* (and *C. ferrugineus*) in a single, complex wide-ranging group containing distinct populations from the Elbe, Main and Upper Danube. Other, different haplotypes were recognised from Polish rivers (Oder and Vistula amongst others), the Upper and Lower sections of the Rhine, the Seine in France and the Adour in the Pyrenees. Genetic structure reflects patterns of colonisation, and subsequent reproductive isolation.

British bullhead populations are most likely to have originated from the Rhine, or via other Atlantic-draining rivers. The diversity of types and relative speed of speciation within the group (Slobodyanyuk *et al*. 1995) leads to the intriguing possibility that British bullheads are genetically distinct from their counterparts on mainland Europe, and also display variation within the UK, originating from different founder lines. Subsequent isolation of populations both between and within catchments (above and below obstructions) is also likely to have contributed to inter-population variation.

Population parameters

There are differences in population density, sexual maturity and longevity in bullhead populations relative to both altitude and latitude. Below, bullhead population parameters have been separated according to lowland and upland situations.

Lowland streams

Productivity is high in hard-water lowland streams, and large densities of bullhead can therefore be supported. Following spawning, densities as high as 75.1 individuals m^{-2} have been recorded in the River Tarrant in Dorset (Mann 1971). Later in the growing season densities inevitably decline, but in the best habitats (such as chalk streams) may still be high. For example, the Bere Stream (a chalk stream in Dorset) when sampled in July had a density of 2.2 individuals m^{-2} (Prenda *et al.* 1997). There is little information available about soft-water lowland streams.

Bullheads grow rapidly, mature early (after one year) but are short-lived in lowland streams, with just three (occasionally four) age classes represented in the population (Mills & Mann 1983, Perrow *et al.* 1997). In order to maintain population size, recruitment needs to be annual and successful. Thus, Perrow and Côté (1999) suggested the proportion of young-of-the-year (YOY) fish should represent approximately 50% of the total density at the end of the growing season. However, this needs to be substantiated through further study.

Successful recruitment also intuitively relies on the presence of large adults: with large females

Niall Grieve

Unlike lowland streams, upland streams, such as this one in Wales, support lower densities of bullhead.

potentially making a high contribution to population fecundity and large males being more likely to attract females and defend their eggs. The presence of large adults >75 mm in fork length, which will generally be male, may therefore be a further indicator of a healthy population.

Upland streams

In contrast to lowland streams, upland (and northern) streams tend to support lower densities of bullhead. Densities in streams sampled in Cumbria ranged from 0.04 to 1.0 individuals m^{-2} (Mills & Mann 1983, Crisp *et al.* 1974). In more extreme alpine conditions in Switzerland, Utzinger *et al.* (1998) recorded densities between 0.002 and 0.41 individuals m^{-2}. However, other studies have shown densities of up to 4.6 m^{-2} from streams in the Yorkshire Dales, with populations towards the end of September typically above 1 m^{-2} and frequently above 2 m^{-2} (K Hendry, pers.comm.).

Growth rates are slower in upland streams, and fish reach maturity later (in some cases three years), but are longer lived. Populations should generally contain four to five age classes, although in some cases more will be present – a bullhead was aged at 10+ from Trout Beck in Cumbria (Mills & Mann 1983, Crisp *et al.* 1974).

As in lowland streams, Perrow and Côté (1999) tentatively suggest a healthy population is represented, in part, by approximately 50% of the population comprising YOY at the end of the growing season, and the presence of large individuals (>75 mm in fork length).

Habitat requirements

Bullheads require various habitats according to different life stages. Coarse substrates with large stones appear essential for breeding (Smyly 1957, Crisp 1963) although other breeding sites may also be used (see above). Shallow, stony riffles are utilised by YOY fish (Gubbels 1997; Prenda *et al.* 1997; Perrow *et al.* 1997; Punchard *et al.* 2000), whereas sheltered sections created by woody debris, tree roots, leaf litter, macrophyte cover or large stones, are preferred by adult fish, at least during daylight (Perrow *et al.* 1997). In times of high flows, all age classes are likely to require slack-water refuges (Perrow *et al.* 1997). Further details of different habitat parameters are supplied below.

Water quality

Little work has been undertaken on the specific aspects of water quality required by bullhead. Philippart (1979) found the lower tolerable pH limit to be 4.7. Although no studies have been conducted to determine the upper tolerable limit, this is known to reach about pH 7 in upland streams and 9 in lowland chalk streams in which bullheads occur. The upper tolerable limit is therefore likely to be >9.0. Brown trout, which typically occur sympatrically with bullhead, require a minimum dissolved oxygen concentration of 40% saturation, and it is likely that a similar level is required by bullheads.

However, it would appear that bullhead are more tolerant to pollution than previously thought. Utzinger *et al.* (1998) found bullheads present directly downstream of sewage treatment works, although in lower densities compared to upstream. Provided oxygen saturation remains high, bullhead can tolerate high concentrations of nitrogen compounds (Utzinger *et al.* 1998, Stahlberg-Meinhardt 1994). In this case dissolved organic carbon (DOC) was apparently the limiting factor: bullhead were not present in concentrations >3 mg l^{-1}. However, some other related variable rather than DOC may be the cause of this pattern.

Eutrophication (nutrient enrichment) is likely to be detrimental above a threshold value as this may favour filamentous algae, which can coat the favoured coarse, hard substrate (see below), and influence food-web dynamics (number and type of invertebrates and other fish species). There is no published information on the tolerance of bullheads towards other typical pollutants of fresh waters, including heavy metals or even ammonia.

The toxicity of many compounds and concentrations of dissolved oxygen are governed by temperature,

Niall Grieve

to which bullhead appear to be particularly sensitive. Elliot & Elliot (1995) found the critical thermal limits of bullhead to be –4.2 and 27.7°C.

Water quantity

Water depth is not critical (Utzinger *et al.* 1998), providing it is >5 cm and flow is adequate (Perrow *et al*. 1997). If flow is inadequate, high temperatures or low dissolved oxygen may be fatal in shallow water, because temperature fluctuations are greater. Typical values may be represented by Roussel & Bardonnet (1996) who found bullhead in depths of 20 to 40 cm in a French lowland stream. However, it should also be noted that bullheads are present in lakes, and Crisp & Mann (1991) found that bullheads were distributed in the deeper areas of Cow Green Reservoir (>20 m maximum depth).

Bullhead utilise a variety of habitats. Sheltered streams with tree roots and vegetation are preferred by adults (right), while YOY fish are found in shallow, stony riffles (below).

Martin Perrow

Bullheads are often found in water of moderate velocity (Smyly 1957; Crisp 1963; Gaudin & Caillere 1990). For example, Gubbels (1997), found most bullheads at flow velocities of 22 cm sec^{-1}, below the average flow rate of the brook (40 cm sec^{-1}). No specimens were found in places with flow rates of less than 10 cm sec^{-1} or more than 38 cm sec^{-1}. In contrast, Roussel and Bardonnet (1996) recorded individuals in flow >40 cm sec^{-1}, whereas A. Strevens (unpubl. data) suggested they preferred velocities >80 cm sec^{-1} and avoided those <60 cm sec^{-1}.

Velocities of this magnitude are not uncommon across riffles in many suitable streams (pers. obs.). However, riffles tend to be utilised by juvenile fish, which occupy the interstitial areas between stones and are thus not subjected directly to the force of the flow. Bullheads are not strong swimmers and are adapted to seeking refuge behind large stones, woody debris and macrophytes/leaf litter (Perrow *et al.* 1997). Therefore, where these are present, bullheads may tolerate considerable flow velocity.

Minimum acceptable flows are likely to exist for bullheads, as below a threshold value the deposition of fine sediment will occur over the preferred hard substrate (see below), oxygen concentrations will reduce and temperatures increase in more slow-flowing water. Any threshold is likely to vary according to stream type and sediment load. It is not possible to state what either these thresholds or the minimum acceptable flows for bullhead actually are.

The bullhead is likely to suffer under low-flow conditions and where this has been reversed, bullhead populations have recovered – for example on the River Misbourne (pers. obs., Environment Agency unpubl. data).

Substrate and macrophytes

Bullheads need a coarse, hard substrate of clean gravel and stones to complete their reproductive cycle (Smyly 1957; Crisp 1963; Mills & Mann 1983), and this is likely to be a critical factor in many situations. As well as spawning grounds, a coarse substrate with larger stones/cobbles provides refuges against flow and predators. While this function may be served by macrophytes and woody debris (Perrow *et al.* 1997, Punchard *et al.* 2000), in experiments conducted in aquaria, Welton *et al.* (1991) discovered that bullhead disregarded macrophytes as refuges if stones greater than 12 cm in diameter were present.

Thus, bullhead densities have been found to be greater in streams with a substrate of stones and gravel than on sandy and silty substrates, regardless of the presence of macrophytes (Smyly 1957, Mills & Mann 1983). Indeed, some forms of macrophyte may be avoided: Gaudin & Calliere (1990) showed that

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Bullheads will use macrophytes as refuges from predators and flows if large stones are unavailable.

bullhead avoided areas where the cover of emergent vegetation was >40%. Moreover, while bullheads may associate with depositional habitats such as pools containing woody debris that are dominated by a silty bed (Perrow *et al*. 1997, Punchard *et al*. 2000), this is only where gravel/stone substrate is not limiting in the river as a whole.

Channel structure

Perrow *et al*. (1997) concluded that a natural, sinuous channel form with associated riffle and pool structure provides the necessary substrates and flows for bullhead (see above), ultimately allowing greater densities of bullhead to be supported than in modified rivers. Naturally wooded riparian margins and shade have been identified as important features of the channel corridor for bullheads (Gaudin & Caillere 1990, Perrow *et al*. 1997). In addition, riparian trees provide valuable refuges from flow and predators, through encroachment of roots into the channel and the input of woody debris and leaf litter.

Potential threats

Utzinger *et al*. (1998) list the commonly accepted reasons for the decline of bullhead populations in Switzerland as the following:

- Chemical water pollution
- Habitat deterioration resulting from river engineering
- Failure to re-introduce bullheads after fish kills
- Prejudice against bullheads resulting from the perception that they may predate salmonids.

The principal threats to the species in the UK are listed below.

Deposition of fine sediments in disturbed catchments

Siltation is a major, but unquantified threat to bullhead populations. Silt deposition over hard, coarse substrate reduces the available habitat that is necessary to bullhead for reproduction and shelter (see above). Any work likely to affect flow dynamics (such as the installation of weirs), and activities that increase siltation (for example, development of intensive agriculture) should be avoided.

Fragmentation of populations

Utzinger *et al*. (1998) concluded that vertical structures of 18–20 cm in height were impassable to bullhead, and that populations upstream of such structures were vulnerable to population fragmentation, isolation and ultimately extinction. The introduction of any sort of vertical structure without the facility for free passage thus poses a threat to bullhead populations.

Channel management

Channelisation, involving any number of a suite of activities including straightening, widening, deepening, removal or modification of natural features and isolating the channel from its floodplain (including lateral connections), is likely to be of detriment to bullhead populations. All such actions change natural flow regimes and sediment dynamics.

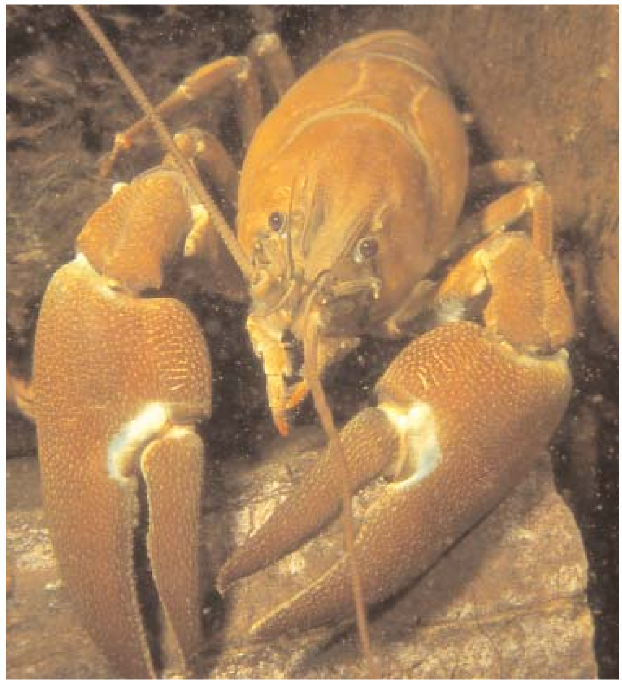
Removal of any hard substrate during dredging operations reduces the habitat available to bullhead. Excessive management of riparian trees and the clearance of woody debris/leaf litter from the channel during routine operations to maintain flood defence capacity is also likely to be detrimental to bullhead abundance. This may be a direct effect of loss of habitat or an indirect effect of exposure to predators such as brown trout. This is particularly an issue where gravel is scarce or not replenished, such as in chalk streams.

Fisheries management

Stocking of brown trout and other species such as rainbow trout (*Oncorhynchus mykiss*) is commonly undertaken in both upland and lowland streams, particularly lowland chalk streams. This practice could have a potentially detrimental effect on bullhead populations, if large numbers of particularly large fish (>75g) were continually introduced and/or habitat was limiting (see above).

Several species of large crayfish such as signal, narrow-clawed (Turkish) (*Astacus leptodactylus)*, and red swamp (*Procambarus clarkii)*, have been introduced to the UK. An indirect effect of this has been the introduction of 'crayfish plague' with disastrous consequences for native white-clawed crayfish (*Austropotamobius pallipes*).

Introduced signal crayfish have been proven to have a detrimental effect on bullhead populations through competition for shelter and food, and also by direct predation (Guan & Wiles 1997). The authors surmised that the further spread of signal crayfish could lead to localised extinctions of bullhead. The introduction of signal crayfish is now illegal except under licence, but escapes do occur and the practice should therefore be discouraged in catchments with important bullhead populations. Control measures should be undertaken where they do exist, with the aim of maintaining/reinstating populations of bullhead as well as native crayfish.



Sue Scott

The introduced North American signal crayfish has a detrimental effect on bullhead, through predation of eggs and adults, and competition for food and shelter.

Summary

A combination of male parental care and nest production, notable semen biology, the production of sounds, potential for mate choice, a high degree of territoriality, and a body profile and eyes adapted to a flowing-water environment, make the bullhead a unique and distinctive little fish.

The possibility also remains that bullheads in the UK are genetically distinct from those in continental Europe, with further genetic differentiation as populations have become fragmented and isolated over time.

The bullhead is a relatively adaptable species with a wide distribution in a range of flowing and still waters. However, its habitat preferences appear to be quite distinct. Natural gravel-bed streams with appropriate channel structure (e.g. riffle/pool sequence), wooded riparian zones or open chalk streams with abundant macrophytes offering shade and refuges from predators and flow, lacking obstructions and containing native, unmanipulated populations of fish and crayfish, represent ideal habitat. In such circumstances, the density of bullheads may be high and may even dominate fish production.

Conversely, where streams have been channelised, the natural flow and sediment regimes modified, or large numbers of other fish or non-native crayfish have been introduced, bullheads are likely to have been seriously adversely affected.

Bullheads may prove to be a valuable indicator of 'naturalness' in stream systems.

Despite this, the bullhead remains poorly studied and even basic aspects of the factors limiting populations remain unknown. This seriously limits the maintenance or attainment of favourable conservation status, both within SACs and across its wider range in the UK.

Research priorities

The following are considered to be key general areas of investigation:

- Factors limiting recruitment strength, with a focus on the availability of nest sites.
- Habitat associations and preferences when foraging at dusk and possibly at night.
- Impact of disturbance, especially in relation to siltation and fish stocking, upon population dynamics.
- Genetic variation of bullheads in the UK in relation to those in continental Europe.
- Verification of the potential indicators of favourable conservation status (population density/biomass, growth and age class structure, presence of key habitat variables).
- Determination of a minimum acceptable flow regime.

References

Billard R (1997). *Les poissons d'eau douce des riviéres de France*. Delachaux et Niestlé, Lausanne. 192 pp.

Crisp DT (1963). A preliminary survey of brown trout (*Salmo trutta* L) and bullheads (*Cottus gobio* L) in high-altitude becks. *Salmon and Trout Magazine* 167, 45–59.

Crisp DT & Mann RHK (1991). Effects of impoundment on populations of bullhead, *Cottus gobio* L., and minnow, *Phoxinus phoxinus* (L), in the basin of Cow Green Reservoir. *Journal of Fish Biology* 38, 731–740.

Crisp DT, Mann RHK & McCormack JC (1974). The populations of fish at Cow Green, Upper Teesdale, before impoundment. *Journal of Applied Ecology* 11, 969–996.

Downhower JF, Lejeune P, Gaudin P & Brown L (1990). Movements of the chabot (*Cottus gobio*) in a small stream. *Polskie Archiwum Hydrobiologii* 37, 119–126.

Elliot JM & Elliot JA (1995). The critical thermal limits for the bullhead, *Cottus gobio*, from three populations in north-west England. *Freshwater Biology* 33, 411–418.

Englbrecht CC, Freyhof J, Nolte A, Rassmann K, Schliewen U & Tautz D (2000). Phylogeography of the bullhead *Cottus gobio* (Pisces: Teleostei: Cottidae) suggests a pre-Pleistocene origin of the major central European populations. *Molecular Ecology* 9, 709–722.

Fox PJ (1978a). Preliminary observations on different reproductive strategies in the bullhead (*Cottus gobio* L.) in northern and southern England. *Journal of Fish Biology* 12, 5–11.

Fox PJ (1978b). Caddis larvae (Trichoptera) as predators of fish eggs. *Freshwater Biology* 8, 343–345.

Gaudin P & Caillere L (1990). Microdistribution of *Cottus gobio* L. and fry of *Salmo trutta* L. in a first order stream. *Polskie Archiwum Hydrobiologii* 37, 91–93.

Guan R-Z & Wiles PR (1997). Ecological impact of introduced crayfish on benthic fishes in a British lowland river. *Conservation Biology* 11, 641–647.

Gubbels REMB (1997). Preferred hiding places of the bullhead (*Cottus gobio* L., 1758) in the Zieversbeek brook. *Natuurhistorisch Maandblad* 86, 201–206.

Ladich F (1989). Sound production by the river bullhead, *Cottus gobio* L. (Cottidae, Telostei). *Journal of Fish Biology* 35, 531–538.

Maitland PS (2000). *Guide to Freshwater Fish of Britain and Europe*. Hamlyn, London. 256 pp.

Maitland PS & Campbell RN (1992). *Freshwater Fishes of the British Isles*. Harper Collins, London. 368 pp.

Mann RHK (1971). The populations, growth and production of fish in four small streams in Southern England. *Journal of Animal Ecology* 40, 155–190.

Mills CA & Mann RHK (1983). The bullhead *Cottus gobio*, a versatile and successful fish. *Annual Reports of the Freshwater Biological Association* 51, 76–88.

Ormerod SJ & Tyler SJ (1991). Exploitation of prey by a river bird, the dipper, *Cinclus cinclus* (L.), along acidic and circumneutral streams in upland Wales. *Freshwater Biology* 25, 105–116.

Pecl K (1990). *The illustrated guide to fishes of lakes and rivers* [translation from Czech by Krojzl C & Krojzl J]. Artia, Prague. 223 pp.

Perrow MR (2000). Ensuring a suitable flow regime for bullhead (*Cottus gobio*). Report to Environment Agency, North Area of North West Region, Penrith. 7 pp.

Perrow MR & Côté I (1999). *The development of ecological requirements to inform the production of conservation objectives for bullhead and spined loach*. Report for English Nature, Peterborough. 26 pp.

Perrow MR, Punchard NT & Jowitt AJD (1997). *The habitat requirements of bullhead (*Cottus gobio*), and brown trout (*Salmo trutta*) in the headwaters of selected Norfolk rivers: implications for conservation and fisheries*. Report to the Environment Agency, Eastern Area, Anglian Region, Ipswich. 61 pp.

Philippart JC (1979). A study of the fish populations in three oligotrophic trout streams in the upper Roer basin (Belgium). *Bulletin of the Royal Society of Liege* 48, 212–227.

Prenda J, Armitage PD & Grayston A (1997). Habitat use by the fish of two chalk streams. *Journal of Fish Biology* 51, 64–79.

Punchard NT, Perrow MR & Jowitt AJD (2000). Fish habitat associations, community structure, density and biomass in natural and channelized lowland streams in the catchment of the River Wensum, UK. In: Cowx IG (ed). *Management and Ecology of River Fisheries*. Blackwell Science, Oxford, 143–157.

Roussel JM & Bardonnet A (1996). Differences in habitat use by day and night for brown trout (*Salmo trutta*) and sculpin (*Cottus gobio*) in a natural brook: multivariate and multi-scale analyses. *Cybium* 20, 45–53.

Slobodyanyuk SJ, Kirilchick SV, Pavlova ME, Belikov SI & Novitsky AL (1995). The evolutionary relationships of two families of Cottoid fishes of Lake Baikal (East Siberia) as suggested by analysis of mitochondrial DNA. *Journal of Molecular Evolution* 40, 392–399.

Smyly WJP (1957). The life history of the bullhead or Miller's thumb (*Cottus gobio* L.). *Proceedings of the Zoological Society of London* 128, 431–453.

Utzinger J, Roth C & Peter A (1998). Effects of environmental parameters on the distribution of bullhead *Cottus gobio* with particular consideration of the effects of obstructions. *Journal of Applied Ecology* 35, 882–892.

Wanzenböck J, Lahnsteiner B & Maier K (2000). Pelagic early life phase of the bullhead in a freshwater lake. *Journal of Fish Biology* 56, 1553–1557.

Welton JA, Mills CA & Pygott JR (1991). The effect of interaction between stone loach *Noemacheilus barbatulus* (L.) and the bullhead *Cottus gobio* (L.) on prey and habitat selection. *Hydrobiologia* 220, 1–7.

Wheeler A (1977). The history and distribution of the freshwater fishes of the British Isles. *Journal of Biogeography* 4, 1–24.

Life in UK Rivers was established to develop methods for conserving the wildlife and habitats of rivers within the Natura 2000 network of protected European sites.

Set up by the UK statutory conservation bodies and the European Commission's LIFE Nature programme, the project has sought to identify the ecological requirements of key plants and animals supported by river Special Areas of Conservation.

In addition, monitoring techniques and conservation strategies have been developed as practical tools for assessing and maintaining these internationally important species and habitats.

The bullhead has several fascinating behavioural traits that make it a unique and distinctive little fish. These include nest production and parental care by the male, defence of territory, visual threat displays and the production of sounds.

It is a relatively adaptable species with a wide distribution throughout Europe, but its distinct habitat requirements mean that it is vulnerable where river channels have been modified or where there is a changed flow regime or increased siltation.

The bullhead is thus a good indicator of the naturalness of streams and is one of the species at the heart of a major European effort to conserve key freshwater animals and plants and the river habitats that sustain them.

This report describes the ecological requirements of the bullhead in a bid to assist the development of monitoring programmes and conservation strategies that are vital for its future.

Information on Conserving Natura 2000 Rivers and Life in UK Rivers can be found at **www.riverlife.org.uk**

This document was produced with the support of the European Commission's LIFE Nature programme and published by Life in UK Rivers – a joint venture involving English Nature, the Countryside Council for Wales, the Environment Agency, the Scottish Environment Protection Agency, Scottish Natural Heritage and the Scotland and Northern Ireland Forum for Environmental Research.