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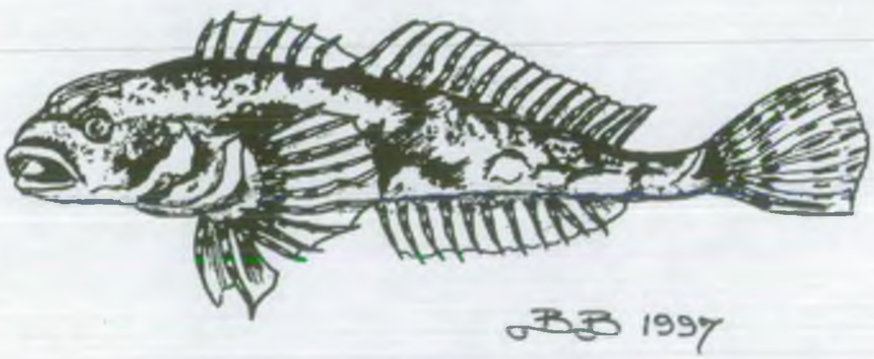
Habitat preferences of the bullhead (*Cottus gobio*) in some Norfolk rivers



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Executive summary

The bullhead (*Cottus gobio*) 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). In this study, the physical micro-habitat preferences, which were largely unknown, were determined in stretches of the Glaven and Stiffkey in North Norfolk and the Upper Wensum and it's tributary the Whitewater stream, in summer and autumn. Point-abundance sampling by electrofishing was the technique used.

Woody debris and associated leaf litter appeared to the optimal microhabitat for bullheads when they were likely to be least active during the day. Where the quantity of woody debris was apparently limiting, bullheads selected for the interstitial spaces between stones which usually occurred in shallow sites on any available riffles. The selection for this microhabitat by 0+ bullheads was thought to be linked to exclusion by larger individuals. In autumn, as the quantity of woody debris and leaf litter in the system increased, small bullheads had the opportunity to also select for this habitat type. It is suggested that the abundance of woody debris may play a significant role in determining the abundance as well as distribution of bullheads within rivers. This has considerable implications for current routine maintenance regimes which result in the removal of woody debris. The adoption of more sensitive regimes, where there is little risk of flooding, in which debris dams are retained is likely to be of considerable benefit to bullhead populations.

Overall, bullheads were considerably more abundant in natural rather than modified rivers, being abundant (0.62 m^{-2}) in the Whitewater and absent in the Stiffkey. The presence of: a well structured riparian zone of deciduous woodland to provide allochthonous input of woody debris and leaf litter; good channel form with natural sediment and flow regimes providing pool/riffle structure, ensuring bed gravels are exposed on riffles and woody material and silt is deposited in pools; appeared essential to promote good populations of bullheads. Although the role of stony substrate was unclear, it is suggested that it is an essential prerequisite to support bullheads. In general, bullhead was thought to be a good indicator of aquatic biodiversity.

A continuation of the current work, with sampling in late winter during peak river flows and early spring during the spawning season, thus completing the seasonal cycle of monitoring, is likely to enable a full habitat description to be determined. This is likely to prove to be a valuable component of river rehabilitation programmes.

Introduction

The bullhead (*Cottus gobio*) is the only freshwater species of the Cottidae in Britain. It is widely distributed in Europe, where its range extends from Greenland and Scandinavia to Italy (Smyly, 1957). Despite is wide toleration of climate and altitude, in Britain the fish is common only in England and Wales where its distribution is fairly local (Maitland, 1969) being rare in Scotland and absent from Ireland (Smyly, 1957).

The fish is benthic and occurs in the margins of a few lakes and particularly in the 'trout region' of rivers (Huet, 1959), where the flow is moderate and the water is cool, clear and oxygen rich. (Smyly, 1957). Bullhead may contribute a major component of the fish production in such habitats (Le Cren, 1969; Mann, 1971, *op cit.* Hyslop, 1982). Non-breeding fish, both males and females, are crepuscular, solitary and non-migratory. Over most of the geographical range of the species, breeding takes place during March and April (Smyly, 1957; Crisp, 1963).

The bullhead is now 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). Detailed habitat prescription is imperative in the designation of such areas as well as providing the necessary information to instigate sensitive management practice in rivers in which it occurs.

Although it is apparently relatively common in the British Isles (Maitland, 1969) the bullhead remains poorly studied. In particular, it's habitat preferences in the field, apart from its tendency to occur in upper reaches of rivers with a gravel substrate and under stones (Smyly, 1957; Welton *et al.*, 1983), are unknown. In aquaria, bullheads prefer a gravel substratum (Smyly, 1957; Welton *et al.*, 1983, 1991) and choose the maximum degree of shelter (Welton *et al.*, 1983) selecting crevices large enough for effective concealment, such as those under large stones. It is possible similar preferences occur in the field. The balance between costs and benefits experienced within the various microhabitats often differs for different age groups (Wooton, 1991) so it is probable that microhabitat separation of fish of different sizes will occur. Also Smyly (1957) observed bullheads tend to drive off smaller individuals. This suggests interactions between age classes may be an important factor in spatial separation. Thus small and large individuals may select differing habitats with larger fish occupying the optimal habitats. Since physical characteristics of rivers vary with season, habitat preferences may also vary accordingly.

Investment by the Environment Agency to rehabilitate river systems is now underway (ECON & Pond Action, 1993). This concentrates on restoring natural hydrological and sediment regimes as far as possible. Benefits to conservation and fisheries are likely to be considerable. The principal conservation strategy is to maintain and/or extend areas of high current value, perhaps population centres of desirable species. However, in order to achieve these goals and ensure the objectives of the project are met, detailed information of habitat requirements of the species of interest are essential. Thus, habitat prescriptions of species such as bullhead and brook lamprey (*Lampetra planeri*), which is also included under Annex II of the EC directive, should be incorporated directly into the planning of rehabilitation programmes.

In Norfolk, the bullhead is known to occur in the upper and middle reaches of most if not all of the major river systems (EA unpubl. data) including the North Norfolk rivers and the Upper Wensum and its tributaries which are recognised of particular fisheries and conservation importance. Along with bullhead and brook lamprey, otter (*Lutra lutra*) (also recognised under Annex II) and several nationally and regionally rare birds, plants, invertebrates are also present (Perrow *et al.* 1996 ab). However, it is clear that even the latter rivers have been considerably modified through a combination of channelization (straightening, widening, deepening), draining of floodplains and riparian zones and regulation of river flows. Many gross changes pre-date Fadens map of Norfolk in 1797, although there is also evidence of a continuing regime of channel modification and maintenance, which has a detrimental impact on current habitat quality. This is likely to have had a detrimental impact, and there is concern that the fisheries (particularly for brown trout *Salmo trutta*) of all rivers are in decline. It is plausible that bullhead has also been affected (Perrow *et al.* 1996a).

Aims

The aims of the present study were to produce a preliminary habitat prescription:

- To identify the key physical micro-habitat preferences of bullhead.
- To discover the effect of season on micro-habitat selection.
- To elucidate the effect of individual size on micro-habitat selection.

Additional benefits also included providing more up-to-date information about the status of bullhead in selected catchments and to elucidate to what extent river engineering and channel maintenance had affected bullhead populations.

Methods

Study sites

Two river systems were the focus of the investigation:

- The Upper Wensum and its tributaries.
- The North Norfolk rivers.

Both of these systems have recently been the target of rehabilitation proposals and both were known to support populations of bullhead (Perrow *et al.* 1996ab). Within a river system, two reaches, one relatively natural and one modified were surveyed. This was necessary to compare highly modified and relatively natural rivers in order to determine the extent to which river engineering had affected the distribution and abundance of bullhead. For the Upper Wensum surveying occurred on the modified section of Upper Wensum below South Raynham Bridge (Table 1, Fig. 1) and the largely natural Whitewater Stream at Whitwell Common where it retains excellent riffle/pool structure (Table 1, Fig. 2). For the North Norfolk system surveying occurred on the largely modified River Stiffkey at Little Walsingham which retains good channel form (Table 2, Fig. 3) and the relatively natural River Glaven around Holt Lowes (Table 2, Fig. 4). Information presented in Perrow *et al.* 1996 ab) formed the basis of the selection.

All of the reaches are known to have good water quality, adequate water quantity and to support reasonable populations of invertebrates (EA unpubl. chemical and invertebrate data). The sites selected were similar in depth (<50 cm) and width (2-4m).

Fish sampling

Sampling was undertaken in the summer (30th July - 2nd August) and autumn (5th - 8th November) periods. Each river was sampled over one day.

Point-abundance sampling (PAS) using electrofishing (Copp & Penaz, 1988) was used. Using a 40 cm anode, the effective sampling zone has been quantified at 1.5 m^{-2}) allowing quantitative estimates of abundance to be calculated. Through taking a large number of samples, PAS has the advantage of allowing sound statistical comparisons (Perrow *et al.* 1996c).

Table 1.

General and specific site details of the Upper Wensum & its tributaries

(after Perrow *et al.* 1996 a)

General details

The Wensum is recognised as being a nationally important river system, as notified by its SSSI status. It is an important fishery with a variety of coarse species; including barbel (*Barbus barbus*) and a good population of native brown trout. However, the Whitewater supports a greater biomass than the Upper Wensum (above Fakenham) itself. Brook lamprey seems to be common in the Upper Wensum, but is not recorded in the Whitewater. Bullhead appears to be ubiquitous, with good numbers recorded (EA unpubl. data).

Site details

Upper Wensum

Norman's Burrow wood to South Raynham Bridge (TF 891 239 to TF 884 241)

The reach sampled flows alongside mixed woodland, through reedbed and arable land. It is very straight and considerably widened to around 4m which results in extensive deposition of fine sediment along with organic matter. There is little instream structure, partly as macrophytes are unable to develop in the shaded channel. However, with some gaps in the canopy, there is littoral encroachment and the reed growth restricts the channel which increases flow diversity. Occasional fallen trees have resulted in natural debris dams and a few habitat features such as bars and pools have been created but these are scarce.

Whitewater Stream (Reepham Stream)

Whitwell common (TG082203)

The reach that flows through Whitwell common Nature Reserve is surrounded by deciduous mixed woodland with some grazing meadows present. Initially it is rather shallow and around 2m wide but becomes sinuous with considerable structural heterogeneity. Fallen trees, particularly alder, and debris dams have constricted the channel to around 1.5m, creating further meanders resulting in high flow diversity and variability in depths and substratum. Therefore excellent riffle/pool structure exists along with undercuts and submerged tree roots.

Table 2.

General and specific site details of the North Norfolk Rivers

(after Perrow *et al.* 1996 b)

General details

The Glaven is of high conservation value supporting populations of bullhead, brook lamprey and otter. Fisheries value is moderately high with reasonable populations of brown trout . The Stiffkey appears to support good populations of brook lamprey throughout its length. The trout biomass is moderate although it appears to have declined considerably in the last decade. Eel (*Anguilla anguilla*) is now the dominant species and occurs in such numbers as to result in a high overall fish biomass. The Stiffkey has been modified to a greater extent throughout its length and the occurrence of natural habitat features is often limited. The Glaven is impounded by four mills along its length, resulting in extensive silt deposition. However, the river generally recovers reasonably natural form downstream of these structures.

Site details

River Stiffkey
Above North Barsham (TF 915 348)
The reach above North Barsham has been artificially widened and is generally around 4m wide. This has exacerbated sediment deposition within the channel. The channel itself exhibits good form in some reaches with considerable sinuosity. In others, the channel is virtually straight with no riffle pool structure and few natural habitats such as debris dams. The riparian zone is structurally poor in all reaches as a result of intensive grazing. It is also evident that the current maintenance regime is harsh, since overhanging trees have recently been cleared with only the stumps remaining.

River Glaven
Around Holt Lowes/Holt Country Park (TG 092 375)
The reach sampled flows through conifer plantation and deciduous mixed woodland, where the shading limits macrophyte growth and prevents littoral encroachment. The banks are relatively steep and the substratum within the channel is particularly stony. The channel is around 2m wide and in places relatively straight. Where clearings in the canopy occur there is encroachment of the littoral zone. Considerable debris accumulation provides additional features and results in good riffle pool structure.

Fig. 1. Typical view of the Upper Wensum

Fig. 2. Typical view of the Whitewater stream

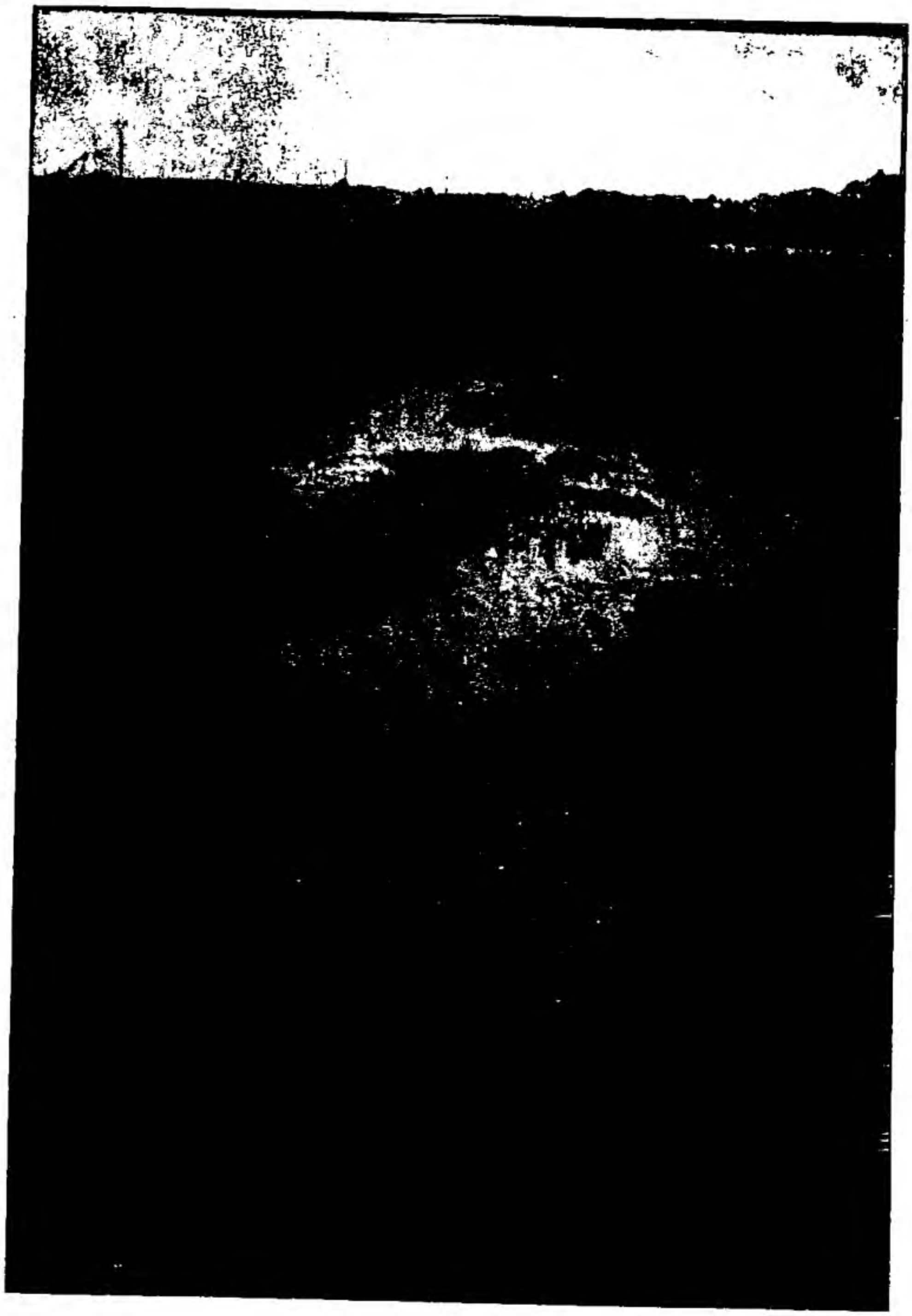


Fig. 3. Typical view of the River Stiffkey

The basic strategy was to sample fish and numerous habitat variables at 100 points within each river. Twenty points were taken in each of five 100 m sections covering the full range of habitats within each river. The points were systematically selected (5m apart) with the electrofishing operator moving diagonally from bank to bank. To ensure the littoral zone was sampled in proportion to its abundance, the area of the zone was determined as a function of total river width. For example, in a stretch 4 m wide, every third point would be a littoral sample.

Electrofishing was conducted by wading, using EA standard safety procedures. High frequency (at 600 Hz) pulsed DC (Electracatch WFC 11-12) gear was used, powered by a generator of 1.9 KVa. An anode fitted with a 100 m extension cable was then used to undertake the actual fishing.

At each point sampled, any fish captured were processed by the electrofishing operator (Dr M. Perrow). These were identified, measured to the nearest mm fork length and a representative sample of specimens of each species was weighed to the nearest gram, before being returned unharmed to the water. At each point, whilst any fish were being processed, a second person (N. Punchard) visually assessed and quantified the following physical habitat variables within the sampling area:

- % cover of three broad categories of substratum- stones, gravel or silt.
- % cover of woody debris and % cover of leaf litter.
- % cover of submerged tree roots.
- % cover of any boulders or logs.
- % cover of macrophytes.
- Flow velocity (m sec^{-1}) using a stopwatch, metre rule and an orange.
- Water depth (cm) with a metre rule.

At each reach the general characteristics of the catchment and channel especially features of the riparian zone were also noted since Milner *et al.* (1985) state that in habitat evaluation, both site and catchment features must be considered since both are important. All of the information was recorded by a third person (M. Peacock, Dr I. Côté)

In order to obtain access to all sites, landowners were contacted by telephone. Contacts were established using information held by the Fisheries team at Environment Agency offices. Permission to electrofish was obtained by completing relevant forms from the Environment Agency.

Data analysis

In order to compare the availability of different habitat variables between rivers Kruskal-Wallis tests on the SPSS statistical software package were conducted.

For the population within a river, where sufficient information was available, length frequency histograms (drawn along with the other figures on Microsoft Excel) were used to separate the 0+ age class from the rest of the bullhead population sampled in order to determine if differences in habitat selection between different size classes occurred. The reasoning behind using 0+ as a separate category is that Smyly (1957) found that some bullheads mature and breed in their first year of life (although many mature at around two years old), therefore it is only 0+ that can really be classed as a separate category since all other age classes will probably contain mature individuals. The bullheads were not sexed since sex determination in the field is almost impossible except in the breeding season (Smyly, 1957).

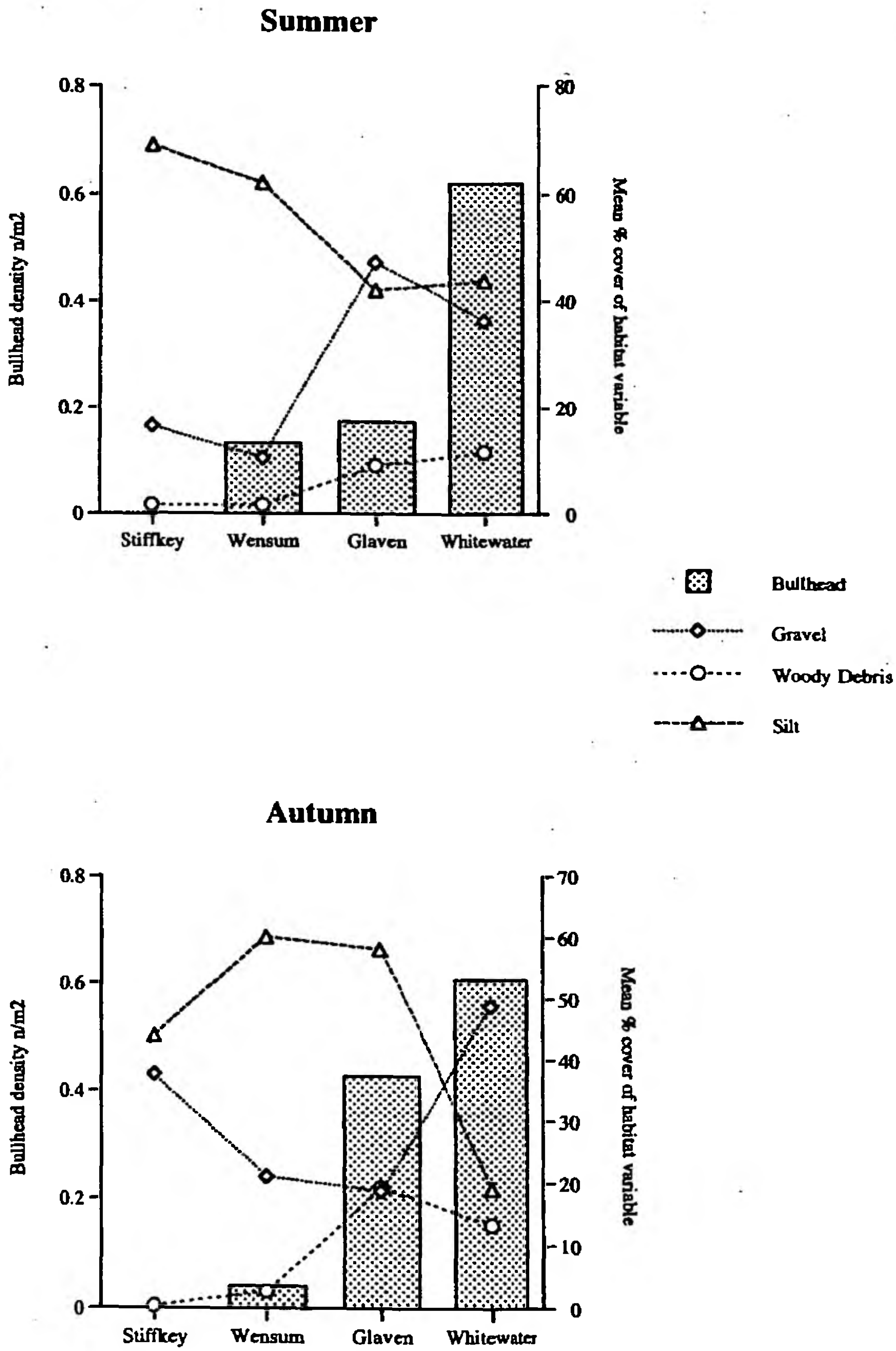
Where possible, for both 0+ and ≥ 1+ bullheads within each river, Mann-Whitney/Wilcoxon U- tests (on SPSS) were used in order to determine whether the percentage of each physical variable differed significantly at points where bullheads were present and absent within the individual reaches. Although macrophytes were recorded at generic level, the occurrence of different groups was sporadic and so these were pooled into a general cover category for the purposes of analysis. As the occurrence of logs and boulders was very rare no statistical analysis was undertaken on either variable. Regressions of mean % cover and number of bullhead were also performed, again on SPSS.

Results

Comparisons of bullhead density and habitat between rivers

The number of bullheads captured varied radically between rivers in both summer and autumn ($KW = 62.1$, $n=4$, $p<0.001$ and $KW= 112.9$, $n=4$, $p<0.001$ respectively). None were caught on either occasion in the Stiffkey, only a low density (0.13 and 0.04 m^{-2}) in the Upper Wensum, a moderate density in the Glaven (0.17 and 0.43 m^{-2}) and a large density in the Whitewater (0.62 and 0.61 m^{-2}) (Fig. 5). This is in general agreement with the amount of woody debris ($KW = 72.0$, $n=4$, $p<0.001$ and $KW= 110.7$, $n=4$, $p<0.001$ summer and autumn respectively) and leaf litter ($KW = 42.0$, $n=4$, $p<0.001$ and $KW= 93.0$, $n=4$, $p<0.001$ summer and autumn respectively) present in each of the rivers (Fig. 5). Although other major habitat variables such as

Figure 5. Relationships between Bullhead density (n/m2) and selected environmental variables.



the proportion of gravel (KW = 52.7, n=4, $p<0.001$ and KW= 38.6, n=4, $p<0.001$ summer and autumn respectively) and thus inversely the proportion of silt (KW = 31.9, n=4, $p<0.001$ and KW= 58.2, n=4, $p<0.001$ summer and autumn respectively) are also significantly different, this does appear to be directly linked to the number of bullheads present. For example, in summer, the Wensum (10%) and the Stiffkey (16.5%) have lower values of stones, with the Glaven the highest (47%), but in autumn, the Stiffkey has the highest proportion of stone (66%) and the Glaven one of the higher values for silt (58%), only the Upper Wensum being higher (60%).

Differences in age structure between rivers

There are considerable differences in the population structure between sites. The large population of the Whitewater stream showed distinct size classes (Fig. 6). Recruitment of 0+ appeared to be very strong. In contrast, in the Glaven, which contained the other significant population, recruitment of 0+, manifested as two small fish in autumn appeared to be poor (Fig. 7). Here what appear to be the 1+ in summer must have grown poorly to only reach this size. This conclusion is substantiated by the fact that little growth had occurred by the time the fish were sampled again in November. In the Upper Wensum., the small population was dominated by smaller individuals, potentially 0+ with only odd larger individuals (Fig. 8).

Habitat preferences within rivers

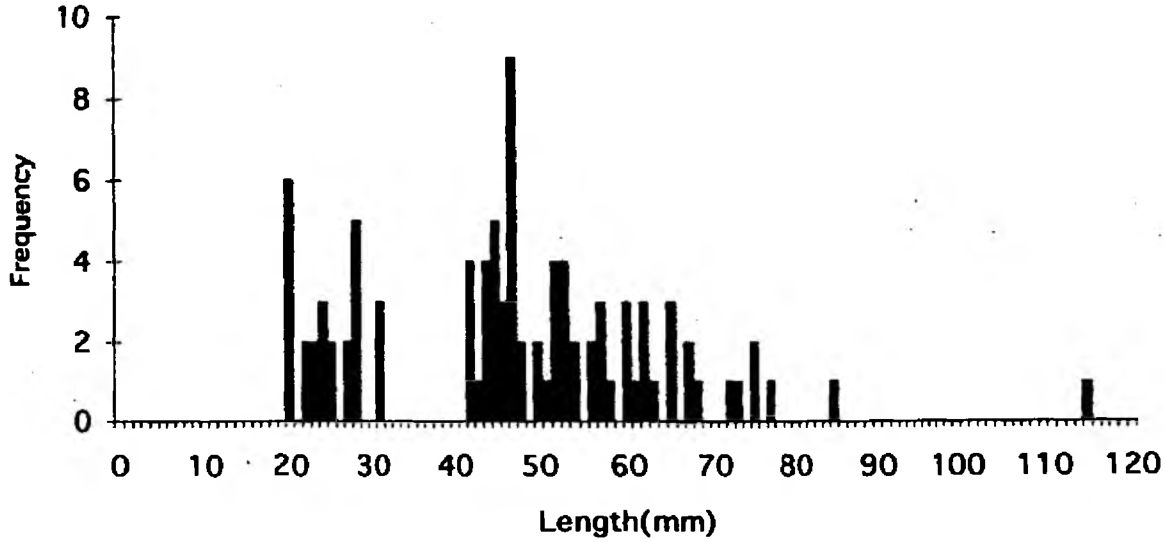
The habitat preferences varied between rivers. For example, in the Upper Wensum points where bullhead were present had a significantly higher percentage of stone than points where they were absent in both summer (Z= 2.19, N=93, $p<0.05$) and autumn (Z= 1.96, N=100, $p<0.05$).

In contrast, in the Glaven in summer, bullheads were significantly negatively associated with gravel (Z= 2.6, N=93, $p<0.01$) and positively associated with several habitat variables including; depth (Z= 2.3, N=100, $p<0.05$), leaf litter (Z= 4.1, N=100, $p<0.001$), woody debris (Z= 2.19, N=93, $p=0.028$) and silt (Z= 2.8, N=100, $p<0.01$). In autumn, bullheads were only positively associated with woody debris (Z= 4.8, N=100, $p<0.001$).

In the Whitewater, it was clear that small and large fish selected for different habitat types. In summer, 0+ fish were significantly positively associated with stones (Z= 3.0, N=100, $p<0.01$) (Fig. 9) and consequently avoided silt (Z= 2.4, N=100, $p<0.05$). Larger fish were positively associated with depth (Z= 2.9, N=93, $p<0.01$), leaf litter (Z= 2.19, N=100, $p=0.028$), silt (Z= 2.3, N=93, $p<0.05$) and woody debris

Figure 6. Length frequency histograms for bullhead on the River Whitewater on the two sampling occasions.

Summer



Autumn

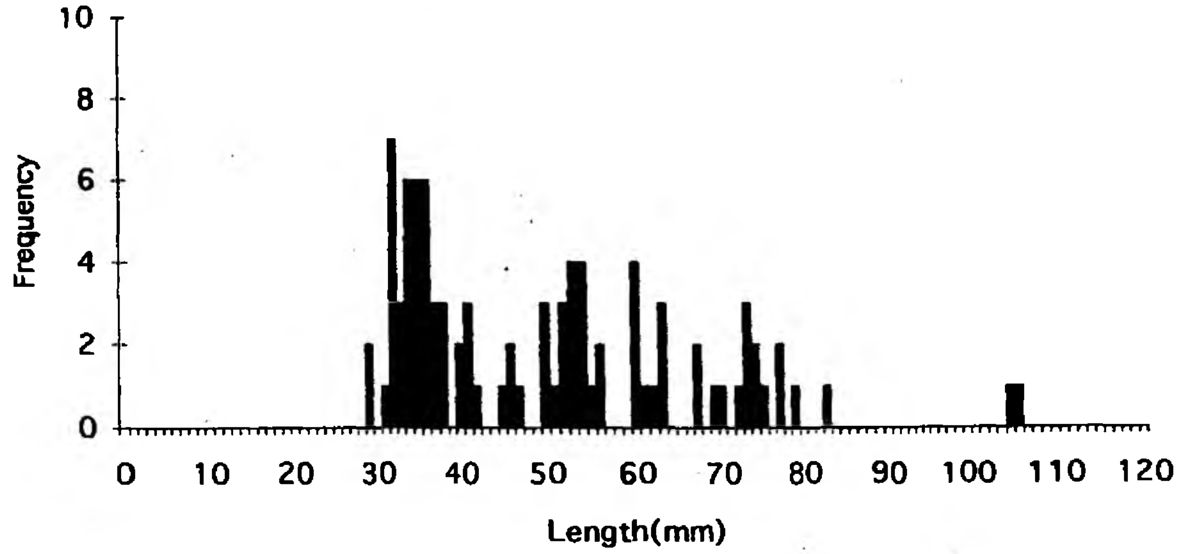


Figure 7. Length frequency histograms for bullhead on the River Glaven on the two sampling occasions.

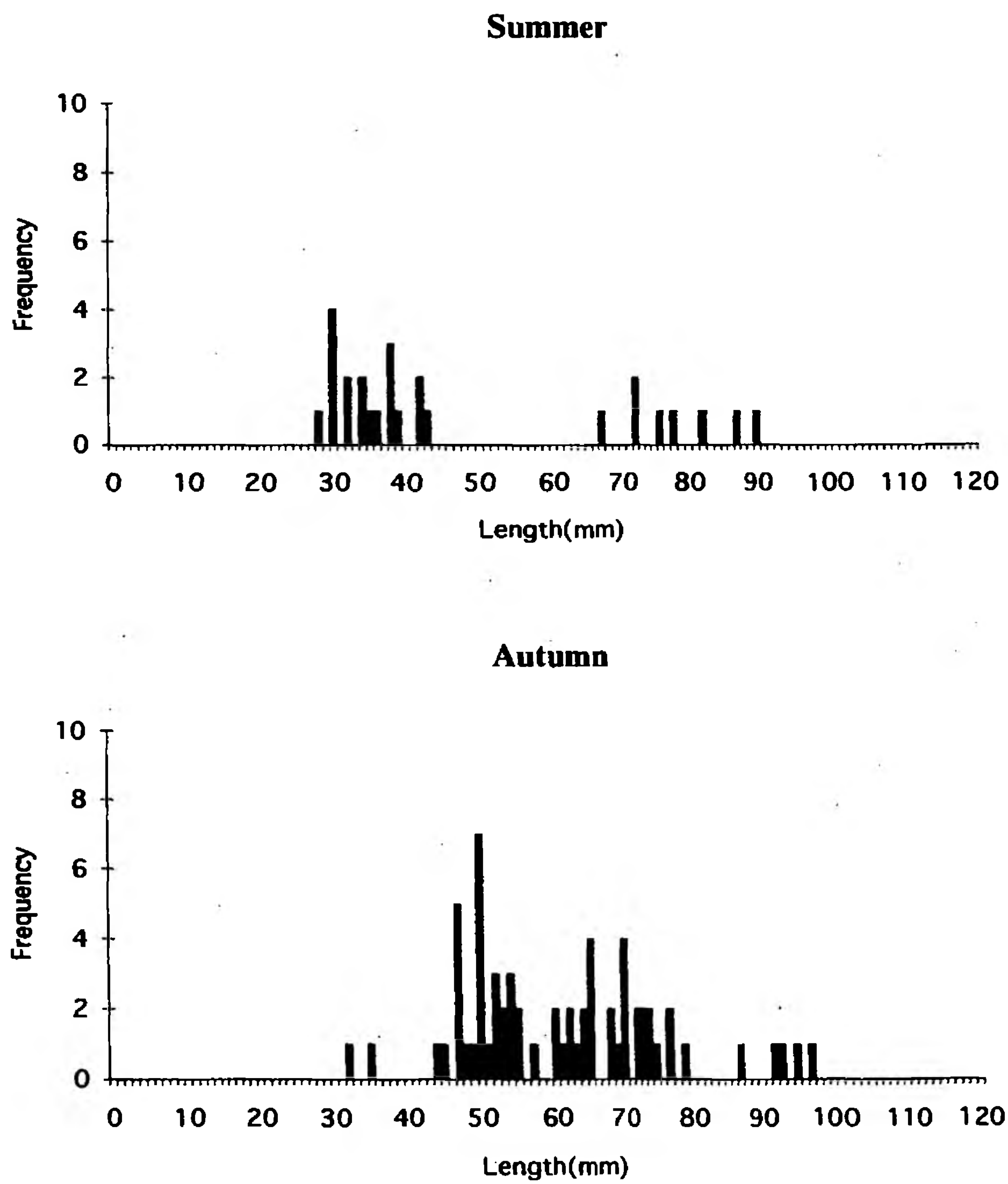


Figure 8. Length frequency histograms for bullhead on the Upper Wensum on the two sampling occasions.

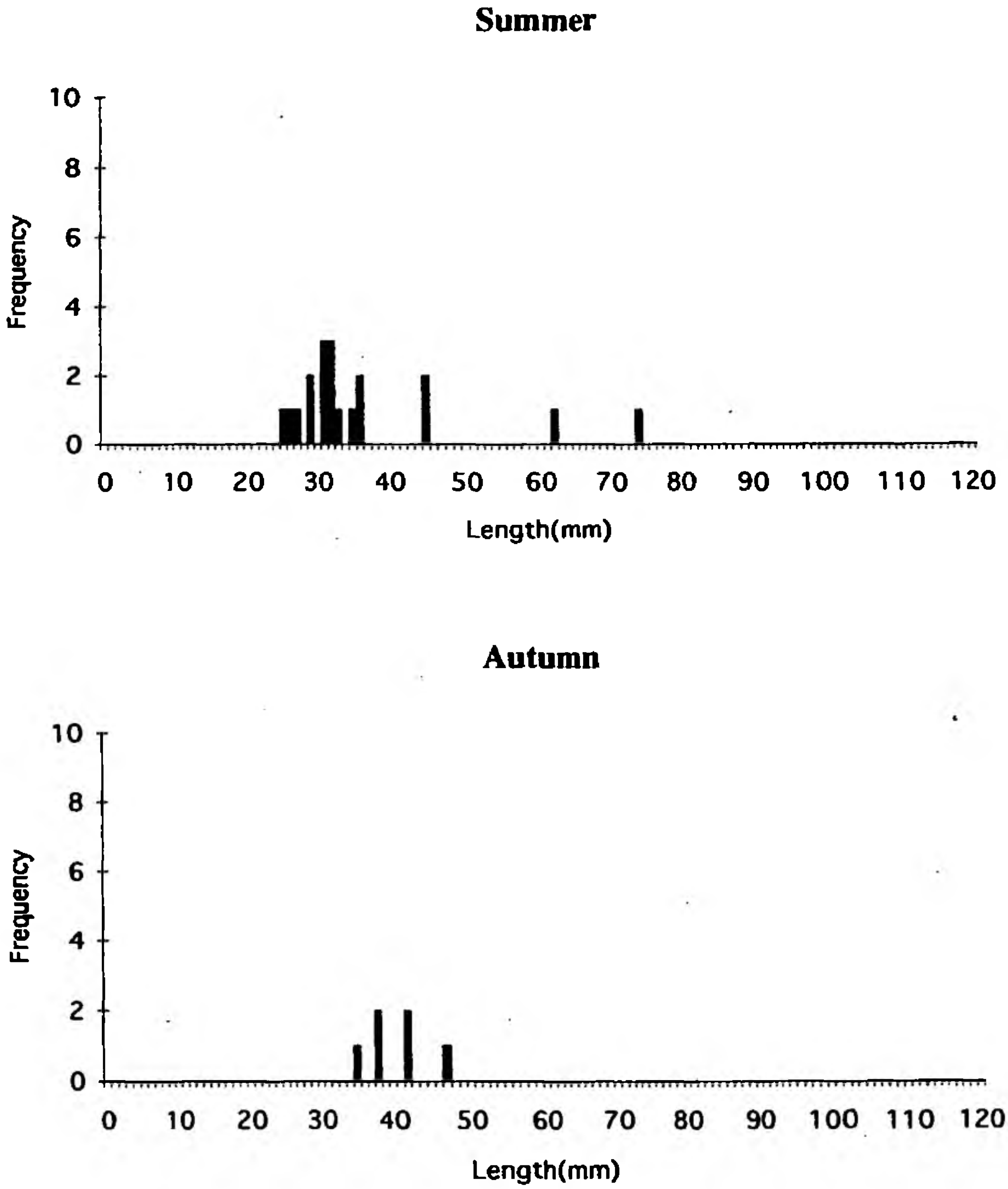


Figure 9. Frequency proportions of % stone and % woody debris for 0+ and 1+ bullheads at points where present and absent in the Whitewater Stream in summer.

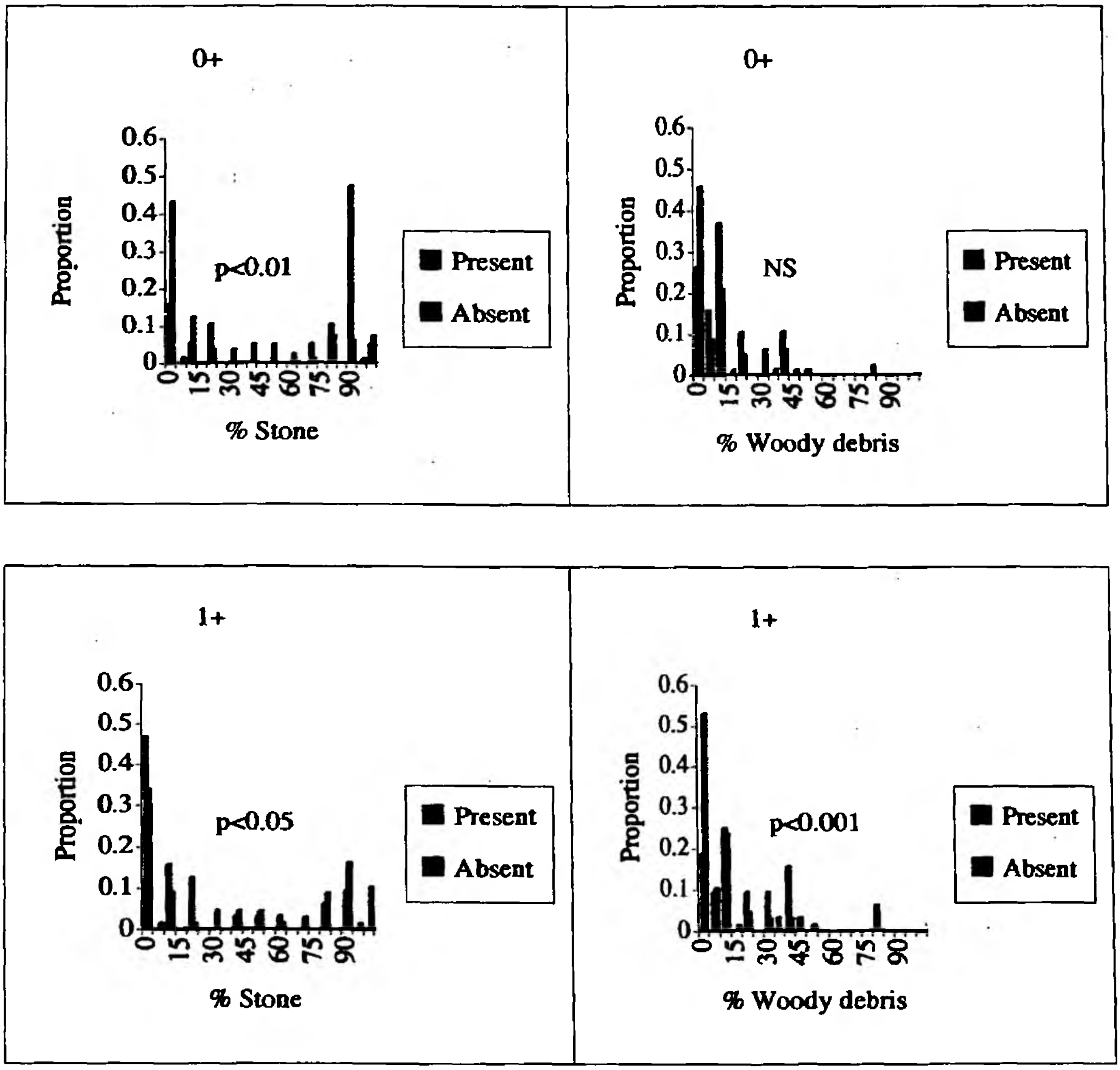
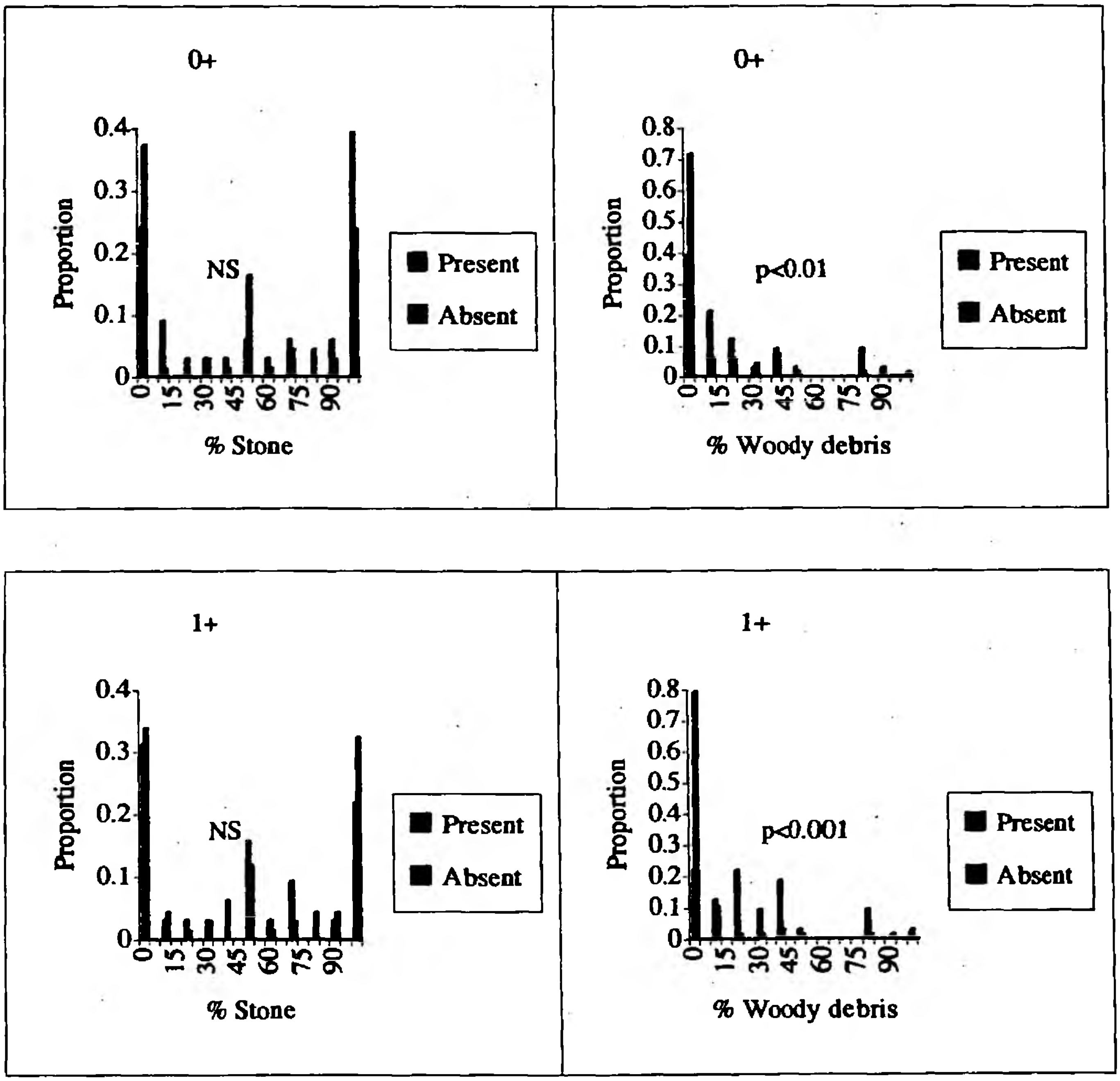


Figure 10. Frequency proportions of % stone and % woody debris for 0+ and 1+ bullheads at points where present and absent in the Whitewater stream in autumn.



(Z= 5.6, N=100, p<0.001) (Fig. 9). By autumn, the 0+ fish had changed preference and selected for woody debris (Z= 2.9, N=93, p<0.01) (Fig. 10) and leaf litter (Z= 2.0, N=93, p<0.05). Larger fish continued in the same vein as in summer, selecting for greater depth (Z= 2.9, N=93, p<0.01), more leaf litter (Z= 2.0, N=100, p<0.05), silt (Z= 2.3, N=100, p<0.05) and tree roots (Z= 3.3, N=93, p=0.001) as well as woody debris (Z= 4.0, N=100, p<0.001) (Fig. 10).

Discussion

Factors influencing the abundance and distribution of bullheads

It is clear that natural rivers with appropriate flow and sediment regime and habitat features support considerably higher bullhead populations than modified rivers. For example, the Whitewater Stream is the most natural of all the rivers sampled. The reaches sampled had a well structured deciduous mixed woodland riparian zone, and were generally quite sinuous with tight meanders supplying an excellent riffle pool structure. It has the largest bullhead population. In contrast, the upper Wensum is the most modified, having been straightened and widened and containing little instream structure, and a high silt loading that covers stones. Few bullheads were present in the sample stretches found. There is further evidence that even relatively natural streams such as the Glaven although they may support bullhead populations, the recruitment of 0+, which is critical to maintain populations of this short-lived species may be poor or sporadic. It is therefore suggested that bullhead may be a useful indicator species (Noss, 1990), not only of deterioration from channel modification, but also improvement with river rehabilitation and more sensitive maintenance techniques (see Kirchhofer 1995).

The habitat preferences exhibited by bullheads in the study sites generally agree with the general feeling that bullheads are associated with stony substrates (Smyly, 1957). Certainly, sites with a low proportion of stones and conversely a high proportion of silty sediments, also indicative of low flow, such as the Upper Wensum and Stiffkey have few or no bullheads. It is also apparent that good channel form, as on the Stiffkey and the potential for higher flows exposing gravels in autumn is insufficient to compensate for the general lack of habitat quality. Where stony habitat is present but limited, bullheads appear to be restricted to this habitat feature. For example, selection for stones occurred in the Upper Wensum in both summer and autumn. Further, since the majority of stones occur on riffles, this probably explains the selection of significantly shallower sites by bullheads in the autumn.

In good quality streams with a selection of habitats and where stony substrate is not limiting bullhead may select for other habitat features that provide the maximum degree of shelter, selecting crevices large enough for effective concealment (Welton *et al.* 1983). Woody debris and its associated leaf litter appears to be particularly attractive. In a natural stream, such material gets washed into deeper sites or pools if present, and so explains why bullheads also selected for deeper sites and accounts for the significant increase in silt where bullheads were present, since silt is deposited in pools where the flow rate is reduced. These pools will obviously contain little stone, explaining why there was significantly less stone where bullheads occurred on the Glaven in the summer.

On the Whitewater Stream where it was possible to consider different size categories, the large individuals in the summer showed the same preferences exhibited on the Glaven in summer i.e. deep silty sites, with relatively little stone, but relatively high quantities of woody debris and leaf litter. Due to the tight meanders and high flow diversity in this reach, undercuts are present and tree roots extend into the stream. The higher percentage of tree roots where bullhead occurred in the autumn was probably because roots are highly ramified, providing additional crevices and act as debris traps that retain leaf litter and woody debris (Smith *et al.*, 1996).

In contrast to the micro-habitat selection of the large individuals, the small individuals selected for the stony, low silt, shallow micro-habitats in the summer. However, they did select for woody debris and leaf litter in the autumn. It is unclear if shallow stony habitats were preferred, offering particular food resources most suitable for small fish or were in fact, sub-optimal and small fish were restricted to them through some form of intraspecific interaction with older individuals, excluding them from optimal woody debris micro-habitats. The large increase in woody debris and leaf litter in the system in autumn, due to the annual allocthonous input may have meant that the resource was no longer limiting, therefore smaller individuals could occupy these micro-habitats.

Towards a full habitat prescription for bullhead

As hinted above, food resources may play an important role in the distribution of fish. The diet of bullhead is comprised exclusively of benthic invertebrates, with both insects and crustaceans, particularly *Asellus aquaticus*, *Gammarus pulex* and chironomid larvae (Smyly, 1957; Crisp, 1963; Welton *et al.* 1983). The choice experiments of Welton *et al.* (1983) in aquaria reveal that bullhead prefer Chironomids which are normally more abundant on silt substrate, but prefer to hunt over gravel. Aquarium observations also revealed that fish normally fed in, or close to the entrance hole of their stone and seldom hunted for food, except in darkness (Smyly, 1957). Bullheads have large eyes and are largely visual feeders, even though the peak of activity is around sunset (Andreasson 1969, Fox 1978 *op cit.* Welton *et al.* 1983). After locating its prey sight the fish stalks it, prior to rushing forward and engulfing it. Since bullheads are crepuscular, it seems that food, if of any importance in determining habitat selection, will have much more significance during the evening or at night and be of little consequence in explaining the distribution of fish during the day. Moreover, food resources are unlikely to account for the different micro-habitat selected by small and large fish since Smyly (1957) found that the nature of the food varies more with season and place than with the size of the fish. Future studies could examine the habitat preferences at night. Sampling invertebrates from the range of different micro-habitats and linking this with stomach content analysis is recommended.

Competition for food resources may have some role in determining the distribution of fish. The focus of interspecific interactions has been with stone loach (*Barbatula barbatulus*). Both are benthic and appear to be exploiting broadly similar food resources (Hyslop, 1982). Welton *et al.* (1991) conducted laboratory experiments to determine whether food preference is a direct result of the preferred habitat and whether habitat partitioning is determined by interactions between bullhead and stone loach. They confirmed that food consumed was dependent on the habitat and not prey preference. After studying the interaction between bullhead and stone loach on prey and habitat selection in the laboratory it was concluded that these two species utilise different components of the available food resources in chalk streams by adopting different habitats and to a lesser extent differing food preferences. Therefore, although competition does not seem to be an ecological factor determining micro-habitat selection of the bullhead although it has probably been very important on an evolutionary scale, shaping its micro-habitat requirements. It would be of value to determine if high densities or biomasses of other potentially benthivorous species have a detrimental impact on bullhead. This is particularly relevant in relation to stocking of other coarse fish species or small trout for angling purposes. Rivers such as the Glaven, with impounded sections caused by mills also have larger populations of coarse fish than would be predicted and it would be of interest if this has any impact on the abundance and particularly recruitment strength of bullhead populations.

Further subtle differences in the abundance and distribution of bullheads may also be caused by predation risk, particularly from trout. Larger trout, >75g, may eat bullheads up to 8 cm (Crisp 1963). The availability of refuges such as woody debris or stones may have an important influence on the distribution of bullhead. It is perhaps no coincidence that colour and pattern of the bullhead i.e. brown and mottled is likely to provide good camouflage amongst woody debris. Further studies determining the impact of large trout on the abundance and recruitment success of bullheads would be of value. This has particular relevance in the stocking of large trout into many parts of the Glaven for example, for angling purposes.

At this stage, there is insufficient information to determine if competition or predation determines population size and habitat size of bullhead in the study rivers. However, if further sampling was to be conducted in late winter and late spring, completing the seasonal cycle, enough information may be gained to begin to tease out some of the impacts. This would also be of benefit in determining the impact of peak flows, which also links with river channel management and maintenance, on bullhead populations.

Sampling in late spring when bullhead are spawning will determine habitat selection at this critical time. Bullheads lay eggs in masses attached to the undersides of large stones (Crisp, 1963). It is the males that guards and cares for the eggs (Fox, 1978) and is evidence that in some rivers only a single brood is produced but in more productive systems, several broods may be raised in a protracted breeding season (Fox, 1978). As the sexes may be easily differentiated by the presence of nuptial colours (dark head and by a whitish yellow edge along the anterior portion of the dorsal fin) in the males and by the females having distended abdomens (Smyly, 1957), it will be possible to determine the spawning habitat preferences of the species. In the rivers sampled there were few boulders/large stones (although bullhead were usually also present under these) and it seems likely that bullheads will select for the underside of any object providing cover such as logs and woody debris, as a nest, especially in the absence of boulders. The abundance of suitable spawning habitat may effectively determine recruitment success and the ultimate health of the population. This may be confirmed by introducing spawning habitat and monitoring the effects on the population.

It is strongly recommended that further sampling is conducted in late winter and late spring to complete the seasonal cycle of monitoring and assessment of habitat preferences of bullhead. This will go a long way towards determining a full habitat prescription for the species that may be incorporated into river rehabilitation programmes and into management regimes.

Implications of current management regimes

It must be emphasised that the findings presented here are preliminary and would benefit from further sampling (see above). However, it is clear that the strong habitat preferences do impinge on current routine management conducted by the Environment

In particular the routine removal minor obstructions and debris dams particularly in upstream wooded sections, where there is no apparent risk of flooding is likely to have a detrimental effect on bullhead populations. It also reduces local flow diversity with obvious detriment to potential habitat particularly for invertebrates and fish.

Two general recommendations may be made:

- The removal of invaluable instream habitat of woody debris and leaf litter, for what appears to be negligible improvement in drainage efficiency should be avoided, particularly where this is a significant distance from sensitive land or property. Adoption of a more sensitive maintenance programme may allow the recovery enhancement of many sections of the Norfolk rivers, with considerable conservation benefit.

- Training operatives in current understanding of ecology and river processes, and current conservation techniques may aid this process and is recommended.

Implications for rehabilitation and designation of protected areas

Modification usually occurs in an attempt to drain land and make it suitable for agriculture. Channelization has several major impacts. First there is a direct effect on the quantity and quality of river habitats. More specifically, with straightening and the loss of riffle pool structure, flow diversity is decreased. Widening may lead to decreased water depth and velocity and deposition of fine sediment (loss of stones). Deepening may have the effect of removing contact with floodplain and riparian habitats, particularly the resources associated with riparian vegetation. Indiscriminate tree and scrub clearance along rivers has naturally had a damaging effect on all forms of wildlife (Purseglove, 1989). Trees were virtually absent in the riparian zone on the Stiffkey which is likely to be the cause of the extremely low quantities of woody debris. Additionally, Mason *et al.* (1984) estimate that fish are provided with four times as large a food source from insects falling into a river from tree lined banks as from bare banks.

The effects of channelization may be exacerbated with an intense regime of maintenance, cutting of littoral vegetation, riparian trees and instream macrophytes and instream dredging. Swales (1982) found that coarse fish populations fall drastically following dredging and recovery is slow.

Increased drainage efficiency from an agricultural catchment is also likely to lead to significant loading of fine sediment. Such sediment is deposited where flow velocity drops, typically in widened sections, which are commonplace on all rivers. As a result areas of extensive sediment deposition are likely to limit gravel areas which appear to be important for bullhead feeding (Welton *et al.*, 1991). This is also likely to severely limit the amount of habitat available for trout, particularly for spawning and reduce stony regions which the present study shows appear to be an important nursery ground for bullhead and also an important habitat when woody debris is limiting.

The abundance and diversity of invertebrates, macrophytes as well as fish, particularly salmonids (Milner *et al.* 1985), is known to be directly related to physical habitat diversity. Therefore the current generally low overall ecological value of many of the Norfolk rivers is likely to be the result of previous channel modification. Furthermore, the recent declines in some rivers may be due to a continuing regime of relatively intense maintenance and there is evidence that the fisheries of all rivers are in decline, particularly with respect to trout populations (EA unpubl. data). There are no data available on the past status of bullhead in the headwaters for comparison, but future monitoring may elucidate further.

Overall, since water quality of the rivers appears good (Perrow *et al.* 1996ab) and water quantity is adequate physical habitat improvement-perhaps in conjunction with hydrological changes to improve contacts between channel and floodplain-is likely to lead to a significant benefit to bullhead populations and also increase both fisheries and conservation value. The basis of rehabilitation is to reinstate natural structure and function. This is considered to be the best option in meeting the principal objective of improving the fisheries and conservation value of the rivers concerned.

Although physical variables such as gradient, altitude and temperature are primary factors determining species richness and community composition of the fish fauna in rivers. The results of Kirchhofer (1995) show that the structurization of the ecotone can be considered as a secondary factor, especially important for the presence of specialised species. Kirchhofer (1995) found the proportion of threatened species was higher if riverbed and -banks were natural, the slope was flat, the variability in depths and sediment composition was high and if the ecotonal zone was well structured.

Highly structured riparian zones and river beds are most important for the conservation of specialist species, requiring particular structures such as woody-debris and overhanging vegetation as hiding places as in the riffle minnow. River management has to take into account the ecological requirements of specialised species (Kirchhofer, 1995). Bullhead appears to be a good indicator of the general health of the system and care is taken to preserve and enhance populations, there are likely to be a number of additional benefits to conservation and fisheries value

The following are preliminary suggestions of the important habitat attributes that are required if bullhead populations are to be preserved:

- Natural channel form i.e. sinuous, high excellent riffle pool structure, high flow variability, high substratum diversity with large areas of stone and gravel beds, undercuts and extension of tree roots into the channel.
- A high natural instream debris content resulting from a highly structured riparian zone

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