ENVIRONMENT AGENCY

AN INVESTIGATION INTO THE SPAWNING AND RECRUITMENT SUCCESS OF BARBEL IN THE RIVER WENSUM 2009

SCIENTIFIC REPORT

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CONTENTS

1 INTRODUCTION

1.1 Background

The River Wensum barbel population is a result of past stocking and natural recruitment; however, there are concerns that although the population may be sustainable, this is not to a level that can sustain a fishery to maintain angling interest.

"Habitat preferences of larval and juvenile barbel *Barbus barbus* have only seldom been investigated, although the presence of sufficient suitable habitats for the young stages constitutes one of the most important factors influencing reproductive success in riverine fishes" (Frehof, 1994).

With respect to the above quotation, only occasional young of the year (YOY) and 1 year old (1+) specimens have been recorded in previous surveys conducted by the EA between 2005 and 2006 (Environment Agency, 2007a). The results currently available therefore lack critical data in assessing temporal and spatial spawning success and the habitat requirements of larvae and juveniles during their most vulnerable life history stages (i.e. eggs, larvae and young juveniles).

Adult fish surveys conducted by the Environment Agency on the River Wensum (Environment Agency, 2007) have however recorded barbel belonging to a broad range of year classes. Assuming that these fish were naturally produced and have not originated from previous stockings, analysis of existing datasets suggest that some level of recruitment has been achieved in most years between 1990 and 2006, with 2002 and 2003 identified as particularly successful years. Although surveys conducted by APEM in 2008 failed to detect the eggs or larvae of barbel, the presence of a small number of 1+ barbel captured during the present study confirm that some recruitment was also achieved in 2008. Due to the age and mobility of these fish, their presence at any one site does not however provide any indication of where successful spawning has taken place, or indeed the range and types of habitat required to satisfy the dynamic stages that coarse fish undergo during early development.

The ability of fish to maintain stable self sustainable populations is extremely complex but can be simplified to always being dependent on a sequence of 7 key factors. These are essentially thresholds which must be achieved in order to progress to the next step in the sequence, and each of these stages can be investigated in the field.

1. Appropriate quantity and quality of spawning stock
2. The availability of appropriate quality spawning habitats and the ability of fish shoals to negotiate barriers such as weirs to access these sites.
3. The successful deposition, incubation and hatching of eggs.
4. The availability of appropriate nursery habitats within close proximity to spawning sites.
5. The availability of appropriate food items to satisfy each stage of early development.
6. Adequate summer growth to build up sufficient lipid reserves to over-winter.
7. The availability of winter refuge habitats and shelter from high flows.

Over the last two years, APEM have investigated a number of these key steps, with a view to both identifying and understanding the specific factors limiting the sustainability of the barbel population within the River Wensum. During the summer of 2009, two surveys were strategically designed to investigate spawning success during June and the abundance and habitat utilisation of juveniles in late July.

1.2 2008 survey

Prior to the initial survey, several key sites on the Wensum were identified, where suspected spawning activity of barbel had previously been reported, either in previous years and/or during the spring of 2008. Following an assessment of available habitat at Taverham during May (APEM, 2008), sampling for eggs and larvae was successfully conducted in July, with a further survey conducted between 21st and 23rd October, designed specifically to detect 0+ barbel recruits within targeted optimal habitat types, such as marginal bays. During 2008, neither the 0+ targeted surveys conducted by APEM nor the EA surveys detected any young of the year barbel. Despite a lack of barbel, healthy recruitment levels were reported for a number of other species, such as chub, bream, roach, dace and gudgeon (APEM, 2009).

Based on the results presented in the 2008 report, it was recommended that future surveys should apply particular focus to the successful deposition, incubation and hatching of barbel eggs and the distribution and habitat utilisation of young barbel during the larval to early juvenile stages of development.

2 2009 EGG SURVEY

2.1 Introduction

Although the 2008 survey focussed on a selection of sites where spawning behaviour was observed during the preceding spring, subsequent surveys failed to find any evidence that eggs were actually laid and fertilised at these localities in 2008. On this basis, the priority of the 2009 study was to apply further attention to Step 3 of the recruitment sequence 'The successful deposition, incubation and hatching of eggs'. Indeed, should fertile eggs be found, this would also qualify points 1 and 2 of the recruitment sequence and provide further guidance as to the subsequent dispersal and distribution of barbel larvae and juveniles which would be targeted in surveys later in the year.

2.2 Methods

2.2.1 Site selection

Consistent with the 2008 surveys, five sites were investigated at Lenwade Bridge, Bernard Matthews, Costessey Mill, Taverham Mill and Hellesdon on the 2nd and 3rd of June 2009. Despite reports of barbel spawning activity at Lyng, this site was not

surveyed during June, due to the sampling restrictions imposed by Norfolk Anglers Conservation Association at this site.

2.2.2 Sampling eggs and larvae

Successful spawning was ascertained via careful extraction of eggs from the downstream end of disturbed gravels (redds). This involved placing a fine meshed invertebrate net immediately downstream of suspected spawning areas while gently agitating the gravels with a metal spike to a depth of 20cm (Figure 1). Where eggs were found to be present, microscopic examination was used to confirm species identification, assess fertilisation success rates and to qualify points 1 and 2 of the recruitment sequence. Drift netting immediately downstream of spawning chub and minnows was also used to assist in defining the relationship between species and egg size range.

The incubation period of barbel eggs is reported as approximately 5.4 days at 16^{o}C (Penaz, 1973) and 3 days to 3 days 18 hours at 20.52 ^{o}C (Krupka, 1988). Based on Krupka's (1988) observations, larvae are not likely to emerge from gravels for at least another seven days, as this was observed to correspond with the transition to mixed feeding and burst swimming activity. These data provide useful guidance as to the duration that barbel eggs and larvae are likely to remain immobile following reports of observed spawning activity. On this basis, several areas where spawning activity had been reported during the two weeks preceding the survey were prioritised for investigation by the field team.

Figure 1. Sampling of eggs and free embryos at suitable spawning sites. The method involves the sensitive mechanical disturbance of the gravel and collection of the drifting eggs in a net positioned immediately downstream.

2.3 Results

Using the above methodology, eggs were found at each of the sites surveyed, although with the exception of Bernard Matthews stretch, all were identified as either minnow or chub. Indeed, minnows sporting full spawning colouration were captured at all sites and a large shoal of chub was observed spawning below the road bridge at Bernard Matthews. The eggs deposited by these fish were collected immediately downstream of spawning congregations to confirm the parentage of these particular size ranges of eggs. Within any one patch of gravel it was not uncommon to find a mixture of both chub and minnow eggs and microscopic examination of these eggs indicated very high fertilisation rates for both species (>95%) (Figure 2). The eggs of minnow and chub were found at various stages of development, ranging from freshly deposited eggs in the early stages of cell division (cleavage phase), to free embryos emerging from the eggs.

Figure 2. Identification, measurement, assessment of fertilisation success and embryonic development of eggs were all assessed in the field.

On 3rd June at noon, a total of five adult barbel ranging between 45 and 70 cm were observed participating in courtship behaviour at Bernard Matthews stretch (Figure 3). This congregation appeared to be composed of two females and three males, with two distinct pairings and a sneaking male which was consistently being driven away by the more dominant males.

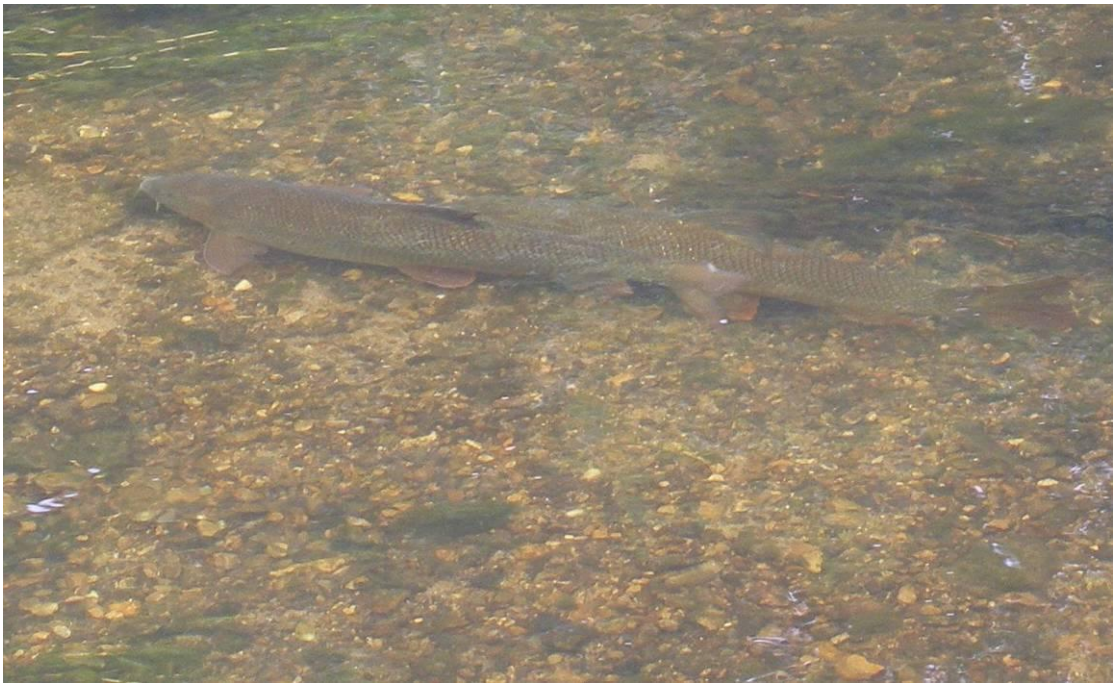

Figure 3. A pair of courting barbel. Image also depicts the substrate from which fertilised eggs were subsequently collected.

While this behaviour did not appear to be particularly intense, focussing of sampling effort in areas where the gravel had been excavated revealed a small number of large eggs (Figure 4) from three separate locations. These eggs were subsequently hatched at APEM's Dorset laboratory (Figure 5) to confirm that they were the products of the adult barbel observed. Prior to transporting these eggs, microscopic examination concluded that only 16 of the 32 eggs collected (50%) had been successfully fertilised and were in the initial stages of cell division (cleavage phase).

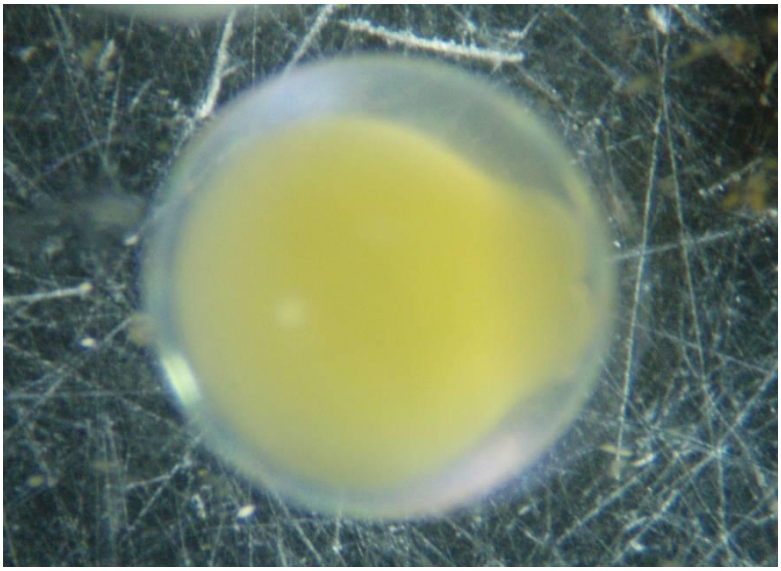

Figure 4. Barbel egg with orange yolk in the early cleavage phase of development (mean diameter = 2.59mm)

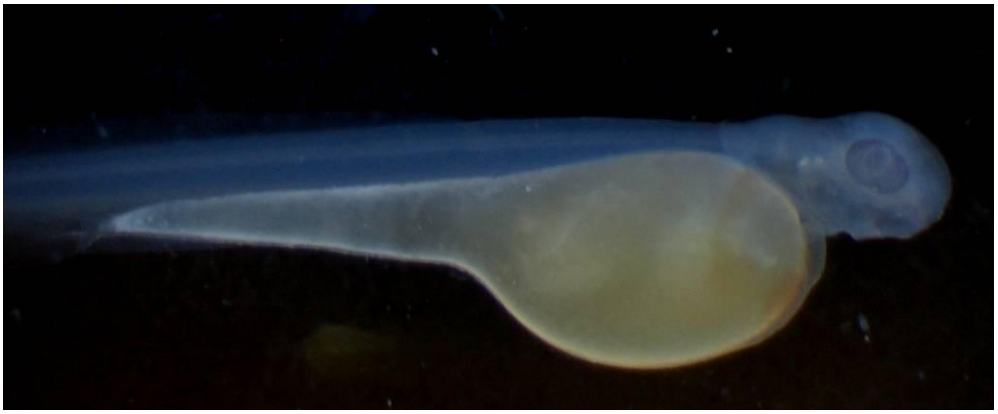

Figure 5. Barbel larva (three days post hatching) successfully hatched at APEM's Dorset Laboratory (total length = 9mm).

2.3.1 Comparison of egg sizes

While the eggs of chub and minnow appeared similar in colour, the range of egg sizes of each species were distinct with no overlap in size between the two species. Barbel eggs were found to be significantly larger than those of chub (P=<0.01), although size ranges between the two species demonstrated considerable overlap. While the largest chub eggs were recorded at 2.36 mm and the smallest barbel eggs 2.06mm, qualitative characteristics such as the bright orange yolks of the barbel eggs proved to be reliable in distinguishing the two species. Figure 6 presents a comparison of egg sizes from a sample of measured egg diameters.

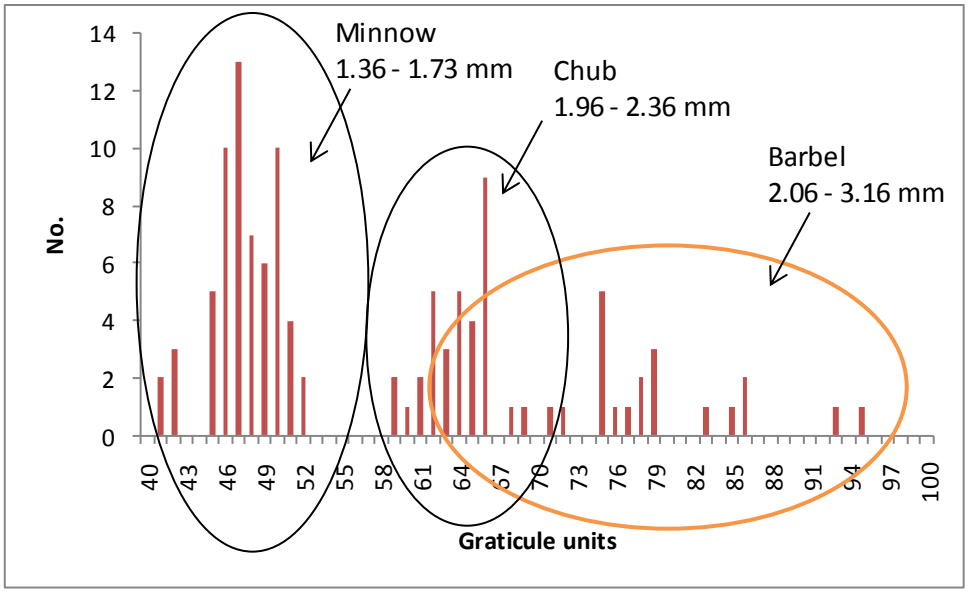

Figure 6. Comparison of egg sizes deposited by minnow, chub and barbel. 30 graticule units on the x axis are equivalent to 1mm.

2.3.2 Habitat characterisation

Barbel eggs were found at three locations within a single riffle approximately 100 metres upstream of the road bridge at Bernard Matthews. The habitat characteristics at all three sampling points were homogenous and are summarised in Table 1.

Table 1. Summary of habitat characteristics at the sites where barbel eggs were collected

Feature	**Units**
Grid reference	TG 10634 10691
Width	8 metres
Depth	40 cm
Mean column velocity	0.5 m/sec
Flow type	Glide (100%)
Substrate	Gravel (90%); Sand & silt (10%)

Although not presented in this report, habitat characteristics were recorded at each of the 17 sites investigated for eggs. These data demonstrate very little variation from those reported in Table 1. This would suggest that the habitats where barbel were observed spawning are not unique, with potential spawning areas available at each of the sites surveyed.

3 2009 JUVENILE SURVEY

3.1 Introduction

Following emergence from redds, larval barbel disperse from the spawning gravels and subsequently drift into more suitable habitats to seek shelter from predation and enhanced feeding and growth opportunities. Past surveys conducted by APEM staff have found marginal bays and areas of shallow slack water to be the preferred habitat of juveniles. Indeed, Bischoff & Freyhof (1999) observed the exclusive use of bays and low velocity marginal habitats until all fin structures were complete and the ontogenetic threshold between the larval and juvenile phase of development had been reached. Accordingly the 2009 juvenile survey was designed to target optimal habitats using a combination of seine netting and electric fishing techniques. While the 2008 survey reported the detailed species composition of the 0+ fish community, the approach of the 2009 survey was to concentrate sampling effort on the presence/absence of barbel. Hence the reporting of other species in the present report is limited to reporting the species present at each of the sites surveyed and some general observations.

3.2 Methods

3.2.1 Site selection

The juvenile survey was conducted on the 20th and 21st July 2009. All sites surveyed for eggs in June were revisited during this survey with three additional sites also included. Sites surveyed are detailed in Table 2.

Table 2 Sites and grid references surveyed for juvenile barbel on 20th and 21st July 2009.

Site name	Grid Reference
Lyng	TG 0770 1760
Lenwade	TG 1020 1820
Bernard Matthews (D/S Lenwade)	TG 1030 1850
Costessey Point	TG 1776 1299
Costessey	TG 1770 1280
Hellesdon	TG 1980 7100
Taverham Mill	TG 1593 1379
Ringland Bridge	TG 4086 1869

3.2.2 Sampling of juvenile barbel

With the exception of Taverham Mill, where high water levels and a number of anglers combined to prohibit sampling, several samples were taken at each of the above sites. Marginal bay habitats (Figure 7) and areas of slack water were targeted using a micromesh seine net (10 x 3m), while a battery powered backpack electric fishing unit, powering a small (15cm) anode ring was used to determine the species occupying habitats in the main flow.

Figure 7. A marginal bay in close proximity of potential spawning habitat at Hellesdon. Surveys from other UK rivers have highlighted such habitat characteristics as being favoured by both barbel and other 0+ fishes.

All fish captured in seine nets were carefully transferred to a tray of water, where they were subsequently returned to the river in small batches after being thoroughly screened for young barbel. At each site, the range of species was noted and any barbel caught were measured (fork length) and photographed, prior to their safe return to the habitats from which they were captured.

3.3 Results

3.3.1 Community structure

Using a combination of seine netting and electric fishing a total of 14 species belonging to the 2009 year class were recorded from the July survey. Table 3 presents the species (0+) captured at each site along with barbel also belonging to the 2008 year class (1+). At all sites, chub and minnow dominated catches with roach also abundant at Costessey.

Table 3. Presence and absence of 0+ species and 1+ barbel at each site (shaded cells = present)

	Lyng	Lenwade	B. Matthews	Costessey Point	Costessey	Hellesdon	Ringland
Barbel 0+							■
Barbel 1+			■			■	
Chub	■	■	■	■	■	■	■
Minnow	■	■	■	■	■	■	■
Roach						■	■
Gudgeon	■		■	■		■	■
Common bream							■
Dace						■	■
Perch	■	■	■	■	■	■	
Pike	■	■					
Bullhead						■	■
Stone loach			■	■			
3–spined stickleback	■			■	■		■
9–spined stickleback							■
Brown trout	■						

3.3.2 Barbel

At Hellesdon and Bernard Matthews, five and one barbel belonging to the 2008 year class were caught respectively. These fish ranged between 65 and 87 mm (mean = 76.5 mm, SE = 3.008). The five fish at Hellesdon were captured from a deep slow glide in the centre of the channel using a seine net, while the single specimen at Bernard Matthews was caught in a slightly faster flow in the main channel using electric fishing gear. The habitat characteristics where these fish were captured are summarised in Table 4 and length frequencies are presented in Figure 11.

Table 4. Summary of habitat characteristics at the sites where 1+ barbel were caught

Feature	Hellesdon	B. Matthews
Grid reference	TG 19878 10380	TG 10784 18712
Width	12 m	11 m
Depth	60 cm	40 cm
Mean column velocity	< 0.1 m/sec	0.274 m/sec
Flow type	V. slow glide	Glide
Substrate	Gravel (70%); Sand & silt (30%)	Gravel (50%); Sand & silt (50%)
Instream vegetation	0 %	50 %
Temperature	16.5^{o}C	16.4

Figure 8. 1+ barbel captured at Hellesdon 21st July 09.

Due to high river levels and angling activity at Taverham Mill, sampling was not possible at this site. In considering alternative sampling opportunities, Ringland Bridge was suggested by the Agency as an additional site. Sampling had not previously been undertaken at Ringland, however the initial walkover assessment of

potential habitats for deploying the seine net was extremely promising, with the presence of substantial areas of shallow marginal bay (Figure 9).

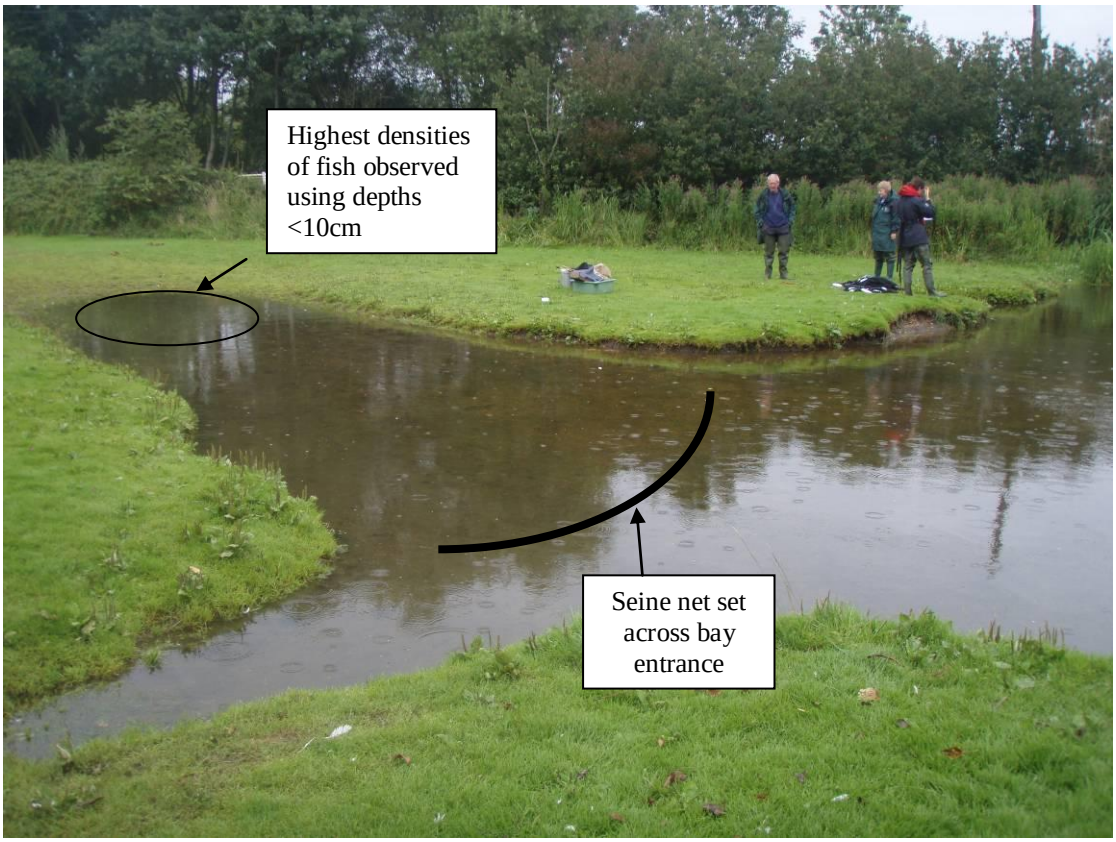

Figure 9. Shallow marginal bay just downstream of Ringland Bridge showing the area sampled with the seine net and the area supporting the highest densities of 0+ fish.

The bay depicted in Figure 9 was no greater than 30 cm deep and gradually shallowed towards the bank, where very high densities of fish were observed in depths of less than 10cm. Substrate was composed of gravel (70%) and sand/silt (30%) and a water temperature gradient was observed in accordance with distance from the main river and depth. Specifically, where depths were reduced to less than 10 cm, temperatures increased from 16.8^{o}C in the main river to 19.9^{o}C. At the entrance of the bay (the interface between the flowing river and the slack water of the bay), the temperature was recorded at 17.4^{o}C, representing a 0.6^{o}C increase on the temperatures recorded in the river.

A single sweep of the seine net was conducted at this site and very high numbers of 0+ and 1+ fish were captured, represented by a total of 10 species. Amongst the catch were a total of 20 0+ barbel ranging between 22 and 36 mm (mean = 28.9mm fork length) (Figure 10).

Despite the availability of smaller areas of marginal bay habitats, additional sampling within these areas returned much reduced catches of similar species composition, although the distribution of 0+ barbel was restricted to the large bay depicted in Figure 9. Length frequencies of all barbel (0+ and 1+) captured during the 2009 survey are presented in Figure 11.

Figure 10. One of the 20 0+ barbel captured at Ringland Bridge 21st July 2009.

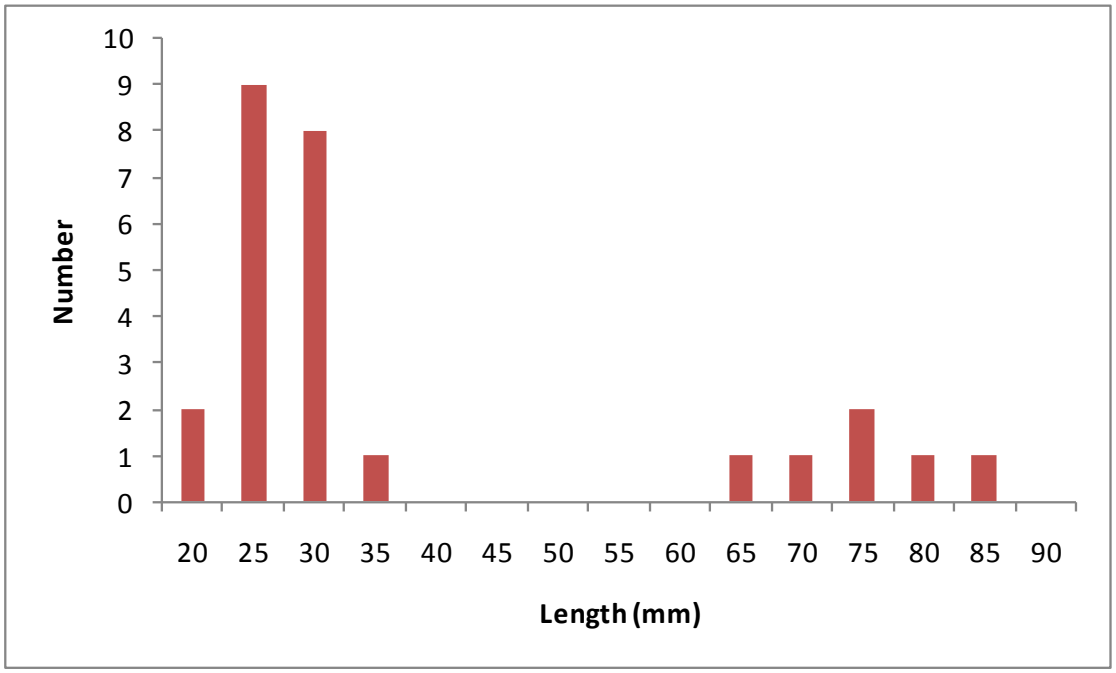

Figure 11. Length frequency of 0+ and 1+ barbel captured on the River Wensum in July 2009

4 DISCUSSION

4.1 Spawning success

The 2009 survey confirmed that successful spawning was achieved by barbel during both 2008 and 2009, at some locations. The presence of 1+ barbel at Hellesdon and Bernard Matthews also confirms that a proportion of the 2008 recruits managed to successfully overwinter, thus surviving the most vulnerable period of their life history (embryo to first year survival). The distribution of these fish in 2009 however, provides little useful knowledge regarding spawning location or the habitats that were required to achieve survival to this stage. Indeed, without taking the efficacy of fish pass design and the effects of instream barriers to migration into account, the individuals caught in 2009 could in theory have originated from any stretch on the river which supports suitable spawning habitats. Based on the characteristics of the habitats from where these fish were captured it is considered that the abundance of suitable habitats throughout the Wensum is unlikely to limit the success of barbel, once they have been successful in surviving their first year of development.

The egg survey conducted in June 2009 has provided the first observations of confirmed spawning. Over the last two years, many sites have been investigated following anecdotal reports of barbel spawning, however such investigations have so far failed to detect either the embryos or larvae of barbel. The spawning activity observed at Bernard Matthews on 3rd June 2009 facilitated the first characterisation of the habitats used for spawning and initial results suggest that the habitats that were selected for spawning are not unique, with many other potential spawning sites distributed throughout the sections of river investigated. However, given the return of fish to their distinct spawning locations year on year, it could be that more subtle differences in habitat characteristics favour selection of these sites over other broadly similar habitats.

The spawning behaviour observed was considered to be relatively reserved which suggests that these fish may have been participating in the early stages of courtship. Indeed, it would seem likely that either previous or subsequent activity may have been more intense resulting in the deposition of larger numbers of eggs with potentially higher fertilisation rates than the 50% observed. These initial observations were however extremely encouraging and provided vital information to direct the spatial design of the juvenile survey to investigate successful hatching and habitat utilisation of barbel during the first few weeks of life.

4.2 Juvenile habitat utilisation

Previous studies conducted by APEM staff have shown young barbel (and many other cyprinid species) to be highly selective in the types of habitat used during early development. Although this may be a gross oversimplification of the range of habitats required by any one species throughout their earliest phases of ontogeny, most species will preferentially select shallow marginal habitats where a lack of flow, reduced depth and direct sunlight all combine to elevate water temperature. Through the analyses of diet, Garner *et al* (1998) demonstrated this to be a trade off between temperature and food and through the artificial construction of marginal bays also

investigated the relationships between bay morphology, temperature dynamics and the utilisation of these habitats by minnows. Previous experience has shown that such habitats are more attractive to young barbel, where the substrate is composed of a mix of gravel and sand, however, with the exception of Hellesdon, such optimal habitats are lacking from sites previously investigated on the Wensum.

The inclusion of Ringland Bridge to the scope of the survey in July 2009 has provided what must be considered as ideal nursery habitats for barbel and indeed, this is the only site to date where 0+ barbel have been found to be present. The presence of 2009 recruits at this site is also indicative of where spawning may have been successful in the preceding months and while many suitable spawning areas exist between Ringland and Lenwade Weir (a likely barrier to migration), it is quite possible that these fish were produced by the adults observed spawning upstream at Bernard Matthews on the 3rd June, seven weeks previously. In terms of characterising the preferred habitat, the key drivers appear to be the provision of a large surface area where depths do not exceed 10cm, a substrate which is largely composed of small gravel, no flow and no shading. Despite the weather being overcast and raining at Ringland on the 21st July, all these factors combined to elevate water temperature within the shallow areas of the bay by 3.1°C to 19.9°C when compared to the ambient temperature of the river, which was recorded at 16.8°C. Such habitats are not only preferentially selected, but will inevitably have a significant effect on growth rate and survival, and are likely to affect the size of the fish at the end of the first growing season, with knock on effects to year class strength.

4.3 Scope of study and current limitations

It is clear from the failure to detect 0+ barbel during 2008 and, with the exception of Ringland, the lack of 0+ barbel from all other sites during 2009, that the sites previously surveyed do not provide a spatially robust representation of available habitats. Preliminary scoping from aerial photography would suggest that a plethora of suitable nursery habitats exist throughout the Wensum. These areas are often positioned either immediately downstream or adjacent to potential spawning sites. As a result, it is expected that further surveys at these locations would have demonstrated greater recruitment success. Now that preferred nursery habitat characteristics have been confirmed for 0+ barbel, it will be most important to identify the abundance and distribution of such habitats with specific attention to the juxtaposition of these areas to suitable spawning areas.

5 RECOMMENDATIONS

It is evident that further investigation is required to gain a better understanding of barbel spawning and recruitment within the Wensum. In particular, the stretch of river between Lenwade and Costessey Weir appears worthy of investigation. This study has previously focussed upon sites with convenient road access. Expanding the survey to incorporate more of the Lenwade to Costessey stretch could require access by boat/kayak and the cooperation of land owners and anglers.

The eggs deposited at the Bernard Matthews site were incubated at APEM's Dorset Laboratory where 100% hatching success of fertilised eggs was observed. Assuming

that hatching was also successful within the gravels, the widespread nature of habitats with equivalent physical characteristics would suggest that the population may be limited by a lack of nursery habitats rather than spawning habitats. However, in order to identify more fine scale habitat preferences for barbel, it is recommended that as a priority, the spatial availability of habitats is further assessed and mapped. Such an assessment should include both spawning habitats and those which are comparable with the habitats where barbel were captured at Ringland, and thereby represent likely nursery habitat for barbel. Indeed, where nursery habitats are lacking, there is clearly scope for the experimental creation of such habitats with a view to enhancing barbel recruitment and ultimately enhancing the self sustainability of the Wensum barbel population. It is anticipated that the results from a walkover survey would also be used to inform and educate the future spatial design of egg deposition and juvenile habitat use surveys on the Wensum.

Many of the flow controlling structures along the Wensum are also likely to govern the success of the barbel population. Although some of these structures may be passable by adult barbel under spate flow conditions, if high flows are not synchronised with a fish's propensity to migrate prior to spawning then opportunities to navigate these may be limited. In addition, where juveniles have to move downstream to find suitable nursery habitats, the downstream traverse of barriers may have the potential to isolate recruits from upstream spawning habitats. On this basis it is suggested that as part of the walkover habitat assessment, a preliminary investigation is conducted into the distribution and potential impact of barriers throughout the river.

Following the collection of these data, future surveys will be better designed to detect the habitats utilised by spawning adults and 0+ barbel. This enhancement to the survey will provide a more substantial sample size which will facilitate fine scale resolution analysis of the habitats required by barbel throughout each life stage. Accordingly, these data will be vital to inform the future direction of fisheries management practices such as habitat preservation/creation on the Wensum in the coming years.

6 REFERENCES

APEM (2008) An ecological appraisal of coarse fish habitat of the River Wensum at Taverham Mill. Report to the Environment Agency. APEM report 410464. 10pp.

APEM (2009). An investigation into the success of barbel and other coarse fish recruitment in the River Wensum 2008. Report to the Environment Agency. APEM report 410597. 30pp.

Bischoff, A and Freyhof, J. (1999) Seasonal shifts in day/time resource use of 0+ barbel, *Barbus barbus. Envirinmental Biology of Fishes*. **56**: 199-212.

Environment Agency (2007). River Wensum barbel and roach studies. Overview document.

Environment Agency (2007a). Assessing the natural recruitment and sustainability of barbel *Barbus barbus* (L.) populations in the River Wensum, Norfolk.

Freyhof, J. (1994) Distribution of YOY-barbel *Barbus barbus* (L) in the River Sieg Germany. In: *Conservation of Endangered Freshwater Fish Species in Europe.* Kirchhofer, A *et al*., (Eds.) Advances in Life Sciences. Birkhauser: Basel.

Garner, P., Clough, S., Griffiths, S.W., Deans, D & Ibbotson, A. (1998). Use of shallow marginal habitats by *Phoxinus phoxinus*: a trade off between temperature and food. *Journal of Fish Biology* 52, 600-609.

Krupka, I. (1988) Early development of the barbel, [*Barbus barbus* (Linnaeus, 1758).] *Prace Ustava Rybarstva a Hydrobiologie* **6**, 115-138.

Mann, R.H.K. (1996) Environmental requirements of Europeannon-salmonid fish in rivers. *Hydrobiologia* **323**, 223-235.

Penaz, M. (1973) Embryonic development of the barb, *Barbus barbus* (Linnaeus, 1758). *Zool. Listy*, **22** (4): 363-374.