Interim Report R&D Project 256/ST

Eel and Elver Studies in the Severn

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SUMMARY

Studies of the Severn elver runs and fishery were carried out by questionnaires, visiting elver stations, observation and hand-net fishing. Little detailed quantitative information was forthcoming from fishermen or elver stations. Mark-recapture studies had to be abandoned because of practical problems and to avoid confusions with a study being conducted by Bristol Channel Fisheries. Information released about this study show recapture rates were very low, suggesting fishing efficiency was low. The accuracy of such techniques for estimating the size of elver populations is criticised. Results and observations show the elver catch was very poor in the 1991 season. The situation was confused by abnormal migration and hence catching patterns due to adverse weather, spate and water temperature conditions.

Twenty traps were designed, built and installed at 10 sites on the Severn and Avon to study upriver migrations. Relatively few elvers were caught at the normal tidal limits at Tewkesbury but they continued to arrive in waves throughout the summer. Large numbers were also trapped at Stanchard Pit, 3.5km upstream of Upper Lode where a branch of the Severn meets the Avon. Most of these had probably been carried up the estuary by tidal transport and managed to scale Upper Lode. Elvers can be carried over this weir by exceptional spring tides but none appeared to be high enough for this to happen in the 1991 season. Very few elvers subsequently reached the next weirs up the rivers.

More juvenile eels than elvers were trapped at all sites. Catches at the tidal limits were large but they were even larger at Stanchard Pit, Tewkesbury, and Diglis, Worcester. Tidal transport up the estuary and scaling of Upper Lode weir is probably a major contributory factor. Larger juveniles became more dominant higher up the rivers as catches fell markedly with each successive weir/sluice. This correlates with previous studies of adult stocks. Results for elver and juvenile eels catches emphasise the importance of such structures as barriers to migration.

Laboratory and field studies indicate differences in trap efficiencies due to location, currents and climbing media. Plans for further studies using present and commercially-available designs are outlined. Elvers and juveniles have been successfully marked using sub-epidermal injections of acrylic paint. Recapture rates via traps have been very low. All but one occurred at the first trap above point of release, however, indicating few have been able to by-pass trapping sites. Studies are outlined which should yield more information in 1992/3.

It is concluded that the current project targets have been met. Future plans regarding additional data acquisition and processing and for 1992/3 field and laboratory work are outlined.

1. PROJECT DESCRIPTION

1.1 Introduction

Elvers (unpigmented 'glass eels') have, in the past at least, entered the Bristol Channel/Severn Estuary in large runs, mainly utilising selective tidal stream transport in the spring. A commercial fishery has developed in the Severn over the last three decades, mainly involving casual fishermen catching elvers by hand nets as they concentrate towards the banks at the turn of major spring tides. Fishing effort tends to be concentrated at certain locations, normally in a zone of about 3km. This zone moves progressively up the Estuary as the main elver runs move further inland with successive tides. Elvers are also caught in other rivers entering the Bristol Channel, especially the Parrett and Wye.

Catches are sold to a number of elver 'stations', concentrated in the Gloucester area, for holding or growing-on until sale. Elvers are generally of good quality, disease-free and unadultered by additions of small juveniles. They therefore generally command good prices, mainly for stocking eel farms and natural waters in mainland Europe. Fishermen and elver stations are unwilling to provide information because of financial and commercial sensitivities. Maximum catches have been estimated at 20-30 (perhaps as high as 100) tonnes per annum but these have fallen since a peak in the late 1970s. NRA Severn-Trent have instituted a net licensing system and are requesting catch returns from 1992 to help monitor the fishery.

Some elvers will migrate up-river, but many others may stop in the estuary or lower river stretches. They grow there until maturing ('silvering'), mainly as males, and returning to sea to breed. Others may resume migration after one or more years as pigmented juveniles (immature migratory 'yellow' eels). Increasing density and competition may promote migration but low densities may have the reverse effect. Migrants can scale or by-pass obstacles such as weirs and sluices but it is reported that few have been seen doing this in recent years. The lack of elver and juvenile recruitment is reflected by low stock densities deeper in the catchments and increasing preponderance of female eels (Aprahamian, 1985, 1988).

NRA are concerned about falling numbers of elvers entering the Severn Estuary, decreases in yellow and silver eels catches and the paucity of upriver eel stocks in the Severn and Avon catchments. Elver runs have declined in many other European rivers in the last few decades (Moriarty, 1990, 1991). Over-exploitation by the elver fishery and weir/sluice barriers have potentially important impacts on migration and stocks in rivers like the Severn and Avon.

1.2 Project description

This project has been designed to assess elver stocks and the effects of exploitation and to study upriver migration of elvers and juvenile eels (White & Knights, 1991, Appendix A). The aim is to assess means of management (including the role of eel passes) to optimise recruitment to the riverine stocks and hence, eventually, to the breeding stocks of Anguilla anguilla.

The specific contract objectives are;-

1. To initiate a long term study of elver/eel abundance using fixed traps on weirs and sluices.

2. To identify the main physical barriers to upriver migration.

3. To evaluate factors affecting upstream migration.

4. To evaluate and recommend elver/eel pass designs appropriate to particular structures.

5. To identify and evaluate factors which affect elver capture.

This Interim Report summarises work completed in 1991 and future plans under the headings of;-

1. Elver migration and exploitation

2. Weir/sluice trapping programme

3. Laboratory studies

4. Mark-recapture studies

5. Additional data collection and analyses.

A literature survey has been completed but is being continuously updated. Relevant references are discussed in this Report, a comprehensive and up-to-date review will be reserved to the Final Report.

2. METHODS

2.1 Elver migration and exploitation

Methods used in the present study to assess the number of elvers entering, being caught and escaping the fishery have been:-

2.1.1 Requesting data from elver stations

This was done by letter, telephone and personal contact. Locations of the elver stations in the Gloucester area are shown in Fig 2.1.

2.1.2 Requesting data from fishermen

One thousand questionnaires were distributed via tackle shops issuing licences and by hand (Appendix B).

2.1.3 Individual catch and CPUE studies

The Project Research Assistant carried out hand net fishing at relevant places (Fig 2.1) during spring tides in March-May. Fishing was carried out alone and as part of commercial teams, to study fishing methods and catches (see Section 3.1 for details and results). The main elver station (Bristol Channel Fisheries Ltd, Fig 2.1) was also visited as catches were brought in. Personal contacts were thus achieved, plus some involvement of individual fishermen and/or teams. A major aim was to assess catch-per-unit-effort (CPUE) and overall catches to compare with NRA data on licence sales and voluntary catch returns.

2.1.4 Assessment of numbers of fishermen

By assessing numbers seen on the banks and at elver stations to integrate with the above information.

2.1.5 Studies of NRA licence sale and voluntary catch-return data

To integrate with above information when the data becomes available.

2.1.6 Elver mark-recapture studies

Elvers were to be marked using vital dyeing of the body surface (2.4.1), released into the estuary and then recaptures counted during hand-netting and by observation of catches brought

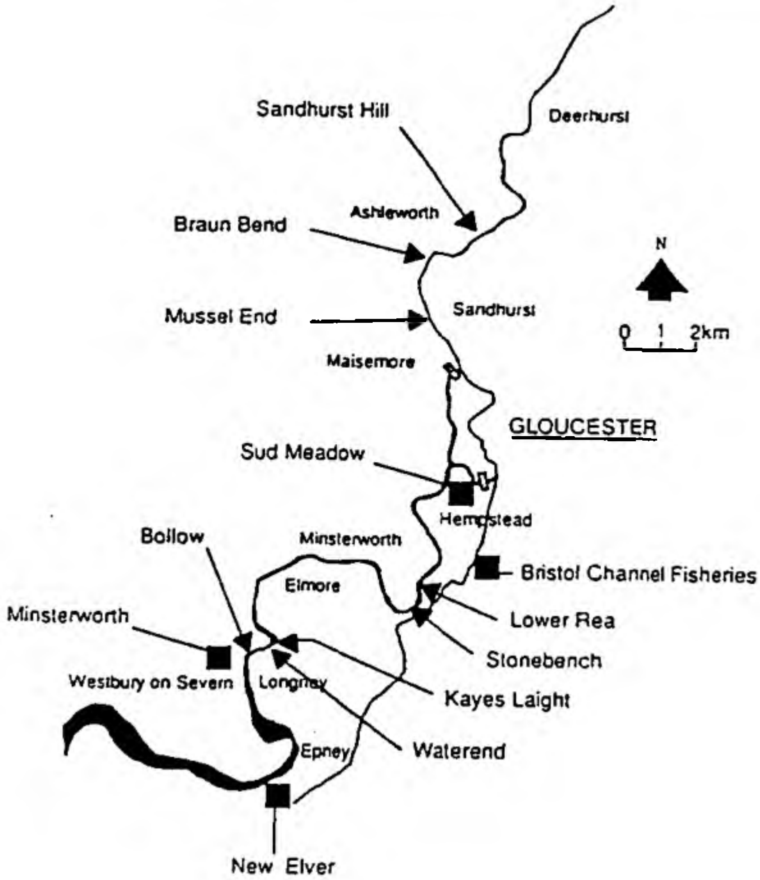


Figure 2.1 Map of the upper Severn Estuary to the tidal limits at Tewkesbury, showing elver stations (squares) and elver fishing points (arrowed)

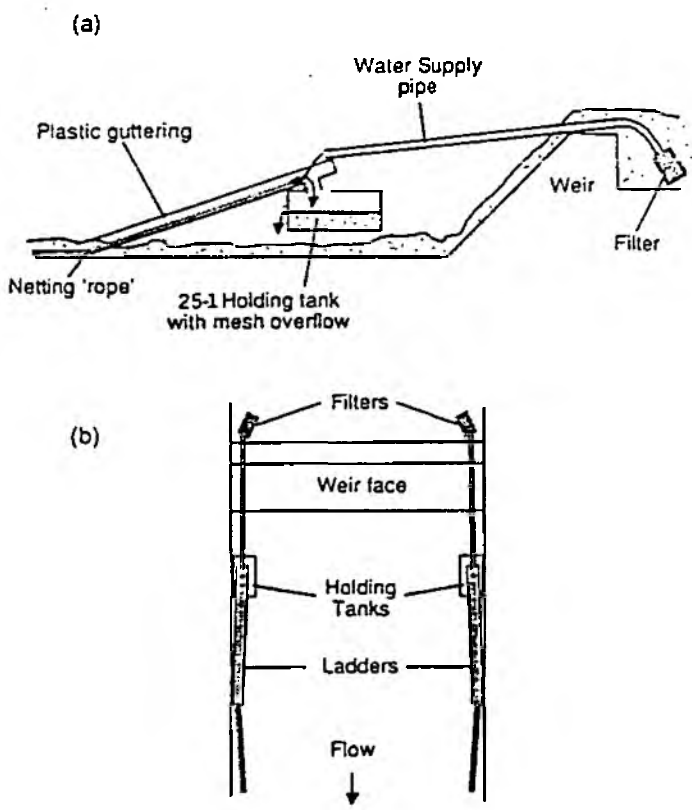


Figure 2.2 Basic design of traps used in the study of migration, (a) side view and (b) from above.

in to the elver stations. The aim was to assess the use of mark-recapture methods to estimate estuarine stocks and levels of exploitation.

2.2 Weir/sluice trapping programme

To assess the numbers and population structures of elvers and eels migrating upriver and the effects of weir/sluice barriers, traps were installed at selected sites. Similar but more substantial structures, without collecting boxes, could be used in the future as eel passes to facilitate migration over obstructions. Initially, various patterns of floating traps with a plastic mesh 'ladder' for eels to ascend were constructed (see diagram in Appendix A). However, these proved to be too difficult to anchor securely in suitable positions. Therefore the designs eventually used were adapted from those of Naismith & Knights (1988), using horticultural netting and/or geotextile materials as climbing medium (Fig 2.2). Traps were suspended from the wing walls of weirs/sluices. Migrating eels, attracted by water flowing down the guttering channel, ascended through the climbing medium and then fell into the holding tank. The base of each trap, together with a 'rope' of climbing medium, was placed in the current to make it as easy as possible for eels to locate and ascend into the holding tank. Traps were emptied as regularly as possible and catches (whole or subsamples) weighed and lengths measured. Numbers caught were recorded or estimated from total catch weight divided by mean body weight determined by subsampling. Subsamples were preserved for ageing via otolith ring counting. The majority of eels were returned to the river just upstream of their point of capture.

During 1991, 20 pass-traps in total were used at 10 sites on the Severn and Avon. These were progressively installed through spring/summer on weirs and/or sluices from the tidal limit upstream as shown in Table 2.1 and Figs 2.3 to 2.5. Sites were chosen for judged attractiveness of water flows to eels, suitability for mounting traps and vulnerability of traps to damage by spates and vandalism. Accessibility and logistics of regular inspection and emptying also had to be taken into account. Where weirs or sluices were positioned obliquely to river flows, traps were mounted on downstream locations because up-river migrants would meet and be attracted by flows from such traps first. Trapping was discontinued in September-October as temperatures dropped below 12-13°C and migration ceased.

2.3 Laboratory experiments on pass/trap designs

To further assess trap designs, especially regarding efficiencies and size-selectivity of climbing materials, laboratory tank experiments have been instituted. Numbers of ascending eels of different size classes are being counted. Variables to be studied include duration of experiment, flow rates, angle of ascent, time of day, density, pheromones, photoperiod and temperature. The main emphasis, however, has initially been put on comparing climbing media, i.e. horticultural netting, geotextiles of different mesh size (Enkamat, Enkadrain and Tensarmat) and nylon brushes of different pattern (as used in passes marketed by the French company Fish-Pass, as discussed in the Report given in Appendix D). Preliminary results are discussed in Section 3.3.

Table 2.1 Details for 1991 of eel trap locations (one trap/structure unless shown otherwise in brackets), dates of operation, distance from tidal limits and normal pound heights.

Sites	Dates	Location	Distance from tidal limit km	Pound height, m
(a) R.Severn				
Upper Lode	15.5-8.10	W. bank	0	1.5
Diglis Weir	4.6-8.10	E. bank	26.5	2.4
Bevere Weir	18.6-18.9	W. bank	30.5	1.5
Holt Weir	4.7-18.9	E. bank	36.0	1.6
Lincomb Weir	7.8-18.9	E. bank	42.5	2.2
(b) R. Avon				
Abbey Mill	23.4-8.10	C[1] Wheel race	0	3.2
		D- Wheel race(2)		
		E- Wheel race		
		F- Vertical sluice		
Stanchard Pit	6.6-3.9	A- Sluice (2)	3.4	1.7
		B- Weir (2)		
Strensham	5.6-3.9	- S. bank of sluice - S. bank of weir	9.5	1.6
Nafford	17.6-18.9	- N. bank of sluice - N. bank of weir	15.0	1.7
Wyre Mill	4.7-28.9	- S. bank of sluice - S. bank of weir	25.0	0.7

[1] Capital letters refer to locations at Tewkesbury, as shown in Fig. 2.4. For maps of other locations, see Figs. 2.3 and 2.5.

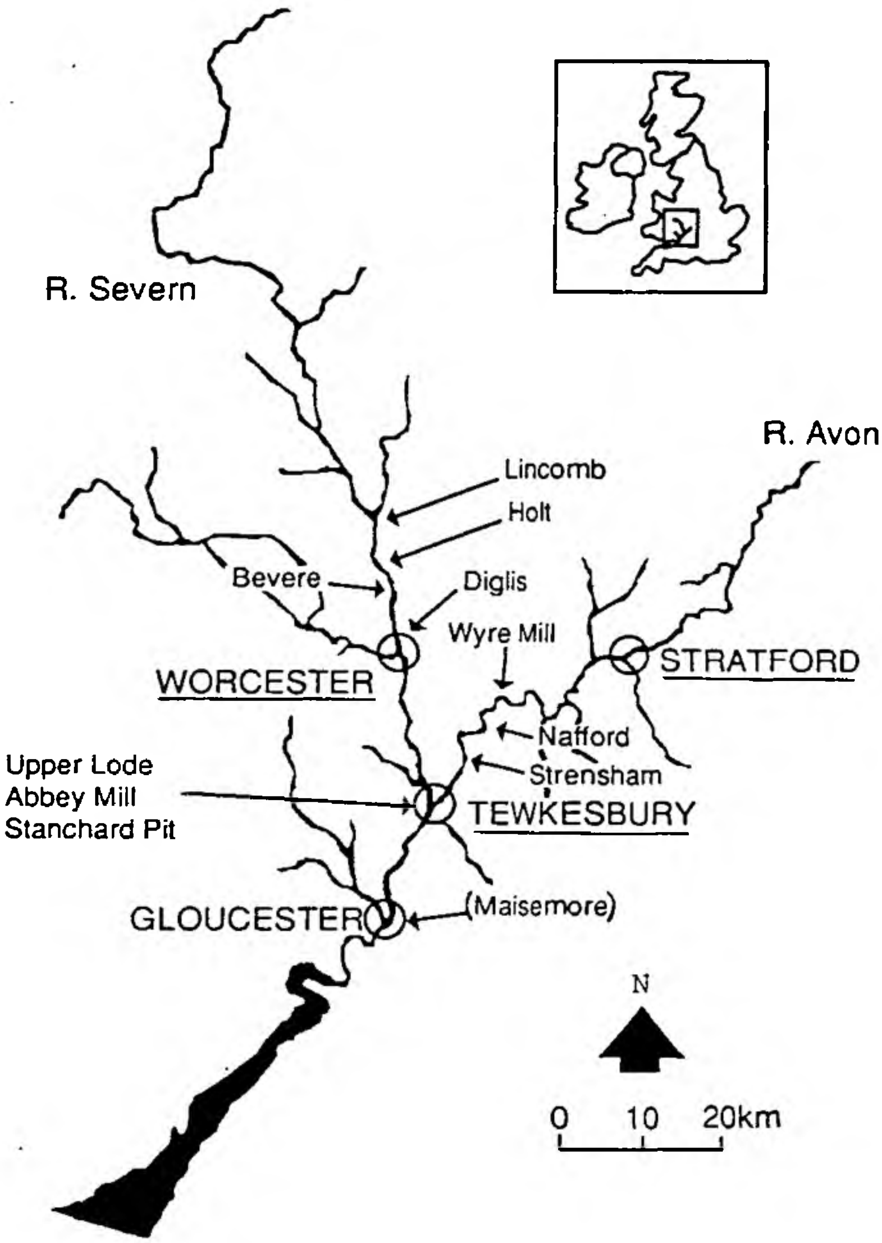


Figure 2.3 Map of Severn Estuary and Rivers Severn and Avon, showing locations of eel trapping sites

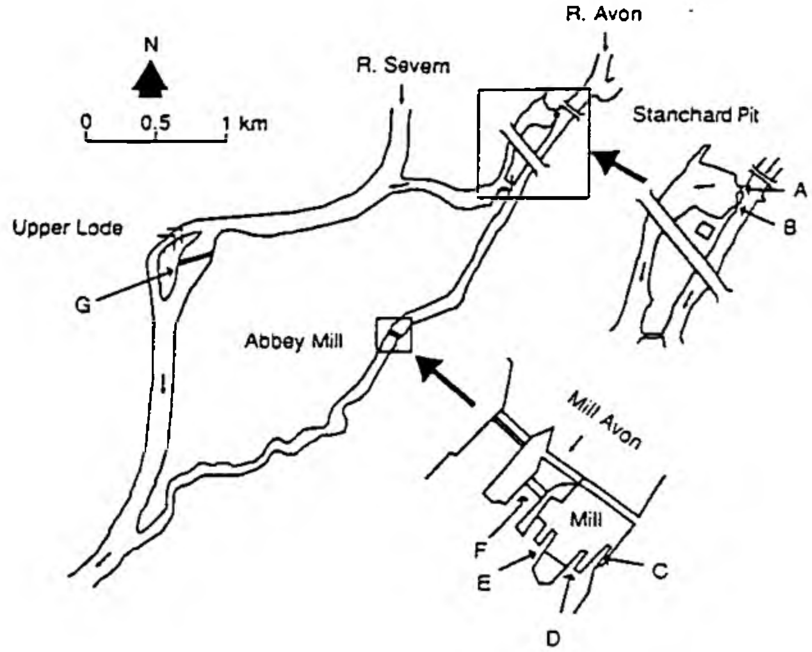


Figure 2.4 **Map showing trapping sites on the Severn and Avon at Tewkesbury. Enlargements show trapping sites (capital letters) at Stanchard Pit and Abbey Mill. See text and Table 2.1 for further explanation of trap arrangements at each site.**

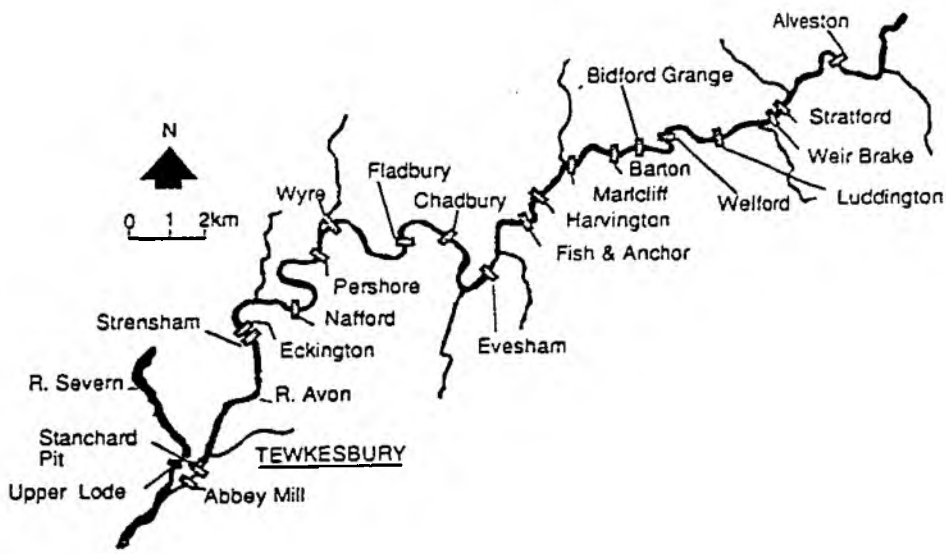


Figure 2.5 Map showing weirs and sluices on the River Avon. See text and Table 2.1 for further explanation of trapping sites used in 1991.

2.4 Mark-recapture studies

2.4.1 Marking techniques

Samples of elvers and juveniles were marked by vital dyeing of the body surface and/or sub-epidermal injections of acrylic paint. The latter has been proved effective (e.g. by Knights, 1987, Naismith & Knights, 1988, 1990). Some vital surface dyes are claimed to be effective though relatively short-lived (e.g. Sakurai et al., 1979; Tzeng, 1984). Experiments were planned to test the effectiveness and longevity of dyes such as neutral red and Bismarck brown on elvers and juveniles in relation to mark-recapture studies. Approximately 150 elvers were exposed to different concentrations of each dye for 2-12 hours and any ill-effects and the longevity of staining recorded, as detailed in Table 3.5.

2.4.2 Elver abundance studies

The planned mark-recapture studies have already been outlined in 2.1.6.

2.4.3 Elver and eel migration studies

Batch and individually-marked fish (using acrylic paint marking) were released at various sites. The aim was to study recaptures (via weir and sluice traps) to assess rates of movement, ability to bypass obstructions and traps and, possibly, estimate numbers of migrants. Four releases were made at Abbey Mill and one at Diglis, involving 242 elvers and 447 juveniles as detailed, together with recaptures, in Table 3.6.

2.4.4 Stocking studies

Juvenile eels were purchased by NRA Severn Trent from a commercial on-growing facility for their Avon stocking programme. Samples were marked with acrylic paint injections and released in different stretches above Pershore Weir. This appears to be a major barrier to migration. Stretches were chosen to represent unstocked and previously stocked areas where traps can be mounted upstream in 1992 and 1993. It is hoped these studies will yield further information about upstream migrations and the possible effects of barriers and stocking density on migration.

Marked fish were stocked just above the following weirs in autumn 1991 thus;-

- Pershore — 100 eels on 24.10.91
  84 eels on 28.11.91
- Wyre Mill — 100 eels on 24.10.91
  98 eels on 28.11.91
- Fladbury — 100 eels on 24.11.91

2.5 Additional data collection and analyses

Additional information is being collected for integration into the study, i.e. hydrographic, water temperature, licence sales and voluntary catch-return data from NRA Severn-Trent. Contacts in Britain and other European countries are being pursued to gather any available data about sales of Severn elvers, as well as about catches from other estuaries. Suggestions for an integrated Europe-wide elver migration survey have also been made to the European Inland Fisheries Advisory Committee (EIFAC) Working Party on Eel (see Appendix A).

3. RESULTS

3.1 Elver migration and exploitation

3.1.1 Data collection from elver stations and fishermen

Only two questionnaires were returned by individual fishermen and no quantitative data was directly available from elver fishermen or elver stations.

3.1.2 Fishing and CPUE studies

These studies were not as productive as hoped because periods of unusual weather conditions with winds opposing the incoming tides, spates and low water temperatures interfered with the expected patterns of elver migration. Many fishermen had poor or no catches and often changed fishing site. Many gave up fishing early on or never started at all. This made attempts to assess the numbers of active fishermen impossible.

The Project Research Assistant was initially accepted by two fishing teams, but although generally known to be 'experts', they abandoned or didn't attempt fishing on many nights. Later in the season, some members of the teams objected and the Assistant was no longer invited to fish with them. However, fishing was attempted on as many nights as possible (15 alone and 6 with teams). Catches were only obtained on 10 nights (Table 3.1). Estimates of overall catches brought into elver stations were made on 23 nights.

The first elver catches were taken on the high spring tides during the period 16-21 March, the last on 27th April. Although catches were sparse, several points are apparent from Table 3.1;-

1. Only four sets of spring tides yielded elver catches. These were generally small. The Project Research Assistants' CPUE averaged 0.56kg over 21 nights, the total catch being 11.69kg (approximately 35,000 elvers, worth about £300-400).

2. There were only 2-3 nights on the first three sets of tides on which elvers were caught in significant quantities, these nights all being on or around the peak tide of each set.

3. Elvers were rarely caught in any great quantity downstream of Llanthony and Maisemore Weirs in Gloucester. This was apparent on all of the fishable sets of spring tides. Elvers carried up the estuary on a rising tide appeared not to 'swim' in freshwater until they had passed over the Gloucester weirs. Consequently most catches were taken between the weirs and Wainlodes. Even then there were only a few good nights on each set of spring tides on which elvers were caught in any numbers. This could mean that there were very few elvers entering the river and that they were fished out very quickly, or that conditions were not favourable for capture often enough.

4. Below the Gloucester weirs, elvers were more likely to be caught being carried back downstream ('sagging') in the current once the tide had turned. This suggests possible unfavourable water conditions. Sagging behaviour was not apparent above the weirs.

Table 3.1 Individual catch per unit effort (CPUE) during 1991 elver season for Project Research Assistant, fishing alone and with teams at sites shown in Fig. 2.1.

Date	Fishing site	Tidal height mAOD	Number of fishermen	CPUE (kg/person/night)	General catches
16.3.91	Waterend	8.8	1	0.02	*[1]
17.3.91	Stonebench	9.1	1	0.1	*
18.3.91	Braun Bend	9.2	1	0	**
19.3.91	Braun Bend	8.9	3	0.65	***
20.3.91	Braun Bend	8.4	3	0.7	**
21.3.91	Kayes Laight	7.6	3	0	*
8.3.91	Braun Bend	8.3	1	0	*
29.3.91	Mussel End	8.8	1	0	*
30.3.91	-	8.9	-	-	***
31.3.91	Braun Bend	9.1	1	0	**
1.4.91	Braun Bend	8.9	3	4.33	**
2.4.91	Sandhurst Hill	8.4	1	4.65	**
3.4.91	Braun Bend	7.4	1	0.7	*
12.4.91	Longney Crib	7.5	3	0.17	*
13.4.91	Bollow	8.2	1	0	*
14.4.91	Braun Bend	8.8	1	0	*
15.4.91	-	9.1	-	-	***
16.4.91	Braun Bend	9.2	1	0.25	*
17.4.91	Braun Bend	9.0	1	0	*
18.4.91	Braun Bend	8.5	1	0	*
27.4.91	Lower Rea	8.2	2	0.12	*
28.4.91	Braun Bend	8.3	1	0	*
29.4.91	Braun Bend	8.4	1	0	*

[1] Estimated quantity of catch at elver station, * poor, ** moderately good, *** good.

Table 3.2 Total numbers of elvers and juveniles caught at each trap site in 1991. For mean catch/trap/night, see Fig. 3.3.

Trap site	Distance from tidal limit,km	Number of elvers	Number of juveniles
(a) R.Severn			
Upper Lode	0	4006	9841
Diglis Weir	26.5	2	12965
Bevere Weir	30.5	0	2988
Holt Weir	36.0	0	371
Lincomb Weir	42.5	0	22
(b) R.Avon			
Abbey Mill	0	269 (Site C)	599
		3067 (Site D1)	4360
		11304 (Site D2)	19432
		1194 (Site E)	513
		1159 (Site F)	930
Stanchard Pit	3.5	4122 (2 weir traps)	28337
		3718 (2 sluice traps)	13840
Strensham	9.0	15 (weir trap)	5205
		2 (sluice trap)	1362
Nafford Sluice	15.0	0	579
Wyre Mill	25.0	0 (weir trap)	68
		0 (sluice trap)	2

5. No significant elver catches were made upstream of Wainlodes which is apparently unusual as large catches have often been made just downstream of Upper Lode Weir.

3.1.3 Elver mark-recapture studies

Plans were made to dye and release elvers caught by the Project Research Assistant. However, individual catches were relatively small and the elver stations were reluctant to provide extra elvers because of generally low supplies. Also Bristol Channel Fisheries Ltd. (BCF) started their own mark-recapture experiments using elvers marked with neutral red, the only successful stain according to BCF and the current study (see 3.4.1). Further mark-releases would have been indistinguishable and studies were therefore abandoned.

3.2 Weir sluice-trapping programme

3.2.1 Trap locations and relative efficiencies

Pershore Weir is probably a major barrier to migration up the Avon (Fig 2.5) but no trap was installed here because of access and mounting problems. No traps were mounted on the main sluice at Abbey Mill because currents were too fast and turbulent. The trap on the west bank at Upper Lode (Fig 2.4, G) was affected by varying tidal and river levels and vandalism. Furthermore, the bank at the weir edge is sloping and not vertical, making it difficult to place the trap in an ideal position to capture migrants. A trap was not placed on the other bank for the same reasons, plus the site was too public and open to theft and vandalism. The same reasons militated against installation of a trap on the west bank at Diglis Weir. The Upper Lode trap and those at at Stanchard Pit, Upper Lode and Nafford suffered occasional damage from spates and vandalism. Trapping at Nafford Weir was abandoned early in the study because traps were swept away in spates. At all other sites, however, traps generally worked successfully throughout the operational period.

More mark-recapture, field and laboratory studies are needed to further assess trapping efficiencies. However, only one marked eel was found to have by-passed the trap above the point of release (Section 3.4.2). Location of the base of traps in relation to currents appears particularly important. These need to be fast enough to attract eels but not too fast or turbulent for them to easily locate the trap gutters. Problems faced by eels in locating trap gutters at Upper Lode are mentioned above. The effects of currents are illustrated by differences in catches at Abbey Mill (Table 3.2). Here, catches were lowest at the undershot wheel race sites C and F (Fig 2.4) and at the vertical sluice site F. Current velocities were very high at the former two sites and very low at the latter. In addition, there was a long apron and vertical drop below the sluice. Currents were also very fast below the westerly radial sluice which probably caused eels to move preferentially up the easterly side of the river.

The effects of different climbing media in traps in the field are illustrated by data in Table 3.2. At Upper Mill Site D, horticultural mesh was used in trap D2 and produced a larger catch than D1 where Enkamat geotextile was used.

3.2.2 Catch numbers with time

Figures 3.1 and 3.2 show trap catches (as catch/trap/night, CTN and cumulative %) with time for selected Avon and Severn sites respectively. Elvers arrived at Abbey Mill (the first trapping site established) on 25 April, but in very small numbers. Elvers were first captured at Upper Lode on 16 May. It is likely that there were arrivals prior to this date, as elver fishermen had been seen working this site during previous spring tides. However, according to the fishermen involved, catches were poor.

The slow rate of elver migration further upriver can be gauged from the fact that elvers were first noted in catches at Strensham on 29 June and at Diglis Weir on 4 July. At Strensham (9.5km upstream of the point of tidal reversal), 17 elvers were trapped but only 2 individuals

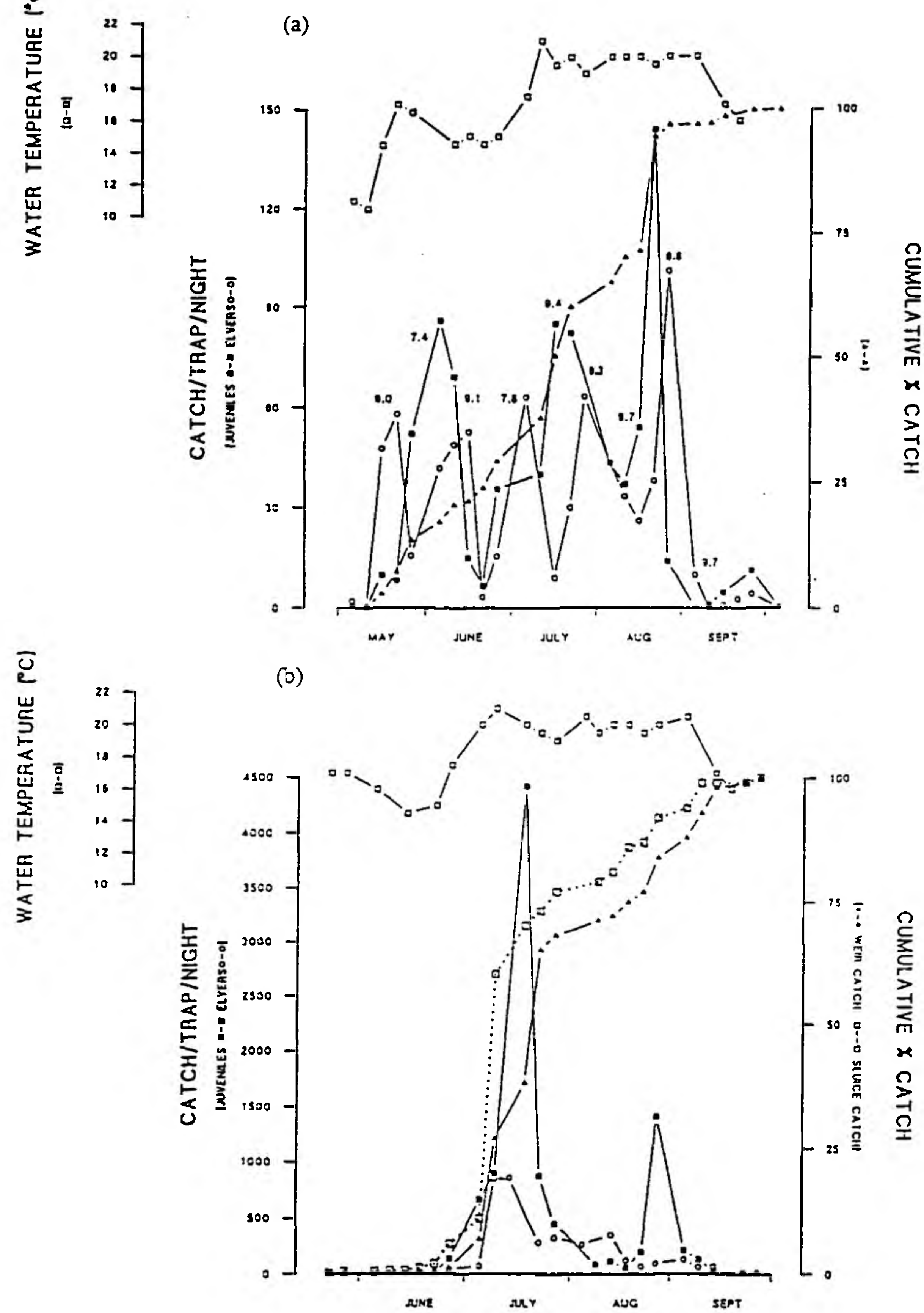
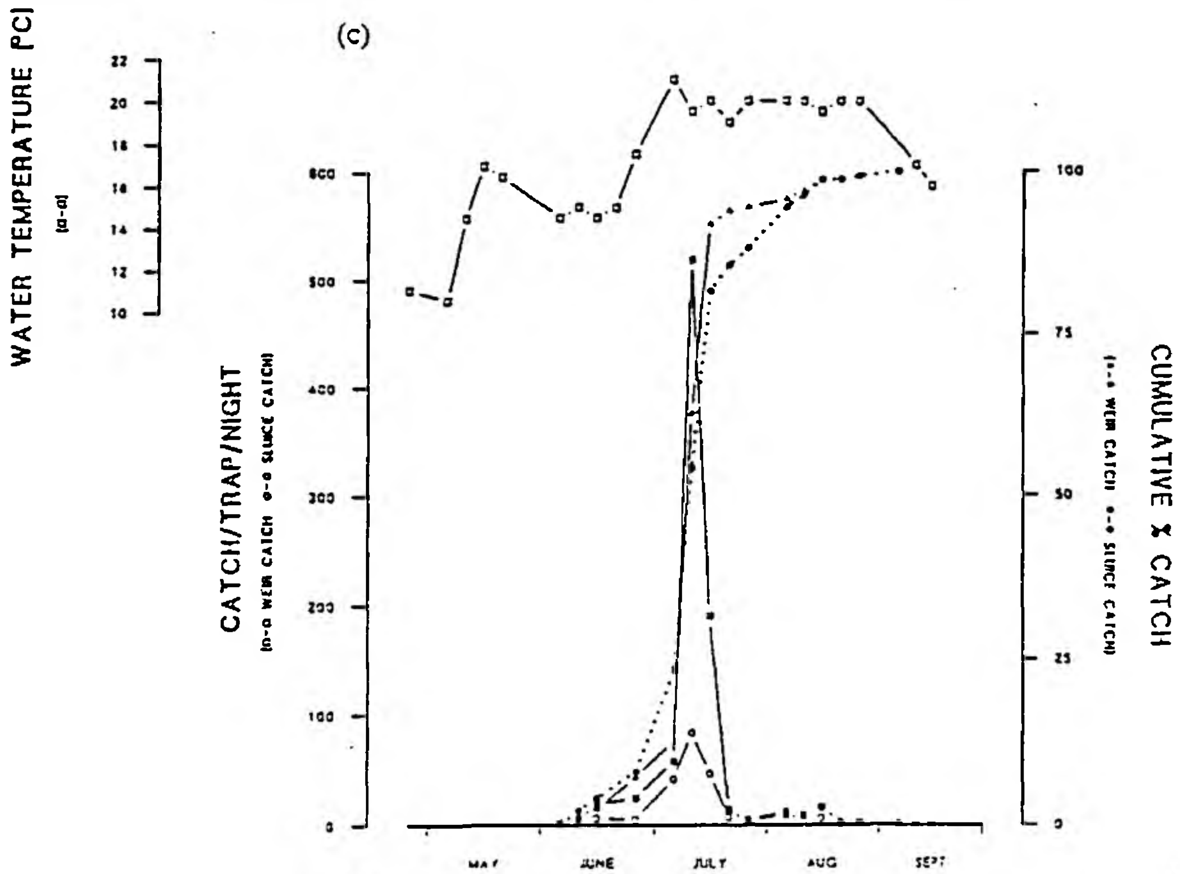


Figure 3.1 Trapping study catch data with time for representative Avon sites at (a) Abbey Mill, (b) Stanchard Pit, (c) Strensham and (d) Nafford. Numbers above peaks in (a) represent predicted high tide levels, mAOD.


(c)
WATER TEMPERATURE (°C)
(□-□)
CATCH/TRAP/NIGHT
(□-□ WEIR CATCH ●-● SLUICE CATCH)
CUMULATIVE % CATCH
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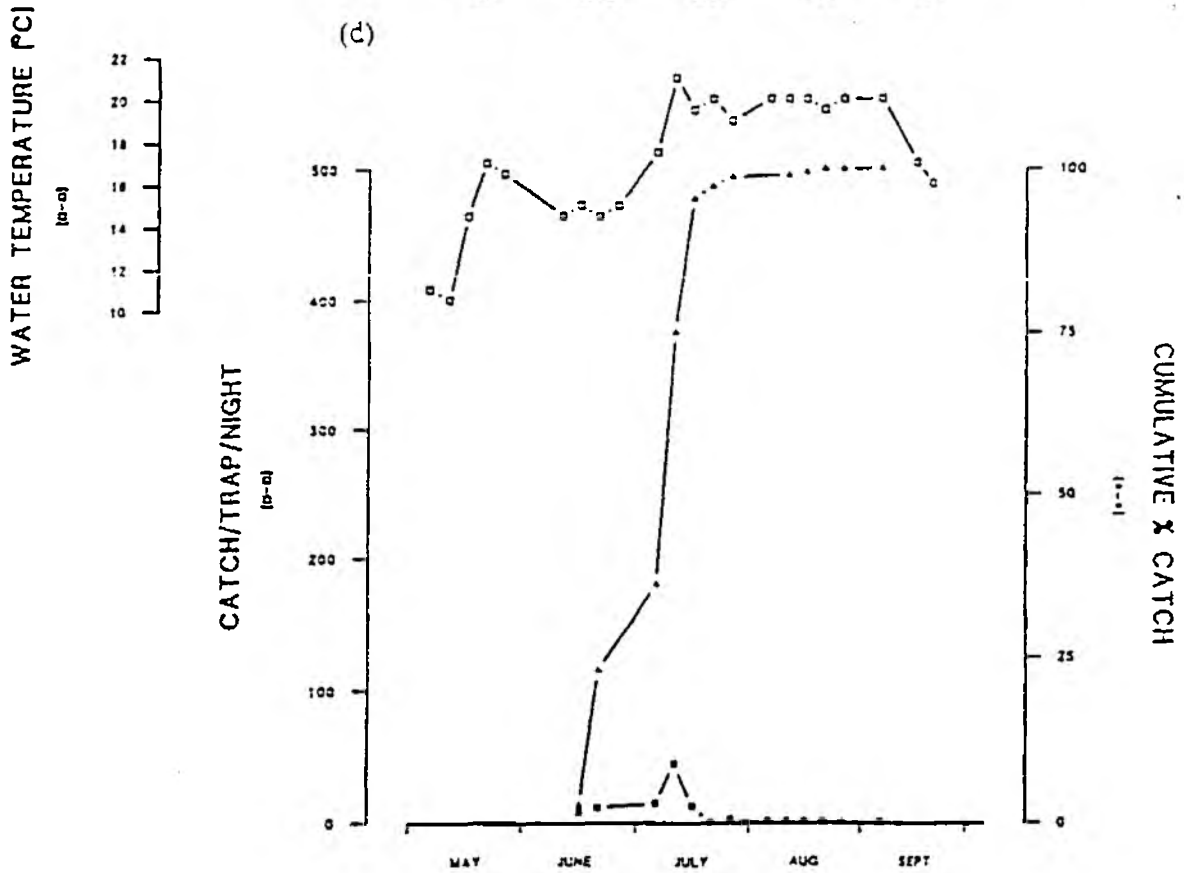
(d)
WATER TEMPERATURE (°C)
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CUMULATIVE % CATCH
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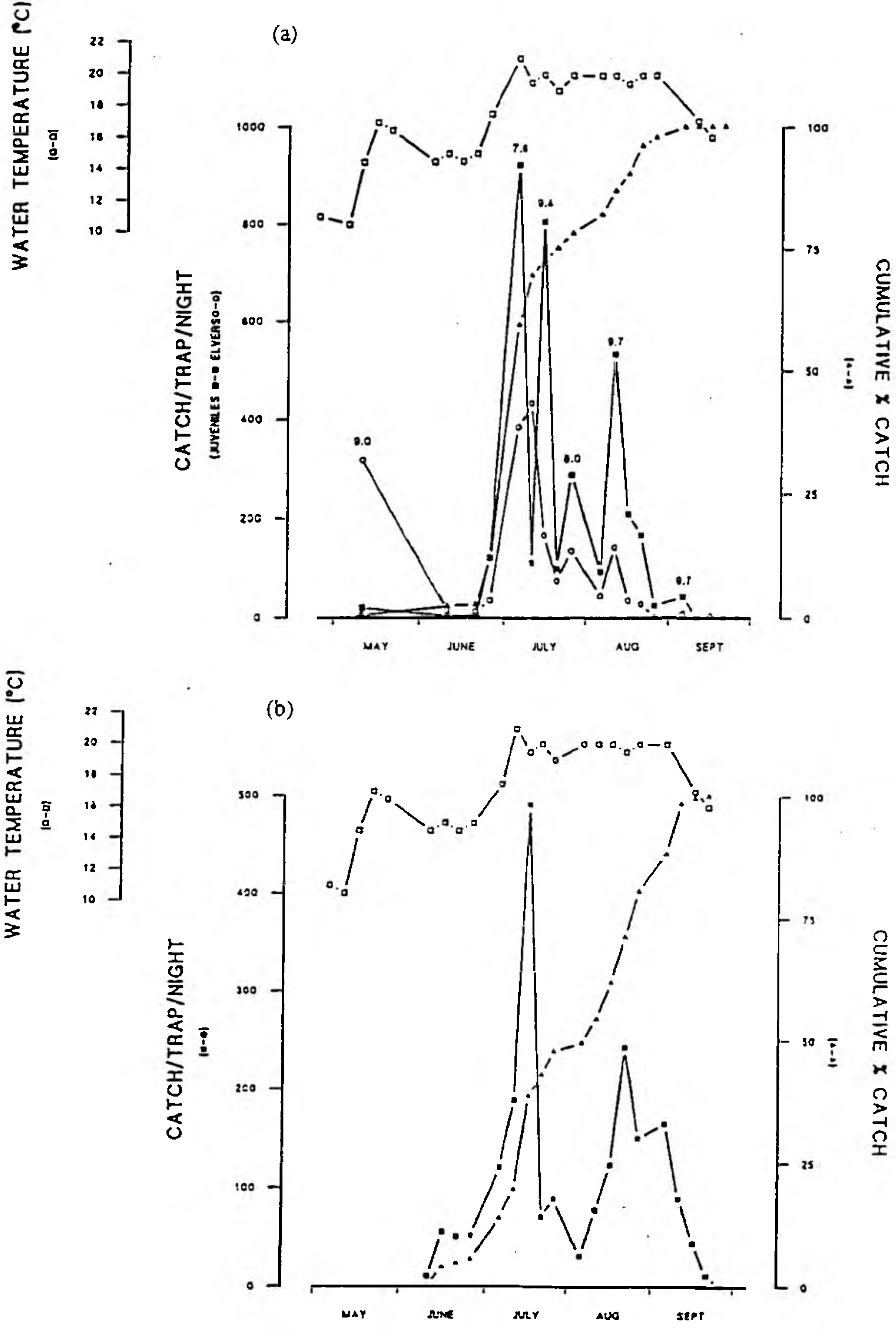
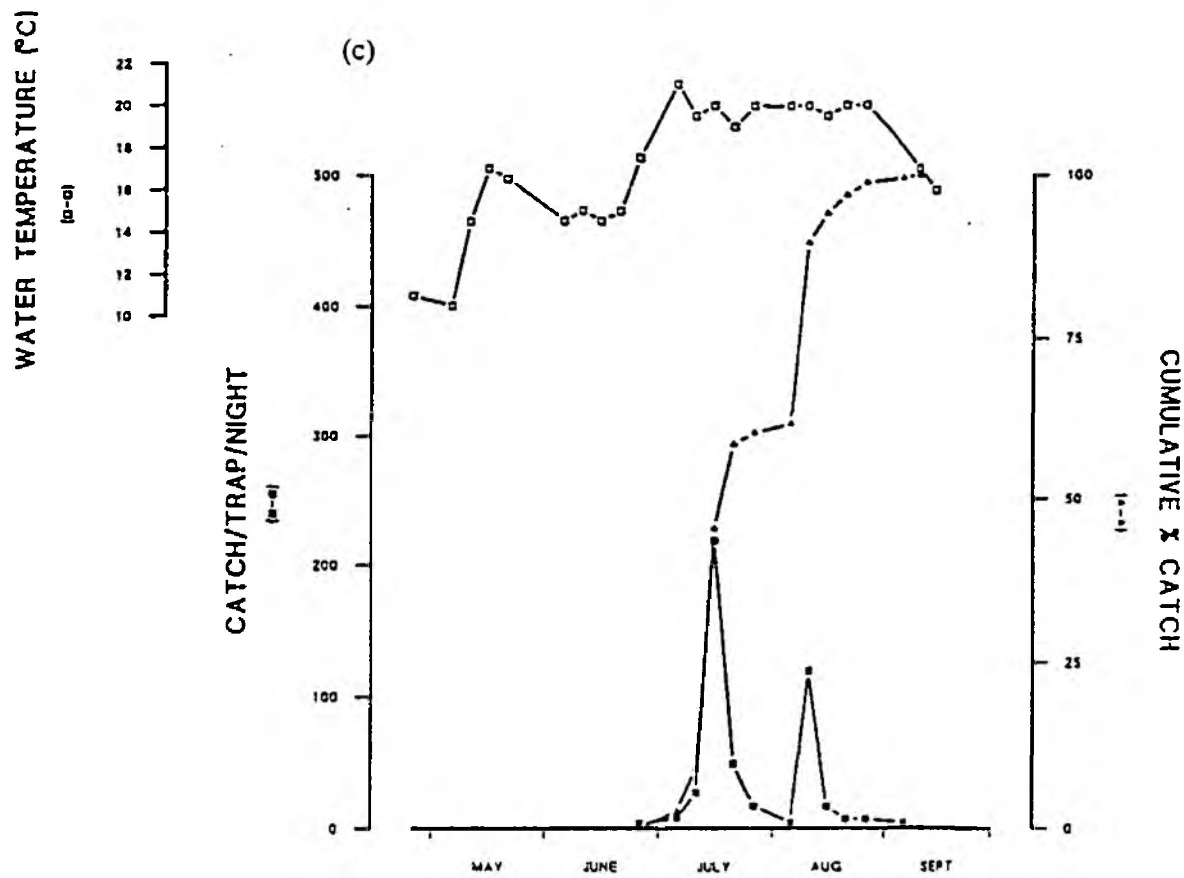


Figure 3.2 Trapping study catch data with time for representative Severn sites at (a) Upper Lode, (b) Diglis, (c) Bevere and (d) Holt. Numbers above peaks in (a) represent predicted high tide levels, mAOD.

(c)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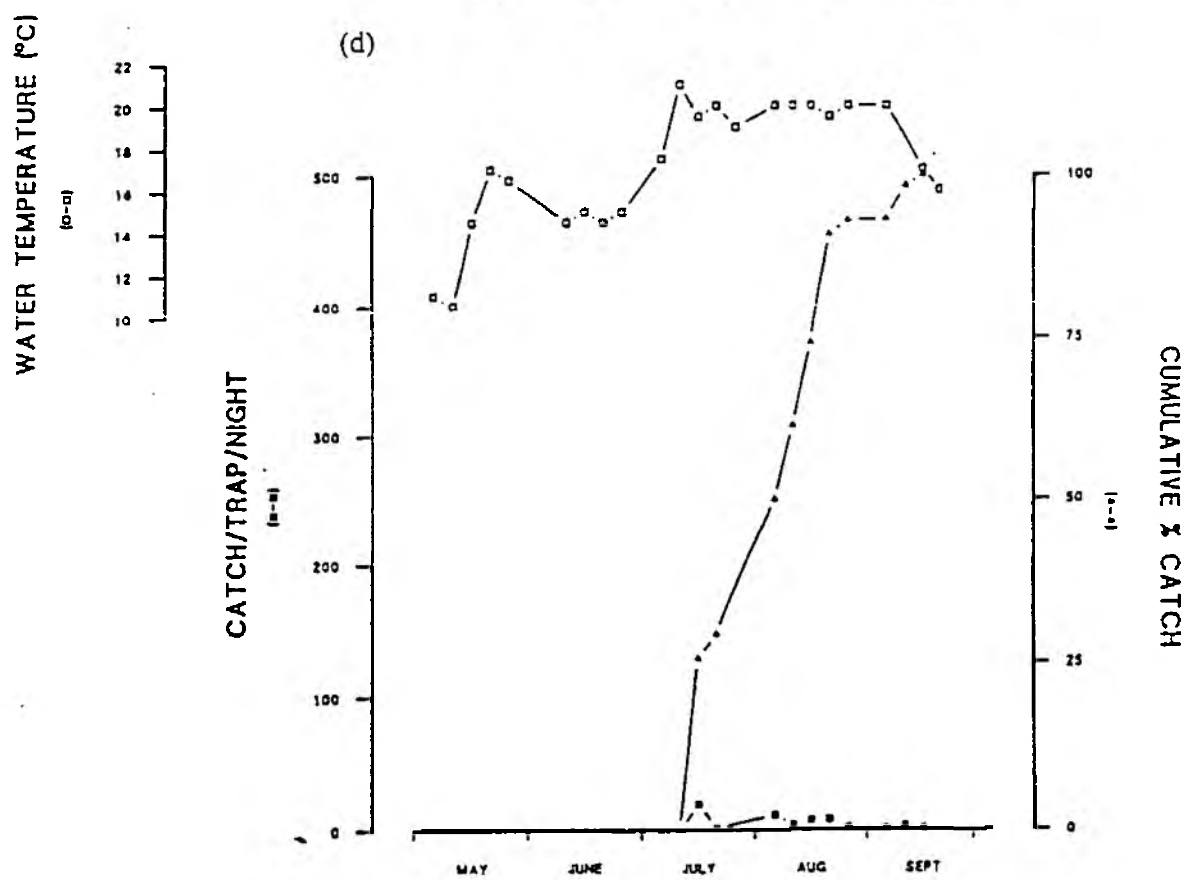
(d)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CUMULATIVE % CATCH
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25
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75
100

The first juvenile eels, i.e. those that have spent one year or more in the estuarine or fluvial zones of the river, were trapped at Abbey Mill on 29 April when the water temperature had reached 10°C, although in very small numbers. Larger numbers of juveniles were captured once the water temperature reached 15°C. Peak catches occurred during the first two weeks of July at all sites except for Abbey Mill Trap D1 (Fig 2.4) where a second larger peak occurred later in August. Other than this peak, the greatest CTN at all traps coincided with an increase in water temperature to >21°C.

Traps at the tidal heads, Upper Lode on the Severn and Abbey Mill on the Avon, showed a multi-peaked catch pattern which possibly correlates with tidal cycles. At all other sites there were two main peaks which were separated by a period of heavy rainfall and hence spate flows at the beginning of August. NRA hydrographic data for 1991 is awaited to assess any correlations between peaks of migration, tidal heights, river flows and water temperature.

3.2.3 Catch numbers with distance from the tidal limit

Figure 3.3 shows the mean CTN per site against distance from the tidal limits. Very few elvers were caught at the tidal limits (about 21,000 in total) compared to the numbers expected, given that lower estuarine recruitment is measured in tonnes. CTNs at Stanchard Pit, 3.4km above Upper Lode, were similar to those at the tidal limit but very few elvers subsequently appeared to migrate further, as noted above. Low catches could reflect poor trap efficiency and/or by-passing of traps (e.g. by climbing faces or banks or via the locks). However, low upriver catches sugggest this is not so. The single Upper Lode trap was probably not very efficient, for the reasons stated above, but the situation is complicated because the weir can be overtopped by some of the highest spring tides. Elver transport over the weir and into the river would explain the waves of catches at Stanchard Pit soon after peak tides. However, no tides were observed to overtop the weir but many eels might were seen to be able to crawl around the banks when tides were at their highest.

The CTN for juveniles greatly exceeded that for elvers. The total catch at the tidal limit exceeded 36,000, the total for all sites exceeded 101,400. The highest CTN occurred at Stanchard Pit. This again is probably due to eels from the estuary by-passing Upper Lode after being carried up-river by high tides. Similarly, catches at Diglis, the first weir up the main Severn, were also very high.

Catches fell very rapidly beyond Abbey Mill/Stanchard Pit on the Avon and Diglis on the Severn, despite the fact that the majority of eels trapped were returned to the river above their point of capture. These findings for the Severn correlate well with the results of Aprahamian (1988). He found that stock densities dropped and age structures of catchment populations of adult eels changed significantly beyond Tewkesbury and Diglis.

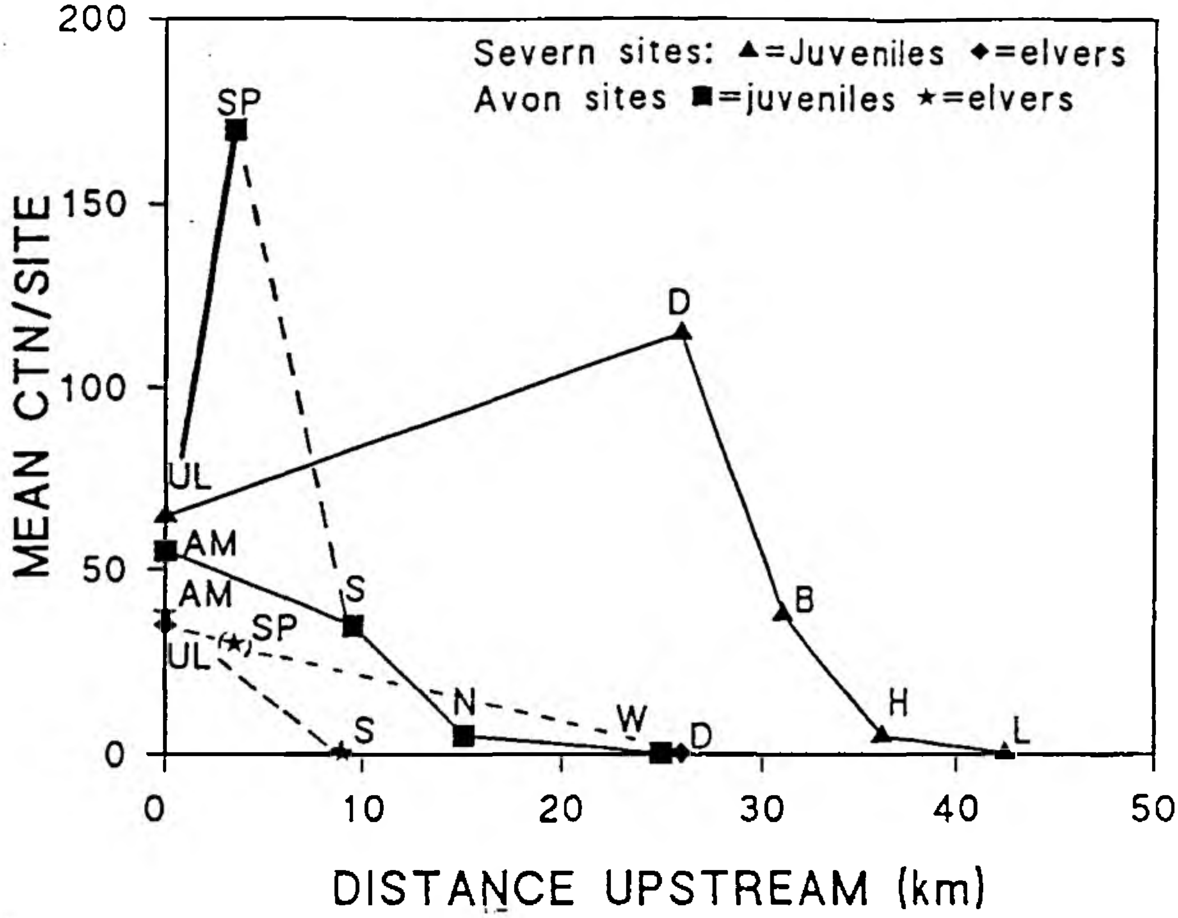


Figure 3.3 Mean catch per trap per night for each trapping site in 1991 (UL, Upper Lode, D, Diglis, B, Bevere, H, Holt, L, Lincomb; AM, Abbey Mill, SP, Stanchard Pit, S, Strensham, N, Nafford, W, Wyre Mill)

3.2.4 Catch composition with time and distance

Mean lengths, weights and condition factors for each month for each trap site are given in Table 3.3 and 3.4. At downstream sites on both the Severn and the Avon, where elvers were trapped in abundance, there was little difference between the monthly means for length or weight. This regime was apparent at Upper Lode, Abbey Mill and Stanchards Pit. For juveniles trapped at downstream sites, mean lengths and weights were similar throughout, although values for Stanchards Pit were about 10% greater than those at Upper Lode and Abbey Mill during May and June. Thus there is an indication that larger individuals tend to migrate earlier in the season.

This becomes more apparent at sites further upstream on the Severn, especially at Diglis and Bevere. Mean lengths and weights are lower during August and September than the previous months. As an example, the length-frequency distributions for each month at Diglis are given in Fig 3.4. This gives a clear illustration that there was a higher percentage of larger migrants trapped during June, July and August than later in the season. This observation is statistically significant when mean lengths for each month are compared (ANOVA $F=8.32$, $P<0.001$). Some of the later arrivals could have originated from downstream trap releases. The lack of marked eels suggests this is unlikely but it is important to note that data sets for some sites are incomplete, therefore rendering an overall analysis less meaningful.

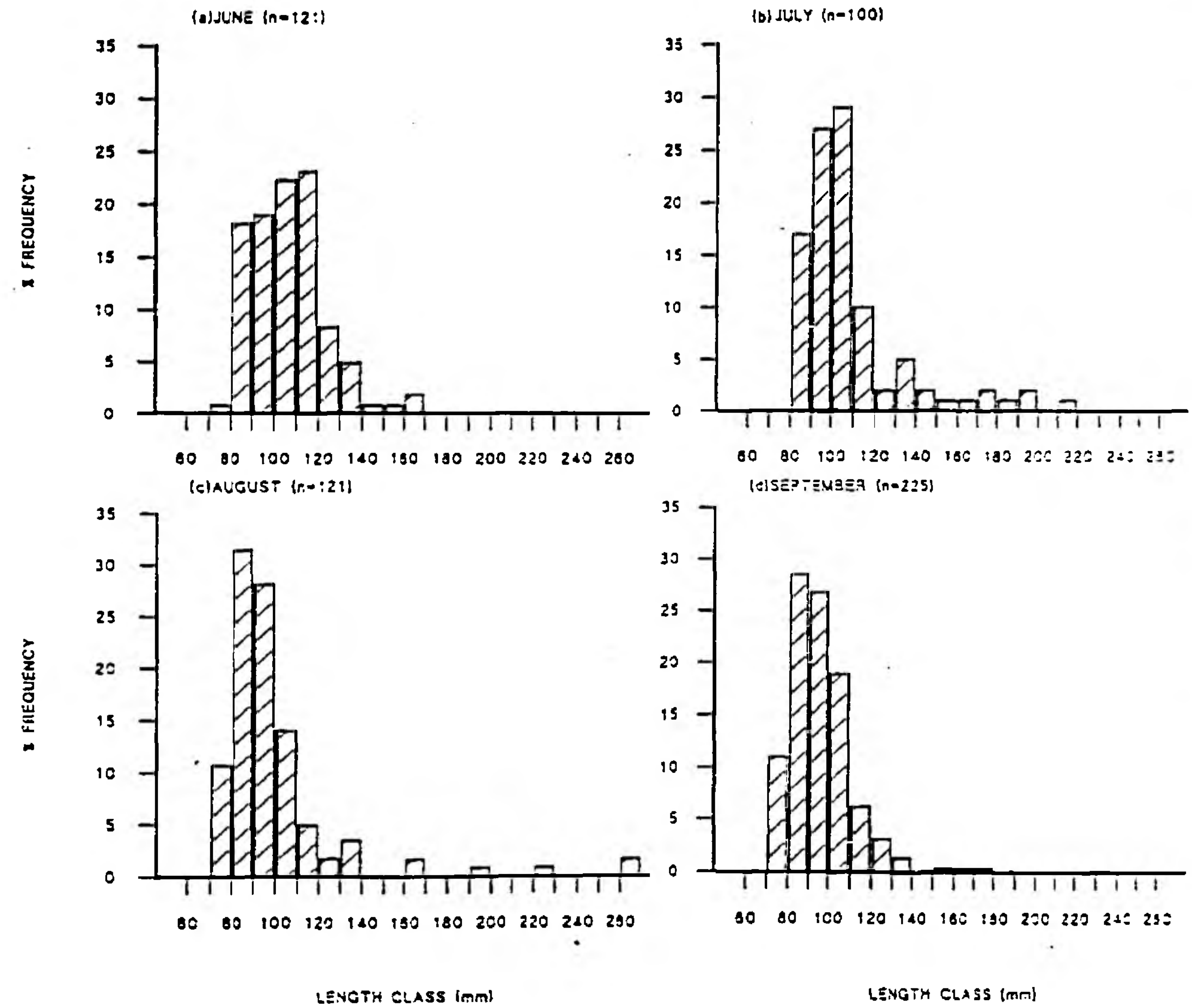
Table 3.3 Mean length (Lmm ± SD), weight (Wg ± SD) and condition factor (CF = (W/L^3) ± SD) for juveniles (or elvers as shown) at each trap site for each month on the Avon. Values in brackets show the range of values.

		MAY	JUNE	JULY	AUGUST	SEPTEMBER
AVON SITES						
Abbey Mill 0km						
	L	87.73±11.92	87.77±15.55	87.49±13.11	85.01±10.90	83.18±7.78
		(70-150)	(69-212)	(68-162)	(71-130)	(70-132)
	W	0.63±0.43	0.80±0.80	0.87±0.54	0.57±0.30	0.47±0.18
		(0.21-3.25)	(0.20-9.61)	(0.25-5.25)	(0.28-2.08)	(0.24-1.82)
	CF	0.85±0.17	0.75±0.14	0.90±0.16	0.87±0.13	0.80±0.12
		(0.49-1.91)	(0.60-1.32)	(0.15-1.76)	(0.49-1.24)	(0.42-1.29)
	L	69.91±0.13	70.14±3.48	68.63±3.16	70.33±3.28	71.10±3.91
		(62-77)	(61-82)	(61-76)	(62-77)	(62-79)
Elvers	W	0.24±0.05	0.21±0.04	0.22±0.05	0.25±0.04	0.23±0.05
		(0.12-0.37)	(0.11-0.45)	(0.11-0.36)	(0.14-0.32)	(0.10-0.30)
	CF	0.69±0.13	0.61±0.08	0.69±0.12	0.71±0.10	0.36±0.06
		(0.41-1.22)	(0.41-0.89)	(0.38-1.08)	(0.45-1.00)	(0.24-0.49)
Stanchard Pit 3.4km						
	L	97.62±21.29	94.98±22.63	85.85±11.44	86.96±11.43	83.86±8.35
		(75-222)	(73-381)	(71-136)	(71-151)	(70-115)
	W	0.97±1.32	0.88±0.77	0.60±0.37	0.58±0.37	0.53±0.20
		(0.25-11.69)	(0.28-9.43)	(0.27-2.6)	(0.27-4.21)	(0.31-1.46)
	CF	0.87±0.17	0.92±0.14	0.87±0.12	0.83±0.12	0.84±0.08
		(0.50-1.32)	(0.64-1.44)	(0.56-1.21)	(0.58-1.22)	(0.70-1.15)
	L	70.60±2.75	71.44±3.79	69.72±2.92	71.62±3.11	71.10±2.7
		(64-75)	(63-79)	(63-75)	(64-78)	(66-76)
Elvers	W	0.24±0.05	0.24±0.05	0.27±0.03	0.26±0.04	0.26±0.03
		(0.15-0.32)	(0.11-0.36)	(0.20-0.32)	(0.17-0.32)	(0.19-0.36)
	CF	0.67±0.13	0.66±0.09	0.34±0.04	0.70±0.08	0.71±0.08
		(0.40-0.83)	(0.38-0.99)	(0.25-0.42)	(0.52-0.83)	(0.53-0.83)
Strensham 9km						
	L		102.58±17.58	103.20±27.13	103.59±28.98	99.18±28.43
			(77-172)	(72-224)	(72-230)	(69-203)
	W		1.23±0.89	1.57±1.98	1.55±2.44	1.17±1.65
			(0.40-6.95)	(0.23-15.28)	(0.33-17.02)	(0.43-3.09)
	CF		1.02±0.17	1.00±0.19	0.97±0.27	0.86±0.14
			(0.62-1.32)	(0.57-1.14)	(0.43-1.3)	(0.60-1.17)
Nafford 15km						
	L		99.18±18.37	113.5±26.43		
			(79-162)	(70-185)		
	W		1.03±0.68	1.85±1.47		
			(0.47-3.62)	(0.26-7.30)		
	CF		0.96±0.12	1.03±0.14		
			(0.68-1.25)	(0.76-1.40)		
Wyre Mill 25km						
	L		120.41±37.34	146.50±29.45		
			(82-230)	(113-213)		
	W		2.44±3.20	3.77±2.84		
			(0.42-16.8)	(1.29-12.09)		
	CF		0.95±0.16	1.04±0.21		
			(0.67-1.38)	(0.81-1.99)		

Table 3.4 Mean length (Lmm ± SD), weight (Wg ± SD) and condition factor (CF = (W/L³) ± SD) for juveniles (or elvers as shown) at each trap site for each month on the Severn. Values in brackets show the range of values.

		MAY	JUNE	JULY	AUGUST	SEPTEMBER
SEVERN SITES						
Upper Lode 0km						
	L	75.57±9.01 (61-102)	89.87±15.02 (77-124)	84.23±20.34 (79-208)	86.38±9.34 (68-115)	83.29±7.26 (70-112)
	W	- -	0.73±0.53 (0.42-2.14)	0.76±1.83 (0.18-19.36)	0.67±0.25 (0.31-1.52)	0.56±0.20 (0.29-1.38)
	CF	- -	0.89±0.12 (0.76-1.22)	0.94±0.50 (0.20-1.58)	0.99±0.10 (0.67-1.32)	0.94±0.13 (0.67-1.32)
	L	- -	70.68±3.36 (62-76)	69.49±3.05 (82-77)	69.22±2.25 (67-76)	69.33±3.37 (61-74)
Elvers	W	- -	0.24±0.03 (0.18-0.29)	0.23±0.05 (0.13-0.29)	0.27±0.04 (0.21-0.34)	0.24±0.03 (0.17-0.28)
	CF	- -	0.67±0.06 (0.57-0.80)	0.69±0.12 (0.40-1.03)	0.83±0.12 (0.64-1.08)	0.74±0.17 (0.54-1.19)
Diglis 26.5km						
	L		106.07±17.20 (72-187)	107.66±25.56 (81-210)	99.54±31.96 (71-285)	95.59±21.30 (73-319)
	W		1.18±0.78 (0.33-5.81)	1.44±1.70 (0.37-10.6)	1.29±2.52 (0.33-31.80)	0.99±2.29 (0.30-33.80)
	CF		0.84±0.12 (0.64-1.25)	0.91±0.15 (0.26-1.35)	0.94±0.14 (0.61-1.72)	0.89±0.17 (0.42-1.31)
Bevere 30.5km						
	L		110.20±22.30 (89-137)	130.62±38.77 (80-252)	105.08±29.82 (77-225)	90.55±9.22 (75-105)
	W		1.64±1.17 (0.79-3.27)	3.00±3.39 (0.38-21.90)	0.97±0.14 (0.67-1.37)	0.66±0.20 (0.31-1.04)
	CF		1.07±0.15 (0.92-1.27)	0.97±0.14 (0.67-1.37)	0.95±0.19 (0.50-2.01)	0.74±0.15 (0.41-1.10)
Holt 36km						
	L			115.94±21.24 (81-172)	141.28±35.22 (83-216)	105.16±21.73 (83-216)
	W			1.84±1.17 (0.45-7.12)	3.81±3.08 (0.54-13.69)	1.30±1.15 (0.54-13.69)
	CF			1.06±0.19 (0.72-1.98)	1.10±0.19 (0.09-1.41)	0.96±0.07 (0.82-1.11)
Lincomb 42.5km						
	L				101.81±21.65 (82-182)	
	W				1.14±1.05 (0.46-4.56)	
	CF				0.93±0.30 (0.64-1.82)	

Figure 3.4 Length-frequency histograms for Diglis weir during June-September 1991.



Condition factors appear to follow a similar trend as lengths and weights, with migrants trapped during September having a lower condition factor than those caught in earlier months. This may reflect the effects of increasing competition as eels grow during the summer and biomass per unit area increases. Condition factors for elvers were consistently lower than those for juveniles.

3.3 Laboratory experiments on pass designs

A vacation student was employed to set up and run these experiments in parallel with field experiments during the summer. Unfortunately this work had to be curtailed because of shortage of funds, but will be resumed when data analysis and report writing is complete. However, some pilot studies of short duration were completed. Results indicate that under the test conditions used, climbing media were most effective and least prone to size selectivity in the order: Horticultural netting > 'Fish-Pass' nylon brush > Enkamat and other geotextiles > Astroturf.

3.4 Mark-recapture studies

3.4.1 Marking techniques

Vital dyeing experiments showed that very few dyes readily stained elvers without affecting health and survival (Table 3.5). Only four dyes actually stained the elvers and of these, basic orange and gentian violet caused mortalities and severe stress. Bismark brown and neutral red were reasonably successful but both, ideally, need further testing to ascertain the optimum dye concentration:elver biomass ratio to produce a good colour without undue stress. However, these stains were only retained for 2-3 weeks, a result that agreed with observations of elvers stained by BCF during their mark-release study.

The staining and mark-release experiments originally planned for the estuary fishery study were curtailed because of;-

1. Potential confusion with the BCF study in the Severn estuary

2. Lack of material during the elver season

3. The lack of time during the upriver migration phase because of the need to install traps as early as possible.

4. The longevity of vital staining is too short relative to the probable length of time taken to migrate from one trap site to the next.

Instead, efforts were focussed at an early stage on more permanent marking of elvers and juveniles with sub-epidermal injections of acrylic paint.

Table 3.5 Results of preliminary trials for staining elvers for mark-recapture studies. All trials were carried out on 50g (approximately 150) of elvers in 1l of dye solution over 2-12 hours, (successful staining = X, unsuccessful = O).

Dye	Concentration cm^3l^{-1} 0.01	0.05	0.10	Comments
Basic orange	X	X	X	Successful but stressful due to solvent
Safronin O (red)	-	O	O	
Toluidine blue	O	O	O	
Gentian violet	X	X	X	Successful but some mortalities and mucous sloughing
Light green	O	O	O	Stained tip of lower jaw only
Methylene blue	O	O	O	Stained gills and olfactory epithelia
Nigrosine (black)	O	O	O	
Lisamine green	O	O	O	
Rhodamine red	O	O	O	Stained at higher concentrations but caused stress
Bismark brown	X	X	X	
Neutral red	X	X	X	

3.4.2 Trap efficiency and migration studies

Injection of acrylic paint as a marking tool was highly effective but time-consuming. Identification of marked individuals amongst large trap catches, often consisting of a thousand or more eels, was also time-consuming. It often proved impossible to examine every individual closely and some marked eels were probably missed.

Of 689 elvers and juveniles marked and released, only 9 were recaptured (Table 3.6). Of these, only one appeared to have by-passed the trap above the point of release, suggesting traps were reasonably efficient. Recaptures occurred between 15-38 days after release. Most of the releases bore batch rather than individual marks. Of the recaptures made, the two at Abbey Mill on 17.7.91 and the one at Strensham on 25.7.91 were identifiable from individual marks. The latter individual had taken 38 days to travel 9.5km, implying a migration rate of 0.25km/day. During this time, length had not changed but the eel had lost about 0.03g in weight. The two individuals caught at Abbey Mill had taken 30 days to cover the 200m from the downstream release site. One of these eels had grown 4mm in length and gained 0.09g in weight, whilst the other had not increased in length, but had lost 0.07g in weight.

Table 3.6 Mark-release data

Release date	Site *	No. released	Recaptures
1 June	Abbey Mill	17 elvers 54 juveniles	0 0
3 June	Abbey Mill	29 elvers 49 juveniles	0 0
17 June**	Abbey Mill	90 juveniles 51 elvers	2 at Abbey Mill, 17 July 1 at Strensham, 25 July
19 June	Abbey Mill	159 juveniles 145 elvers	0 0
19 June	Diglis Weir	95 juveniles	4 at Diglis,4 July 1 at Diglis,9 July 1 at Diglis,17 July

Notes: * All batches were released below the weir/sluice at each site
** Juveniles and elvers given unique individual marks, all others were given batch marks only.

3.4.3 Stocking studies

No information can be gained from the marked fish stocked into the Avon until 1992.

3.5 Additional data collection and analyses

This section of the project is proceeding as data becomes available and will be covered in future Progress and Interim Reports. Unfortunately, the EIFAC Working Party on Eel was not able to guarantee international support for the suggested collaborative migration study (Appendix A). Personal contacts are, however, being maintained and relevant data from Europe collected.

4. DISCUSSION

4.1 Elver migration and exploitation

4.1.1 Questionnaire and field studies

Some elver stations and fishermen were willing to communicate verbally with the Contractors but would not provide written information. In general, most fishermen were secretive about times, places and quantities of elver caught. However, the questionnaire approach will be attempted again in 1992 but using more direct and personal approaches on the river bank.

Although elver catches were generally poor, the individual catch data collected by the Project Research Assistant appeared to follow the general catch trend for the fishery, as judged from non-quantitative observations of catches brought into the elver stations. The 1991 elver season was said by many of the older, more experienced fishermen to have been the worst in living memory. The elver run was poor but the effects of weather, spates and low river temperatures on expected migration patterns were obviously of major importance. Churchward and Hunt (1977) also noted that rain and cold weather deter elver movements which should follow fairly predictable pattern of selective tidal stream transport (Creutzberg, 1961; McCleave and Kleckner, 1982). The lack of elvers caught below Gloucester correlates with fishermens observations that the emphasis of the fishery has shifted upstream of the Epney region in more recent years. This, and the sagging behaviour of elvers, could relate to the deterioration in water quality in that area noted by NRA (1991), due to increases in organic loads from Gloucester STW. Further studies are perhaps needed here. It will be interesting to see if catches of 1 year old juveniles at the tidal limits are larger in 1992 than 1991. If this occurs, it could imply that many elvers were unable to migrate through the estuary but did manage to survive.

Annual catches of elvers for many European rivers have shown a decline over the last decade or two (Moriarty 1990, 1991). No detailed figures are available from the elver stations for the Severn fishery, only NRA estimates exist. However, the Project Research Assistant was able to examine (but not record) a detailed catch data set belonging to a team of 10 elver fishermen who have been fishing together since the late 1970s. Records kept since 1978 showed a serious decline in catches from 1983 in comparison to catches taken in the late seventies and early eighties. This agrees well with with published data presented by Moriarty (1990), especially for French rivers, and by Belpaire (1987) for the R. Yser in Belgium. The years 1987 and 1988 showed improvements in general catches but more recently catches again showed declines (Moriarty, 1991). Gerault et al. (1991) have also confirmed a decline in the French elver fisheries through contact with fishermen, who claimed a general decrease in catches from 1977 onwards.

It was hoped the 1991 study might throw some light on the Severn fishery and the reasons for declining migrations but, as pointed out above, the season was probably an aberrant one. However, indirect sources suggest the Severn catch was about 7 tonnes, an approximation confirmed by Peter Wood of BCF. Catches from the Parrett were poor, those from the Wye negligible. Catches in the northerly French fisheries were very low in 1991 but those in the south were about 3 times the 1990 level. Reports indicate that elver catches in the south of France this spring (1992) are currently much lower than those of 1991.

4.1.2 Elver mark-recapture studies

From the experience of 1991, the problems involved in initiating a large scale mark-recapture study to estimate elver numbers in the tidal zone of the Severn are manifold. Apart from perfecting a marking technique, detailed data including the number of marked fish returned to the elver station, the sources and weights of the individual catches containing the marked fish and the total catch from the fishery for each night would be required.

Some information was gained indirectly and from Peter Wood about the BCF study. Two batches of dyed elvers, one of 10kg and one of 5kg (i.e. about 45,000 elvers in total) were released. Information about actual numbers and release sites was not available but only a few hundred were recaptured (P.Wood, Pers. Comm.). BCF has estimated total elver numbers from this study but results have not been released. Elver recapture rates have been found to be very low in other studies, e.g. Domingos (1991), using elvers dyed with neutral red and Bismark brown in the Mondego estuary, Portugal, only achieved $<1\%$ recapture on each night up to 5 nights after release. She concluded that rapid upriver dispersion on tides and overall high abundance were the causes. Recapture rates were also small in a tributary of the River Thames (Naismith and Knights, 1988). However, Tzeng (1984), using fluorescent dyes to mark Anguilla japonica elvers in a Taiwanese study, recovered 47.15% of the marked individuals. These were all caught by fishermen in coastal and tidal waters. Some variation in recapture rates did occur and the marked individuals were found to be widely dispersed. These studies, although successful, did not attempt any quantitative estimates of elver numbers from the data collected. Size and openness of estuaries, rapid dispersion and variable tendencies to migrate are probably major factors influencing elver movements and hence capture.

Eel population estimation by mark-recapture are fraught with potential errors, being strongly dependent on the following (Naismith and Knights, 1990);

1. Constant effort being used

2. No emigration, immigration, recruitment or mortality

3. No catchability bias

4. Marked individuals are easily recognisable.

It is difficult to say whether a constant effort was applied to the elver fishery in this unusual season. However, the first three criteria in (2) above are certainly not satisfied as the elver stock does not represent a closed population. Also, dyed elvers may be more stressed and prone to natural mortality and predation than unmarked individuals. Catchability bias (criterion 3) was certainly introduced because some fishermen threw away dyed elvers, assuming them to be unsaleable. In relation to (4), vital dyes have been noted earlier in this Report to only be recognisable for a relatively short time (e.g. 2-3 weeks for neutral red). It was also difficult to count marked elvers amongst the thousands brought in to BCF, especially as colours began to fade.

An interesting point arising from the BCF study is that at least one marked elver released in the Gloucester area was reported to have been recaptured, not long after release, in the River Parrett, near Bridgwater, another being found in a river near Weston-super-Mare. If correct, this implies that elvers can drop back downstream a considerable distance. This could be a common but so far unrecorded phenomenon, perhaps connected with the very large tidal movements in the Bristol Channel. It could, however, be due to the unusual flow and temperature conditions in the Severn estuary this spring. Alternatively it could have been due to aberrant behaviour following the stress of capture, marking and release.

4.2 Weir/sluice trapping programme

4.2.1 Trap efficiency

The success of the first years' trapping programme was encouraging. Some migrants were observed climbing weirs and some were caught by hand-netting near and under traps. However, only one marked eel was found to have by-passed traps. The trap at Upper Lode was probably the least efficient, for the reasons stated earlier. Eels could migrate via locks but Liew (1982) found that few did this in the St. Lawrence River probably because current velocities are less attractive than those in the main river channel. Elvers are attracted by moderately fast currents but are inhibited by very fast ones (Tesch, 1977; Deelder, 1984). Maximum current velocities should generally be less than 0.6 ms^{-1} for elvers, 1.5 for larger juveniles (Sorenson, 1951). In the present study, traps mounted on sluices consistently caught fewer migrants than those on weirs at the same sites. The attractive flow from weirs may be greater than that of sluices, or possibly, the site-specific orientation of the latter may be important. Further field and laboratory assessment of trap efficiencies are planned, including comparisons of commercial designs.

The data collected per site with time are not fully comparable because traps had to be mounted sequentially as suitable sites were located. There were also delays whilst necessary permissions were gained and the traps designed, made and mounted according to individual site characteristics. Experience gained will allow earlier and simultaneous installation in 1992.

4.2.2 Upriver migration of elvers and juveniles

Mean CTNs for elvers and for juveniles were similar at both Abbey Mill and Upper Lode, despite the different number of traps at each site. Many eels probably surmounted Upper Lode, as witnessed by the larger CTNs at Stanchard Pit. The large CTN of juveniles at Diglis was probably mainly due to eels that had entered the non-tidal river in preceding years.

Total trap catches of elvers at Tewkesbury appear relatively low at about 19,500 (6.5kg), or 27,400 (9.1kg) if the Stanchard Pit catches are included. This compares to the estimated yield of the fishery of about 7 tonnes (21 million). It must be remembered, however, that an unknown amount of elvers were brought in from other rivers such as the Parrett and, it is believed, from rivers as far away as the south and north-west of England and from Wales. It is doubtful that the Severn fishery could have removed virtually the whole of the local elver run. Instead, the run was probably very poor and migration was further interrupted by weather and temperature.

Elvers naturally delay migration at the main salt/fresh water interface in estuaries as they adapt to the change in salinity (Deelder, 1984). According to Domingos (1991), migration is inhibited when the sea water/river temperature difference exceeds 3-4°C and if the water column is strongly stratified. Low water temperatures have been noted to delay migration in various European rivers, e.g. the Gudena in Denmark (Dahl, 1983), Imsa in Norway (Hvidsten, 1985) and Shannon in Ireland (Moriarty, 1986). The same effects, especially when exacerbated by strong cold winds blowing down the estuary, are claimed to occur in the Severn (Churchward and Hunt, 1977). These conditions probably existed this spring, helping to explain poor catches above the saline front in the Gloucester area and the sagging behaviour below Maisemore and Llanthony Weirs. Poor water quality due to organic loads from Gloucester STW (NRA, 1991) could also play a part. These possibilities will be further explored as relevant hydrographic data for 1991 becomes available. It is likely that natural mortality of elvers would have been very high. Elver survival will be indicated by the number of 1+ juveniles trapped in 1992. Moriarty (1986), for example, found juvenile migrations in one year in the Shannon reflected the size and success of elver recruitment in the previous year.

On the basis of only one years data, it is difficult to meaningfully compare the number of elvers migrating beyond the tidal and fishery limits with other rivers. Furthermore, many differences exist in methodologies, physiography, distances involved and large variations between years (Deelder, 1984). Elvers did not appear to reach Tewkesbury in any numbers until mid-June/early July and migration continued into September. The data of Moriarty (1986) and Naismith and Knights (1988) suggest inverse relationships between the duration of runs and the quantity of recruits to rivers. Late migrants caught at Tewkesbury in 1991 could have been delayed in the estuary or represent late arrivals from the Atlantic to the Bristol Channel/Severn Estuary. Aging and examination of pigmentation of elvers will help clarify these points.

Timing of runs in the Severn and Avon appear to be strongly related to water temperature. Elvers were caught in the traps at the tidal head when the water temperature was around 10°C. Juveniles, however, were not caught until the water temperature reached 14-15°C. This is in agreement with the observations of Moriarty (1986) who first noted eels migrating at 13-14°C, but slightly greater than the 10-14°C measured by Naismith and Knights (1988). Deelder (1984) quotes that main elver and juvenile runs commence in a range of rivers between 10-17°C.

Peak catches correlated with a rise in water temperature to around 21°C. This temperature was the greatest recorded. In previous years the highest water temperature corresponded with the lowest river flow rates (unpublished NRA data), indicating that river flow may also be an important factor. Indeed, the double catch peaks so prominent in the data at Stanchard Pit (Fig 3.1) and Diglis and Bevere (Fig 3.2) were separated by a period of heavy rainfall and hence increased river flow. This suggests that the migrations of juvenile eels is triggered and controlled by abiotic factors.

The length-frequency composition (no aging has yet been possible) of the migratory population in the Severn and Avon appears to be the opposite to that found by Moriarty (1985) in the River Shannon. There he found smaller migrants (< 10cm) tended to move during the period mid-June to mid-August, larger individuals (> 15cm) migrating continuously throughout the season. In the present study, smaller eels were trapped at the downstream sites throughout the trapping period, with the larger migrants being caught from June to August. Although fewer small migrants were found further upriver, they continued to migrate throughout the season. These could have originated from trap catch releases but few marked eels migrated very far. Catches fell rapidly with distance from the tidal limits up both the Avon and Severn. Aprahamian (1985, 1988) concluded that elvers should theoretically be able to migrate at least as far as Diglis up the Severn and Wyre Mill up the Avon in their first riverine year. The obstructions at Abbey Mill, Stanchard Pit and Diglis appear to be major barriers to migration, movement over Upper Lode being improved at times of high tides and occasional overtopping. The effects of these physical barriers will be exacerbated if migration is density-dependent, i.e. low recruitment to a stretch leads to low densities and hence competition which may then reduce the migratory urge. Agonistic behavioural effects will also be reduced (Knights, 1987). Furthermore, Pesaro et al. (1981) have shown eels release pheromones which might be attractive to potential migrants. These would decrease in concentration in river flows if upriver densities were low.

The effects of these barriers on migration correlate with the absence of eels or low adult stocks (except where augmented by artificial stocking) deeper in the Severn catchment according to Aprahamian (1985, 1988). Furthermore, he found population densities decreased by one or two orders of magnitude above Diglis on the Severn and Tewkesbury on the Avon. The change in biomass was not so marked because of an increasing preponderance of females that mature later than males and at a larger size. A similar situation was seen in the Thames by Naismith and Knights (1992). Stocking at low densities help encourage the development of females to counterbalance the preponderance of males in the estuary and lower river.

4.3 Laboratory experiments on pass designs

Elver/eel passes have been installed on many dams, weirs and sluices throughout Europe (Rigaud et al., 1988). In Denmark, for example, there is a statutory obligation for any weir or sluice owner to furnish the structure with an eel pass at his own expense (Dahl, 1991). However, there appear to have been few objective studies of the best designs or the most efficient climbing media, especially in relation to different sit-specific characteristics.

It would seem from the pilot experiments carried out here that there is a distinct difference in the efficiency of different climbing media. Enkamat is recommended by Dahl (1991), whilst Legault (1991) advocates the use of nylon brush type climbing media. Neither of these appear to be as efficient as the simple horticultural mesh used extensively during the trapping programme in this study. Furthermore, there is evidence that materials such as Enkamat are size-selective, allowing the passage of smaller eels more readily than larger ones. Experiments, both in the laboratory and in the field, will be continued to investigate these factors.

4.4 Mark-recapture studies

4.4.1 Marking techniques

Vital staining of elvers with neutral red and Bismark brown showed some promise mark-recapture studies but the method suffers limitations as discussed earlier. The method is not applicable to marking juvenile eels because their skin does not stain and is too dark, at least on the back and flanks. Sub-epidermal injections of acrylic paint have worked well, despite the time involved and problems of locating marked fish in large catches. This method will continue to be used for marking fish to study migration, trap efficiencies, etc. in 1992.

4.4.2 Trap efficiency and migration studies

The 1991 results, although sparse, do show that the migratory urge is variable within the population. This was exemplified by the fact that only 9 recaptures occurred from 689 releases over 15-38 days. A similar scenario was noted by Naismith and Knights (1988). Only one release apparently by-passed the trap above the release point. This individual, caught at Strensham Weir after release below Abbey Mill, had moved approximately 0.25km/day. Two other individuals released at the same time and location took a similar period to move only 200m. More recaptures should be expected in 1992 and 1993.

4.5 Additional data collection and analyses

These will proceed as data becomes available and will be included in future Reports.

5 INTERIM CONCLUSIONS

5.1 Elver migration and exploitation

Cooperation from fishermen and most elver stations was minimal. However, fishing studies, observations and information gained indirectly showed that elver catches for 1991 were very low at about 7 tonnes. This approximation has been confirmed by Peter Wood of Bristol Channel Fisheries. Elver runs appeared to be low but expected migration and fishing patterns were abnormal because of spates, unfavourable winds and low water temperatures. Water quality below Gloucester might also be important. New studies are planned for 1992 when, hopefully, a more normal season will occur. Correlations with NRA hydrographic data will be examined when available. Insufficient data is available at present to assess fully the role of density-dependent factors but further studies are planned.

5.2 Weir/sluice trapping programme

Trap designs and sites used yielded good results. Elver runs appeared low but continued in waves at the tidal limit traps from May to September. Above the tidal limit on the Severn, many elvers reached Stanchard Pit, probably due mainly to them scaling the banks at Upper Lode weir on the highest spring tides. Very few, however, reached the next upstream barriers (Diglis on the Severn and Strensham on the Avon) and none were caught further upstream.

Juvenile migrations exceeded those of elvers, running again from May to September. Large catches occurred at the tidal limit but the largest were at Stanchard Pit. This again is possibly due to tidal transport of eels from the lower estuary and scaling of Upper Lode Weir. The next largest catch was at Diglis Weir. Beyond these barriers, catches fell progressively to very small numbers and these tended to be dominated by larger (and hence presumably older) juveniles. Aging of 1991 catch samples is planned for spring 1992.

All weirs and sluices (other than Upper Lode when overtopped) appear to be major barriers to migration, correlating with data on upriver stocks in the Severn. Low densities may in turn reduce migratory urges in potential migrants. The use of passes on such obstructions would be beneficial to recruitment. Even so, low densities may still not encourage migration deeper into the catchment. In this case, addition of traps to passes would provide material for restocking. Restocking at low densities could then help increase the relative proportion of females to recruit to the migrant breeding stock. Further studies on passes and traps are planned.

5.3 Laboratory studies

Pilot studies indicate varying efficiencies and size-selectivity of different climbing media. Horticultural netting, as used in the present study, appears preferable. Further laboratory (and field) studies are planned for 1992.

5.4 Mark-recapture studies

Vital dyeing and mark-recapture methods for studying elver recruitment and exploitation appear less viable than hoped. However, marking by sub-epidermal injection of acrylic paint has proved viable for studying elver and juvenile migration. The method is, however, time-consuming and very few have been recaptured in traps so far. Only one marked eel has by-passed the trap(s) above the point of release, indicating traps are working effectively. More information will be gained from possible recaptures and further experiments in 1992/3.

5.6 Contract Objectives, Strategy, Targets and Timescales

All of these for 1991 have been completed and the Contract is on target according to the agreed timescales.

6. FUTURE PROGRAMME

All current PIA targets have been met or are in progress according to time scale, although elver exploitation studies were less successful than hoped.

From the results of this years work and in consultation with the NRA Nominated Officer, the following future plans and priorities have been decided, adjustable if necessary according to time and funding limitations;-

6.1 Elver migration and exploitation

6.1.1 Data from elver stations

Contacts will be maintained with elver stations and efforts continued to obtain catch and other relevant data from them.

6.1.2 Obtaining data from fishermen

Efforts will be switched into making more direct personal contacts, asking for information and giving out questionnaires on the river bank and, if possible, at elver stations. The former will be done in conjunction with licence-checking visits by NRA bailiffs.

6.1.3 Individual catch and CPUE studies

Hand-netting studies yielded some useful contacts, experience and information. They were, however, very time consuming relative to the amount of data gained. Therefore more effort will be switched to the methods described above.

6.1.4 Assessment of number of fishermen

Information will be gained during bank-side surveys for comparison with NRA licence-sales data. If possible, this approach will be extended to carrying out a 'mark-recapture' survey of fishermen.

6.1.5 Elver mark-recapture studies

The practical problems and accuracy of such methods in assessing exploitation have been questioned in preceding discussions. Such methods will therefore not be used in 1992. BCF are not planning to repeat mark-recapture studies but are planning mid-water trawl surveys in the Bristol Channel/Severn Estuary. It is hoped that collaboration and discussions achieved so far with BCF can be developed further in 1992-3.

6.2 Weir/sluice trapping programme

6.2.1 Pass-trap studies

Installing, maintaining and emptying widely dispersed traps is time consuming and costly but studies have yielded good results. Therefore prototype pass-traps proven successful in 1991 will be mounted on the same weirs and sluices in 1992. More robust and permanent structures (together with commercial designs purchased by NRA) will be installed at Stanchard Pit and Strensham weirs and/or sluices when they are refurbished (see Appendices C-D).

The following extension studies are also planned as time and funds allow;-

1. Stanchard Pit and Strensham; comparisons of relative efficiencies of trap designs and climbing media.

2. Maisemore Weir; this weir, 21km below Upper Lode (Fig 2.1), is the last estuary barrier regularly overtopped (by about 60% of spring tides). Removeable traps will be used so that they can be put in place before and after spring tides to assess the number of elvers and juveniles potentially available for migration up the Severn to the tidal head(s) at Tewkesbury. Comparison with catches at Tewkesbury traps will help provide more information about migration through the upper estuary and possible effects of the fishery in this region.

3. Upper Lode; in addition to the trap on the west bank of the weir (Fig 2.4,G), a removeable trap will be placed on the east bank over selected nights. As discussed previously, the weir/bank configuration here makes it difficult to mount a permanent trap that will work efficiently under all water level and flow conditions. Ease of accessibility is also a problem, as is exposure to vandalism. Hence this trap will be placed at dusk and removed early the following morning at selected times to provide more information about migrants reaching Upper Lode.

4. Overnight studies at Tewkesbury; some overnight/24 hour trapping studies will be carried out at Upper Lode, Abbey Mill and Stanchard Pit to assess diurnal/nocturnal patterns of migration and also the effects of selected tides.

5. Avon weirs; additional traps will be run, if possible, at Fladbury and Chadbury (Fig 2.5) to study migration of marked eels released during the NRA stocking programme experiments (Section 2.4.4).

6.2.3 Aging

Data on migrants is currently based only on lengths and weights. Samples preserved in 1991 will be aged by otolith ring counting to provide further information on growth rates, age at migration, etc. Elvers will be classified according to pigmentation stages. These studies will be conducted before field work begins.

6.2.2 Assessment of eel density

To assess densities, suitably adapted fyke-nets and traps will be used if time allows in 1991

6.3 Experimental trapping site studies

The use of small tributaries or other natural or artificial channels will be explored. These could be useful as mesocosm systems for controlled experiments on effects of stocking density on migration, comparison of trap efficiencies, etc.

6.4 Laboratory experiments

These will be continued before field work commences and during the year as necessary. These will be integrated with field trials as appropriate.

6.5 Mark-recapture studies

Catches will be examined for eels marked in 1991. More eels will be marked with acrylic paint as time allows for release to further study study rates of migration, trap efficiencies, etc.

ACKNOWLEDGEMENTS

The Contractors would like to thank Alan Churchward and other NRA fisheries staff and engineers, Peter Wood and the staff of Bristol Channel Fisheries and his staff, British Waterways Board, Lower Avon Navigation Trust, Geoff Rudman and Greg Spring for assistance during this first year of the programme.

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APPENDIX A

EIFAC WORKING PARTY ON EEL, DUBLIN MAY 1991

THE CURRENT STATUS OF ELVER RUNS THROUGHOUT EUROPE: SUGGESTIONS FOR AN INTERNATIONAL INTEGRATED STUDY IN 1992-3

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Catches of elvers in the Severn Estuary in England have fallen since the late 1970s and this seasons catch will probably be less than 50% of last years (Pers.comm. P.Wood *et al.*). Upriver stocks are also considered low and overfishing of elvers has been suggested as a main cause. Weirs and similar structures could pose obstacles to upriver migration and pollution might also have an affect on recruitment. Concerns about possible overfishing have led the UK National Rivers Authority (NRA) to consider a close-season for the elver fishery beginning in early June. However, the NRA has decided first to fund a 3 year study by Brian Knights and Edward White of the Applied Ecology Research Group to provide management data. This involves estimating ;-

(i) the number of elvers entering the Estuary,
(ii) the number caught by the fishery,
(iii) the effects of barriers to migration
(iv) the possible benefits of elver passes.

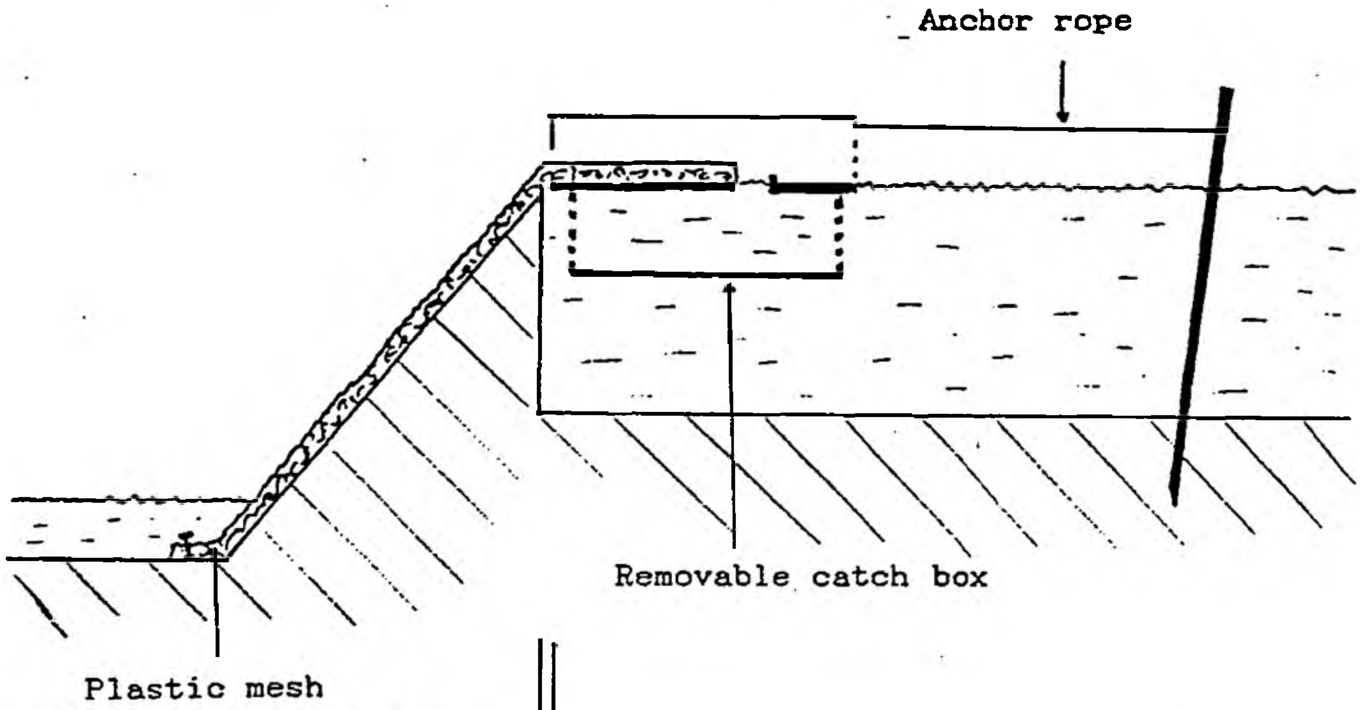
The number of elvers entering and caught in the Estuary is proving very difficult to estimate. The four elver-collecting stations on the Severn are unwilling to provide any data. One station, Bristol Channel Fisheries, has marked (with neutral red) and released 15kg of elvers but less than 1000 individual elvers have been returned (Pers.comm. P.Wood *et al.*). Such a low recapture rate makes accurate population estimation by mark-recapture impossible (Naismith & Knights, 1990). Some 600-700 questionnaires have been distributed through angling shops selling licenses to elver fishermen, but responses have been virtually zero. The secretiveness and mobility of the fishermen has made it difficult to estimate their numbers or catches-per-unit-effort (CPUE). Edward White has spent some time fishing with cooperative fishermen to yield a CPUE of about 0.5kg per night. It is difficult to say whether this is truly representative of the fishery as a whole, but catches have generally been low this year. High river flows and low temperatures (<11 degrees C) have probably contributed to this.

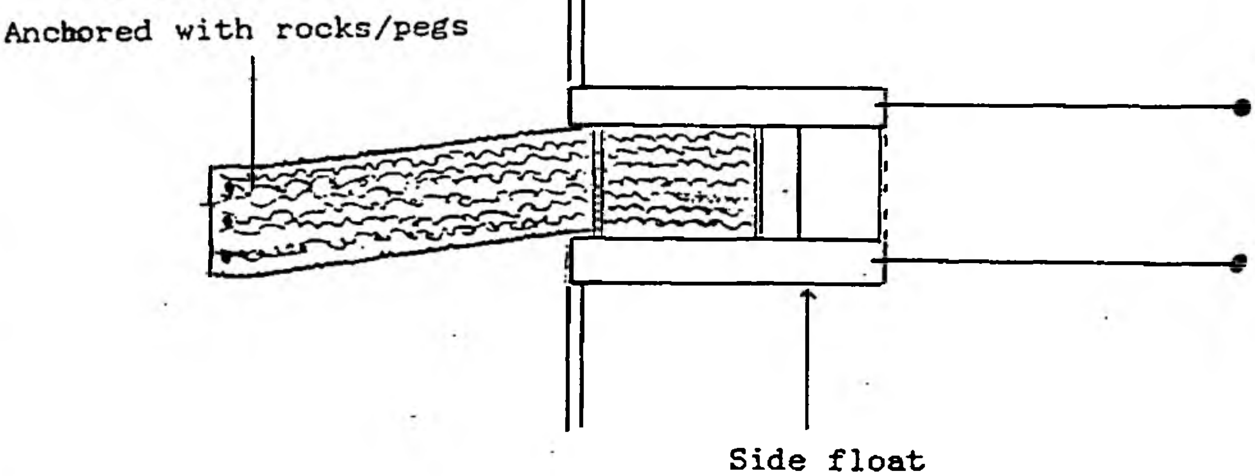
The problems associated with estimating elver recruitment and fishing mortality in the Estuary make it even more important that recruitment to the freshwater catchment is accurately assessed, particularly with regards to possible barriers to

PLANS OF PROTOTYPE ELVER PASSES FOR SEVERN AND AVON WEIRS

(NB not to scale, maximum dimensions of trap head < 50-100cm)

Side-view





View from above

migration facing elvers and juveniles. Weir traps of the type used by Naismith and Knights (1988) have been deployed at the tidal head but catches so far have been very low. High flow rates and low temperatures have probably been important deterrents. Traps with geotextile matting or horticultural mesh have been designed and built, adapted from patterns described in Naismith & Knights (1988) and Rigaud et al. (1988). The latter types will be used on larger weirs and sluices but it has not yet been possible to deploy them because of flooding and high river flows. They are of simple and cheap construction, allowing for losses due to theft, vandalism and flooding. The efficiency of the traps is being tested in the laboratory and, via dye and acrylic paint injection marking, will be field-tested when river conditions allow. Traps further upriver will yield information on upriver migration and recruitment. They will also show how important weirs, etc. are as barriers to migration and whether elver passes might be effective in enhancing recruitment.

SUGGESTIONS FOR A COLLABORATIVE EUROPEAN STUDY

SOME ELVER FISHERIES ARE ABLE TO MAKE REASONABLY ACCURATE ESTIMATES OF CATCHES. DATA SUGGEST ELVER NUMBERS ARE FALLING IN MANY PLACES THROUGHOUT EUROPE BUT THAT DIFFERENCES OCCUR BETWEEN SITES EACH YEAR. WHAT IS NEEDED IS AN INTEGRATED STUDY ON AS MANY ESTUARIES AND RIVERS IN AS MANY COUNTRIES AS POSSIBLE IN 1992 AND 1993, DRAWING ON EXPERIENCE GAINED FROM THE SEVERN STUDY IN 1991. TRAPS WOULD NOT BE EXPENSIVE, BUT REGULAR INSPECTION AND DATA COLLECTION WOULD BE ESSENTIAL. THIS WOULD ALSO BE AN OPPORTUNITY TO SIMULTANEOUSLY COMPARE TIMINGS OF RUNS AND EFFECTS OF ENVIRONMENTAL VARIABLES THROUGHOUT EUROPE.

We welcome offers of collaboration. We hope that sufficient interest will be shown to gain the support of EIFAC, ICES and governmental and fisheries agencies for this collaborative programme.

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APPENDIX B

NRA

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EEL AND ELVER RESEARCH PROJECT BY THE APPLIED ECOLOGY RESEARCH GROUP OF THE POLYTECHNIC OF CENTRAL LONDON

A QUESTIONNAIRE FOR EVERY SEVERN ELVER FISHERMAN

The concern expressed over the decline of elver stocks in the River Severn has resulted in the National Rivers Authority funding a 3 year study to investigate this problem. As an independent body, the Applied Ecology Research group of the Polytechnic of Central London have been asked to carry out this study (please see the attached letter).

This questionnaire is the first step required to assess the elver fishery and the effect it is having on the elvers entering the river. For this project to work we need your help! Therefore we would be very grateful if you could answer the questions below as best you can and place the form in the box provided. Alternatively this form can be returned to the either Ed or Brian, with any additional information you are willing to provide, to the Polytechnic address. We hope to meet many of you during fishing!

(1) Is this your first year elver fishing? YES NO

If no, state how many years you have been fishing for elvers

....

(2) Do you fish for elvers every year? YES NO

(3) Do you fish in a team or on your own? ....

(4) Which village or town do you live in? ....

(5) Do you think there has been a decline in elver catches during the period you have been fishing?

YES NO

DON'T KNOW

If yes, what reasons would you give for this decline?
(i) there are too many people fishing ....
(ii) there are too few elvers entering the river......
(iii) river pollution ....
(iv) other reasons (please specify) ....
....
(v) don't know....................................

(6) Do you fish each individual tide on which it is possible to catch elvers?

YES NO

(7) About how many times did you go fishing last season?

....

(8) What was your total catch last year? ....(kg)

(9) For what reason do you fish for elvers? FOOD TO SELL

BOTH

(10) If you only keep some elvers for food, what proportion do you keep?

..........(%)

(11) Which elver station(s) do you usually sell your catch to?

....

If more than one station, state how much you usually sell to each ....

(12) Are you in favour of a closed season for elver fishing?

YES NO

DON'T KNOW

If yes, when do you think it should start?

(i) end of March.......
(ii) mid April..........
(iii) end April..........
(iv) mid May............
(v) end May............

(13) Would you agree to a restriction in the number of net licences available to elver fishermen?

YES NO

DON'T KNOW

(14) Do you have any other suggestions, apart from a closed season, for managing the elver fishery?

....
....
....

(15) To assist our research into the Severn elver stocks, would you be prepared to keep a diary of when and where you fish and how much you catch each time you go fishing?
(THIS INFORMATION WOULD BE KEPT CONFIDENTIAL)

YES NO

If possible, would you be willing to provide similar detailed information you have collected in previous years?
(AGAIN, THIS INFORMATION WOULD BE KEPT CONFIDENTIAL)

YES NO

If you answered yes to either question in (13) above, please write your name and address below

Name..
Address...
....
....
Telephone number......................................

Thankyou for your co-operation,

Ed and Brian.

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STUDY OF ELVER AND EEL STOCKS

IN THE SEVERN

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Dear Sir,

STUDY OF ELVER AND EEL STOCKS IN THE SEVERN

As you have probably heard, NRA Severn-Trent Regional Fisheries Advisory Committee have decided not to impose a close season on elver fishing until the completion of a three year study of stocks. The NRA are obviously as concerned as you are about possible falling catches, loss of income and effects on stocks of eels further upriver. They have therefore asked the Applied Ecology Research Group of the Polytechnic of Central London to carry out a study to estimate;-

1. The number of elvers entering the estuary.

2. The number that are then caught by fishermen.

3. The number that then survive and are able to climb weirs and other barriers to get up the main river and tributaries.

4. The possible use of passes on weirs to help eels get upriver and survive and grow to breeding size and help maintain stocks.

The research will be carried out by Edward ('Ed') White, under the supervision of Brian Knights. Ed has studied fisheries management at Sparsholt College, has a BSc in Biology and an MSc in Fisheries Biology. He has worked in the past for the Brown and Forrest elver station on the Severn. Brian is Principal Lecturer at the Polytechnic and is Chairman of the Thames Eel Fishermens' Association and represents eel and other commercial fishing interests on the National Rivers Authority Regional Fisheries Advisory Committee for the Thames Region. He has previously supervised a three year survey of eels in the River Thames to provide information to help manage the fykenet fishery in the estuary.

HOW YOU CAN HELP

To get the best information possible on how to manage the Severn elver fishery and whether a close season or other forms of control are needed, Ed and Brian need your help.

STOP PRESS:

LOCAL ADDRESS FEBRUARY-JUNE 1991

25 PEAR ORCHARD
TEWKESBURY
GLOUC. GL50 8RG

Tel. 0684 850975

Brian Knight

Edward White

IN EVERY CASE, WE PROMISE NOT TO REVEAL YOUR NAME OR ANY INFORMATION YOU GIVE US TO ANYBODY ELSE WITHOUT YOUR PERMISSION

1. Please could you fill in the questionnaire you are given when you apply for a licence. This will give us an idea of where elver fishermen come from, where they fish and how much they catch.

2. As many volunteers as possible are needed to keep detailed diaries of when and where fishing goes on and how many elvers are caught. Ed and Brian will be carrying out some experimental fishing but the more reliable information we have from serious fishermen, the better our estimates of elver numbers and the effect of fishing will be. If you are prepared to provide us with information from past years and/or keep records this year, please could you give your name and address to fisheries staff for passing on to us OR contact us directly at the address/telephone number above. ANY INFORMATION YOU GIVE US WILL BE KEPT CONFIDENTIAL.

3. We also hope that elver stations will help by giving us information on catches, both for past years as well as over the next three years.

4. We are planning to mark some eels by dyeing the skin or injecting pigments. We hope you will cooperate by reporting any marked fish you find to us or via the elver stations or fisheries staff. THESE MARKINGS WILL NOT BE TOXIC (WE DON'T WANT TO KILL THE FISH!) AND WILL SOON BE LOST AS THE FISH GROW, SO THEY WILL NOT AFFECT THE VALUE OF YOUR CATCH!

5. We are going to put a number of elver traps on selected weirs to catch eels for counting and to see if passes on weirs might help fish survive and get further upriver. Please could you help by ensuring these traps and passes work well and are protected from theft and vandals.

The National Rivers Authority Severn Trent Region have promised to add their full support to elver fishermen and the elver stations in this study. Their aim, like ours and yours, is to make sure this study provides some really good results so that the Severn elver fishery can be managed for the benefit of all.

APPENDIX C

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STANCHARDS PIT AND STRENSHAM WEIR REFURBISHMENT ENVIRONMENTAL ASSESSMENT WITH PARTICULAR REFERENCE TO FISH PASSES

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Presented to NRA Severn-Trent Fisheries
by

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August 1991

STANCHARDS PIT AND STRENSHAM WEIR REFURBISHMENTS

ENVIRONMENTAL ASSESSMENT

WITH PARTICULAR REFERENCE TO FISH PASSES

INTRODUCTION

A. STANCHARDS PIT WEIR

The River Avon connects to the Severn and thence to the Severn Estuary at Tewkesbury via Abbey Mill and sluices, Avon Lock and the Stanchards Pit Weir/sluice complex. Rebuilding of Stanchards Pit Weir is planned for March-August 1992. The current weir forms a major barrier to migratory fish (primarily eels and salmon) and the situation will be exacerbated by the vertical drop of about 1.5m and 5.5m flat crest. Abbey Mill and sluices are also major barriers and the only access will be an intermittent one via Avon Lock.

Eel migration

An NRA contract has been awarded to the authors of this assessment to study elver and eel migration into the Severn and Avon and the effects of the commercial elver fishery and of barriers on migration and riverine stocks. Furthermore, NRA Severn-Trent have been restocking the Avon with eels purchased from a commercial supplier. Thus this is an opportune time to consider the possibility of building eel passes at the new weir. Experience gained would be invaluable in planning new weirs and sluices for the Avon (and Severn) and could be integrated into the national NRA Research and Development Programme on Fish Pass Design and Evaluation.

Salmon migration

In addition to considering eel passes, this is also an opportune time to consider the possibility of including salmon passes in the Stanchards Pit refurbishment.

B. STRENSHAM WEIR

Strensham Weir is the next weir/sluice barrier to migrant fish, some 9km upstream of Stanchards Pit. The normal impoundment head is similar (1.6m), the crest is flat but the downstream face is sloped. This weir is therefore much less of a barrier to salmon migration than Stanchards Pit and a stepped pass is probably not necessary. It is, however, a barrier to eels and eel passes would be advisable, as discussed below

RECOMMENDATIONS FOR SALMON AND EEL PASSES

A. SALMON PASSES

The Avon is not reknowned as a salmon river, possibly because it has been weired and impounded for so long. Upper waters probably do contain suitable redd areas and some large salmon have been reported. Salmon ascend Upper Lode Weir into the lower Severn and a pass at Stanchards Pit would remove the first major barrier to migration into the Avon. Furthermore, the Lower Avon Navigation Trust (via the Avon Weirs Trust) is in the process of raising money to refurbish weirs under its control and it might be possible to include further salmon passes upriver in future. The inclusion of a trap would be useful to assess migration and to provide fish for stocking into upper waters, as has been successfully practised on the Thames. With a normal pound level difference of about 1.5m, provision of a pass and trap would not require major engineering works and costs (eg see Mills, 1991 and Thames Salmon Trust/NRA Thames Reports on Thames passes and traps).

As pointed out above, such a pass is desirable but not so essential at Strensham.

B. EEL PASSES

In preliminary studies, the Authors have found that small juveniles dominate trap catches at Stanchards Pit and Abbey Mill, with the incidence of pigmented elvers increasing in late July and August. Numbers of eels trapped at Stanchards Pit up to early August are in excess of 12500 individuals from sluice traps and 18000 from weir traps. In contrast, catches at Strensham, the next weir some 9km upstream, are in the order of 5500 from weir and 1500 from sluice traps. Catches at the highest current study site on the Avon, Wyre Mill (some 25km inland), number less than 100 and are dominated by larger juveniles. Thus it is evident that the weir at Stanchards Pit and subsequent weirs, such as Strensham, are important barriers to upriver migration and passes would be of great value. Provision of integral traps would also be very useful for study purposes and to provide eels for future restocking, especially at Stanchards Pit. A pass channel is already planned for the weir face at Strensham. However, to allow for continued research into migration and to test different patterns of passes and traps, it is advisable to make provision for the attachment of prototypes to the side walls of both weirs. Pass/traps at both sides would enhance capture rates.

Migrating eels are attracted to relatively high flows of water and will ascend in water flowing down slopes of varying angle (and even vertical surfaces) with suitable medium to aid climbing, eg in the form of a mesh, brushes, vegetation, etc. (Rigaud _et al_, 1988; Dahl, 1991; Legault, 1991). Such materials can be placed in channels or pipes to connect the upper and lower pound levels.

Creating suitable flows can be achieved in two ways, passive devices relying on natural flows, active ones on pumping.

(a) Passive pass/traps

These can consist of a simple channel or pipe which is open to water flow from the river. They need to be firmly attached and robust to cope with the large changes in levels and flows and floating debris found in the Avon. They have the advantage of not requiring an external power source. They would be prone to blockage but larger items of debris can be deflected by a coarse screen and minor items like weed, etc. have not been found by the Authors to prevent eel ascent. The head of the pass could also be placed out of the main river flow to minimise such problems and to protect it from damage by floating logs, etc. An ideal pattern would be a channel (eg of heavy gauge aluminium) with a removable cover to prevent predation, vandalism, etc but to allow occasional inspection, cleaning and replacement of the climbing medium. A length of the lower channel should be left uncovered to allow eels to locate the flow despite changes in the lower pound level.

A trap-box could be mounted at the head of the pass with an upstream mesh of suitable aperture size to allow water flow through whilst retaining eels (eg see Knights, 1982). A removeable mesh cage with funnel entrance and escape-proof lip could then be placed inside the box. Meshes would be prone to blockage but the box and cage would only need to be in place during the eel catching season.

Alternatively, a removable box could be mounted part of the way up the channel. On reaching a break in the climbing medium, eels would fall into or be washed by part of the flow into the box mounted below or to the side (eg see Rigaud _et al_., 1988).

(b) Active pass traps

These would involve similar designs to those discussed above except that they could be suspended out of the main flow and rely on pumped water flow. The pump intake would have to be suitably screened but this design has the advantage that it would not be affected by the large variations in discharge flows in the Avon. The main disadvantages are the capital costs involved in arranging a power supply, pumps, mountings and ancillary works and also the problems of power failure and maintenance needs. Power is not immediately available at Strensham but at Stanchards Pit, power cables run between the sluices and gauging station beside the walkway across the current weir.

(c) Climbing medium

Geotextile mesh materials such as Enkamat are recommended by Dahl (1991) and nylon brushes by Legault (1991) and are used by his French company, Fish-Pass*. Both materials are resistant to water contact, abrasion and UV degradation and brushes are easy to rake clean. Both are, however, expensive. Furthermore, initial studies by the Authors indicate differences in size selectivity of these materials. Enkamat, Enkadrain and Tensarmat tend to be less suitable for larger migrating juveniles. Different types of brushes are selective for eels of different sizes but this entails selecting mixtures appropriate to each site. Catches at Stanchards Pit are dominated by small migrants and thus geotextiles are preferable but average size tends to increase further inland. However, the Authors have found, as did Naismith and Knights (1988), that cheap and commonly available garden netting (2-3.5cm stretched mesh aperture) is an efficient and robust medium which is not prone to size selectivity of catch. Further work on this is proceeding.

(d) Attachment of pass traps

Work is proceeding on the optimum slope of pass and flow rates but these factors appear relatively unimportant if the appropriate climbing material is provided. Of more importance is to ensure the downstream end is positioned correctly. This needs to be sufficiently near the weir for an attractive flow rate but not so close as to enter eddy or turbulent zones which might interfere with eels finding the base of the pass.

C. STANCHARDS PIT PASSES

At Stanchards Pit, the normal pound level difference is 1.4-1.7m and flow velocities will be reduced when the weir is widened from 8 to 40m. The bottom of the pass would therefore need to be 5-10m from the base of the weir, at an angle of 20-35 degrees. To provide attachments for brackets on which to suspend pass channels, stainless steel bolts (protruding by 5cm) would need

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to be let into the sheet piling walls at about 1m intervals. Alternatively, threaded sockets for stainless steel bolts (allowing 5cm protrusion) could be let into the sheet piling to maintain the integrity of the wall. Sockets could be blanked off if not used. Channels could be suspended by brackets secured by bolts/nuts to these attachment points, the vertical arm of each bracket being slotted to allow the ssuspension height and slope to be varied as necessary. The lowest attachment point should be at or near the normal lower pound level of 8.10m AOD so that the bottom of the pass can always be immersed.

Passes would have to run across the flat 5.5m weir crest. Channels can be mounted in the same way as above, bolts or sockets being let into the RC weir abutments at about 40cm above the crest height. It would be an advantage if these could be mounted around onto the upstream faces of the abutments so that the passes can be continued out of the main flow. These would also allow for the attachment of catch boxes. Alternatively, boxes could be attached to the floating boat guard.

Attachment points would generally need to be about 1m apart for maximum security and flexibility. Ideally, provisions should be made for attachments at both N and S sides of the weir as work to date indicates eels preferentially migrate around the margins of the Pit, especially when flow velocities are high.

D. <u>STRENSHAM WEIR</u>

An eel pass channel up the weir face is already included in the design. However, further experience from studies of traps suggest this is not an ideal arrangement. It will be difficult to attach and service the channel, detachable cover and trap box, particularly during periods of high flow. Furthermore, entry of eels at the base of the channel will be discouraged by the turbulent water at the foot of the weir. It might therefore be better to abandon this idea and make provision for side-mounted pass channels, as at Stanchards Pit. Sockets or bolts should be mounted at about 1m intervals, starting from the upstream faces of the abutments, across the crest (at about 40cm above normal pound height) and thence at an angle of 20-30 degrees so that the lowest attachment point is at or near the normal lower pound level, at the downstream edge of the abutment.

RECOMMENDATIONS

1. The feasibility and benefits of incorporating a salmon pass into Stanchards Pit Weir during refurbishment should be considered.

2. Provision should be made for the attachment of eel passes and traps to both sides of Strensham and Stanchards Pit Weirs, as suggested as above but with exact details to be discussed with the relevant engineers/contractors.

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APPENDIX D

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COMMENTS ON 'FISH-PASS' REPORT AND ESTIMATES (SEPT.1991) TO NRA SEVERN-TRENT FOR EEL PASSES & TRAPS AT STANCHARD PIT, R.AVON

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Presented to NRA Severn-Trent Fisheries
by

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September 1991

COMMENTS ON 'FISH-PASS' REPORT AND ESTIMATES (SEPT.1991) TO NRA SEVERN-TRENT FOR EEL PASSES & TRAPS AT STANCHARD PIT, R.AVON

1. The document is difficult to understand and lacks sufficient information in many places but contains many interesting ideas.

2. PROJECT 1 (Pumped pass-and-trap system)

2.1 Siting of base of eel ladders

The double set of crawling gutters, plus 'resting pools', are presumably arranged thus to ensure the bases of the ladders are situated at the bottom of the downstream face of the weir. When the weir is reconstructed with a vertical rather than sloping downstream face, this is where eels, attracted by flows, might be expected to congregate. However, during high river flows (even with reduced flow rates over the weir when it is widened), it is possible eels may not be able to approach the bases of the ladders. Our work suggests that single gutters attached to the side walls and with lower ends some distance from the weir face are effective under a range of water flow conditions (see previous Report to NRA). It is worth considering adding an extra gutter located in this fashion to feed into the 'resting pool'.

2.2 Vulnerability to damage

Storm flows, floating debris and vandalism have occasionally resulted in damage to our traps, problems that will be exacerbated by winter storm flows. Strong supports, more substantial construction materials (eg aluminium rather than polyester) and gutters with removable lids are advisable for permanent structures at Stanchard Pit.

2.3 Eel pipes (EP)

These are needed to carry eels from the 'trapping/irrigation kit' (TIK) to the 'fish preserve' (FP). Running this through the pile wall/abutments would add extra complications during construction, could lead to points of structural weakness and it would be difficult to gain access in the event of a pipe blockage. Instead, these pipes could be run along the face of the piling and traps mounted on the boat guards or upstream faces of the abutments, as suggested in our earlier Report.

2.4 Electrical system

The extra capital, running and maintenance costs and reliability compared to gravity/flow fed systems needs consideration.

2.5 Costs

The quotation appears to only cover the materials listed and not labour and expenses. At least one weeks work would be involved, plus travel and accommodation. Costs also do not include pipe laying or arranging the electricity supply and access ladder. These points need clarification.

3 PROJECT 2 (gravity/flow fed pass-or-trap system)

3.1 Eel ladders

The concept of a double-sloped crawling gutter (presumably to offer a range of flows through the climbing material as the difference in pound heights varies) is interesting. However, early consultation with engineers is advisable because of the necessary changes in crest design and construction. Cutting the channels (maximum 0.8m deep) into the vertically-piled weir next to the side walls will introduce structural weaknesses. Extra costs may then be entailed in providing further strengthening.

3.2 Closing off the ladders

The ladders appear to have 'slides' to close them so that eels are redirected to the trap. More information is needed on how these work, presumably vertical slots would be needed for insertion of boards? From our experience, many eels would congregate in the climbing material and thus, ideally, 'slides' should be located at the bottom of gutters to prevent entry, rather than at the top. Access to enable the slides to be opened and closed will, however, then be more difficult.

3.3 Eel traps

Mounting these so that the ends of the ladders are located at the base of the vertical weir face is an interesting idea (but note the comments made in 2.1 above). Pipes passing through walls will lead to the complications mentioned in 2.3.

The addition of an extended secondary pipe to provide an 'attractive flow' at the base of each climbing gutter is interesting but these pipes will be particularly vulnerable to damage (see 2.2). From our experience, flows down the gutters may be sufficiently attractive without the need for extra pipes.

Stronger materials for construction of traps and gutters (plus removable lids) are advisable (see 2.2).

3.4 Costs

These again appear to be incomplete (see 2.5).

4. CLIMBING GUTTER SUBSTRATUM

Brushes used in 'Fish-Pass' designs are size-selective. Our work has shown Stanchard Pit catches are dominated by elvers and small juveniles, brush patterns and intertuft dimensions therefore need to be chosen appropriately. As an alternative, horticultural mesh could be used, as described in our earlier Report. Current work suggests that such netting has a low size-selectivity bias and would not exclude occasional larger juveniles.

5. STANCHARD PIT 'GATE' (ie sluice)

This (uncosted) suggestion involves a Project 2 trap mounted on the sluice gate with a hole cut through the gate to supply the water flow. Whether this arrangement would be acceptable to NRA engineers needs to be determined. Comments made above on construction materials again apply.

The sluice is of undershoot design, meaning there are and turbulent and strong flows from its base. From our experience, this probably prevents eels getting near the base and that traps mounted on the side walls with downstream gutter ends would be more efficient.

6. OVERVIEW AND CONCLUSIONS

6.1 All options suggested have interesting features but include construction, engineering and cost implications that need clarification.

6.2 Project 2 eel passes are probably not feasible because of the short time available to incorporate the changes in plans and construction for the weir. Project 2 eel traps are interesting in design but cannot be used as passes. Therefore, Project 1 designs which include both trapping and pass capabilities are probably worth most careful consideration.

6.3 Our work suggests that simpler and cheaper designs of traps/passes may be efficient and reliable, as outlined in our earlier Report. If Stanchard Pit is to be used as a major test of eel pass and trap designs, it is worth considering a combined study, involving a Project 1 system on one side of the weir and the adaptable support system suggested in our Report on the other. A similar dual approach could be used on the sluice. These suggestions have major benefits to NRA in that various commercially-available and novel prototype systems could be compared objectively over the next two years as part of our ongoing contract to study elver and eel recruitment. The only costs extra to those encompassed by the 'Fish-Pass' designs would be provision of supports for prototypes and, possibly, unbudgeted costs for more substantial construction materials.