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SURVEY OF THE COARSE FISH OF THE RIVER TEES – EFFECT OF A BARRAGE

Final Report

J S Welton, J E G Masters, W R C Beaumont, A C Pinder and M Ladle

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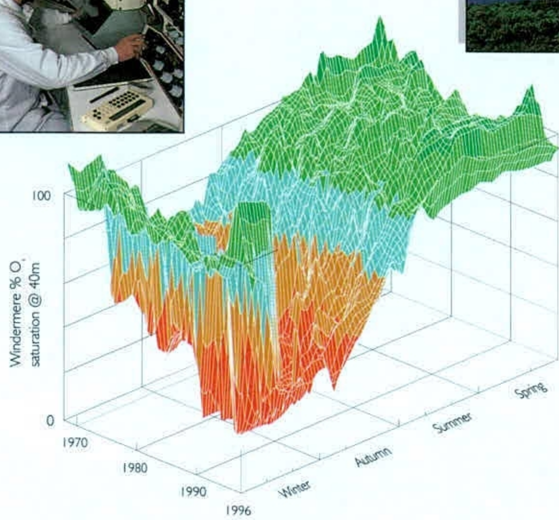

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EXECUTIVE SUMMARY

The study was initiated to look at the effect of a barrage on the coarse fish populations of the lower Tees. It started in 1991 and annual surveys of fry and adults were undertaken for 4 years prior to the impoundment of the river following construction of a barrage at Stockton-on-Tees in December 1994. Approximately 20 km of river was affected. Post-barrage surveys have been carried out annually until the end of the study in 1998.

The timing of the fry survey was a compromise between discovering the spawning sites of dace, which is an early spawner, and sampling fry from other species. Before the closure of the barrage the main spawning sites were found to be at Yarm, Low Worsall, Low Moor and Low Dinsdale. The former two were in the area of river expected to be impounded and the latter were upstream of the influence of the barrage. Pre-barrage, fry were dominated by dace, chub and roach by numbers and this has not changed post-barrage. Results suggest the dace and chub proportions have decreased whilst the roach proportion has increased, although this cannot be shown statistically for the river as a whole because of large variations between years and within sections of the river.

Nine species of angling interest were found as fry. The most significant changes since the impoundment of the river have been the appearance of perch and bream fry in the river below Preston Park. This is an early indication of a change in the coarse fish community caused by the barrage.

Although results show that the areas at Yarm and Low Worsall are no longer important as dace spawning sites, dace fry are still numerous in the river and the predicted decline in dace is likely to occur over a long period and not instantaneously as previously feared.

At present there appears to be little evidence that fish are spawning in the specially created fish havens but there is evidence that fry are moving in later and growing more quickly than those in the main river. The barrage has had little effect on the growth of fry, primarily because the temperature in the impounded sections is not different to sections unaffected by the barrage.

Fry are much more widespread in the impounded section due to the large increase in suitable habitat. Spawning habitat now favours roach, bream and perch whilst species such as dace and chub which require fast-flowing water are disadvantaged.

Surveys were undertaken in September to collect data on adult fish populations. During the course of these surveys, approximately 40,000 fish from 19 species were sampled and returned alive. Dace, chub and roach were the main species in the river before barrage completion with dace forming half of the fish caught. After barrage closure, the proportion of dace fell to 38% and those of roach and chub increased, although these changes could not be shown statistically because of year to year variations.

Overall, numbers of fish have increased post-barrage. The area of river between the barrage and Thornaby is now suitable for coarse fish as it is no longer saline and this area has been colonised particularly by young fish. In other impounded areas, there have been significant increases in the number of fish per 100 m of bank for chub and roach but not for dace. Results show a decrease in numbers of dace per 100 m apart from the area previously uninhabited. There has been no difference in numbers per 100 m in areas upstream of the influence of the barrage.

Growth rates of young dace and chub are significantly lower in the impounded reaches whereas roach have not been affected. Survival, however, appears to be enhanced. By predicting, from pre-barrage data, numbers expected post-barrage, it has been shown that for years when strong year classes were expected, the actual numbers present were lower than expected for dace and higher than expected for roach. Chub data fall between the two. Thus the introduction of the barrage has favoured roach over dace.

Anglers have seen a radical change in their sport due to the barrage. They now fish deep slow flowing water instead of a fast tidal river. Anglers catch weights in matches have improved since the closure of the barrage and are now double those in the final year before closure. Even though the mean catch weight per peg has fallen in all periods except Feb/Mar, the distribution of fish has altered such that anglers have a chance of winning matches from any peg. This is seen as an improvement over the times when matches were won or lost at the draw for pegs. Even though the proportion of dace is falling, catches still comprise a high proportion of small dace. Large dace and chub have reduced proportion in catches although proportions of large roach have remained the same.

It is concluded that there have been changes in the coarse fish population in terms of numbers, population structure and species composition. These changes however, have not been as rapid as was expected before this study started. It is predicted that bream, perch and pike will increase in numbers and become a significant proportion of the population. It is further predicted that dace will continue their slow decline and that roach will continue to increase in numbers. It could be at least 10 years before a relatively stable fish population is seen.

1. INTRODUCTION

In order to aid in the regeneration of disused land along the River Tees in Stockton-upon-Tees, the construction of a barrage was considered. The purpose of the barrage was to improve the water quality and to increase the level such that unsightly mud banks were submerged at all states of the tide. There were various environmental concerns, one of which was the coarse fishery. The lower Tees was a very good fishery renowned for its populations of drift-feeding species. It was expected that these species would be deleteriously affected when the river was impounded and that species favouring the new habitat would flourish but take time to exploit the new conditions. Thus there would be a hiatus during which time the fishery would be depressed. To address this, the Tees Development Corporation provided money for construction of works to mitigate habitat loss and to the NRA (and now the Environment Agency) for a survey of the coarse and salmonid fish populations before and after the construction of the barrage. The Institute of Freshwater Ecology (IFE) were awarded the contract on the coarse fish after a competitive tender procedure.

The barrage was finally completed and closed in December 1994, after which approximately 20 km of river became impounded between Stockton (NZ 463191) and Low Worsall (NZ 395103).

2. SAMPLING SITES AND METHODS

The IFE has carried out two surveys in the lower River Tees in each year since 1991. The first survey took place in June 1991 and served as a base line survey of coarse fish. The study area was split into 25 sections, where Section 1 began at the downstream point of the study area (the site of the barrage) and Section 25 ended at the furthest upstream point of the study area (Low Dinsdale, NZ 347114) (Fig 1). Section lengths were dependent on the number of fish caught during the base line survey. The first post-barrage surveys took place in 1995. Prior to the barrage, saline intrusion caused most of Section 1 to be uninhabitable to coarse fish; the lower limit of fish caught during this period was Thornaby (NZ 448163), some 5 km upstream of the position of the barrage. After closure, this area became available to coarse fish, and due to the increase in numbers of fish caught in Section 1, was subsequently divided into Sub-sections A to E.

The survey was split into two parts, firstly a summer survey of fry to give an indication of spawning areas, particularly of dace the most important species in terms of angler catches, and an autumn adult survey. In addition, temperature data were collected to help in the interpretation of data from the surveys and angling data were collected from Yarm Angling Club whose water is situated in the centre of the length affected by the barrage.

Fry were sampled each summer (June or July) from 1992-1998 using a micromesh seine net and back-pack electric fishing point-sampling gear. Boom boat electric fishing surveys, sampling all ages of fish, took place in each September from 1991 to 1998. Details of the specific methods employed each year can be found in the Interim Reports, one for each year of the study.

Angling data from the Yarm area have been collected during the survey, with anglers completing data forms based on match catches. Historical data on catch weights from the 1977/78 angling season to the present were also collected.

Temperature was recorded at Low Moor, (Section 21, NZ 364106), above the influence of the barrage, and at Ingleby Barwick (Section 5, NZ 431136) in the middle of the affected stretch. An additional site was monitored before Barrage closure at Stockton Marina (Section 1, NZ 451193).

3. FRY SURVEYS

3.1 Introduction

Fry surveys were conducted in early summer, with the timing of the surveys being a compromise between sampling dace before they left the margins and the appearance of fry from all coarse fish species. The 1992 and 1993 fry surveys took place in July, at a time when it was expected that coarse fish fry of all species would be present. As by July, dace fry have dispersed, the 1994-98 fry surveys were undertaken in June specifically to assess the effect of the barrage on dace spawning. Fry were sampled using a combination of micromesh seine netting, random or targeted point-sample electric fishing or hand netting. In response to a paucity of fry found in the lower sections of the river and a lack of chub fry in June 1996, a second, smaller scale fry survey took place in July 1996.

3.2 Species Composition

Comparisons between years are complicated by differences in the timing of surveys. Timing of spawning can also vary between years, as it is dependent on water temperature. Comparisons between sections and between years are further complicated by the different sampling methods used, with micromesh seine netting generally catching larger numbers of fry than point sampling. With the increase in water level post-barrage, the number of sites where micromesh seine netting was possible was very limited.

The following species were found during the surveys: barbel *Barbus barbus* (L.), bullhead *Cottus gobio* L., common bream *Abramis brama* (L.), chub *Leuciscus cephalus* (L.), dace *Leuciscus leuciscus* (L.), flounder *Platichthys flesus* (L.), grayling *Thymallus thymallus* (L.), gudgeon *Gobio gobio* (L.), ide *Leuciscus idus* L., minnow *Phoxinus phoxinus* (L.), perch *Perca fluviatilis*, roach *Rutilus rutilus* (L.), three spined stickleback *Gasterosteus aculeatus* L., stone loach *Barbatula barbatula* (L.) and rudd *Scardinius erythrophthalmus* (L.).

Table 1 shows the numbers of each of the major coarse fish species caught during each of the fry surveys from 1992 to 1998, together with the percentage of the catch formed by each of these species in each year. The percentage of the catch formed by each of these species is also shown in the form of histograms in Fig 2.

3.2.1 Dace, chub and roach

Percentage data were suitably transformed (arcsine) in order to test for significance between pre- and post-barrage. With the inconsistencies detailed in Section 3.2, and the between year and within river variation, it was not possible to show any change in species composition of dace, roach and chub associated with the barrage on a whole river basis (Table 2). The results, however, suggest that dace and chub have reduced and roach has increased in proportion but that significances are masked by the large variation (as seen by wide confidence limits (CLs)).

Table 1 **Numbers of each major species caught during fry surveys together with the percentage composition of the catch (eels, minnows, sticklebacks and stone loach removed) 1992 to 1998**

	July 1992	July 1993	June 1994	June 1995	June 1996	July 1996	June 1997	June 1998
Barbel	124	156		6	64		24	21
%	*6.77*	*6.09*		*0.18*	*3.49*		*0.53*	*0.57*
Common bream						2		
%						1.11		
Chub	470	980	448	1092		31	748	628
%	*25.67*	*38.28*	*8.85*	*32.49*		*17.22*	*16.60*	*16.92*
Dace	936	1010	4216	526	932	20	2448	2043
%	*51.12*	*39.45*	*83.30*	*15.65*	*50.79*	*11.11*	*54.33*	*55.05*
Flounder		6	5					
%		*0.23*	*0.10*					
Grayling		5	83	5			3	4
%		*0.20*	*1.64*	*0.15*			*0.07*	*0.11*
Gudgeon	168	30	2	91	27	21	917	136
%	*9.18*	*1.17*	*0.04*	*2.71*	*1.47*	*11.67*	*20.35*	*3.66*
Ide							1	
%							*0.02*	
Perch			1				8	10
%			*0.02*				*0.18*	*0.27*
Roach	133	371	306	1641	812	106	357	869
%	*7.26*	*14.49*	*6.05*	*48.82*	*44.25*	*58.89*	*7.92*	*23.42*
Rudd		1						
%		*0.04*						

Table 2 **Overall mean ± 95%CL percentage composition of fry (three main species only) before and after construction of the barrage**

	Pre-barrage %	**Post-barrage %**	**t**	**Significance**
Dace	62.8±52.4	49.0±36.4	0.95	ns
Chub	27.0±41.1	18.1±22.0	0.54	ns
Roach	10.2±12.3	32.9±30.2	1.78	ns

Data were then stratified into shorter reaches. Data were compared for the major dace spawning sites identified in the study. For dace, Sections 7 and 8 (Yarm, NZ 418132), Section 17 (Low Worsall) and Sections 20 and 21 (Low Moor) were chosen as these were the sites considered to be the major spawning areas in the area affected by the barrage.

There was a significant reduction in percentage composition of dace post-barrage at Yarm where spawning gravels have been drowned out (very deep slow flowing water compared with fast shallow water pre-barrage) (Table 3). This was apparent even though the pre-barrage estimates of dace are considered to be underestimates due to the years when sampling was carried out in July, after the initial dispersal of dace fry.

At the two upstream spawning sites which are unaffected by the barrage, there has been no significant change in the proportion of dace fry although there appears to have been an increase at the most upstream site (Sections 20/21). It is likely that dace which previously spawned at Yarm have now moved upstream into more suitable conditions. This may have resulted in an increase in spawning activity in Sections 20/21 which are directly below a weir that may be impassable to dace at certain times of the year.

Data from the annual surveys showed percentage composition of roach increasing in downstream sections. In addition to the above reaches, therefore, Section 5 was also analysed. At this site, the proportion of chub, pre-barrage, was high and a reduction was expected with an associated rise in roach proportions. However, although there was an indication of this, the data show no significant change in proportion of the three main species (Table 3).

Table 3 **Overall mean ± 95%CL percentage composition of dace fry (as a proportion of the three main species only) before and after construction of the barrage**

	Species	Pre-barrage %	Post-barrage %	t	Significance
Section 7/8	Dace	77.8±42.7	12.8±15.3	5.58	sig $p<0.01$
Section 17	Dace	64.1±118.8	61.6±41.4	0.43	ns
Section 20/21	Dace	42.3±69.9	68.3±50.3	1.25	ns
Section 7/8	Chub	17.9±50.0	69.9±22.2	4.23	sig $p<0.01$
Section 7/8	Roach	4.3±9.2	34.7±69.9	1.23	ns
Section 5	Dace	37.0±75.8	33.3±69.1	0.16	ns
Section 5	Chub	40.9±38.5	38.6±56.4	0.12	ns
Section 5	Roach	22.1±78.0	28.2±56.7	0.24	ns

Whilst it is accepted that analysing percentage composition can cause errors due to the interrelations between the components, the actual numbers of fry caught show the same trends (Table 4) lending support to the above hypothesis of roach increase.

Table 4 **Total number of fry caught in pre- and post- barrage years (1996 data removed as chub spawned late).**

	Species	Pre-barrage	Post-barrage
Section 5	Dace	374	73
Section 5	Chub	300	101
Section 5	Roach	70	120
Section 7/8	Dace	843	61
Section 7/8	Chub	130	317
Section 7/8	Roach	62	54
Section 20/21	Dace	671	1053
Section 20/21	Chub	77	99
Section 20/21	Roach	467	185

3.2.2 Other species

Apart from the three major species discussed above, fry from nine other species of angling interest were sampled. Comment is inappropriate on the single specimens of rudd and ide found and, in addition, the point-sampling method was not applicable to grayling and barbel, which are not confined to the margins at the time of the surveys.

Bream and perch fry (apart from one specimen) were found in the post-barrage period only. Although numbers were low, this gives an early indication of a change in the species composition caused by the barrage.

Flounder fry were limited to pre-barrage samples and although much of the water was deep after barrage closure, none was found post-barrage in the upper reaches which were generally unaffected. It was anticipated that the adult flounder might find the barrage an obstruction to migration into the river and this result fits this theory.

Although gudgeon show an increase in proportion (of the 4 major species only) post-barrage, confidence limits of the mean, calculated from Table 1, are again wide (3.7±13.2% pre- and 7.1±14.3% post-) and no significant difference could be shown statistically ($t = 0.576$ after arcsine transformation and F test showing equal variances).

3.3 Distribution of Fry

Graphs of the number of fry for each of the three main species, dace, roach and chub, in each section, in each year have been drawn separately for sections in which fry were seine netted and sections where point sampling took place (Figs 3–5).

Generally in, and downstream of, Section 10, dace are present in lower numbers than in pre-barrage years, although this may largely be dependent on sampling technique.

In 1992, Sections 7, 8, 17, 20 and 21 were identified as probable dace spawning areas. Section 17 seems to have retained its importance as a dace spawning site after the closure of the barrage, as have the other upstream sections. Downstream sections no longer seem important for dace spawning.

High numbers of roach were caught in Section 1 in 1998, signifying an increase in the importance of this section to roach since the barrage closure. Generally, more roach fry are now caught in all sections than was the case in pre-barrage years.

As with dace and roach, large numbers of chub were caught in Section 1. Generally, chub fry are more widely distributed than in pre-barrage years. No chub fry were caught in June 1996, probably due to this species not having yet spawned.

3.4 Length Frequency Distributions of Dace Fry

A sub-sample of fry from each section was measured, with lengths subsequently assigned to unmeasured fry based on the length frequency distribution of measured fry in the relevant section. In 1996, 1997 and 1998, dace fry have exhibited a bimodal length frequency distribution, rather than the single modal distribution seen in previous years (Fig 6). This has been interpreted as two separate spawning events, although it could also result from movement of batches of fry from other locations. The distribution of the dace fry was investigated in 1997. Individuals from both modal groups were found in 17 out of the 22 sections sampled (Fig 7). The two modal groups were quite often found separately, with 46% of samples containing one size group only. Fry from both modal classes were found in higher numbers in the upstream sections of the river, above the influence of the barrage. The bimodal pattern of dace fry length:frequency distribution was not seen prior to barrage closure. However, for chub and roach, bimodal patterns were seen in July 1992 which were in the pre-barrage period (Fig 8). Bimodality was not seen in any other year for these species although most sampling occurred in June, relatively early in the spawning season, probably before any break in spawning could occur. Even though the chub and roach results show bimodality before the construction of the barrage, the fact that this did not occur in dace until post-barrage years, suggests that the introduction of the barrage was probably responsible for this phenomenon.

3.5 Comparisons with Environment Agency Fish Haven Data

The EA have been conducting a quarterly sampling programme in the fish havens, to monitor their usage by fish and to identify preferred design features. The 'River Tees Fish Haven Monitoring 1996' report (Jenkins 1998) concludes that all four of the havens are used by a range of species, at varying degrees of abundance according to location and season. It states that roach and bream spawn in at least two of the fish havens although the very low numbers of small fry quoted would seem to indicate that the havens are not making a significant contribution to recruitment in the river. The report also suggests that dace, chub and gudgeon move into the havens from the main river.

Of particular note is the high proportion of bream in the fish haven samples, with the exception of Low Worsall where bream have been absent in both years. The Preston Park and Holmes fish havens seem to be of particular importance to this species. This is in contrast to the low numbers of bream caught by the IFE over the course of the survey in the main river.

Low Worsall, Preston Park and The Holmes have all been found to contain large numbers of roach, indicating that the havens may be a favourable habitat for this species. However, large numbers of roach have been caught outside of the havens by the IFE in post-barrage years (Table 1), so the effect of the current fish havens on the population of roach may therefore be insignificant.

Numbers of perch in the River Tees have increased in recent years although relatively few fry have been caught by either the IFE or the EA. All ten perch fry caught by the IFE in June 1998 were caught in the Black Bobbies fish haven. In June 1997, significantly larger perch fry were found in a Section 1 fish haven than in the main river. The majority of perch fry caught by the IFE in fry surveys have been caught in Section 1. More havens in this area may increase the rate of population growth in this species.

3.6 Growth

The relationship between growth of fry and temperature was established using mean growth in length between the fry survey and the September survey and the number of degree-days above 12°C between these times. Data were split into pre- and post-barrage (Fig 9). The slopes of the chub relationships show the biggest difference and for this reason, a statistical test on the error of the slopes (from regression analysis) was performed to see if they were significantly different. The values of the slope were 0.046±0.011(SE) and 0.068±0.020 pre- and post-barrage respectively. With overlapping SE limits, it was concluded that there was no significant difference between the two relationships. Consequently, there was considered to be no difference in the relationships for dace or roach (Fig 9). This suggests that the growth of fry has largely been unaffected by the barrage (given that the temperature regime post-barrage is very similar to pre-barrage) (see Chapter 5).

The mean lengths of dace, chub and roach fry as found in each September survey have been plotted against mean summer water temperature (Fig 10), where mean summer water temperature is the mean of monthly temperatures at Low Moor and Ingleby Barwick between May and August. In 1997, two loggers were used at the Ingleby Barwick site, one logger recording surface temperatures and one recording temperatures at depth. Results from both of these loggers were used in the calculation of mean summer water temperature as in previous years the logger had been situated at a depth intermediate to these two. From Figure 10, it can be seen that, for each of the three species, there is a general pattern of increasing September length of fry with increasing mean summer water temperature. Mean water temperature has been similarly calculated between June and August. These June to August temperatures are more relevant to the growth period of chub and roach, species that spawn later than dace. Mean September length of 0+ dace, chub and roach has been plotted against mean June-August temperatures in Fig 11. Again there is a pattern of increasing length with higher mean temperatures.

3.7 Discussion

The fact that numbers of coarse fish have increased markedly since the barrage construction suggests either an increase in spawning or an increase in survival rate. As there was little macrophyte growth in the lower tidal river pre-barrage, it was expected that species spawning on the marginal vegetation would have suffered from poor survival of eggs due to dewatering at low tide. After the barrage construction, it was expected that survival would increase resulting in an increase in juvenile fish in the first instance. Roach and bream were expected to benefit from this habitat change. This has been borne out by the results. Dace and chub, however, were expected to reduce in numbers due to a decrease in spawning sites. They require a gravel substrate in fast shallow water for successful spawning. After construction, the water depth and velocity change made the area unsuitable for spawning. Dace fry numbers fell post-barrage at Yarm, a known spawning site, although some fry were still present, indicating a reduced hatch either to low numbers spawning or poor survival of eggs. Chub fry unexpectedly increased in number at this site. It is possible that individuals of these two species still spawn at this site. Dace, spawning earlier and consequently taking longer to develop from egg to fry (approximately one month), are subjected to siltation to a greater extent than chub, spawning later and taking only a week to hatch. Thus the survival rate of chub could be higher than dace.

It is also possible that fry survival has increased post-barrage because of the lack of current. Pre-barrage, fry were subjected to fast tidal flows and mortality was likely to have been high due to physical abrasion and washout into unsuitable areas, in particular saline areas downstream of Thornaby. Post-barrage, dispersal and washout was very much reduced and suitable nursery habitat has been greatly increased.

4. SEPTEMBER SURVEYS

4.1 Fish Numbers

Total numbers of fish caught in the September survey in the first two years post-barrage were similar to the numbers caught in three of the pre-barrage years (Fig 12). This occurred even though the conditions for electrofishing were completely different. Post-barrage conditions were similar to high tide conditions pre-barrage. The increased water depth resulted in decreased efficiency of fish capture. Out of necessity (breakages in the copper braids and supports resulting in individual droppers overlapping), the droppers on the anodes of the boom boat were changed prior to the 1997 fishing. They were replaced with solid copper droppers altering the anode cathode ratio. Whilst the efficiency may have increased relative to 1996 because of this, the increased catch almost certainly reflects an overall increase in the fish population of the Tees. This view is supported by the observed increase in annual mean catch weights by anglers (see below).

The total number of fish caught in all September surveys combined is 39706 (excluding eels). In total 19 species have been caught, these being:

> barbel *Barbus barbus* (L.), bullhead *Cottus gobio* L., common bream *Abramis brama* (L.), chub *Leuciscus cephalus* (L.), dace *Leuciscus leuciscus* (L.), eel *Anguilla anguilla* (L.), flounder *Platichthys flesus* (L.), grayling *Thymallus thymallus* (L.), gudgeon *Gobio gobio* (L.), ide *Leuciscus idus* L., minnow *Phoxinus phoxinus* (L.), perch *Perca fluviatilis*, pike *Esox lucius* L., river lamprey *Lampetra fluviatilis* (L.), roach *Rutilus rutilus* (L.), salmon *Salmo salar* L., three spined stickleback *Gasterosteus aculeatus* L., stone loach *Barbatula barbatula* (L.) and trout (brown and sea) *Salmo trutta* L.

In addition to these species, one roach/chub hybrid was caught in 1993. The most common species overall have been dace, chub and roach, forming 86% of all fish sampled.

4.2 Species Composition

The overall percentage compositions of fish in the September survey for pre- and post-barrage are given in Fig 13. Despite a doubling of the percentage composition of roach, no statistical significance was indicated (Table 5). Neither the increase in chub nor the decrease in dace proved significant.

Table 5 Overall mean ± 95%CL percentage composition of dace, chub and roach before and after construction of the barrage

	Pre-barrage %	Post-barrage %	t	Significance
Dace	48.2±28.6	38.2±15.7	1.26	ns p = 0.26
Chub	14.7±8.0	22.4±8.4	2.19	ns p = 0.08
Roach	13.8±9.12	27.0±21.5	1.60	ns p = 0.17

Pie charts of species composition in pre- and post-barrage years, showing the percentage of dace, chub and roach caught in each year are shown in Figs 14 and 15. All other species, excluding minnows, are pooled into the 'others'. An unusually high percentage of roach were caught in 1991 (34%), although dace were still dominant (44%) (Fig 14). Dace form the largest portion of the catch in each of the pre-barrage years, with roach and chub forming approximately equal portions in 1992, 1993 and 1994. In post-barrage years, the proportion of the catch that is dace decreased from 51% to 28% between 1995 and 1997, before increasing slightly to 34% in 1998 (Fig 15). Post-barrage roach increased from 13% to 43% between 1995 and 1997, before falling slightly to form 33% of the catch in 1998. In pre-barrage years, percentage composition of chub ranged between 11% and 18%. In post-barrage years, chub have increased from 15% in 1995 to over 20% in 1996, 1997 and 1998. It is partly due to the extent of between year variation that no significant differences have been seen between overall pre- and post-barrage species compositions.

In the second post-barrage year, 1996, an interesting feature of the September sampling was the exceptionally high numbers of sticklebacks present. This species was so numerous in Section 1 that it was not cost-effective, in terms of time, to process this species. In subsequent years, stickleback numbers have been in decline.

4.3 Density

Densities of dace, chub and roach in each section, expressed as numbers of fish per 100 m of river, were calculated following each year's September survey. Valid comparisons between sections and years may be made only after due consideration has been given to the different efficiencies with which each section is fished. Sections are more comparable post-barrage as the variability of factors such as depth and state of tide has been substantially reduced or eliminated. Table 6 and Figs 16-18 show the mean density (number/100 m) of dace, chub and roach in pre- and post-barrage years. The study section was split into four sections, the lower section, Reach 1 (Sections 1A-3), originally affected by a salt water wedge; Reach 2 (Sections 4-9), the sections up to Yarm; Reach 3 (Sections 10-15), from Yarm to the top of the affected part of the river and Reach 4 (the control, Sections 17-25), above the influence of the barrage.

There were no significant differences in density in Reach 4 (control) between pre- and post-barrage values for dace, chub or roach (Table 6). All three species, however, showed significant increases in density post-barrage in Reach 1, the area formally unsuitable due to salt water intrusion. A significant increase in chub density was also found in Reach 2. Roach also show an increase in Reach 2 whilst dace have decreased although these changes cannot be shown statistically. In Reach 3, chub and roach both showed a significant increase in numbers but the decrease in dace was not shown to be statistically significant.

Table 6 **Comparison of mean densities (number/100 m ±95%CL) of dace, chub and roach in the River Tees before and after construction of the barrage. Reach 1 = Sections 1A-3, Reach 2 = Sections 4-9, Reach 3 = Sections 10-15 and Reach 4 = Sections 17-25 (only 19, 21 and 25 fished). *** = significantly different at p = 0.001, ** = significantly different at p = 0.01, * = significantly different at p = 0.05, ns = not significant**

	Pre-barrage density	Post-barrage density	t	Significance
dace				
Reach 1	1.54 ± 2.73	17.18 ± 4.25	6.42	***
Reach 2	24.36 ± 20.78	18.56 ± 6.84	0.56	ns
Reach 3	21.25 ± 7.41	17.27 ± 6.19	0.86	ns
Reach 4	35.38 ± 23.45	26.10 ± 12.61	0.84	ns
Chub				
Reach 1	0.09 ± 0.18	8.11 ± 3.37	4.91	***
Reach 2	3.86 ± 2.06	8.53 ± 3.14	2.6	**
Reach 3	5.38 ± 1.71	12.63 ± 4.74	2.96	**
Reach 4	12.16 ± 7.03	18.33 ± 8.47	-1.38	ns
roach				
Reach 1	0.38 ± 0.71	23.14 ± 10.38	4.53	***
Reach 2	5.42 ± 3.31	10.33 ± 4.99	1.71	ns
Reach 3	4.34 ± 2.10	8.48 ± 3.26	2.21	*
Reach 4	5.44 ± 3.60	30.28 ± 33.70	1.88	ns

4.4 Length Frequency Distribution

Length frequency distributions for major species have been shown in each of the annual reports. All length frequency data from pre- and post-barrage dace have been pooled to form two length frequency histograms (Fig 19), from which it can be seen that fewer large dace (≥15cm) have been caught in post-barrage years than in pre-barrage years. There is no obvious decrease in the number of large chub (≥30 cm) present after the closure of the barrage, although the 20-30 cm size classes are reduced post-barrage (Fig 20). From examination of age data (see below) these fish are from the strong 1989 year class. Substantial increases in roach numbers are apparent but there has been little change in the number of large roach caught (Fig 21).

The major changes post-barrage are the large increases in young fish, up to 12 cm in dace, 15 cm in roach and 20 cm in chub (Figs 19-21).

Length frequency histograms have been drawn for pre- and post-barrage flounder in Section 21 (Fig 22). As electrofishing is relatively inefficient in deep water, sampling efficiencies for flounder differ between pre- and post-barrage years in all impounded sections. However in Section 21, pre- and post-barrage conditions are broadly comparable. The numbers of small (10-15 cm) flounders caught have declined since the barrage construction. This implies that access to the river has been inhibited by the barrage. No young of the year flounder were caught in Section 21 in either pre- or post-barrage years.

4.5 Length-Weight Regressions

Sub-samples of fish were weighed in all years of the survey, except 1996 and 1997. Length-weight regressions were calculated for all age groups combined for each year from the equation:

$$\log_{10} \text{weight} = \log_{10} a + b(\log_{10} \text{length})$$

The constants for each regression are given in Tables 7-9.

Table 7 Values of the length-weight regressions for dace in the R. Tees

Year	$\log_{10}a$	b	r^2(%)	No. weighed
1991	-2.33	3.37	98.4	366
1992	-2.29	3.35	96.5	219
1993	-2.31	3.37	98.7	225
1994	-2.51	3.52	96.0	176
1995	-2.36	3.38	96.5	31
1998	-2.19	3.25	98.4	118

Table 8 Values of the length-weight regressions for chub in the R. Tees

Year	$\log_{10}a$	b	r^2(%)	No. weighed
1991	-2.03	3.11	99.6	129
1992	-1.93	3.04	98.3	112
1993	-2.00	3.10	99.2	307
1994	-2.05	3.13	99.7	186
1995	-2.22	3.25	99.2	78
1998	-2.02	3.10	99.4	196

Table 9 Values of the length-weight regressions for roach in the R. Tees

Year	$\log_{10}a$	b	r^2(%)	No. weighed
1991	-2.05	3.22	96.9	364
1992	-2.11	3.28	97.6	89
1993	-2.12	3.28	98.6	140
1994	-2.26	3.39	97.9	74
1995	-2.07	3.23	99.4	17
1998	-2.02	3.18	97.3	111

These regressions, calculated for dace, chub and roach, were tested for between year differences. Comparisons were made between pairs of lines and intercepts using the t test after first testing error variance using an F test. Significant differences between years were found for dace, chub and roach (Tables 10-12). In dace, the 1998 length-weight regression had a significantly lower slope than in any other year, suggesting there may have been a change in body form so that fish were thinner for their length. (there is evidence of a decrease in instantaneous growth rate in dace- see Section 4.7). 1998 slopes of the length-weight regression for chub and roach were within the range of values seen in previous years, although in roach, the slope was lower than all other years except 1995 (which may be inaccurate due to low sample size).

Differences can reflect biological changes or may be the result of different proportions of mature and immature fish in the samples but is often constant for fish similar in these respects (LeCren 1951). Length frequency histograms for weighed fish in each year have been drawn for dace, chub and roach (Figs 23-25). From these figures, it can be seen that different proportions of each size cohort have been sampled in each year. This differing proportion of mature and immature fish weighed, together with the relatively low sample numbers in 1995, may account for the unexpected variation in length-weight regressions.

Table 10 Comparisons of length-weight regressions of dace between years

a) between slopes. * = significantly different at p = 0.05, ns = not significant

Year	1991	1992	1993	1994	1995
1998	*	*	*	*	*
1995	ns	ns	ns	*	
1994	*	*	*		
1993	*	*			
1992	ns				

b) between intercepts . * = significantly different at p = 0.05, ns = not significant, nt = not tested

Year	1991	1992	1993	1994	1995
1998	nt	nt	nt	nt	Nt
1995	ns	ns	ns	nt	
1994	nt	nt	nt		
1993	nt	nt			
1992	*				

Table 11 Comparisons of length-weight regressions of chub between years

a) between slopes. * = significantly different at p = 0.05, ns = not significant

Year	1991	1992	1993	1994	1995
1998	ns	*	ns	*	*
1995	*	*	*	*	
1994	*	*	*		
1993	*	*			
1992	*				

b) between intercepts . * = significantly different at p = 0.05, ns = not significant, nt = not tested

Year	1991	1992	1993	1994	1995
1998	ns	nt	*	nt	nt
1995	nt	nt	nt	nt	
1994	nt	nt	nt		
1993	nt	nt			
1992	nt				

Table 12 Comparisons of length-weight regressions of roach between years

a) between slopes. * = significantly different at p = 0.05, ns = not significant

Year	1991	1992	1993	1994	1995
1998	*	*	*	*	ns
1995	ns	ns	ns	*	
1994	*	*	*		
1993	*	ns			
1992	*				

b) between intercepts . * = significantly different at p = 0.05, ns = not significant, nt = not tested

Year	1991	1992	1993	1994	1995
1998	nt	nt	nt	nt	ns
1995	ns	ns	ns	nt	
1994	nt	nt	nt		
1993	nt	*			
1992	nt				

4.6 Condition Factors

Condition factors were calculated for dace, chub, roach and gudgeon in years when fish were weighed (1991-95, 1998) using the formula:

$$\text{Condition Factor} = \frac{W}{L^b}$$

Where W = weight (g), L = length (cm) and b = the slope of the appropriate length-weight regression ($\log_{10}W = \log_{10}a + b\log_{10}L$).

There were significant differences between the gradients of the length-weight equations in different years in dace, chub and roach. Therefore it was not valid to compare condition factors using the above formula between years with significantly differing values of b.

In order to allow between year comparisons, condition factors were recalculated using the equation:

$$K = \frac{W}{L^3}$$

where K equals condition factor.

K values were calculated for each individual fish weighed in each year with data split between control sections (18 – 25) and impounded sections (1 – 17). Each year's data was grouped into 5cm length categories (0.0 – 4.9 cm, 5.0 – 9.9 cm, 10.0 – 14.9 cm etc.). For dace, chub and roach, further analysis (two tailed t tests) was conducted between pre- and post-barrage data (Tables 13-15). Post-barrage data was only collected in 1995, when few fish were weighed, and 1998.

Table 13 **Comparisons of condition factors of dace pre- and post-barrage from impounded areas (Sections 1-17) and unaffected areas (Sections 18-25)**

Size cm	Pre-barrage		Post-barrage		p	Significance
	mean K	number	mean K	number		
Sections 1-17						
0 - 4.9			0.87	3	nt	
5 - 9.9	1.10	33	1.11	31	ns	
10 - 14.9	1.24	139	1.21	36	ns	
15 - 19.9	1.43	216	1.33	39	***	pre > post
20 - 24.9	1.54	133	1.28	9	***	pre > post
25 - 29.9	1.53	1			nt	
Sections 18 - 25						
0 - 4.9		0		0	no data	
5 - 9.9	1.20	10	1.31	2	ns	
10 - 14.9	1.21	22	1.21	15	ns	
15 - 19.9	1.37	49	1.31	12	ns	
20 - 24.9	1.43	16	1.33	1	nt	
25 - 29.9		0		0	no data	

Table 14 **Comparisons of condition factors of chub pre- and post-barrage from impounded areas (Sections 1-17) and control areas (Sections 18-25). *** = significantly different at p = 0.001, ** = significantly different at p = 0.01, * = significantly different at p = 0.05, ns = not significant, nt = not tested**

Size cm	Pre-barrage		Post-barrage		p	Significance
	mean K	number	mean K	number		
Sections 1 - 17						
0 - 4.9		0		0	no data	
5 - 9.9	1.29	9	1.11	27	ns	
10 - 14.9	1.29	53	1.22	32	ns	
15 - 19.9	1.34	85	1.25	78	***	pre > post
20 - 24.9	1.37	195	1.30	43	***	pre > post
25 - 29.9	1.40	104	1.44	10	ns	
30 - 34.9	1.46	9	1.42	19	ns	
35 - 39.9	1.45	17	1.46	4	ns	
40 - 44.9	1.49	10	1.44	3	ns	
45 - 49.9	1.39	11	1.30	1	nt	
Sections 18 - 25						
0 - 4.9		0		0	no data	
5 - 9.9	0.99	1	1.15	2	nt	
10 - 14.9	1.24	8	1.26	9	ns	
15 - 19.9	1.25	13	1.28	19	ns	
20 - 24.9	1.32	37	1.31	18	ns	
25 - 29.9	1.42	34	1.36	2	ns	
30 - 34.9	1.46	7	1.36	1	nt	
35 - 39.9	1.35	6	1.30	3	ns	
40 - 44.9	1.37	3	1.39	2	ns	
45 - 49.9	1.46	1	1.47	1	nt	

Table 15 **Comparisons of condition factors of roach pre- and post-barrage from impounded areas (Sections 1-17) and unaffected areas (Sections 18-25). *** = significantly different at p = 0.001, ** = significantly different at p = 0.01, * = significantly different at p = 0.05, ns = not significant, nt = not tested**

Size cm	Pre-barrage mean K	Pre-barrage number	Post-barrage mean K	Post-barrage number	p	Significance
Sections 1 - 17						
0 - 4.9		0		0	no data	
5 - 9.9	1.42	17	1.45	31	ns	
10 - 14.9	1.60	81	1.49	52	***	pre > post
15 - 19.9	1.70	153	1.68	15	ns	
20 - 24.9	1.83	22	1.64	4	*	pre > post
25 - 29.9	1.63	1	1.65	4	nt	
Sections 18-25						
0 - 4.9		0		0	no data	
5 - 9.9	0.84	1	1.11	2	nt	
10 - 14.9	1.55	5	1.49	13	ns	
15 - 19.9	1.64	19	1.66	7	ns	
20 - 24.9	1.75	4		0	nt	
25 - 29.9		0		0	no data	

For all three species, in controls (Sections 18 to 25), there were no significant differences in condition factor pre- and post-barrage (Tables 13-15). However, in impounded sections, there were significant reductions in condition factor post-barrage in the 15–19.9 cm and 20-24.9 cm size categories for both dace and chub (Tables 13 and 14).

For roach, significant differences were found in impounded sections between pre- and post-barrage mean condition factor in the 10 – 14.9 cm and 20 – 24.9 cm categories, both of which show lower mean condition factor in post-barrage years (Table 15).

4.7 Instantaneous Growth Rate

Instantaneous growth rates (G) were calculated using the method described in the 1995 Interim Report (Section 5.6). The means of the true instantaneous growth rates were calculated from 1991 to 1997 year classes only. As G is calculated using back-calculation from scales, the most recent measure of G0 available was 1997. In order to obtain comparable data for the 1991 year class, G0 was calculated from 1+ fish caught in 1992. Setting these criteria increases the proportion of young fish in the sample, reducing the possibility of Lee's phenomenon affecting the mean instantaneous growth rates in the younger age groups, where growth is most rapid.

Instantaneous growth rates were calculated for each year class (Table 16). These show that for dace and chub, post-barrage, the growth rates were lower for G0 and G2 with G1 slightly higher. For roach, post-barrage results are lower for G1 and G2 and the same for G0.

Typically, factors affecting coarse fish in the first year of life have the greatest effect on the resulting year class strength. For this reason G0s have been analysed for differences in pre- and post-barrage years using two tailed t-tests (Table 17).

Table 16 **Instantaneous growth rates of dace, roach and chub for pre- and post-barrage periods**

	G0	G1	G2	G3	G4	G5	G6
Dace							
Pre-barrage	6.56± 0.05	1.53± 0.06	1.17± 0.07	0.85± 0.16	0.66		
Post-barrage	6.44± 0.07	1.55± 0.07	1.02± 0.10				
Chub							
Pre-barrage	6.64± 0.05	1.32± 0.05	1.37± 0.05	0.98± 0.07	0.78± 0.11	0.57± 0.20	0.33± 1.61
Post-barrage	6.44± 0.07	1.55± 0.06	1.04± 0.07				
Roach							
Pre-barrage	6.50± 0.07	1.55± 0.08	1.09± 0.09	0.78± 0.14	0.68± 0.14	0.45± 0.26	0.70
Post-barrage	6.51± 0.07	1.35± 0.08	1.04± 0.09				

Table 17 **Mean G0 values for pre- and post-barrage dace, chub and roach. *** = significantly different at p = 0.001, ** = significantly different at p = 0.01, * = significantly different at p = 0.05, ns = not significant, nt = not tested**

		mean	t	Significance
Dace	pre	6.56	-2.93	**
	post	6.44		
Chub	pre	6.64	4.55	***
	post	6.44		
Roach	pre	6.50	0.10	ns
	post	6.51		

G0 values for both dace and chub were significantly lower post-barrage, whereas for roach, there was no significant difference (Table 17).

Mean G0s were plotted against mean May – August temperatures for dace and against mean June to August temperatures for chub and roach (Fig 26). There was a general pattern of increasing G0 with increasing temperature in dace and roach, whilst in chub the pattern was not clear.

Monthly mean temperatures pre-barrage were sometimes significantly different from post-barrage but were always within 1°C suggesting that any significant differences in growth rates between pre- and post-barrage years were either minimal or dependent on factors other than temperature.

4.8 Relative Year Class Strength

Relative year class strengths were calculated for dace, roach and chub using the Mann (1973) method as described in the 1995 Interim Report (Section 5.3.1). To calculate the Mann relative year class strength (Ma), the mean value of the proportion of each age group in the population is calculated, using data from all years of the survey (measured and assigned ages). Ma for each year class is a measure of the proportion of that year class compared to the calculated average for the appropriate age class, in each year in which the year class has been captured. Due to differing sampling efficiencies, data from fish aged 0+, 1+ or 2+ in the year of capture are excluded from the analysis, therefore 1995 is the most recent Ma value available. An Ma value of 100 indicates an average year class, > 100 indicates better than average, < 100 indicates below average. 1989, 1994 and 1995 were above average year classes for all three species (Fig 27).

An alternative method of calculating relative year class strengths was developed based on a method used by Linfield (1981). In the original Linfield method, the proportion of fish in each age class was compared with an expected proportion, this expected proportion being an intuitively produced UK average. The Linfield relative year class strength (L) compares the proportion of fish in each age class in post-barrage years with expected values based on pre-barrage data. An L value of 0 indicates a year class strength equal to what would be expected based on pre-barrage data. An L value of 100 indicates twice as many fish of that age class were caught than would be expected. An L value of –100 means that no fish of that year class were caught post-barrage. After closure of the barrage, all dace pre-barrage year classes were present in lower proportions than would be expected based on pre-barrage data. Most chub and roach pre-barrage year classes were also present in lower proportions than expected (seen as negative values in Table 18). This may be due to increased mortality, post-barrage, as a result of migration to deeper waters where electric fishing efficiencies were lower or out of the study area to more natural sections of the river. It is also likely that fish from the older year classes had, by this time, died out.

L can be plotted against Ma for each of the three species (Figs 28). Due to the method of calculation, all below average Ma values will return a negative L value. In roach, strong year classes (Ma > 100) all occur in higher proportions than expected based on pre-barrage data (L > 0), indicating good post-barrage survival. The opposite is true for dace, where all but one of the strong year classes are present in lower proportions than would be expected based on pre-barrage data, indicating poor post-barrage survival of older fish in this species. Post-barrage survival in chub appears to be intermediate between dace and roach.

Table 18 **Values of Linfield Relative Year Class Strength (L) for Tees dace, chub and roach**

Year Class	Dace	Chub	Roach
1980		113.2	
1981		-100	
1982		-37.9	
1983		-92.8	
1984		-83.5	
1985		-92.1	
1986		-73.3	
1987	-100.0	-90.0	-100.0
1988	-100.0	-87.5	-100
1989	-92.9	6.8	527.3
1990	-95.7	-90.2	-82.2
1991	-90.2	-87.9	-91.2
1992	-91.0	-75.9	-93.8
1993	-76.4	-84.9	-83.4
1994	-20.7	0.2	9.6
1995	68.8	135.0	88.4
1996	5.0	-57.4	125.5
1997	51.9	84.7	93.6

4.9 Predicting Dace Relative Year Class Strength

Mann relative year class strength (Ma) was plotted against the number of 0+ dace, chub and roach caught in all years (Fig 29). The Ma value excludes data from fish aged 0+, 1+ or 2+ in the year of capture. There was a general pattern of increasing year class strength with increasing number of 0+ caught in September. Linear regressions gave r^2 values of 61.9%, 90.3% and 45.3% for dace, chub and roach respectively. Using these relationships, it is possible to estimate the Mann relative year class strength, based on the number of 0+ fish caught in the IFE survey, with the estimate for chub being the most reliable, although changes in sampling technique or post-barrage survival rates may affect our ability to predict year class strength in this way.

Year class strength, in dace, is dependent on growth in the first summer and that growth is, in part, dependent on temperature (Mills and Mann 1985). For Tees dace, plotting Mann relative year class strength (Ma) against mean summer water temperature (T), for pre-barrage years, gives a linear relationship of:

$$Ma = 32.36T - 425.17 \qquad (r^2 = 68.9\%) \qquad \textit{Equation 1}$$

Using Equation 1, Ma values of 93, 136 and 67 can be predicted for the post-barrage year classes 1995, 1997 and 1998 (no temperature data exist for 1996). Due to the method of calculation, 1995 is the most recent year for which an Ma value has been calculated. For dace, the 1995 Ma is 166, which is based solely on 3+ dace caught in September 1998.

Calculated Ma for the 1995 year class of dace is therefore higher than would be expected based on 1995 mean summer water temperature.

The growth of fry from hatching to September is reflected in the mean length of 0+ fish in September. Although year class strength is thought to be related to growth in the first year, plotting Ma against September length of 0+ dace gives a poor linear regression ($r^2 = 14.2\%$).

A good relationship has been found between the number of 0+ dace caught in September and the Ma value for that year class (see above). Ma has been related to the number of 0+ caught during September surveys (#0+), for pre-barrage year classes only, giving the equation:

$$Ma = 0.0352(\#0+) + 57.836 \qquad (r^2 = 82.4\%) \qquad \textit{Equation 2}$$

From Equation 2, Ma values of 108, 70, 117 and 151 can be predicted for the 1995, 1996, 1997 and 1998 year classes respectively. Again the calculated 1995 Ma value (166) exceeds the prediction (108).

Equation 2 can be rearranged to predict the number of 0+ that would be caught in each post-barrage year if the temperature/Ma relationship (Equation 1) has not altered. In 1995, based on mean summer water temperatures (T) the catch can be predicted as:

$$\#0+ = \frac{(Ma - 57.836)}{0.0352} \qquad \textit{Equation 3}$$

where 93 is the predicted Ma value for 1995, based on the relationship between Ma and T (Equation 1). Solving this equation gives a predicted catch of 999 0+ dace in September 1995. The actual number of 0+ caught in 1995 was 1422 (1.4 times the predicted catch), indicating enhanced survival of fry in the first post-barrage year. By substituting the predicted 1997 and 1998 Ma values into Equation 3 (136 and 67 respectively), the predicted catches of 0+ dace in 1997 and 1998 are calculated as 2234 and 264 respectively. The actual number of dace fry caught in 1997 was 1681 ($^3/_4$ of the predicted catch), and in 1998 the actual catch of 0+ dace in September was 2670, just over ten times the predicted number.

In summary, the number of 0+ dace caught in 1997, a warm year, was close to what would have been expected based on the relationship between mean summer water temperature and Mann relative year class strength in pre-barrage years. The number of 0+ dace caught in 1998, a colder year, was over ten times greater than would have been expected and the number of dace caught in 1995, an average year in terms of water temperature was 1.4 times the expected value. (In 1995 the impounded sections were significantly colder than upstream as the barrage was closed in December 1994 and the river filled with cold water. Regardless of the fact that 1995 was warm in terms of air temperature, the water temperature was only average.) The 1995 year class has a measured Ma value of 166 (based on 3+ dace caught in September 1998), this is greater than predicted Ma based on water temperature or number of 0+ caught in 1995. Indications are that survival of young dace has increased since barrage closure, with the greatest effect being in colder years, when there is also the most room for improvement. In pre-barrage years, colder summers may have been associated with higher rainfall and increased water velocities, leading to increased displacement of dace fry from suitable habitats. This effect has probably been reduced by the barrage closure and may in part explain the large number of 0+ caught in 1998.

4.10 Predicting Chub Relative Year Class Strength

A similar series of calculations was performed for Tees chub. The relationship between mean summer water temperature (T) and Mann relative year class strength for pre-barrage chub was poor ($r^2 = 35.7\%$). As chub spawn later than dace, Ma was plotted against mean June to August temperature (T). A linear regression was calculated using this data, giving a relationship of:

$$Ma = 51T - 775.08 \qquad r^2 = 65.8\% \qquad \textit{Equation 4}$$

Using Equation 4, Ma values of 103, 110 and 21 were predicted for the 1995, 1997 and 1998 year classes of Tees chub.

As in dace, plotting Ma against September mean lengths gave a poor relationship ($r^2 = 0.4\%$).

A good relationship was found between the number of 0+ in caught in September in pre-barrage years and Ma:

$$Ma = 0.4081(\#0+) + 21.716 \qquad r^2 = 86.3\% \qquad \textit{Equation 5}$$

From Equation 5, Ma values of 160, 68, 203 and 549 can be predicted for the 1995, 1996, 1997 and 1998 year classes of Tees chub.

Equation 5 can be rearranged to predict the number of 0+ caught in September given the Ma value expected from the mean June to August water temperature. So, in 1995, when the predicted Ma is 103:

$$\#0+ = \frac{(Ma - 21.716)}{0.4081} \qquad \textit{Equation 6}$$

The predicted catch of 0+ chub in 1995 was 199. The actual catch was 338 chub, 1.5 times the predicted number. Substituting the 1997 and 1998 Ma values predicted from T (110 and 21) into Equation 6, returns predicted catches of 216 chub in 1997 and –2 chub in 1998. The actual numbers of chub caught in the 1997 and 1998 September surveys were 444, roughly twice the predicted value and 1293 respectively. Accepting that a predicted catch of –2 chub is unrealistic, indications are still for a low number to have been caught in 1998. The actual 1998 catch far exceeds the predicted catch.

In summary, the calculated Ma value for 1995 was 199 (based on the number of 3+ chub caught in September 1998). This was higher than both the estimated Ma value of 103 based on water temperature and the estimated Ma value of 160, based on the number of 0+ caught in 1995. The number of 0+ caught in 1995 was 1.5 times greater than would have been expected based on mean June-August water temperature. The number of 0+ caught in September 1997 was twice as large as predicted from water temperature, whilst the 1998 catch of chub far exceeded the predicted number. As with dace, survival of chub appears to have increased post-barrage, presumably from lack of flow either directly or indirectly, with the greatest effect occurring in the coldest year.

4.11 Predicting Roach Relative Year Class Strength

For Tees roach, plotting pre-barrage Ma against either mean summer temperature or mean June-August temperatures gave a poor linear relationship (r^2 = 11.2% and $r^2 < 0.1\%$ respectively). The slope of the regression line was also negative, which was unexpected, as it would mean stronger year classes being produced from colder years, when growth would be less. Plotting Ma against the mean September length of 0+ roach in September also gave a poor regression (r^2 = 9.4%). Plotting the number of 0+ caught in pre-barrage September surveys against either mean summer temperature or mean June to August temperature gave poor regressions.

4.12 Parasitic Copepods

By subjective assessment, many of the dace caught in 1998 were in poor condition and a relatively large proportion were carrying parasitic copepods. Of 125 dace scaled for age examination, 32 (25.6%) were recorded as having copepods present. These parasitised fish were distributed throughout the study area. Copepod carrying fish were found in 9 sections (Sections 1-5, 11, 16, 21 and 25), with the highest numbers in Sections 2, 4 and 25 (5 dace, 7 dace and 9 dace respectively). No copepods were found on dace in 3 other sections (Sections 8, 13 and 14). A comparison has been made with numbers of copepods on dace in 1997, 1996 and 1992 (Fig 30). In 1992, 25 (10.8%) of 231 scaled dace were carrying copepods, whilst in 1996 and 1997, 6 (7.4%) of 81 scaled dace and 17 (11.6%) of 147 scaled dace had copepods present. The proportions of parasitised dace in 1992, 1996 and 1997 were similar, whilst the proportion of infected dace rose in 1998 to more than twice that level. The increasing population of copepods may be a result of the barrage, but there is no evidence that copepod parasitism was increased above pre-barrage levels in 1996 or 1997.

In addition to the dace, two chub were recorded as being parasitised by copepods in 1998. Both of these chub came from Section 25, where the infestation of dace was at its heaviest.

The species of copepod found in the surveys is likely to be *Tracheliastes polycolpus* von Nordmann, 1832. This is a parasitic freshwater copepod which can be found on the fins of cyprinid fish, particularly dace and sometimes chub (Fryer 1982).

5. TEMPERATURE

5.1 Introduction

Continuous temperature recording was started in early 1992 at Low Moor (Section 21), above the influence of the proposed barrage and at Ingleby Barwick (Section 5), in the expected impounded section. Temperatures were logged every hour using Squirrel loggers in 1992-95 and miniloggers in 1997-98. Details of the methodology can be found in the Annual Reports. Monthly means were calculated from daily means of hourly measurements between 0900 h and 0859 h (to be compatible with Met office data). The monthly mean temperatures at the two sites were compared for months when records were available (Table 19).

5.2 Results

Pre-barrage, the difference in temperature between Low Moor (upstream control) and Ingleby Barwick (expected impounded) was less than 0.5°C, within the error limit of the temperature thermistor. In 1995, the year following the closure of the barrage, temperature data were available for May to August only at both sites. Temperatures at the impounded site were 2.5-3.5°C colder than at the control site upstream. The barrage was closed in December of the previous year, and the river filled with cold water. It is apparent that this large volume of cold water took a long time to warm.

Comparisons in 1997 and 1998 showed that temperatures were never more than 0.8°C different between the two sites in any month. Although the difference was significant in 1997 (two-tail t test on the difference) with Low Moor temperatures higher, the difference is again within the errors expected from the thermistor.

Table 19 Mean monthly temperatures of the R. Tees at Low Moor (unaffected by the barrage) and Ingleby Barwick (impounded)

Low Moor	1992	1993	1994	1995	1996	1997	1998
January		3.1	3.0				4.5
February	5.7	5.0	2.1				6.6
March	6.5	6.2	5.4	1.4			7.2
April	8.6	9.0	8.0	8.6			8.5
May	15.1	12.0	12.3	13.9			14.5
June	18.8	16.1	16.4	16.2		12.8	14.3
July	18.0	16.7	19.4	19.9		16.5	16.6
August	16.2	15.1	16.6	19.6		19.8	16.0
September	12.6	12.5	12.5			13.0	15.3
October	7.7	8.1	9.4			10.0	
November	5.2	4.6	8.1			7.5	
December	3.6	3.4				5.3	

Ingleby Barwick	1992	1993	1994	1995	1996	1997*	1998
January	1.8	3.1	3.1	2.6			5.3
February	4.3	4.9	2.3				6.6
March	6.4	6	7.7				7.3
April	8.7	8.8					8.5
May	15	11.9		10.8			13.6
June	18.4	16		13.7		12.9	13.9
July	18	16.7		16.4		17.1	16.7
August	16.4	15		17.5		20.4	16.2
September	12.7	12.5	12.4	13.2		13.8	15.2
October	7.8	7.9	9.3	11		10.8	
November	5.1	4.6	7.9	6.9		7.3	
December	3.6	3.7	4.8			5.9	

* mean of surface and bottom where appropriate.

5.3 Comparisons with the Dorset Frome

The monthly mean temperatures on the Tees were compared with those on the Frome. In no year was the temperature of the Tees significantly higher than that of the Frome when calculated on an annual basis. In four of the six years, however, the Tees temperatures were significantly lower than those of the Frome (Table 20). This may have been due to winter temperatures only. Calculations were repeated for summer (May – August) temperatures comparing the difference between the means. For this statistic, $t = 1.19$, $p = 0.25$ and it is concluded that there is no significant difference between summer temperatures in the Frome and the Tees.

Table 20 Comparisons of Tees temperatures at two sites with temperatures from the River Frome in Dorset. Ns = no significant difference, * = Tees significantly lower than Frome at p = <0.05, ** lower at p = <0.01, * lower at p = <0.001**

	Temperature of Tees significantly lower than Frome	
	Low Moor	**Ingleby Barwick**
1992	Ns	Ns
1993	***	***
1994	**	**
1995	Ns	Ns
1997	**	*
1998	*	*

6. ANGLING

6.1 Introduction

Yarm Angling Club fish water which is in the middle of the impacted part of the river (Sections 5-11) and could provide comparative data from angling matches from pre- and post-barrage periods. Yarm AC provided historical catch weights from matches and agreed to complete an angling survey at each match. This provided, not only catch weights, but the composition of the catch in terms of species, numbers, sizes and distribution of fish. There were no other angling clubs able or willing to provide data from the affected reach.

Initially, the angling club had reservations about calculating mean catch per angler. Many anglers did not wait to weigh in their catch if poor relative to others, thus the mean catch per angler might be artificially high. As this was the pre-barrage control they felt that the statistic should reflect the true picture. For this reason, the mean catch for the top 10 anglers in a match was calculated. Whilst it is recognised that this is not a true reflection of the mean catch, it does provide a basis for comparison with post-barrage results. Both means are given in this report.

Data have been collected from 3 pre-barrage angling seasons (91/92, 92/93 and 93/94), one intermediate year in which the barrage was shut mid-season (94/95) and 3 post-barrage years (95/96, 96/97 and 97/98).

6.2 Catch weights

Mean catch per angler and mean catch per angler for the top ten anglers in each match, together with confidence limits, are displayed in Figs 31 and 32. The 1997/98 values of mean catch per angler and per top 10 anglers were significantly greater than for any other post-barrage year. Catch weights have increased from low levels immediately prior to the closure of the barrage and are comparable to the high catch weights found before the pollution event of 1983, and in the early 1990s.

Catch results were split into 4 periods. These were unequal in terms of time but related to the anglers' perception of how the river fished and where fish were at particular times of the year. During the periods June to August and September to October, there were significant decreases in mean catch weight per peg following closure of the barrage (Table 21). More pegs were fished post-barrage (Fig 33). The pegs not fished pre-barrage in matches were a result of anglers' experience in knowing from pleasure fishing that poor results would be obtained. From a comparison of pre- and post-barrage mean catch weights at each peg along the river, in each season, post-barrage catch weights seem more evenly distributed (Fig 33). The maximum catch weights for each peg were lower post-barrage than they were during pre-barrage years (Fig 33). The pre-barrage, high catch weights during the November 1 – February 14 season have been replaced, post-barrage, by a more even distribution of catch weights during that period. There was a significant decrease in mean catch weight per peg. During the February 15 – March 14 season, the high pre-barrage catches from the alphabet pegs were not seen post-barrage. The range of mean catch weights in this season was lower after the barrage closed, but was still more variable than the other post-barrage seasons.

Although the distribution of catch weights changed, the overall mean weight per peg was the same (Table 21).

Table 21 **Mean catch weight per peg (oz) for four seasons on the R. Tees. *** = significantly different at p = 0.001, ** = significantly different at p = 0.01, * = significantly different at p = 0.05, ns = not significant, nt = not tested**

Season	Mean catch weight per peg		t	Significance
	Pre-barrage	Post-barrage		
Jun 16-Aug 31	60.1±7.6	37.9±2.9	5.39	***
Sep 1-Oct 31	54.4±6.0	44.4±2.6	3.00	**
Nov 1-Feb 14	76.8±18.4	57.1±3.8	2.09	*
Feb 15-Mar 14	44.6±15.2	44.6±6.9	-0.01	ns

6.3 Species Composition of Catches

Species composition has again been split into the four time periods and into pre- and post-barrage periods (Fig 34). Little difference can be seen in the first two periods other than an increase in the proportion of perch caught.

In the two periods covering November to March, however, dace formed an increasing proportion of the catch post-barrage at the expense of roach in the third period and both roach and chub in the fourth period (Fig 34). These findings, however, cannot be shown statistically (t tests on arcsine transformed data) except in the November to February season when the post-barrage proportion of dace was significantly greater than in pre-barrage years (p = 0.03).

Considering the data on an annual basis, there is a suggestion that the proportion of roach is increasing in the summer and autumn and dace and chub may be decreasing (Fig 35).

6.4 Size Composition of Catches

Anglers' catches of dace, chub and roach have been recorded as numbers of large and small fish, with large dace and roach being >6 oz (170 g) and large chub being > 1 lb (454 g). Catches were split into proportions of large and small fish of each species in each of the four angling periods to determine whether the size distribution of each species in the catch had altered (Fig 36). Although no species in a single season shows any significant difference in proportion between pre- and post-barrage catches (p> 0.05 for t tests in all cases), it is clear that the proportion of large dace and chub post-barrage is lower than pre-barrage when all seasons are combined (Fig 37). This can be shown statistically at the 5% level for dace using a paired t test (p = 0.02) but not for chub (p = 0.08), although it is significant at the 10% level. In the case of roach, a similar proportion of large fish is apparent before and after closure of the barrage (Fig 37).

6.5 Distribution of Fish

In the June 16 – August 31 period, large roach and chub were more widespread after the closure of the barrage. Large chub were limited to the upstream Sections (10 and 11) pre-barrage whereas post-barrage large chub were caught in Sections 9 and 5 in addition to Sections 10 and 11. Large roach were spread out over the whole of the angled reaches post-barrage whereas they had been confined to 5 pegs in Section 11, and 10 pegs in Sections 6 and 5 before the closure of the barrage (Fig 38). Large dace, expected to reduce in numbers post-barrage were caught over the whole stretch post-barrage. Small chub seem slightly more widespread post-barrage; otherwise little change can be seen.

In the September 1 to October 31 season, large chub seem more aggregated after the closure of the barrage and large dace, although spread out, were caught at fewer pegs than pre-barrage. Large roach were evenly spread in both pre- and post-barrage periods. The distribution of small fish did not change with catches of all three species at most pegs both before and after closure (Fig 38).

In the November 1 to February 14 season, small fish were concentrated on the 'alphabet pegs' (No 88a-88i) pre-barrage. Angling was limited to Sections 9-11 with the perception that pegs further downstream did not fish well at this time of year. These pegs were fished post-barrage and catches were good at all pegs. Large dace and large roach were almost ubiquitous, as were small fish from all three species (Fig 38).

The February 15 – March 14 season shows the most dramatic changes. Pre-barrage catches of large and small dace, large and small roach and small chub were all centred around the alphabet pegs. Post-barrage, these fish are more evenly distributed along the whole reach (Fig 38).

6.6 Angler Assessment

Although no direct angler assessment was conducted, the match statistics show that the number of anglers has increased after the closure of the barrage. Angling match statistics from the three pre-barrage years were compared with the three post-barrage years. The 1994-1995 season was excluded as the barrage was closed in December 1994. The number of anglers increased significantly after the closure of the barrage from a mean of 30.9 to 57.3 ($t = 6.93$, $p<0.001$). In addition there was a significant decrease in percentage of anglers that failed to catch (down from 21.8% to 13.7%, $t = 2.18$, $p<0.05$). This shows that for at least match anglers, their perception is that the fishing is better than it was before the barrage. The decrease in blanks shows that the fish are now more evenly distributed in the river.

Anglers' complaints now centre around the subject of predation by cormorants. These comments are appended to match results in a sporadic way (depends on persons filling in the sheets) such that it is not possible to assess whether the problem is greater or lesser since the closure of the barrage.

7. HABITAT

Before the closure of the barrage the river was tidal and on flood tides the river flowed upstream, not just in the lower sections but up to Section 15 at Low Worsall, some 20 km upstream of Stockton. On flood tides, as exposed mud banks were inundated, fine sediment was suspended and turbidity increased. Whole tree trunks and branches drifted upstream and downstream and could be present until a flood washed them downstream. Water level changed from deep at high water to un-navigable by boat at low water in certain areas. Boulders and bedrock became visible. The substratum in shallow areas was gravel or bedrock. Little aquatic vegetation was present and marginal vegetation was largely limited to *Phragmites* beds in Sections 2-4. Elsewhere, banks comprised grass, herbaceous vegetation, scrub or were tree covered above the high water mark. Water level varied greatly (c. 10 m) and the valley and banks were steeply sloping in many areas, particularly upstream. Some flood defence work had been completed.

After construction of the barrage, the river level has been stabilised at the high water springs level. During flood events, the river can still rise rapidly even if the barrage gates have been lowered. Many trees and shrubs were removed from the banks prior to barrage closure, in areas calculated to be inundated with water. The habitat is now more homogeneous and the river can be categorised into a few broad types:

1. Banks constructed of new concrete and steel sheet pilings, old wooden staging and bank support, gabions or rock reinforcement. In Sections 1, 6,7,9 and 10

2. Reaches with low unimproved grassland banks. In Sections 1, 2, 4 and 5.

3. Reaches with low wooded banks. In Sections 2, 4, 6, 10-12.

4. Reaches with dense stands of *Phragmites* in the margins. In Sections 2-4

5. Reaches with low improved grassland banks. In Section 4,7

6. Reaches with steep banks to improved grassland/arable. In Sections 4, 5, 7.

7. Reaches with steep wooded banks. In Sections 13-20, 23-25.

8. Reaches with branches of trees and shrubs in the water. Difficult access to the bank. No macrophyte growth. In Sections 6 and 14.

Types 2, 3, 6 and 7 may contain some macrophyte growth estimated to be <5% of the surface area when present. *Phragmites* beds are present in other sections to a limited extent. These may be important spawning habitats particularly for bream and roach.

8. DISCUSSION

8.1 Effect of the barrage

8.1.1 General

After closure of the barrage in December 1994, the river changed from a fast flowing relatively shallow tidal river to a slow impounded deep body of water. The river was affected from Stockton (the site of the barrage) to Low Worsall, some 20 km upstream. It was expected that species normally inhabiting flowing waters would be deleteriously affected whereas species which naturally inhabit still or slow flowing habitats would flourish.

8.1.2 Fry

Fry of most coarse fish occupy the margins of rivers and can be particularly susceptible to washout especially when very young. Critical velocities for fry occur mainly in the early post-hatch stage (Pearsons *et al.* 1992). Larval dace and roach fry select velocities <2 cm s^{-1} (Mann and Mills 1986, Lightfoot and Jones 1979, respectively). Post-barrage, the areas of river with these low velocities will have increased markedly, such that practically all river bank margins are suitable for fry. This contrasts with the situation before the barrage when fry had not only to find areas out of the flow but also these areas changed depending on the state of the tide. Critical displacements can still occur in flood conditions or by artificially increasing flow by lowering the barrage gates.

Statistically significant changes in species composition could not be demonstrated between fish communities pre- and post-barrage. This is in part due to the method of sampling where consistent effort was not applied either within or between years. There was a shift in emphasis away from seine netting, post-barrage, due to the increase in water depth. There were also differences between years in conditions that control the onset of spawning and growth of fry. The fry sampling was only carried out for one week a year thus results were dependent on conditions. This explains results such as in 1996 when no chub fry were recorded and a second survey had to be carried out. The timing of sampling was at best a compromise between identifying dace spawning sites, such that the survey had to be carried out before fry became too mobile, and waiting for all fry species to appear. Inevitably, this increased the variability of data. Examination of the data does however suggest that there has been a shift in the species composition of the three major species and that roach are increasing in proportion whereas both dace and chub are decreasing.

In the Yarm area (Sections 7/8), a known dace spawning site when the river was not impounded, the proportion of dace fry was significantly reduced after closure of the barrage. Dace spawn in shallow water on clean gravel (Mann and Mills 1986), the reduction in the proportion of fry was therefore expected as Sections 7/8 should no longer have been so attractive for spawning due to the increased depth and associated sediment deposition. There was an associated increase in chub fry. It was expected that chub, which also spawn on clean gravel, would also decrease. At the other identified dace spawning sites in Sections 17 and 21, which are both above the influence of the barrage, there was no reduction in the proportion of dace fry post-barrage.

These data should be interpreted carefully, remembering that when dealing with proportions, for instance, an increase in numbers of one species will inevitably cause a decrease in the others even if their numbers have not changed. Also proportions do not reveal whether overall numbers are increasing or decreasing. It is extremely difficult to obtain quantitative estimates of fry in large lowland rivers. An extensive sampling programme is required and meaningful results are not guaranteed.

Early indications of a change in species composition can be seen by the appearance of bream and perch fry. Both of these species have the potential to do well in this impounded system. In contrast, there has been a noticeable reduction in flounder fry since the construction of the barrage. Although the increased depth precluded effective sampling in the impounded reaches, numbers were very much reduced in the unaffected upstream reaches suggesting that the reduction is a consequence of fish being impeded by the barrage.

Post-barrage, the distribution of fry changed. Fry were present in the lowest section (Section 1), previously uninhabitable by fish. This large increase in habitat for juveniles has resulted in an increase in fish numbers generally. Post-barrage, dace fry were present in reduced numbers downstream of Section 10, areas previously colonised from the dace spawning site at Yarm. In general, fry were widely distributed along the whole of the study reaches. Prior to the barrage, it was concluded that fry were distributed with the flow, both in an upstream and downstream direction associated with the tide. Post-barrage, however, passive distribution was limited due to the lack of flow and the presence of fry is more likely to be associated with local spawning areas.

In future, the sampling of fry should be limited to identifying spawning sites of the different species. This will require more frequent sampling and should be responsive to changes in river conditions. Species composition is better left until fry become juveniles and can be sampled by boom-boat electric fishing later in the year.

8.1.3 Adult survey

Although the methods employed to sample the adults did not change after construction of the barrage, the efficiency almost certainly altered. Several factors were responsible which would either have decreased or increased the efficiency. Decreased efficiency would result from the increased water depth, increased engine noise (post-barrage it was necessary to motor, pre-barrage electrofishing was by drifting with the tide), fish not being oriented in the same direction, post-barrage, such that they would not necessarily be facing the anode when galvanotaxis was initiated. Increased efficiency would result from easier manoeuvrability of the boat and easier netting.

Numbers of fish increased post-barrage reflecting an increase in habitat (areas uninhabitable due to salt water before barrage closure) and possibly an increase in survival of juveniles. Although quantitative data were not collected, an estimate based on numbers caught per length of riverbank was calculated for comparative purposes. Inevitably, these estimates had wide error limits and as a consequence, showing statistically significant differences was not possible in all cases. This does not detract from the overall result which showed that densities of roach and chub increased whilst those of dace decreased, with the exception of the lowest sections where no fish were found pre-barrage. Interestingly, densities in the control sections, above the influence of the barrage, showed similar trends to the impounded sections.

Length frequency information shows that the increase in numbers is largely due to increases in the younger age classes and that in dace the number of fish in older age classes may have decreased. Thus, the fish populations are at present in a state of flux and several more years' data will be necessary to evaluate the post-barrage population.

Condition factors were calculated for dace, chub and roach for years when weights of fish were available. In control sections, upstream of the barrage, there were no significant differences between pre- and post-barrage data for any of the length classes of fish. In the impounded sections, the condition factor of both dace and chub in the two length classes 15-20 cm and 20-25 cm showed significant reductions post-barrage. Whilst this may have been predicted for riverine species, the significant reductions in the 10-15 cm and 20-25 cm classes for roach, which are also lacustrine, post-barrage were unexpected. It is possible that the impounded sections have yet to achieve a natural balance in terms of zooplankton and other food, resulting in sub-optimal conditions at times. It was noticeable, that the dace in particular looked in very poor condition in 1998, and in addition, one quarter were infected with a parasitic copepod.

Year class strengths were calculated in two ways and by comparison, it was possible to eliminate the effect of temperature and determine that in good years, roach survival, post-barrage, was higher than predicted from pre-barrage data. The opposite was true for dace, with poorer post-barrage survival than expected.

8.1.4 Temperature

Apart from the year following the closure of the barrage, the mean monthly temperatures in the impounded sections were the same as in the control sections upstream for all months of the year. There was a suggestion that stratification may be taking place in the deep impounded sections. Temperature records for Barwick Farm showed lower bottom temperatures with daily variation of <1°C in August 1997 compared with 4°C at the surface and 2°C at Low Moor.

8.1.5 Angling

A major objective of this work was to gather information on the coarse fish stocks of the Tees so that the Agency would be fully prepared to deal with anglers should any complaints arise from the construction of the barrage. The anglers have had a major change to their sport in terms of methodology. Before the barrage, in a fast tidal river, running line float fishing was the preferred method. Experience dictated at what states of tide it was possible to catch fish, such that, at certain times in a match, anglers would not bother to actually fish. Once the river became impounded, anglers switched to pole fishing and with the lack of tide, were able to catch fish throughout a match.

During the pre-barrage years of the study, the mean catch weight per angler fell from >70 oz (1991/92) to 30 oz (1993/94). Anglers at this time were blaming cold compensation water from Cow Green reservoir, released (they claim) at weekends, and/or cormorants. After closure, catch weights have increased, and are at present (1997/98) >60 oz per angler. The 50% increase in this season corresponds to the increase in numbers seen in the September 1997 survey. Catch weights are now comparable with pre-pollution values (flux oil used in Tarmac making entered the Tees in October 1983 killing large numbers of coarse fish). It is expected that weights will increase as the young fish (which are responsible for the increase) grow. Anglers are, at present, happy with the fishing, there are fewer blanks in matches, fish are more evenly distributed and it is felt that matches are no longer won or lost at the draw for pegs. Complaints now centre around predation by cormorants.

Contrary to the changes in species composition of the adult fish as shown by the September surveys, anglers catches comprise a larger proportion of dace, since the closure of the barrage, in the two periods between November and March. This is due to small fish, with the proportion of large dace decreasing since the closure of the barrage. These small fish are not expected to remain in the impounded sections when they mature, it is likely that they will migrate upstream to the unaffected part of the river where spawning conditions remain unchanged. Over the year as a whole, roach can be seen to be forming an increased proportion of catches in the summer and autumn at the expense of dace and chub. Proportions of large roach have remained constant and it is expected that their numbers will increase as the young fish grow. It is expected that the proportions of each species will continue to change in the coming years as bream, perch and pike increase in numbers. It is further expected that the proportion of roach will increase and dace and chub will decrease.

8.1.6 Habitat

The change from a fast flowing tidal river to a deep, slow flowing body of water has repercussions on the fish community. Spawning habitat is altered. Species requiring fast flow, such as dace and chub have decreased spawning habitat and it is unlikely that any major spawning will occur for these species in the 20 km downstream of Low Worsall. Species spawning on marginal vegetation, such as reeds, are likely to proliferate since eggs are no longer left above the waterline, as was the case at low tide before the construction of the barrage. Species such as bream and roach will increase in numbers. Bream fry have already been found but will take time to increase from such a small initial number of adults in the river. Roach have already increased in number and are expected to continue to increase.

Perch spawning substrate is now plentiful with the increase in tree branches in the water and subsequent growth of tree roots particularly from willows. In addition, it is likely that they will also spawn in the fish havens on macrophytes. As with bream, this species is starting from a small initial stock and may take several more years to reach its full potential.

Pike spawning areas have not increased to the same extent. Pike prefer slack ditches and backwaters with macrophyte growth. These areas have increased since the introduction of the barrage but the main spawning areas for pike are likely to be in the fish havens, which are likely to provide ideal shallow, weedy slack areas.

Fry survival is improved mainly due to the lack of flow. Fry habitat is now very abundant and little losses occur due to washout, unless there are floods at a critical time and the barrage gates are lowered. Food abundance and quality is unknown and changes associated with the introduction of the barrage have not been studied. It is likely that food supply has increased if only due to the lack of washout. Phytoplankton and subsequently zooplankton are not expected to increase dramatically due to the peaty colour of the water and the lack of shallow areas. Given that the water temperature has not changed since the introduction of the barrage, food supply becomes the major factor in growth of fry. Samples of fry from June are available for pre-barrage and post-barrage years. Their guts could be analysed to determine whether feeding strategy has altered.

It is known that fry migrate into the fish havens and growth and survival in these areas is expected to be better than the main river due to enhanced water temperatures. Bream fry in particular, have been found to be more common in the fish havens than in the main river, based on IFE surveys and Agency surveys of the fish havens. It is possible that bream may use the havens for spawning, seeking out warmer water. It is important, therefore, that access to and from the havens for fry and adult fish is managed so as to optimise production in the required manner.

8.1.7 Comparisons with data from other rivers

Comparisons of length in September (or at Age I [May] if data not available) shows that 0+ growth of dace is comparable to that in the southern chalk streams and faster than a large lowland river such as the Great Ouse (Table 22). The similarity between the Tees and Frome would be expected since there was no significant difference between summer temperatures on the Tees and those on the Frome. Similarly, roach can achieve the same lengths as in the Frome and Stour in a good year but growth is generally less fast and in poor years specimens of < 2 cm have been found in September. The range is higher in the Tees than in the Thames and Great Ouse, possibly due to the possibility of colder conditions in the Tees. The median size in the Tees is similar to that given for various lakes and is only less than in Tjeukmeer, which has the highest mean lengths recorded for age I fish. Initially, Tees chub appear to grow faster than those in the Great Ouse but slower than in many other rivers in Britain and the rest of Europe. The mean length of 0+ gudgeon in the Tees in September is very similar to the lengths at age I reported for the Frome and Stour. Young of the year Tees perch compare favourably with lengths reported at other locations, whilst pike growth appears to be lower in the first year in the Tees than in the Dorset Stour and Frome. Mean lengths of age I pike from various lakes also exceed September lengths recorded in the Tees. The lengths of 0+ pike from the River Tees were calculated from data collected in September 1998 when the number of pike caught exceeded that found in any other year of the study. Temperatures were relatively low in 1998, so growth in length of 0-group pike may be found to be greater in future years.

Kempe (1962), describing the damming of a river to form a reservoir in Sweden, noticed an extremely strong year class in the first year of damming followed by a series of poor year classes. There was an explosive increase in roach, perch and pike and he considered this to be a natural transition towards the natural population of fish in a lake in which perch may dominate. The Tees has mirrored this to some extent with a population increase, although not in the first post-barrage year. The appearance of pike and perch and the increase in roach numbers suggest that there is a transition occurring towards a lake population.

Instantaneous growth rates from the Tees pre- and post-barrage are compared with data from other rivers in Table 23. It can be seen that the G0 values for the Tees are both higher than for the Dorset Stour and Frome for dace and roach. Chub G0 values are lower than those calculated from the Stour. Instantaneous growth rates generally compare favourably with the other rivers except for chub, which are consistently lower than for the Dorset Stour. The calculated instantaneous growth rates show that the Tees is an extremely good coarse fishery but that the introduction of the barrage has, in some cases, adversely affected the growth of all three species.

Table 22 **Mean or median length of dace, roach and chub in September or at Age I. Data for other rivers were taken from the following sources: Great Ouse (IFE unpublished), Thames (IFE unpublished, Williams 1967), Willow Brook, (Cragg-Hine and Jones 1969), Stour (Mann 1973, 1974, 1976a, 1976b, 1978, 1980), Frome (Mann 1973, 1974, 1976a, 1980), Tjeukmeer (Mooij and van Tongeren 1990), others referred to in Mann 1976b (chub), Goldspink 1978 (roach), Mann 1978 (perch) and Mann 1976a (pike).**

Location	**Mean length mm (range)**					
	Dace	**Chub**	**Roach**	**Gudgeon**	**Perch**	**Pike**
Tees	5-6 (3-7)	2.5-5 (1.5-6.5)	2.5-5 (1-6)	4.3 (1.1-6.9)	7.9 (6.7-9.1)	19.4 (13.5-23.5)
Great Ouse	4.5-5.5 (3.4-5.7)	1.9-2.6 (1.6-4.5)	3-5 (2-5.5)			
Thames			3-3.5		6.9 at age I	
Willow Brook		8.9 at age I	4.8 at age I			
Stour	5.1	4.4 at age I	5.0 at age I	4.5 at age I	7.5 at age I	25 at age I
Frome	4.7-6.4		5.0 at age I	4.2 at age I		21.5 at age I
Tjeukmeer			4.9-6.3			
Lakes (various)			2.5-4.5 at age I		5.1-7.6 at age I	21-23 at age I
Welland		6.4 at age I				
Rest of Europe		3.6-6.4 at age I			6.8-10.6 at age I	

Table 23 **Comparisons of Mean Instantaneous growth rates between the Tees and other rivers for dace, chub and roach. Other data from Mann 1974, Williams 1967 (dace), Mann 1973, Williams 1967 (roach), Mann 1976b (chub).**

	G0	G1	G2	G3	G4	G5	G6
Dace							
Tees pre-barrage	6.56	1.53	1.17	0.85	0.66		
Tees post-barrage	6.44	1.55	1.02				
Thames			0.71	0.54	0.38		
Stour	6.16	2.17	1.11	0.58	0.26		
Frome	6.30	2.23	0.96	0.59	0.27		
Chub							
Tees pre-barrage	6.64	1.32	1.37	0.98	0.78	0.57	0.33
Tees post-barrage	6.44	1.55	1.04				
Stour	7.03	1.80	1.59	1.01	0.64	0.72	0.35
Roach							
Tees pre-barrage	6.50	1.55	1.09	0.78	0.68	0.45	0.70
Tees post-barrage	6.51	1.35	1.04				
Thames		1.53	0.77	0.57	0.39	0.19	0.20
Stour	5.63	2.04	1.08	0.83	0.44	0.26	0.22
Frome	6.11	1.96	1.26	0.74	0.56	0.44	0.35

Median lengths of dace, chub and roach from the September surveys on the Tees have been compared with data from the literature from other rivers. These data are back-calculated lengths at each age. Dace lengths are in general smaller than for the Frome, very similar to those from the Stour and larger than those from the Thames (Table 24). Chub lengths compare favourably with data from the Stour. Most information is available for roach. Tees roach are smaller than Frome roach, similar in length to those from the Stour and Lugg and larger than Thames and Willow Brook roach. Lengths from lakes are very variable, with Tees fish in the middle of the range (Table 24).

Table 24 Comparison of lengths of dace, chub and roach in September on the Tees with lengths at ages from back calculations in other rivers (where separate values are given for males and females, means are given here). Other data from references as above, Lugg (Hellawell 1972).

	Tees	Frome	Thames	Stour	Lugg	Willow Brook	Lakes
Dace							
1+ (II)	9.5-10.5	11.2	8.0	9.2			
2+ (III)	14.0	15.4	10.0	13.3			
3+ (IV)	15.0-18.5	18.4	11.9	16.2			
4+ (V)	17.0-20.0	20.3	13.4	18.4			
Chub							
1+ (II)	8.0-10.5			8.0			
2+ (III)	11.0-13.5			13.8			
3+ (IV)	16.0-20.5			19.4			
Roach							
1+ (II)	8.5-9.5	9.2	7.6	10.0		7.0	5.0-12.0
2+ (III)	10.5-14.0	13.1	9.6	14.0		9.3	7.0-17.5
3+ (IV)	14.0-15.5	16.4	11.4	15.0	15.5	12.0	8.0-22.6
4+ (V)	14.0-17.0	19.4	13.0	18.0	16.5	13.1	9.5-27.9
4+ (V)	21.5-23.0			21.0			

8.2 Prediction of Future Changes in Fish Community

As already stated, it is expected that dace numbers in the lower river will fall, despite the fact that very young dace appear to do well. Conditions are not ideal for chub either, and again, despite the increase in numbers of young fish, the species is not expected to do well in the long term. Roach and bream, however, are expected to increase in number due mainly to the increased survival of eggs resulting from the stable water level. Growth and survival of perch and pike fry is expected to be very good, given the abundance of small fish available as food, thus these species are expected to increase in number resulting in large specimens. It may be at least another ten years before the community is reaching equilibrium.

8.3 Recommendations on Future Management

Originally, it was expected that dace and chub would rapidly decrease in numbers and that it would take some considerable time for roach and bream to increase in numbers. In the meantime, there would be a hiatus, where anglers had an impoverished community to fish for. In fact, this has not happened, and anglers are extremely pleased with the fishery. Matches are held on most weeks and are usually sell outs with up to 200 anglers participating. There is thus some evidence to suggest that no management is necessary at all, and the community should be left to reach its own equilibrium.

However, there are management options available. Initially, fish havens were constructed on the lower river to create habitat particularly for young fish. Whilst these fish havens are being utilised by some species, it is unlikely that the small number is having any significant effect on the numbers of coarse fish in the Tees. They may, however, be enhancing certain species in the short term, allowing numbers to increase more rapidly than if they were confined to the river only. Perch and bream seem to be benefiting in this way. It is not recommended that new fish havens be constructed but that those present are maintained, especially important being the removal of debris and marginal macrophytes from the entrances to facilitate fish movement as required.

Originally there was consideration to scallop the banks to provide shallow areas for fry. In many places this would be difficult, as banks are steep and access is difficult. Also it would be difficult to create shallow areas on these steep banks. Since the construction of the barrage, fry habitat has become very widespread, and bank scalloping would not significantly increase the area available to fry.

8.4 Recommendations on Future Monitoring

Given that the fish community structure is still changing following the closure of the barrage and that it is expected to take at least 10 years to reach any equilibrium, it is recommended that monitoring is continued for at least 6 years. Results of the fry survey have shown how difficult it is to show differences following a change in a river. Quantitative information is very difficult to achieve without substantial manpower inputs, and even then, there is no guarantee of obtaining precise information. The fry survey is best considered as an early indicator of changes in species composition. Several surveys in a summer need to be carried out in order to sample all species present if spawning sites need to be recognised. Otherwise, young of the year can be recorded in the September adult survey.

It is recommended that the September survey continues but with reduced effort. It is unnecessary to electrofish all sections but it is felt that it is important to keep basically the same fishing team and equipment to give some consistency to the effort and efficiency. Five sections have been chosen to represent the different habitats along the whole length of the impounded reaches, plus one control section above the influence of the barrage. Section 1E represents the lower river, a section with low banks and unimproved grassland and scrub. Section 3 represents sections with reed lined banks. Section 5 represents low improved grassland banks. Section 7 represents the area downstream of previously good dace spawning habitat where some macrophyte growth is starting to appear. Section 12 is characteristic of reaches with steeper tree lined banks. Section 15, Low Worsall, represents the upstream sections of impoundment, with steep improved grassland banks and tree lined reaches.

Samples of young of the year should be compared with those from the Agency fry surveys to give growth estimates and indications of good or bad year class strengths. They should be related to temperature, which should be permanently logged.

Scale samples should be taken at intervals of 2 years to check on the age structure of the population. Due to the difficulty of accurately reading ctenoid scales, most authors (Williams 1967, Mann 1978) have used opercular bones when ageing perch. Due to the increasing significance of the perch population, it may be necessary to collect perch opercular material.

Significant increases in density have already been shown for the lower, middle and upper sections of river affected by the barrage for chub and roach, with the exception of the middle sections for roach. It is predicted that one further year at the mean post-barrage density, which is twice the pre-barrage density, will be enough to show a statistical difference. Overall, dace densities have fallen (apart from the lower section, previously uninhabitable), but it would take a halving of the pre-barrage density for 1999 the following 10 years, before a significant difference from pre-barrage levels could be demonstrated. Taking one section in isolation, eg Section 7 (Yarm), it would take 10 more years at half the pre-barrage density to show a statistically significant difference and 5 years to show a change at 20% of the pre-barrage density.

Taking the trend lines for changes in density for dace, chub and roach in Sections 1E and 3, 5 and 7, 12 and 15 as representatives of the lower, middle and upper reaches of impounded river, (Fig 39-41) it can be seen that chub and roach densities are still increasing sharply and even dace are increasing in some sections despite an overall decrease. Thus monitoring should be continued to study these trends even though an effect of the closure of the barrage has already been shown.

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Fig 1. Map of the R.Tees showing sampling sections

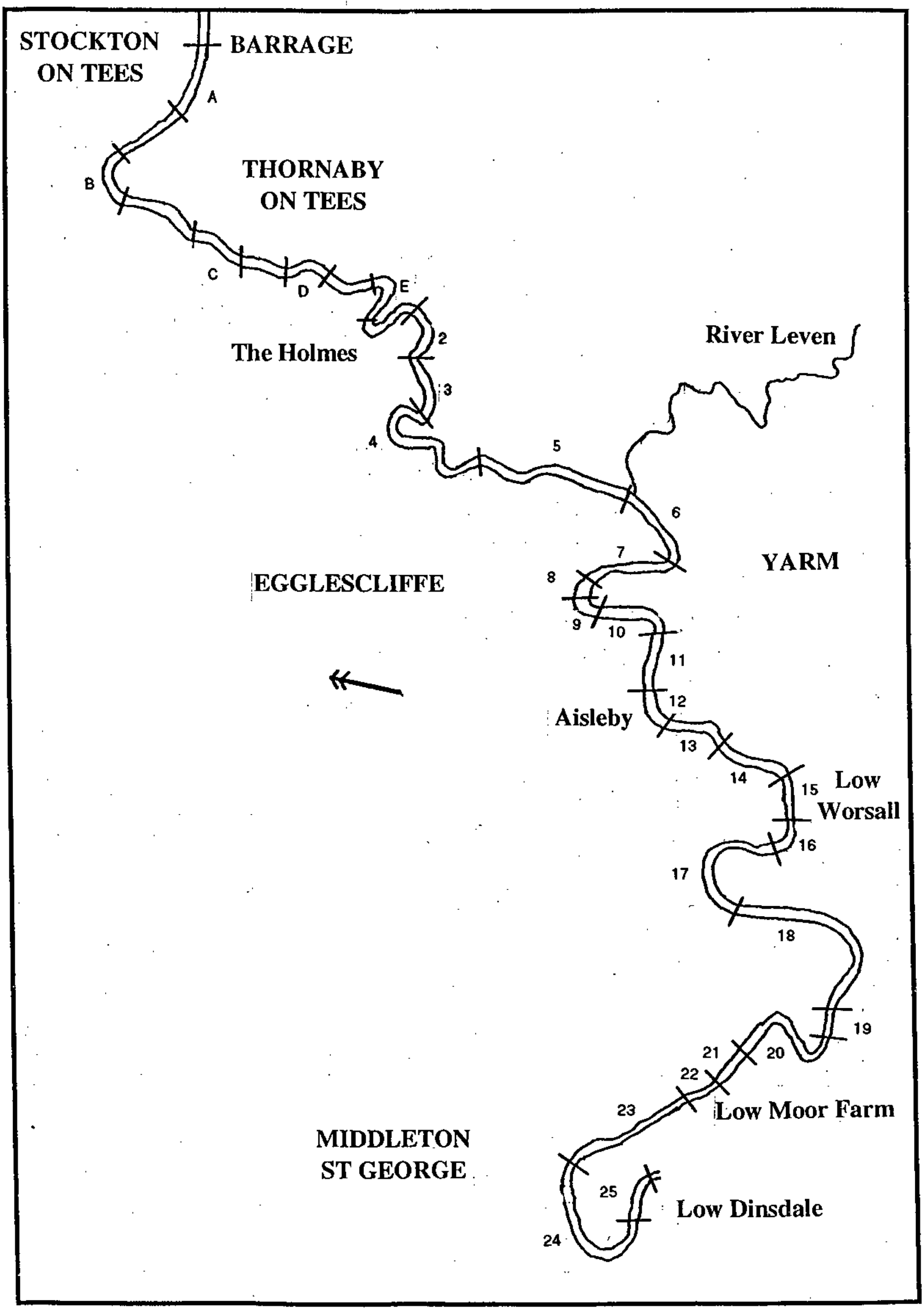


Figure 2. Percentage catch of each species comprising >2% in each of the fry surveys (minnows, stone loach, sticklebacks, bullhead removed)

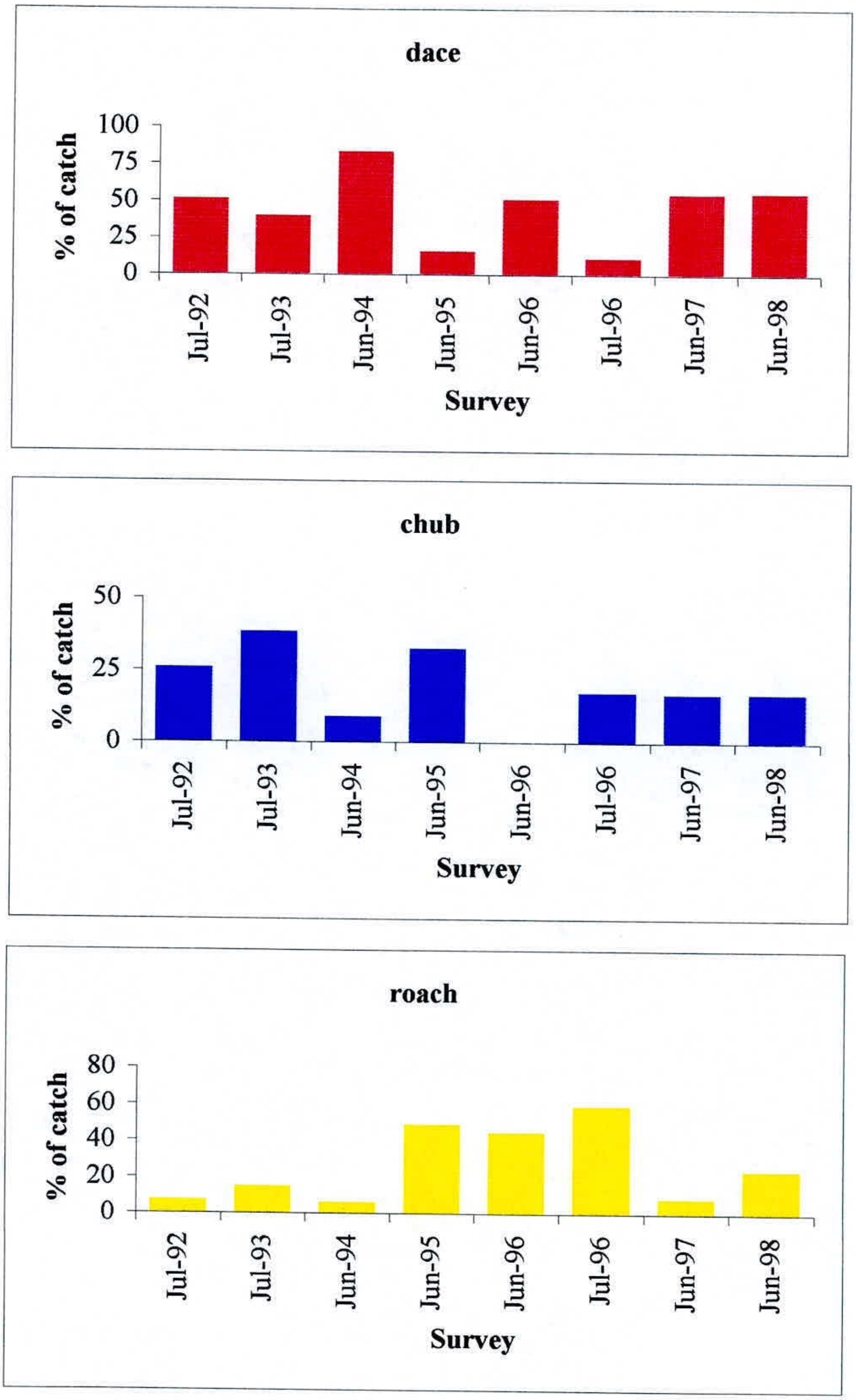
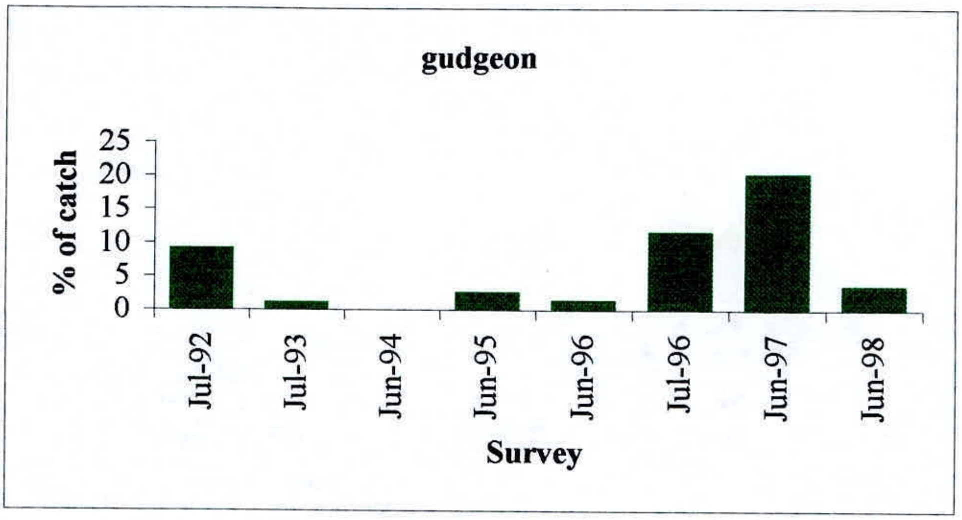


Figure 2. Continued



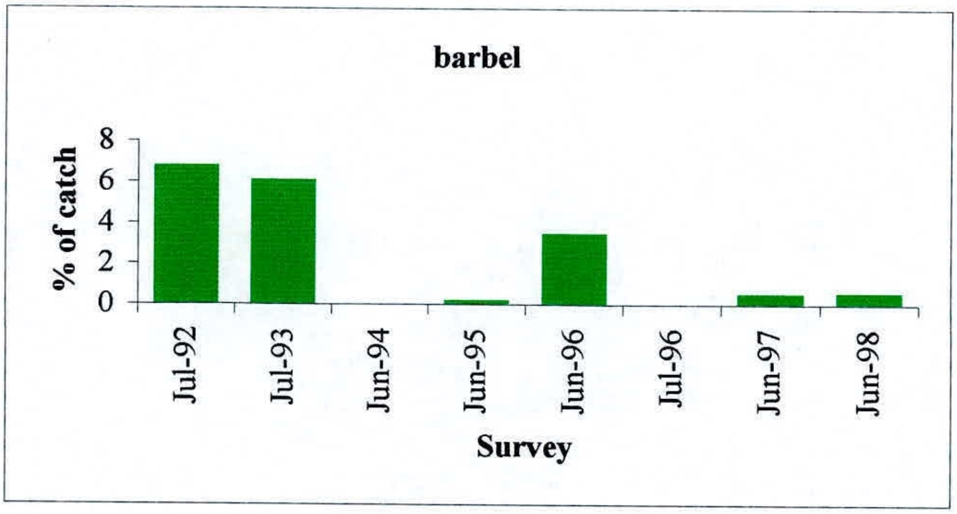


Figure 3. Number of dace fry in each section in each year
a) point sampling b) samples in which seine nets used

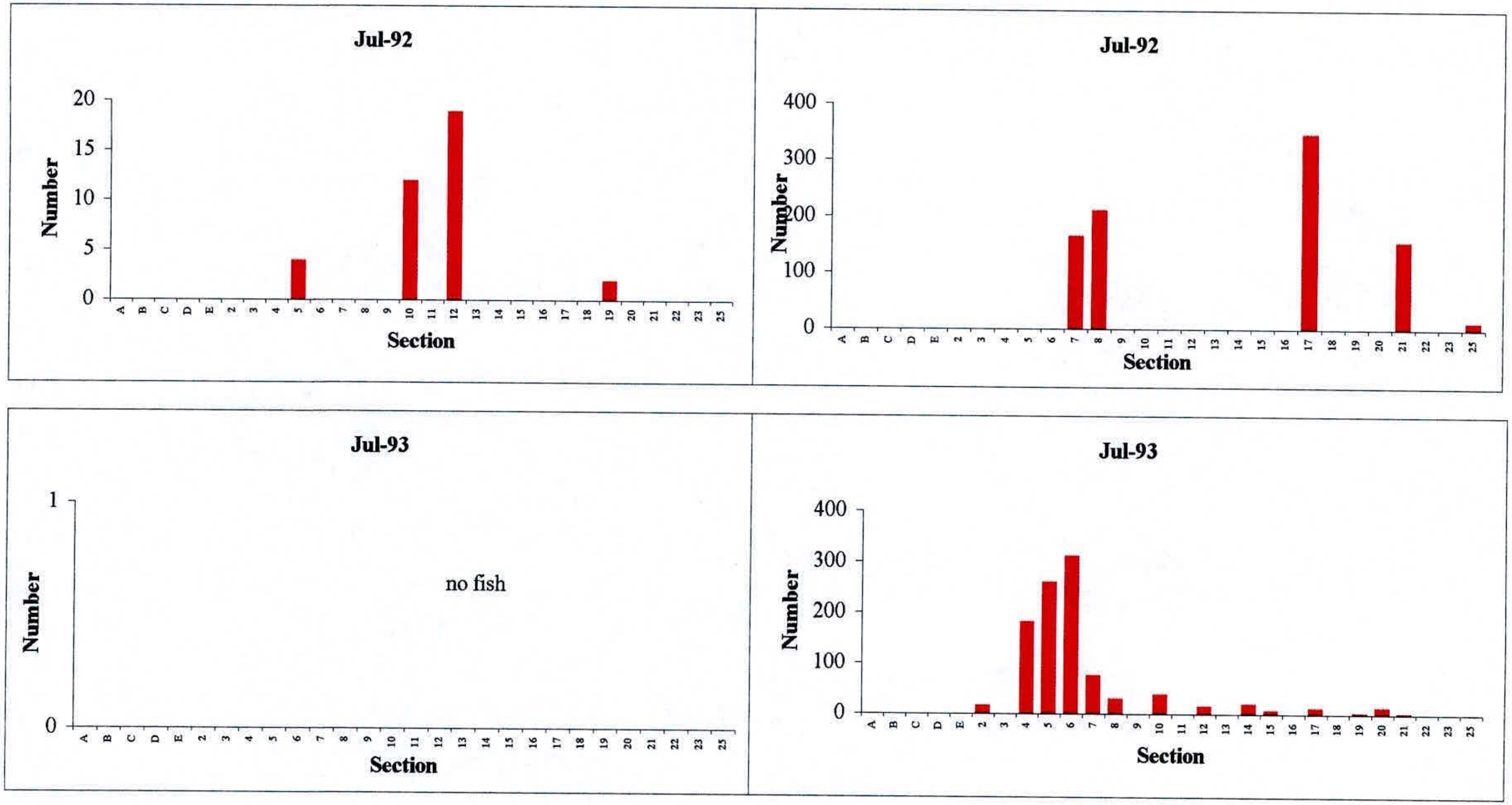
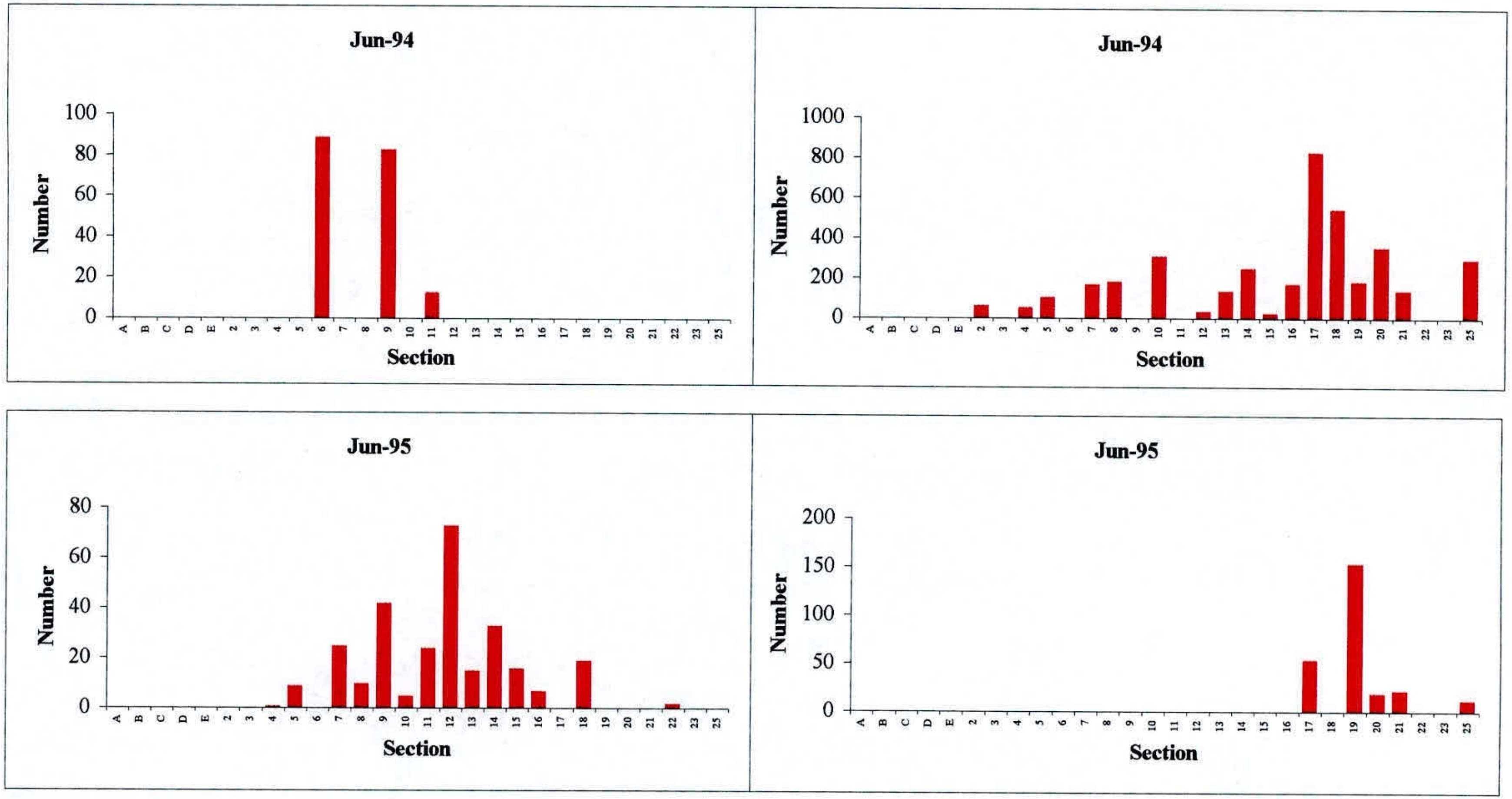


Figure 3. Continued

a) point sampling **b) samples in which seine nets used**



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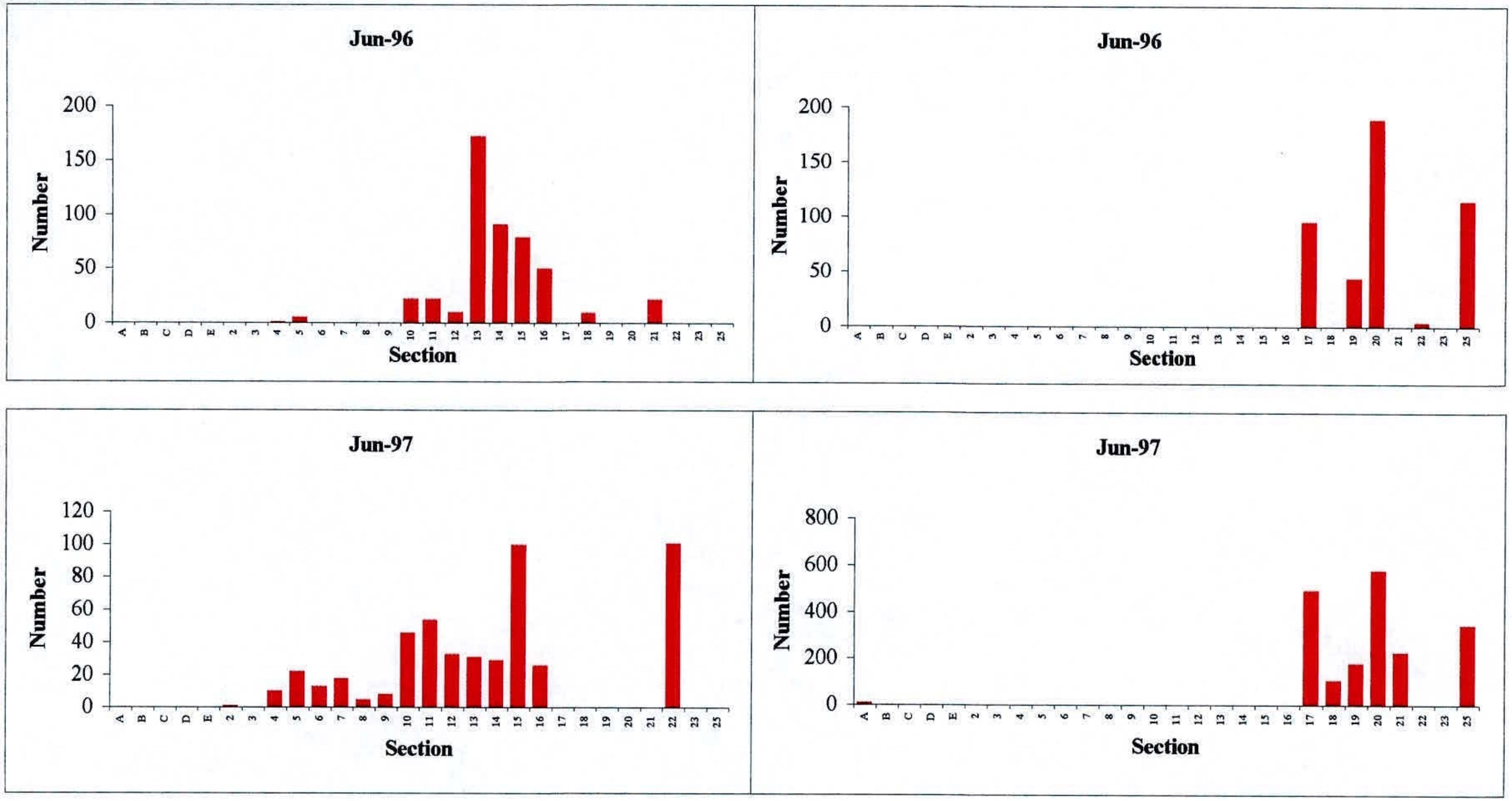

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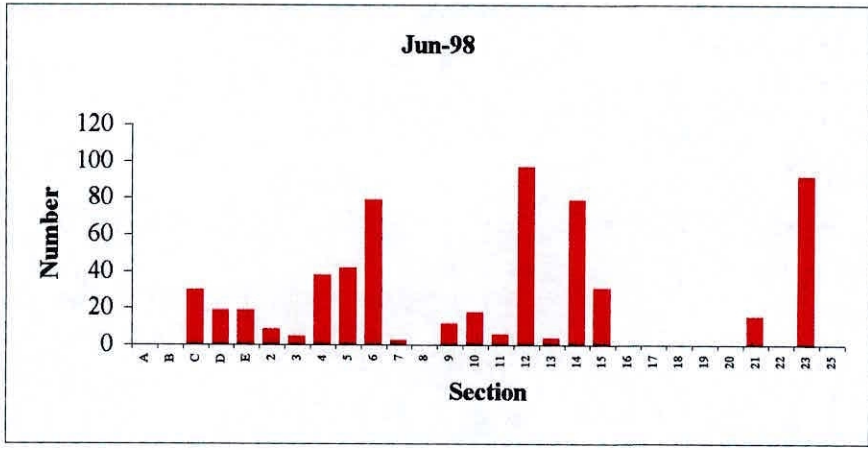


b) samples in which seine nets used

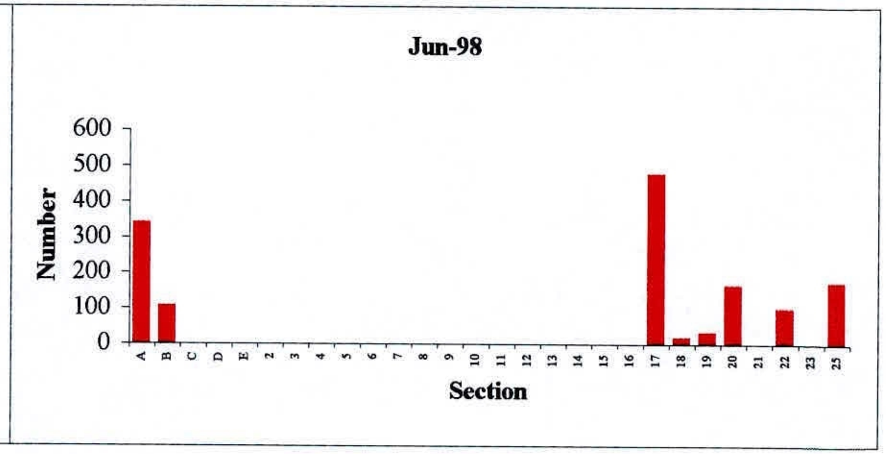
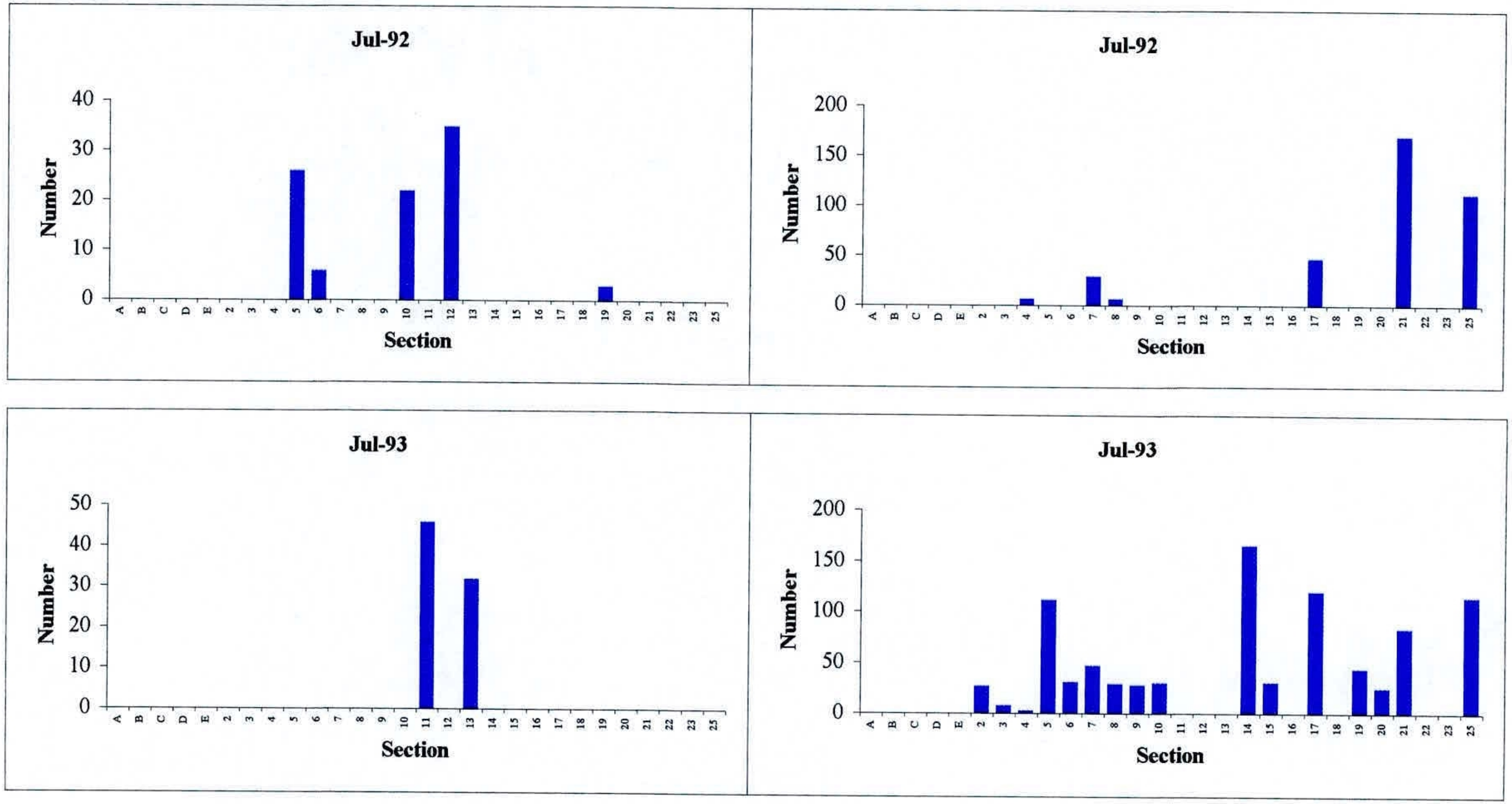


Figure 4. Number of chub fry in each section in each year
a) point sampling
b) samples in which seine nets used



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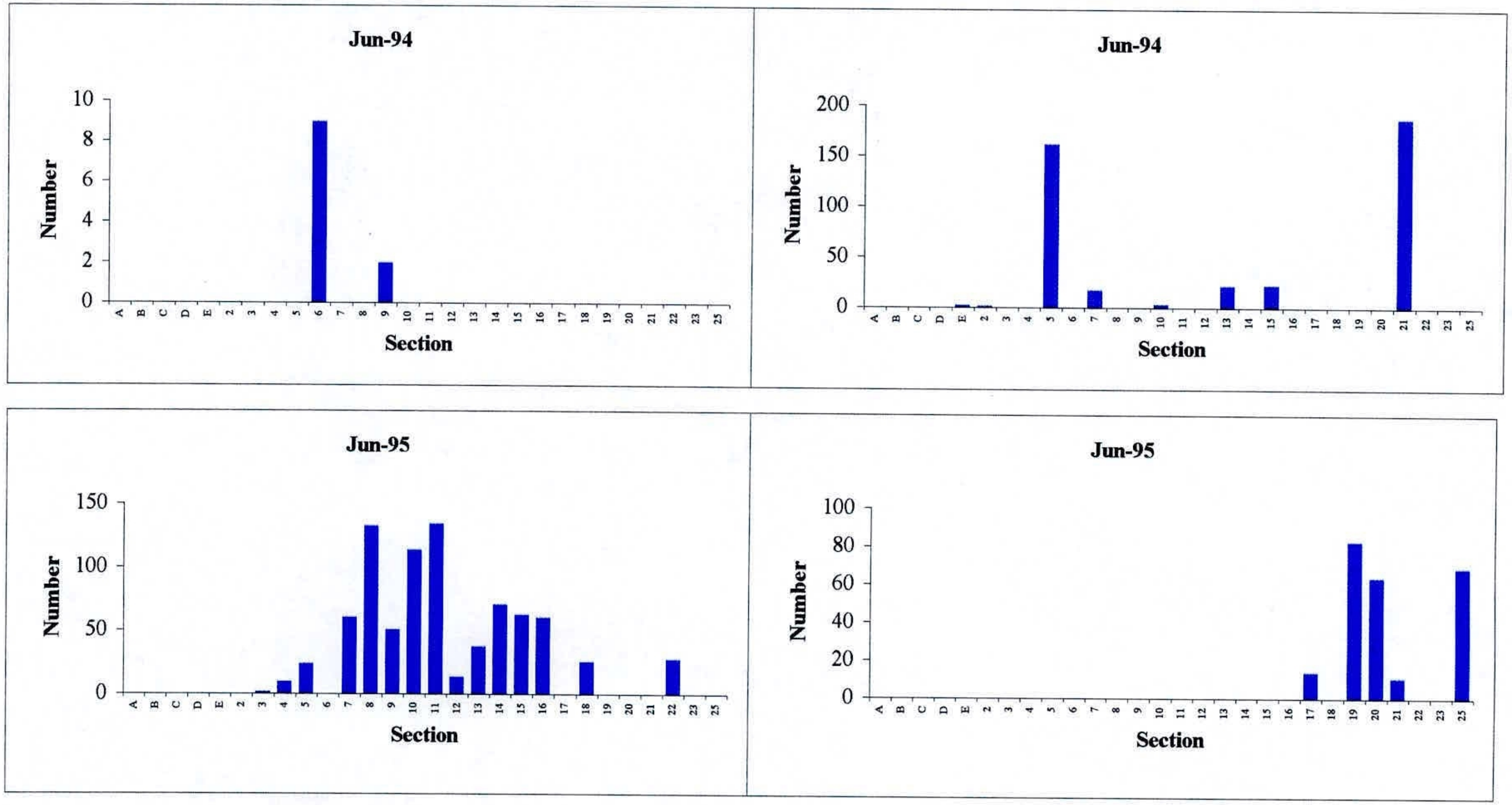

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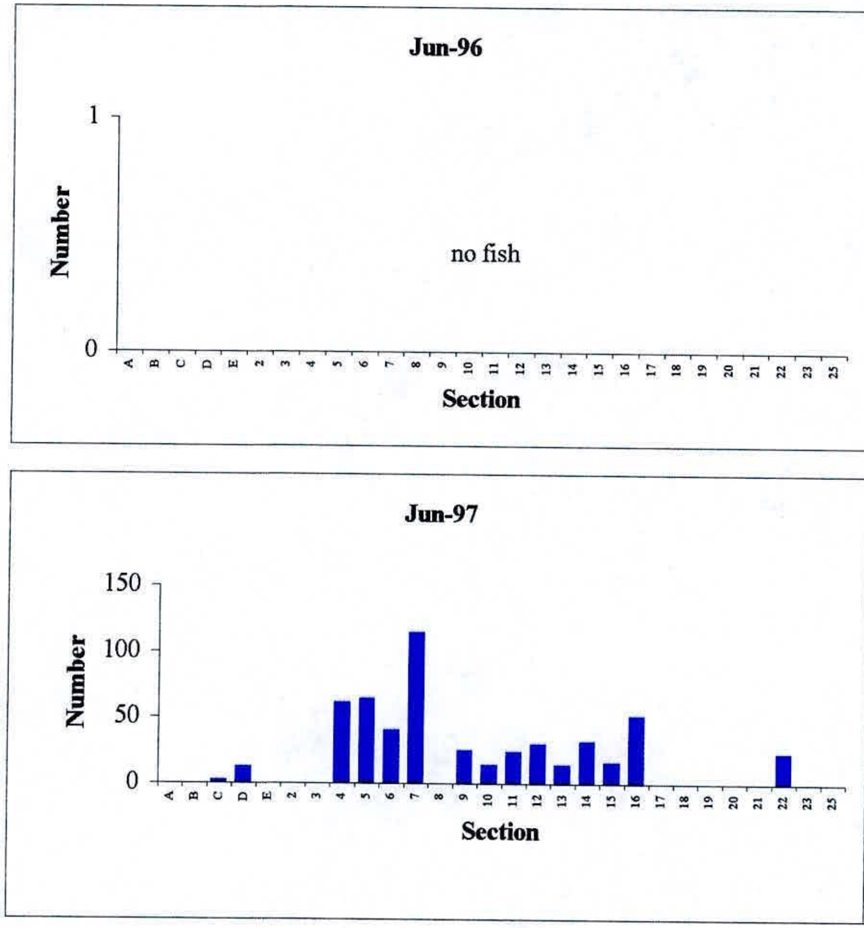

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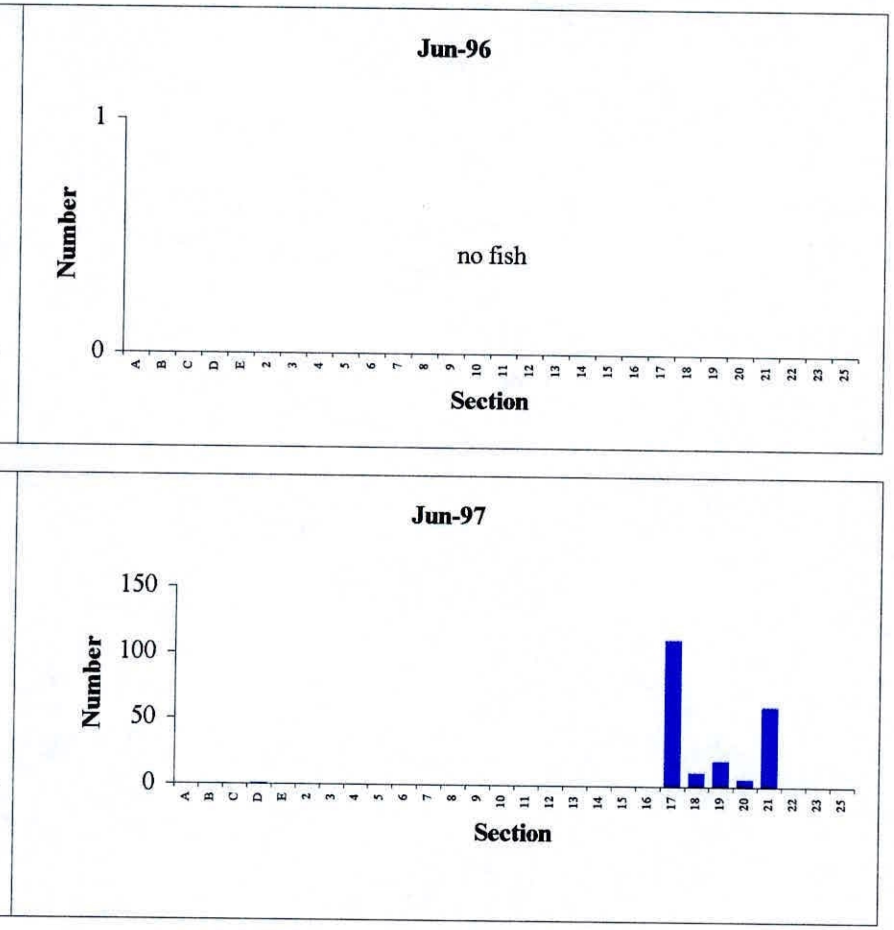

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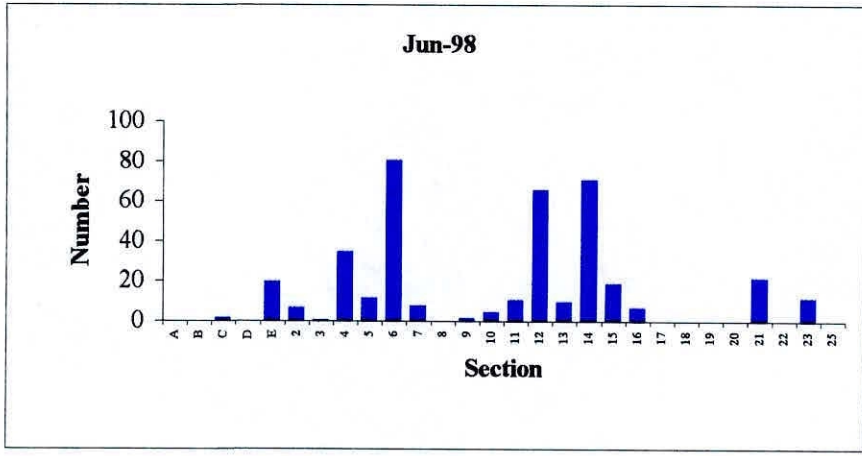


b) samples in which seine nets used

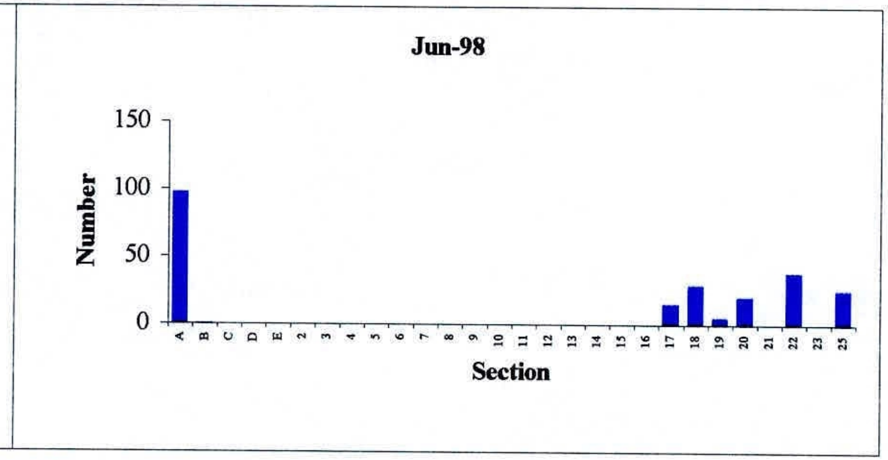
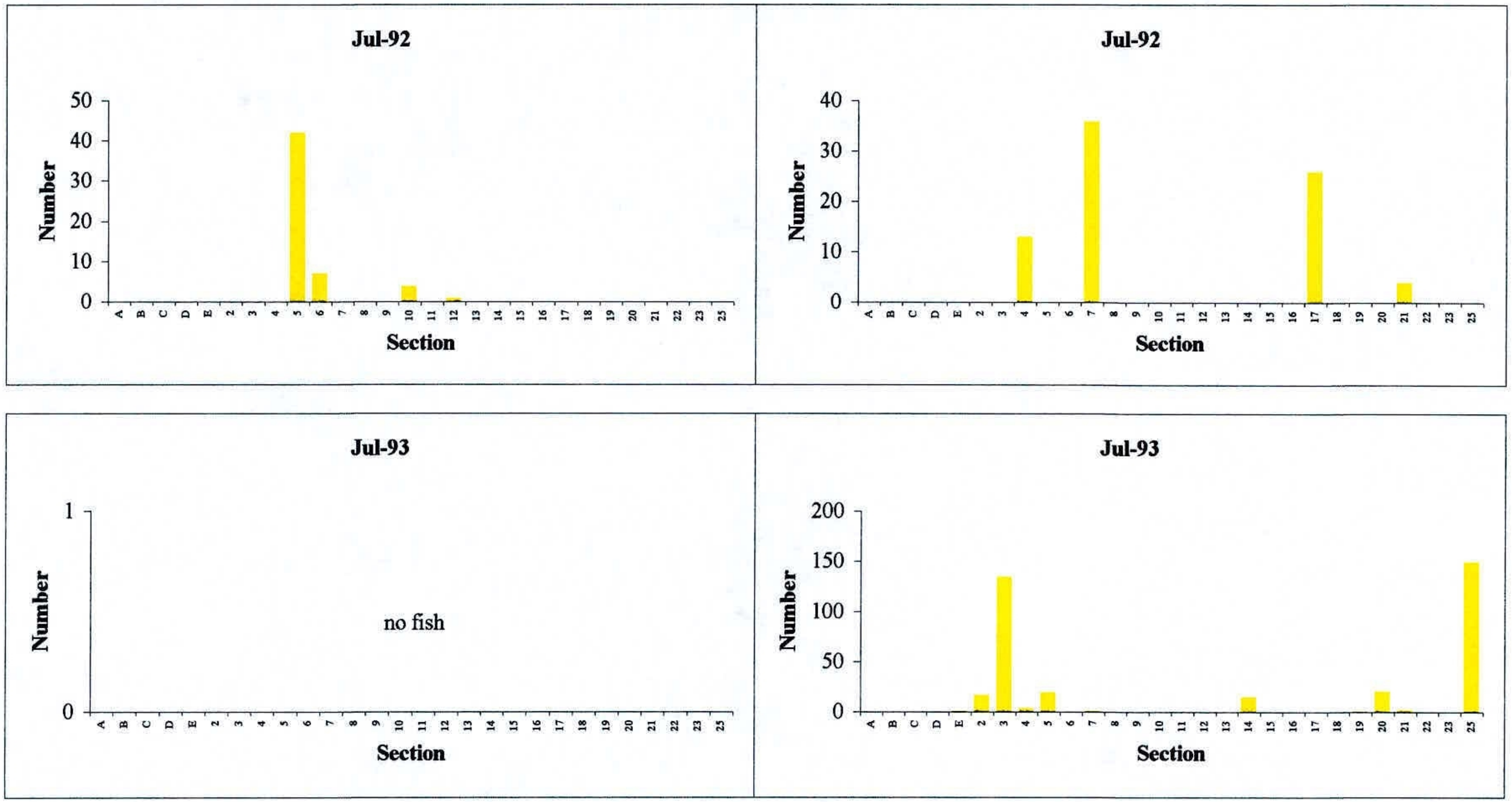


Figure 5. Number of roach fry in each section in each year

a) point sampling b) samples in which seine nets used



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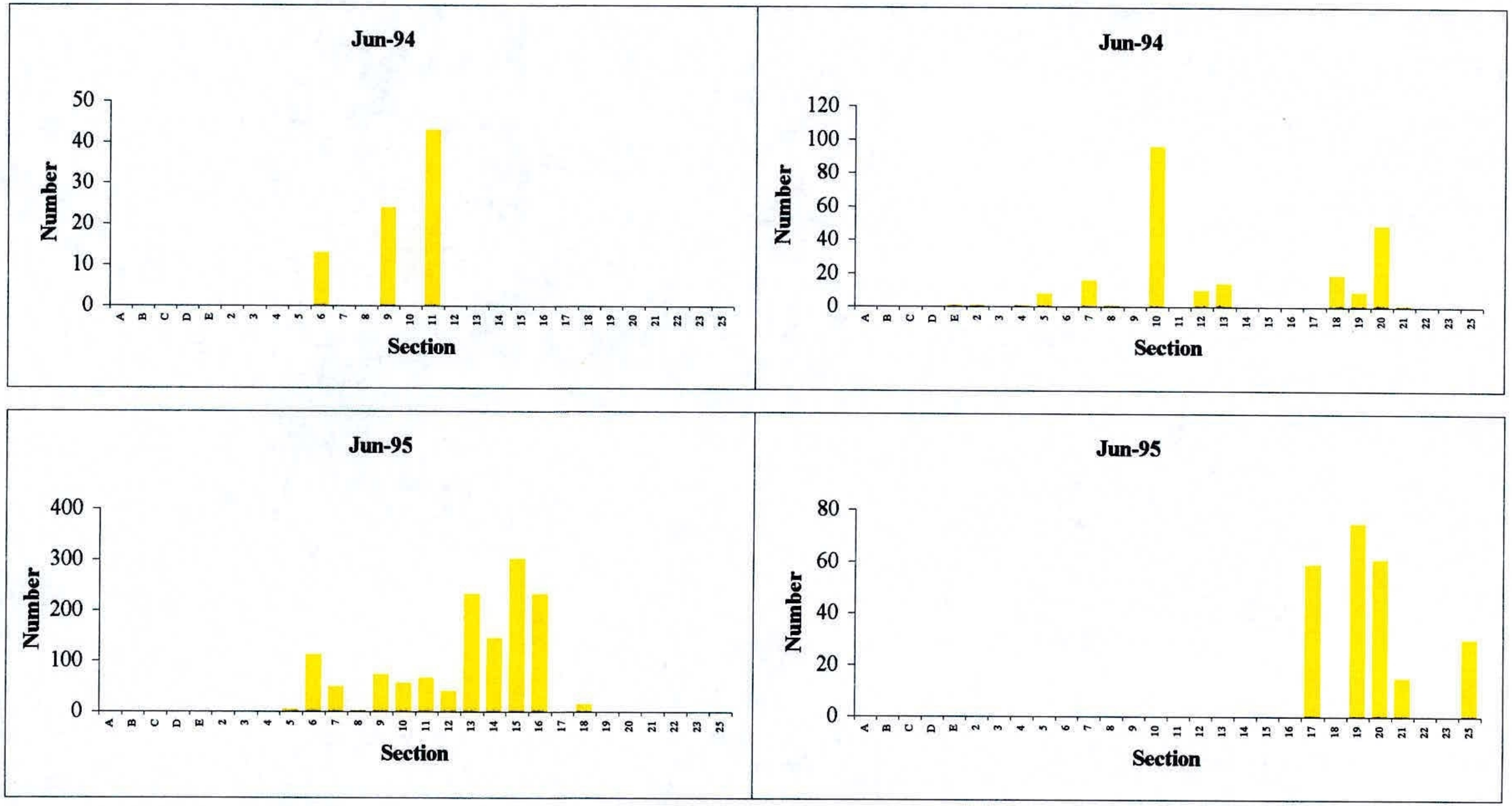

Figure 5. Continued

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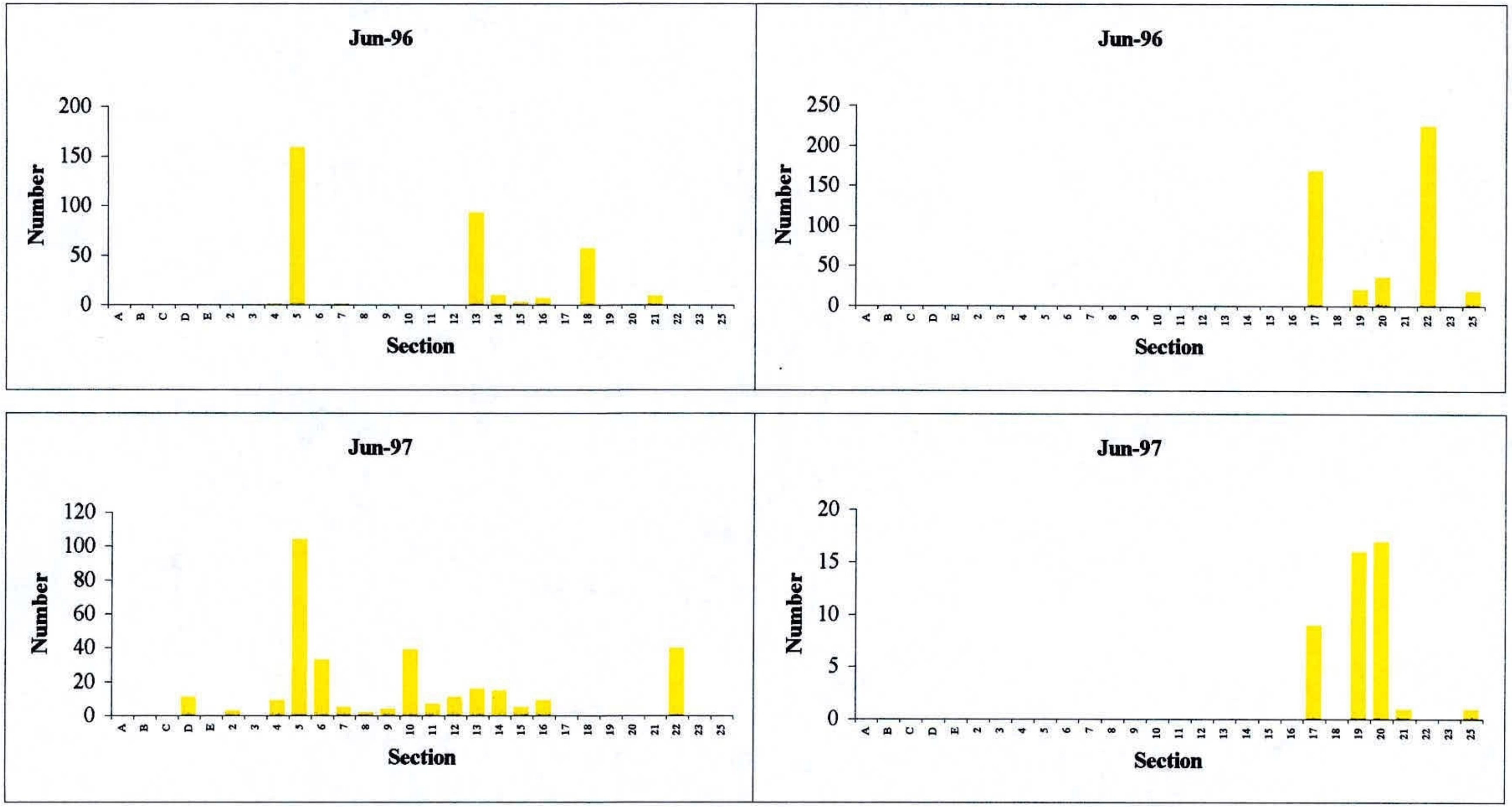
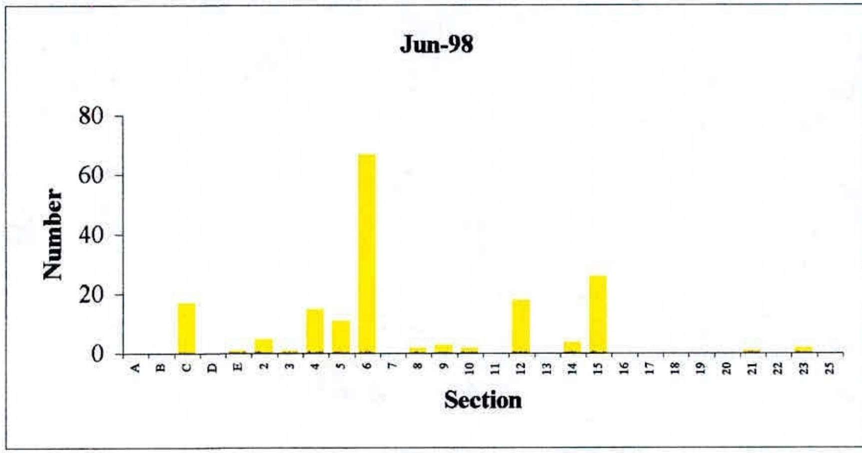


Figure 5. Continued

a) point sampling



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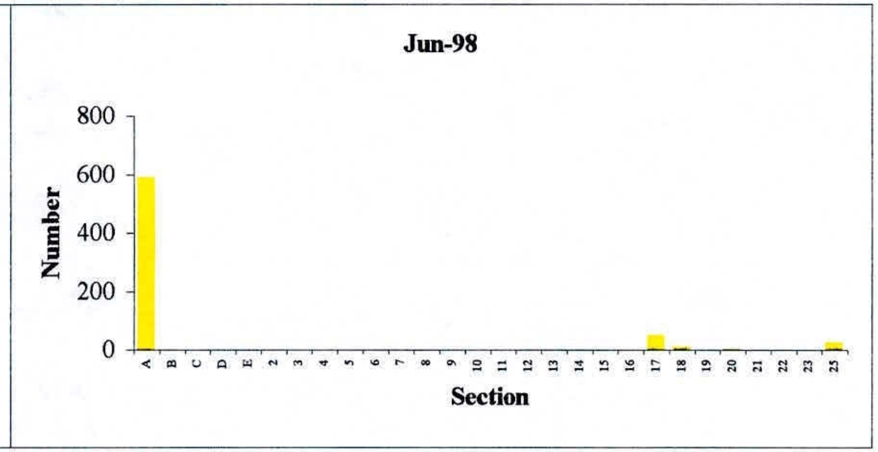
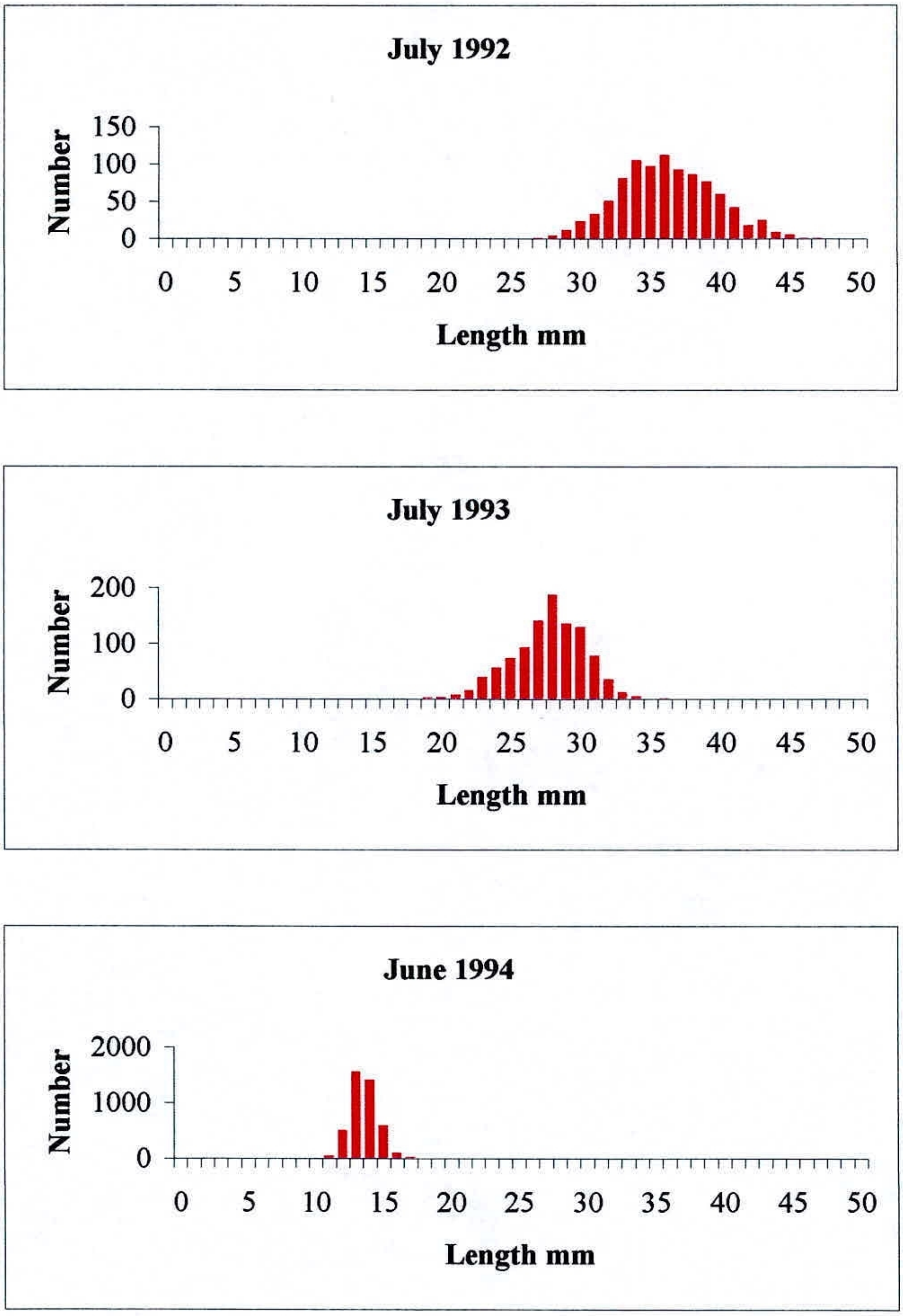


Figure 6. Length frequency distributions of dace fry in all summer fry surveys



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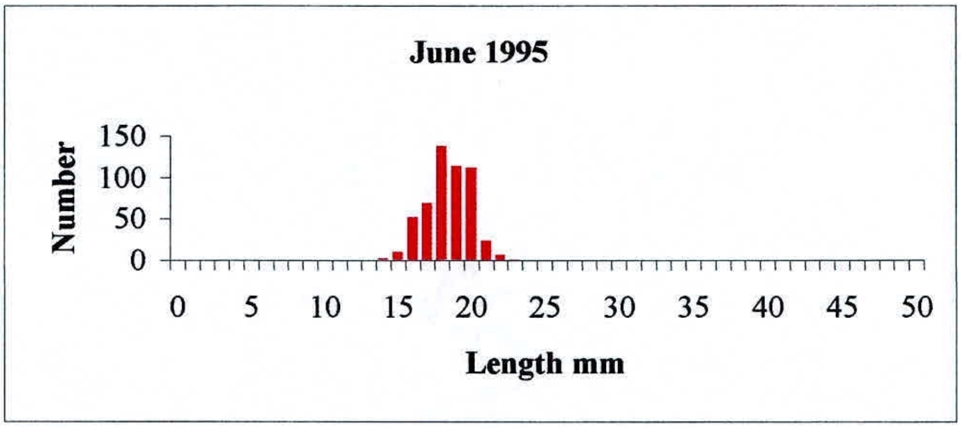
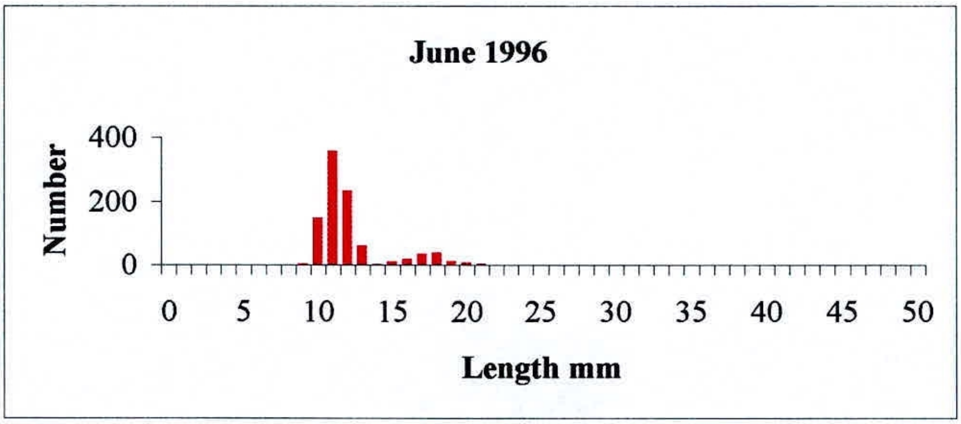
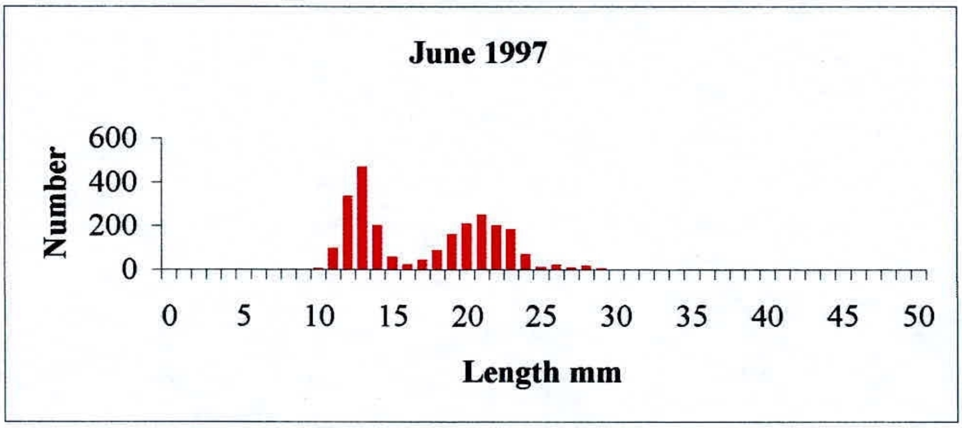






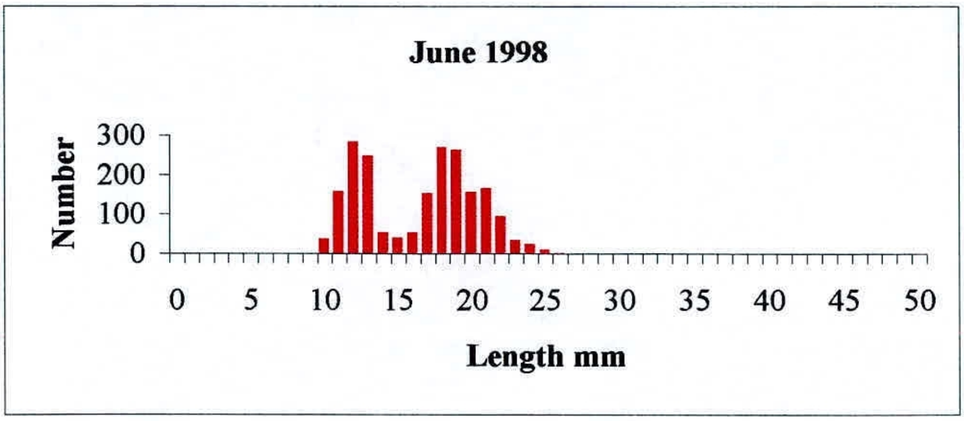
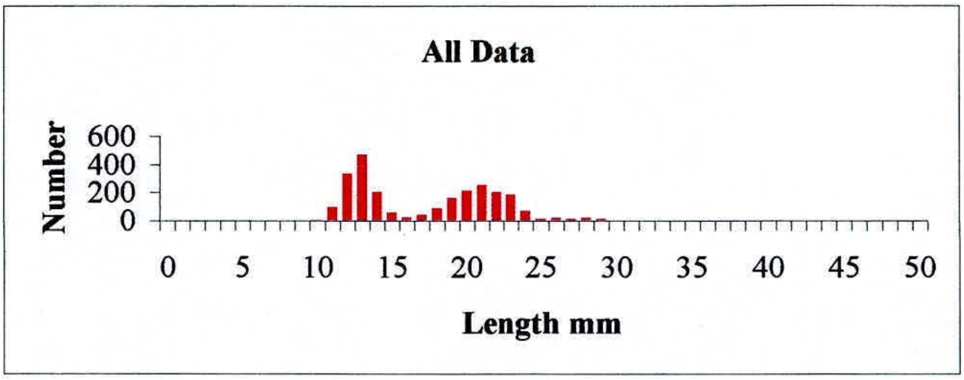
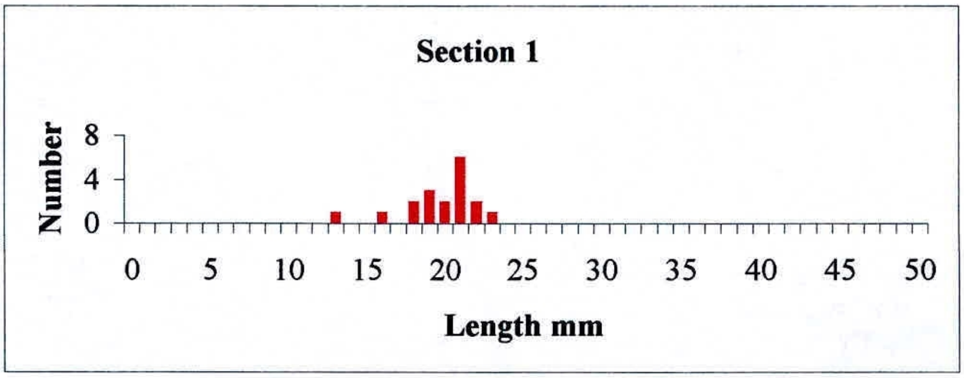
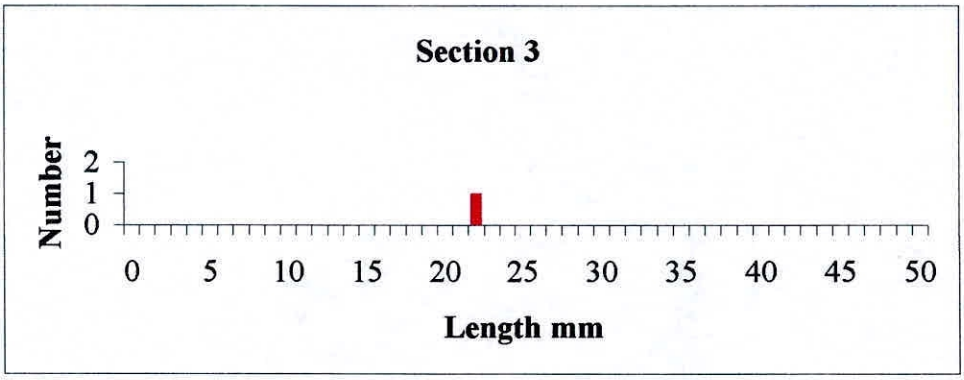


Figure 7. Length frequency distribution of dace fry in each section of the R.Tees in June 1997







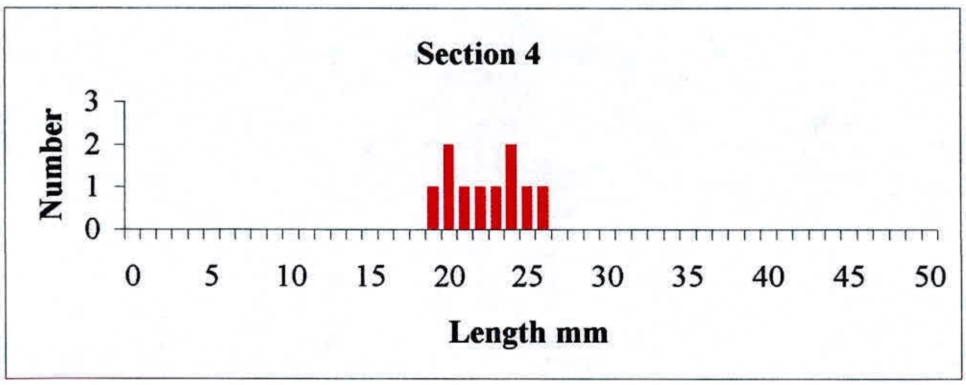
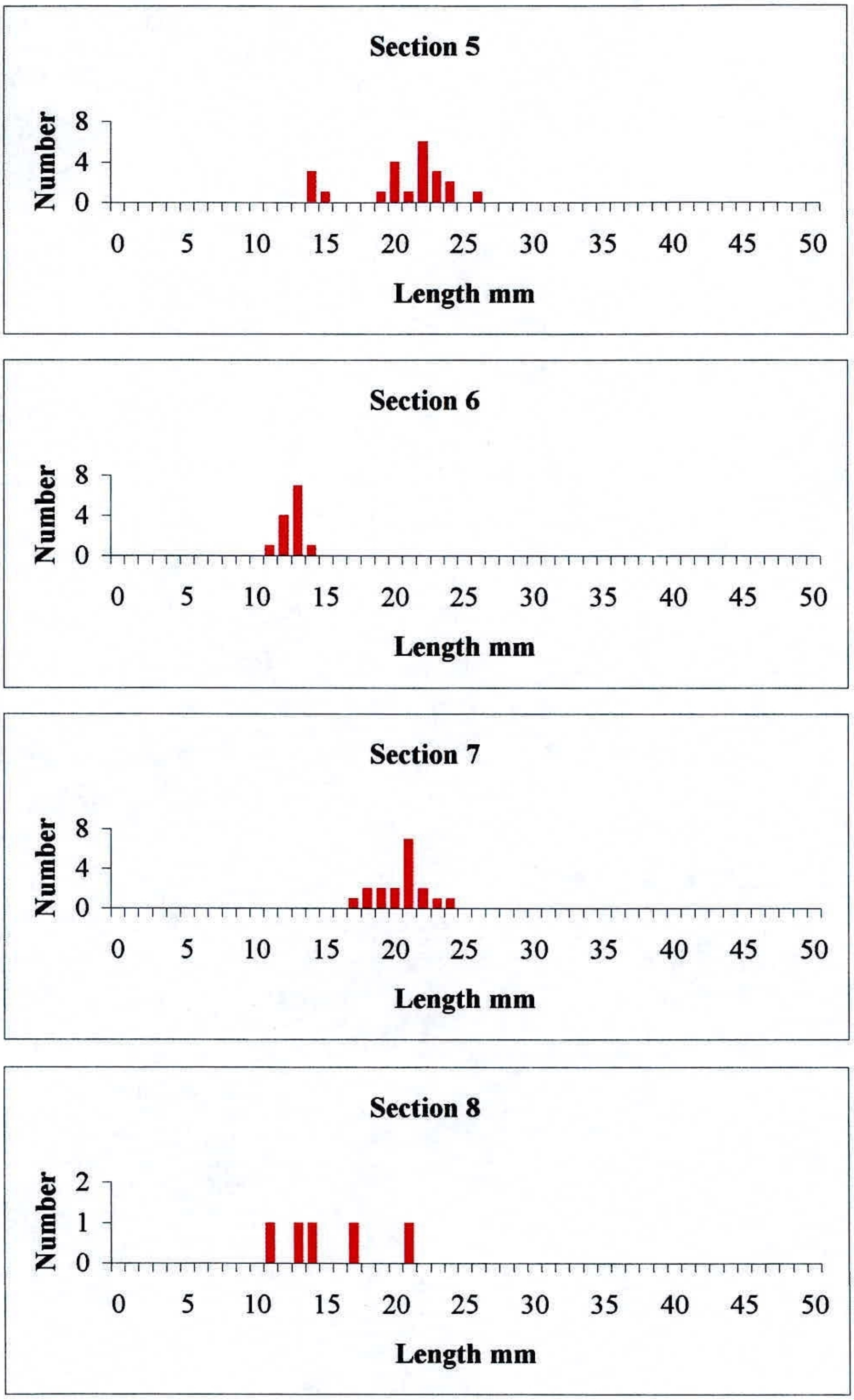


Figure 7. Continued



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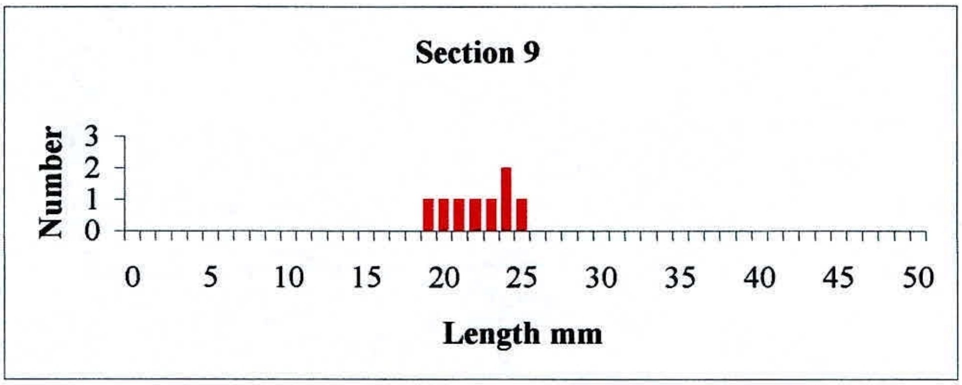

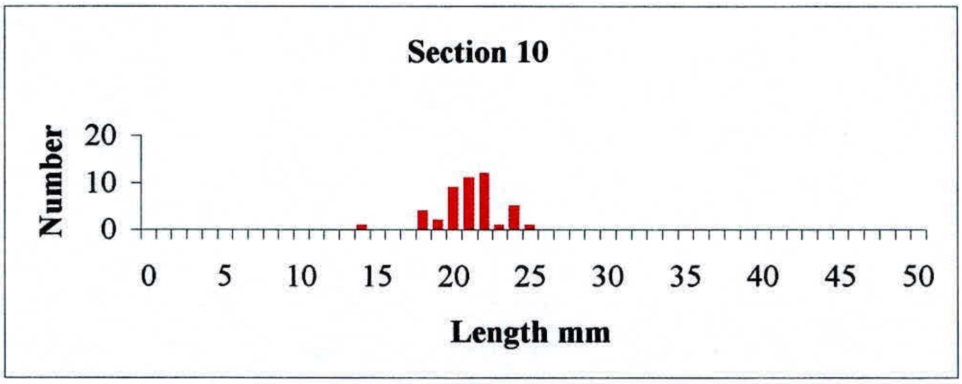

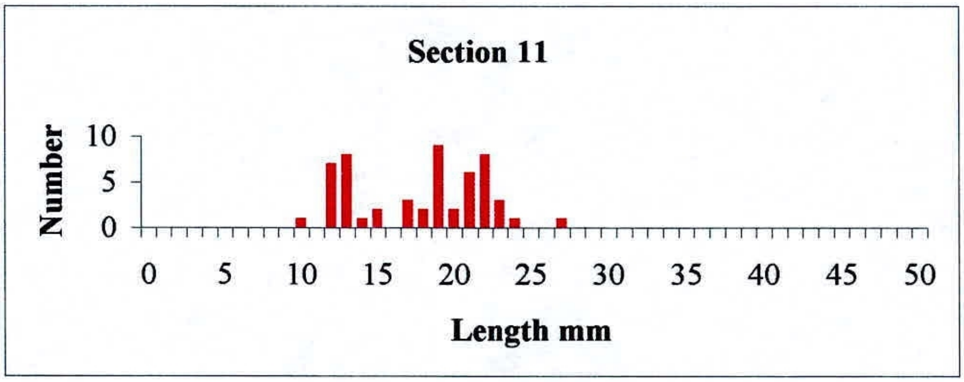

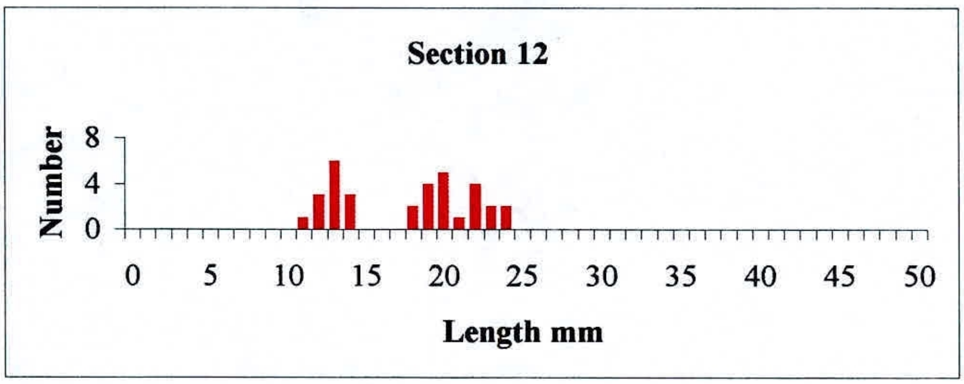

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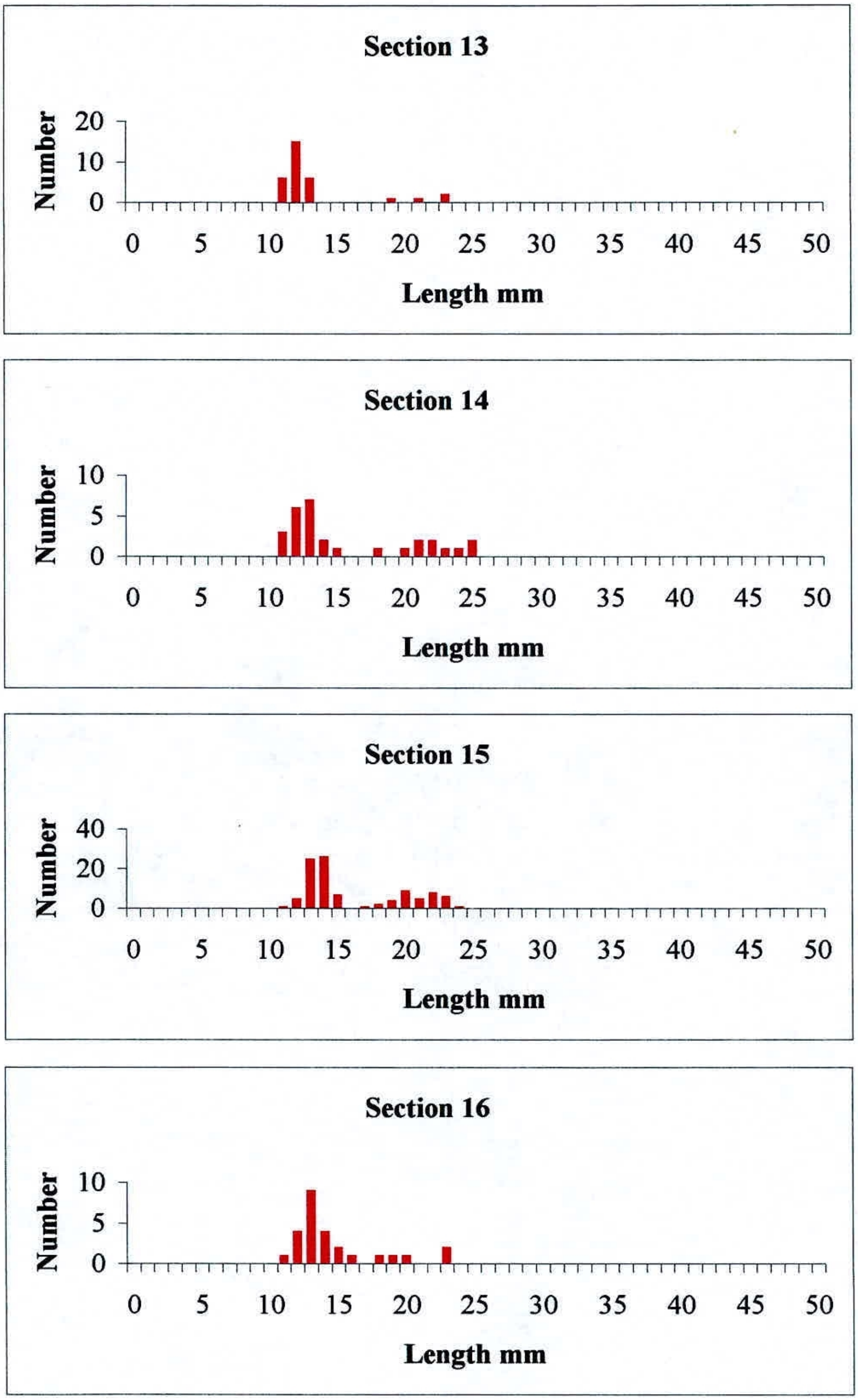

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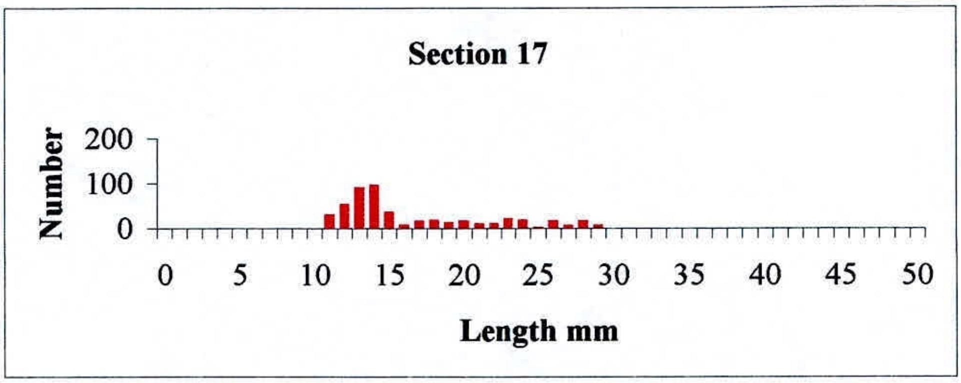

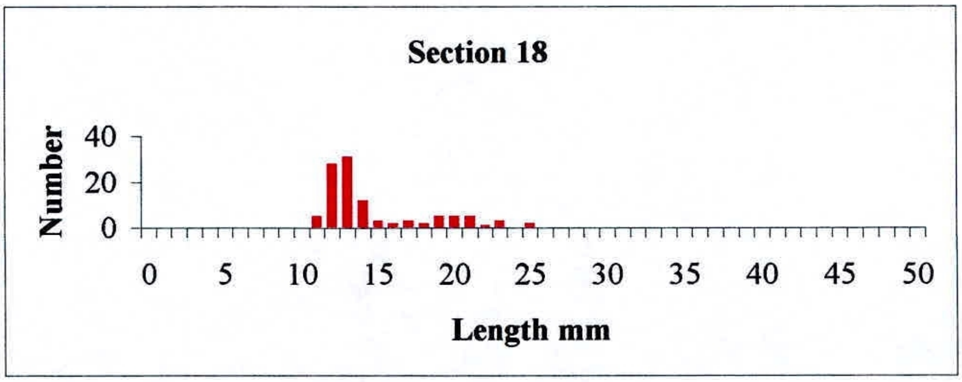

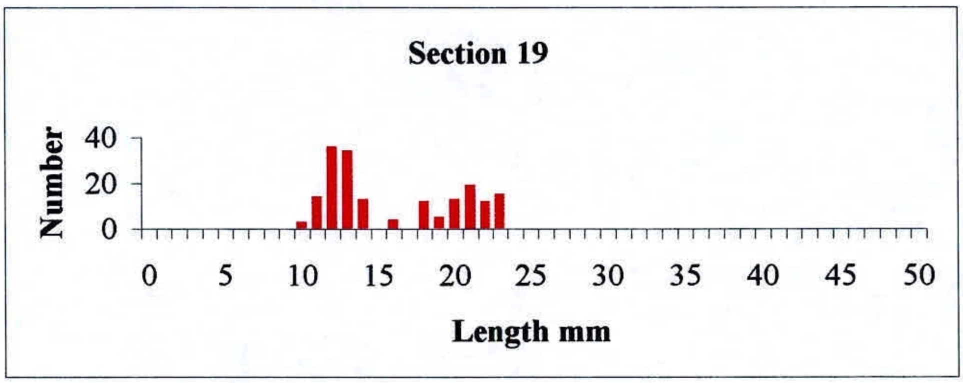

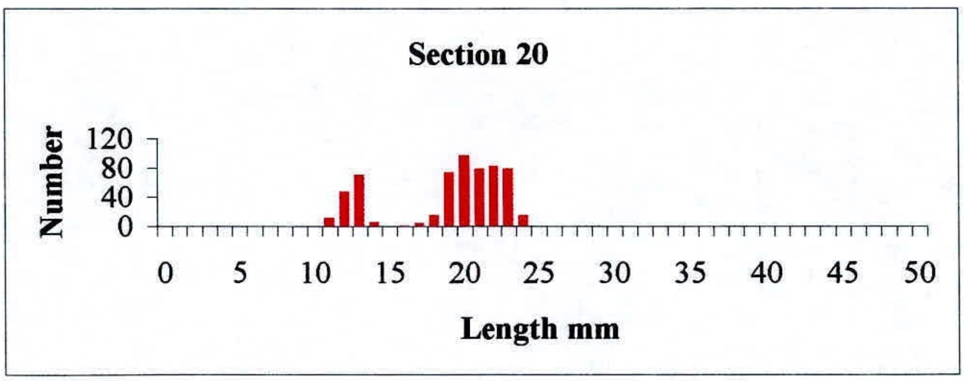

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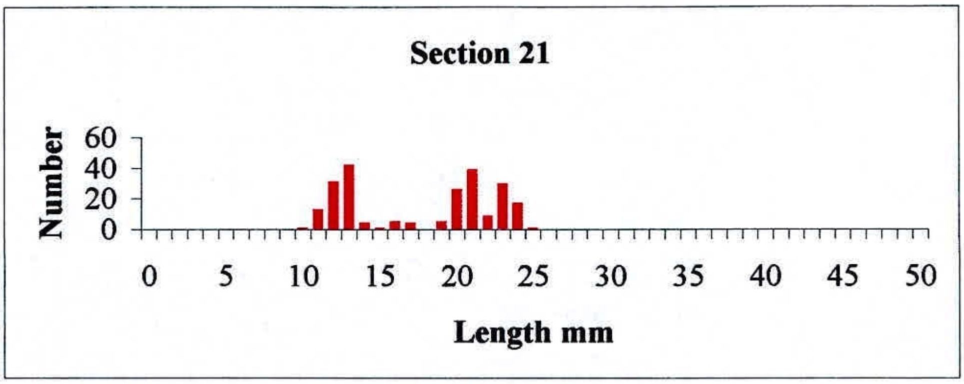
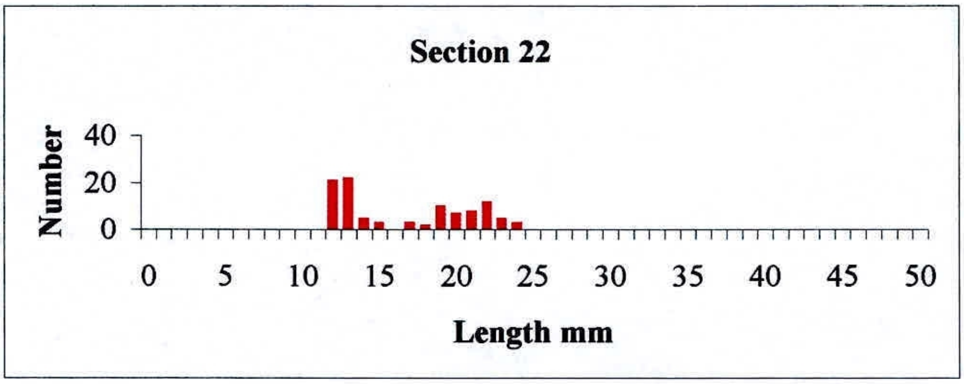




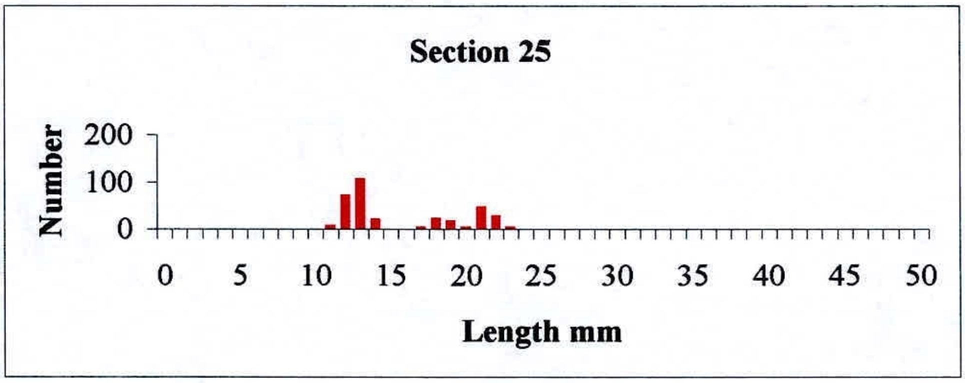


Figure 8. Length frequency distributions of a) chub and b) roach fry in July 1992

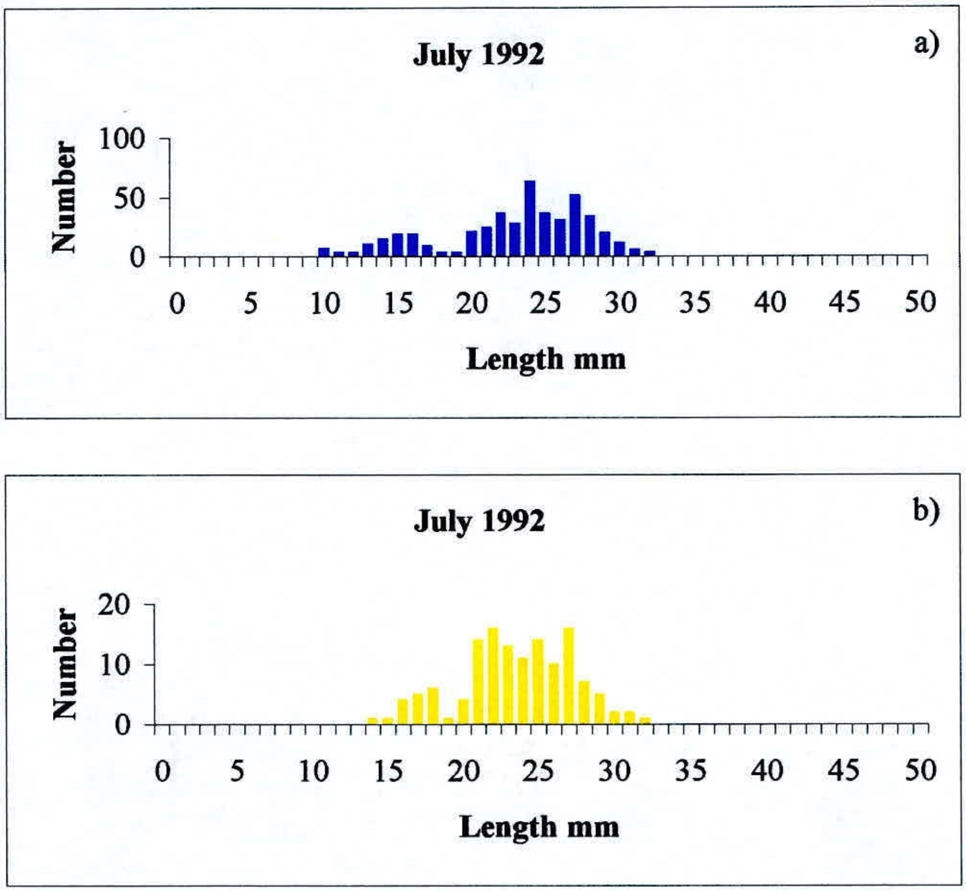
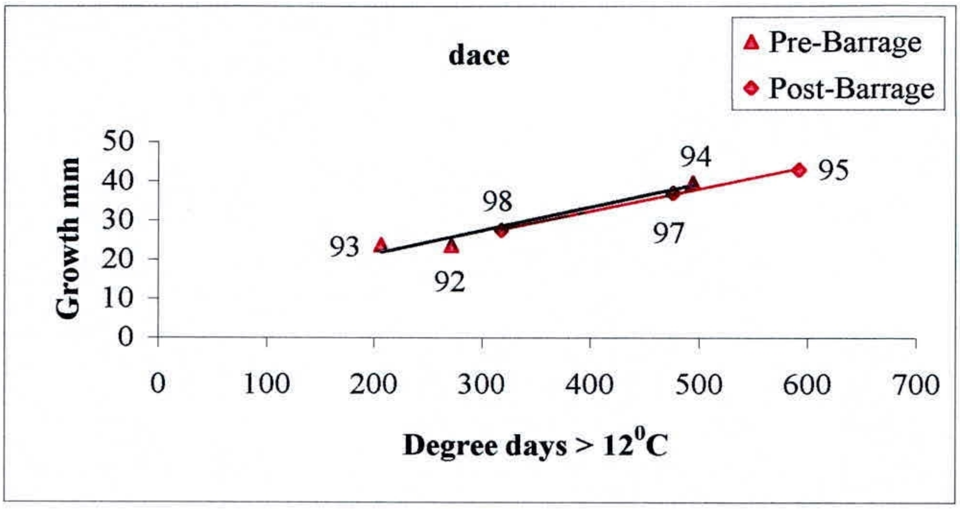
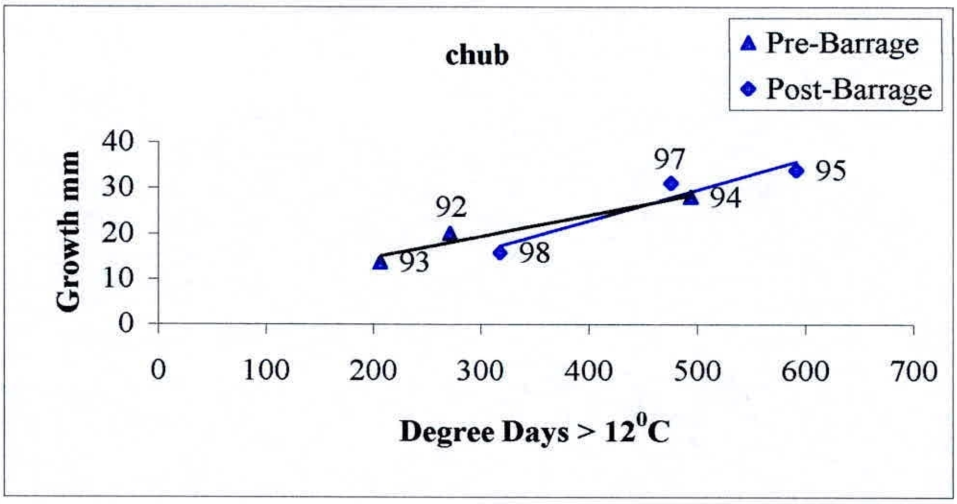


Figure 9. Relationship between growth of dace, chub and roach fry and temperature (degree days > 12^{0}C) between the summer fry survey and the September survey





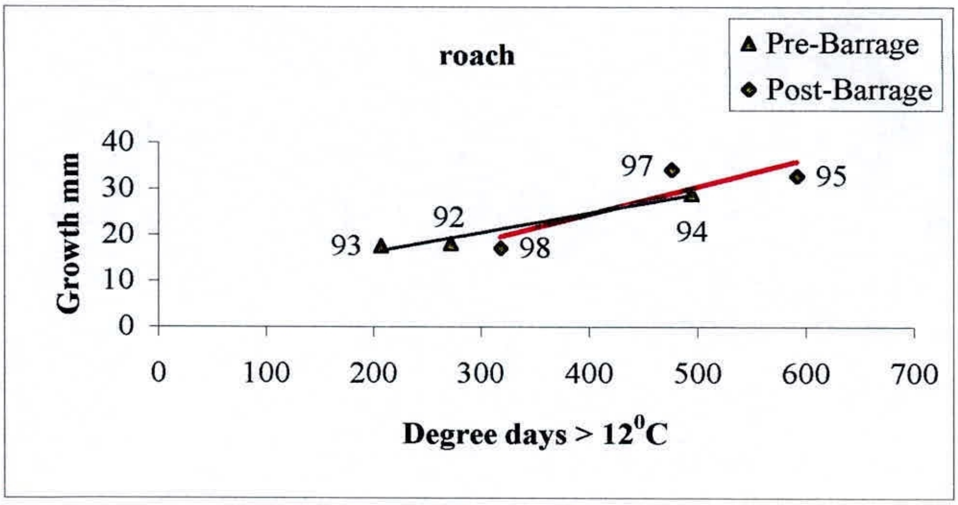


Figure 10. Relationship between September mean length of fry and mean summer water temperature

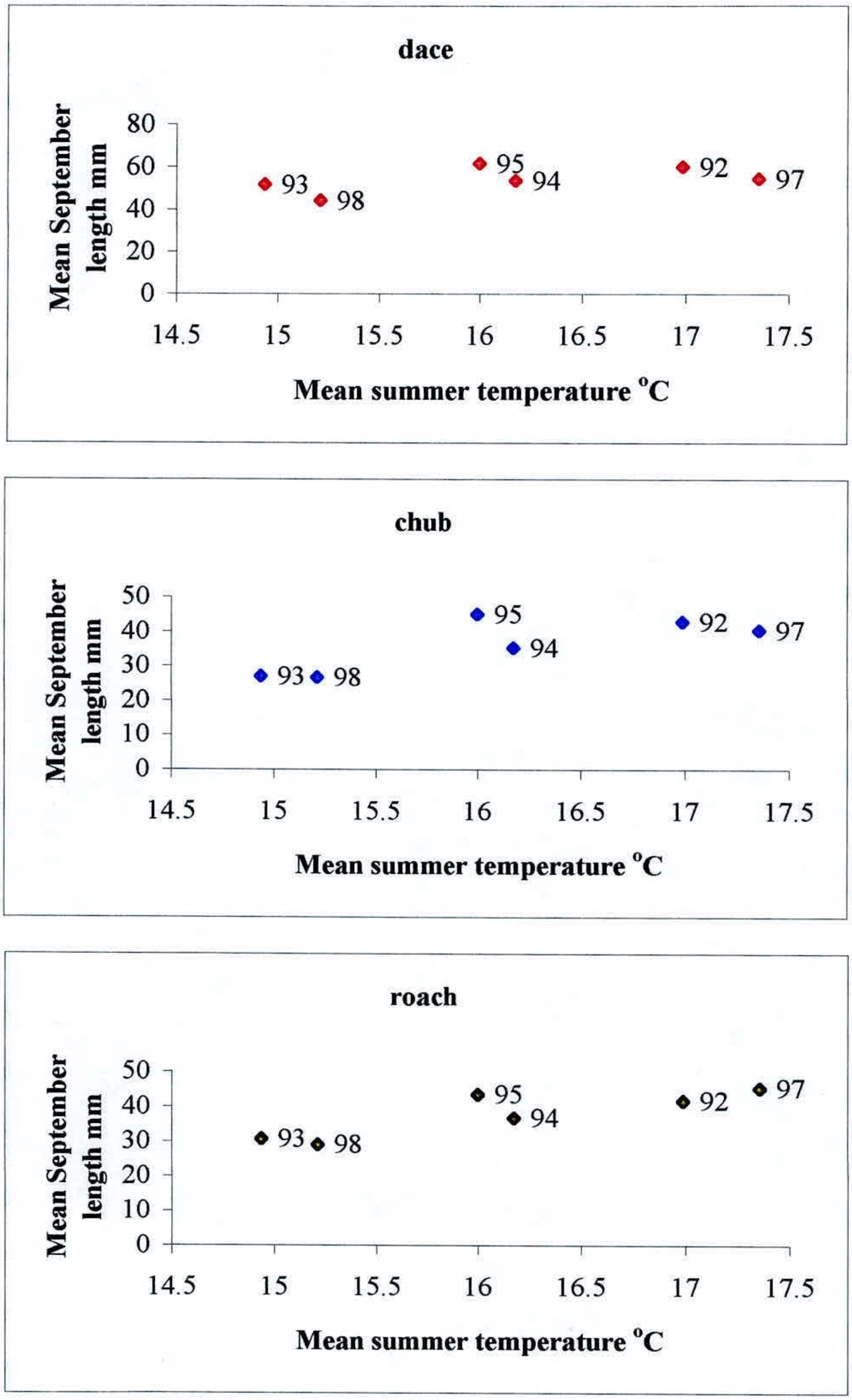
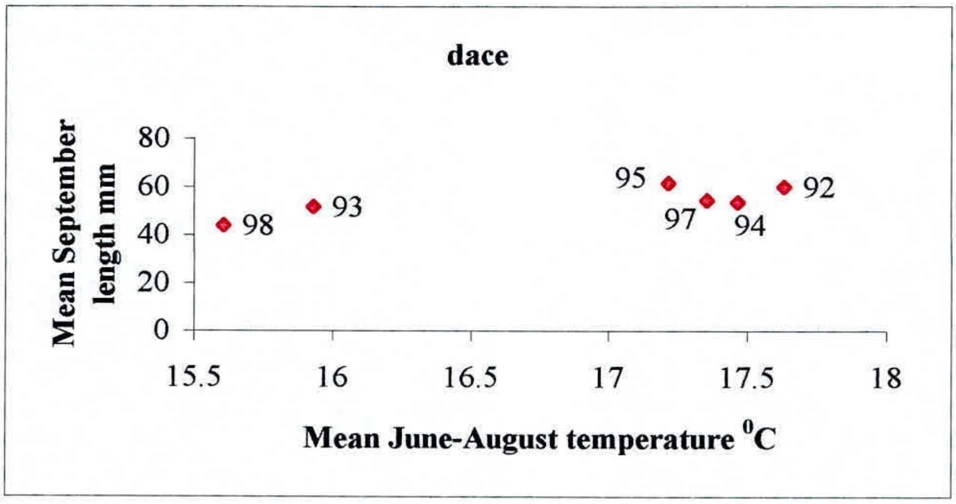
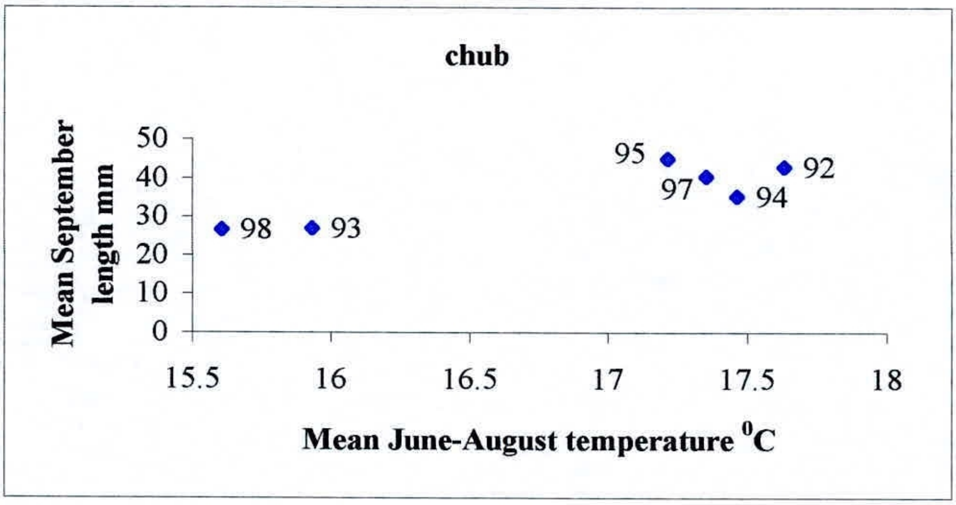


Figure 11. Relationship between September mean length of fry and mean water temperature between June and August





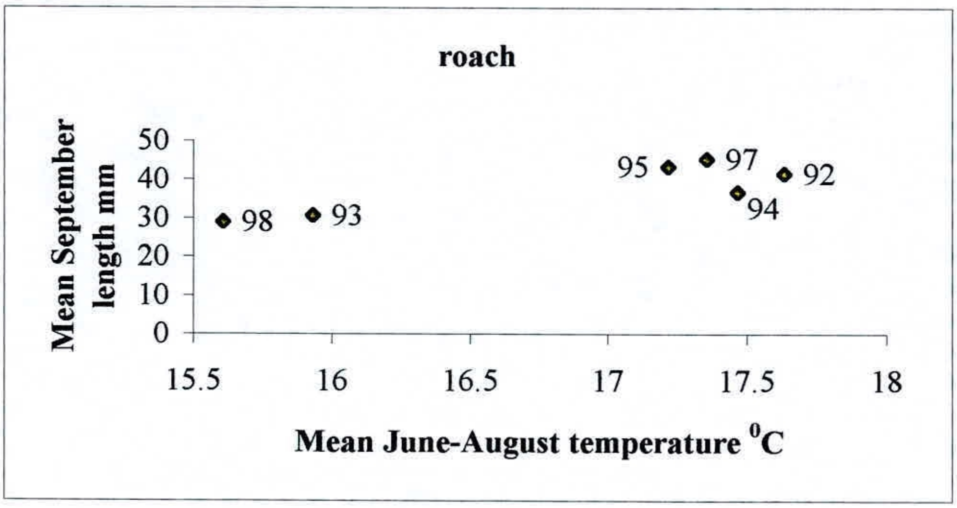


Figure 12. Total number of fish caught in each September survey (excluding eels)

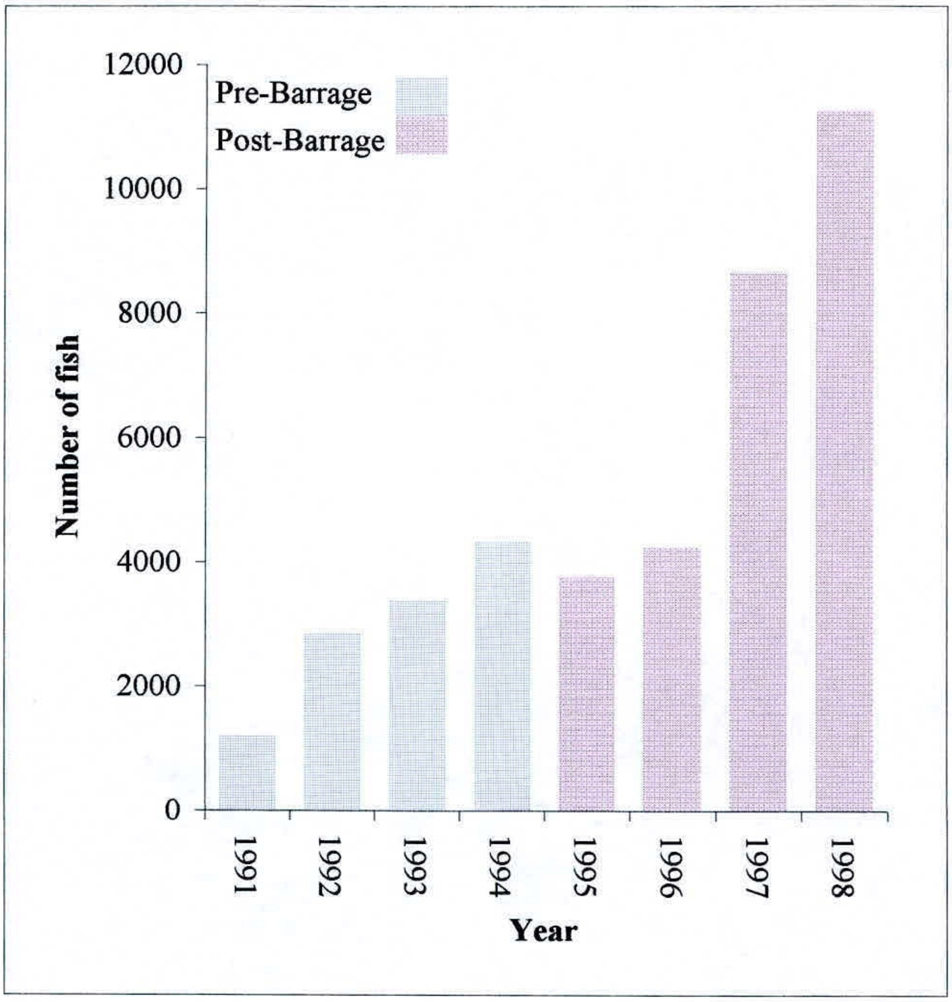
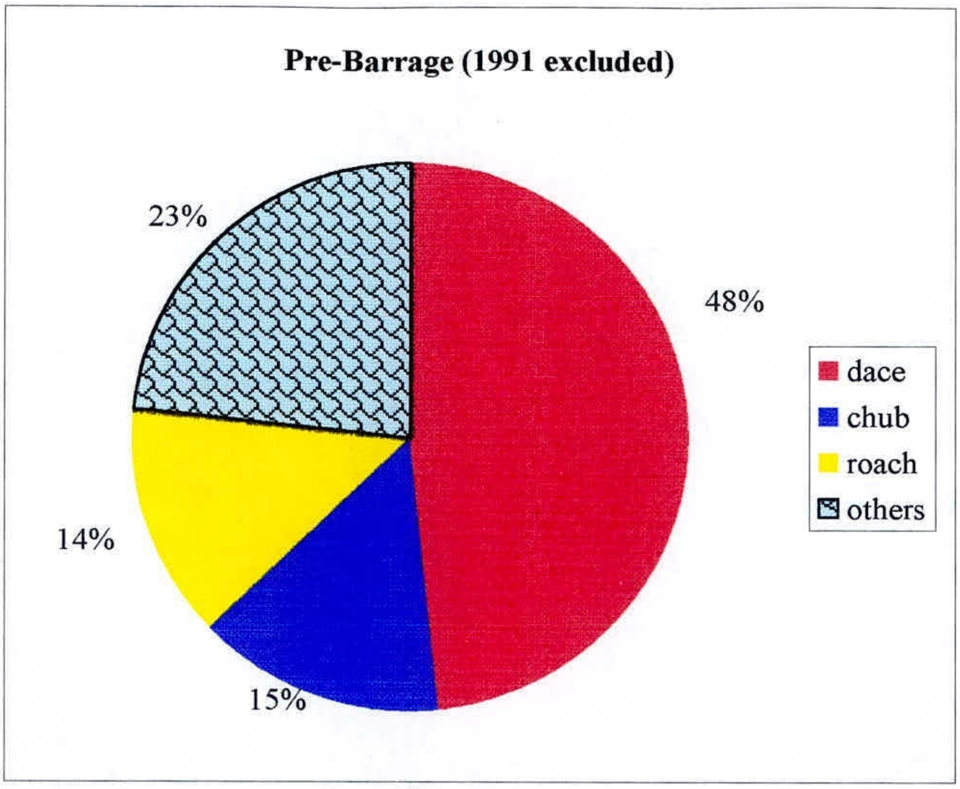


Figure 13. Proportion of dace, chub, roach and other species in the R.Tees in pre- and post-barrage years (1991 excluded)



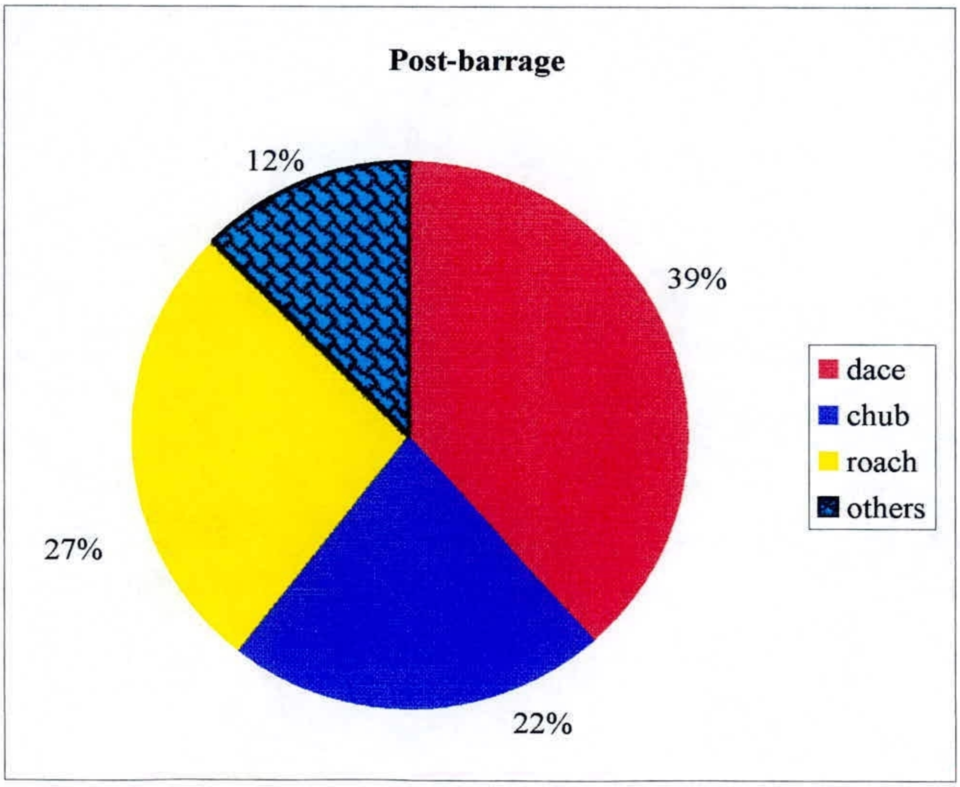


Figure 14. Proportion of dace, chub and roach caught in September surveys in pre-barrage years

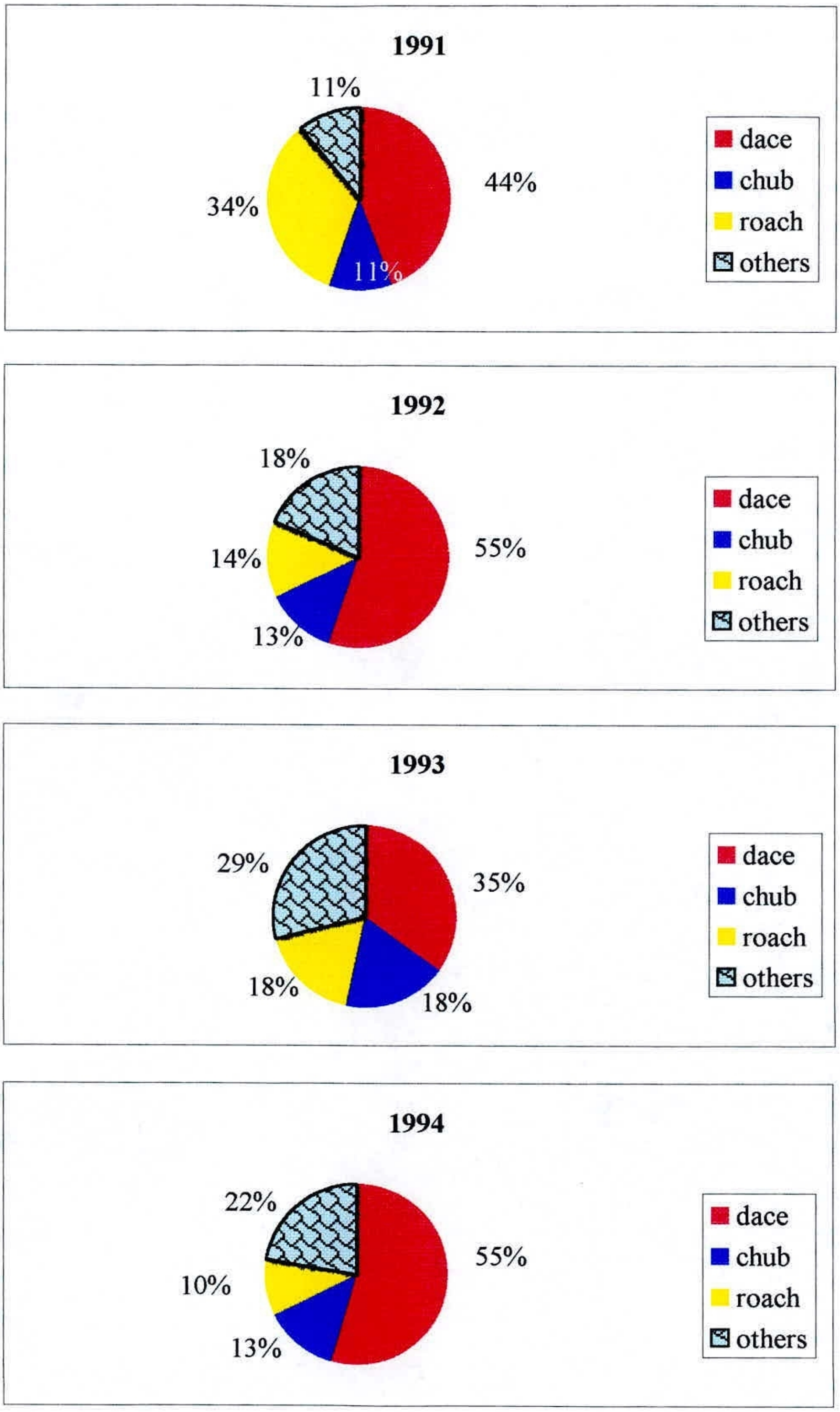
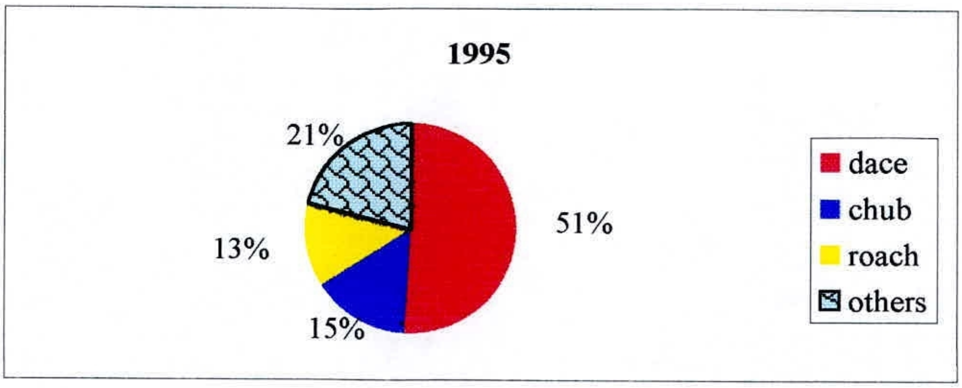
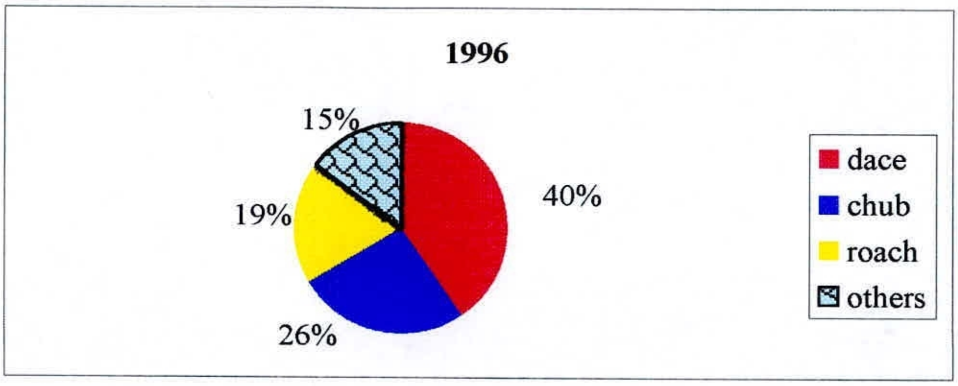
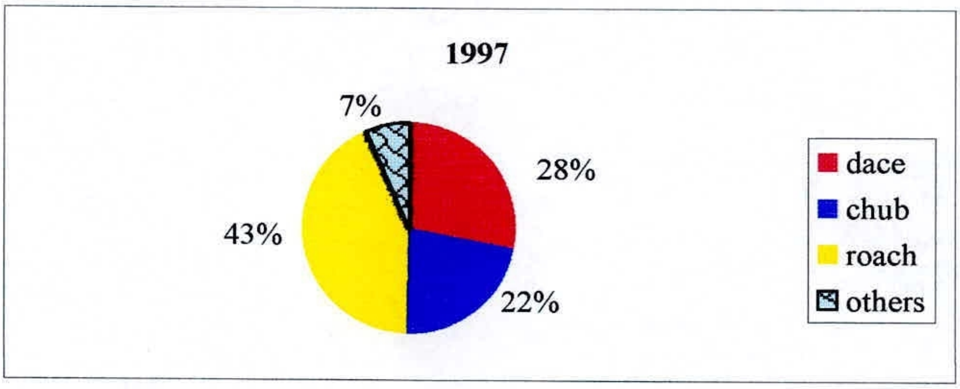


Figure 15. Proportion of dace, chub and roach caught in September surveys in post-barrage years







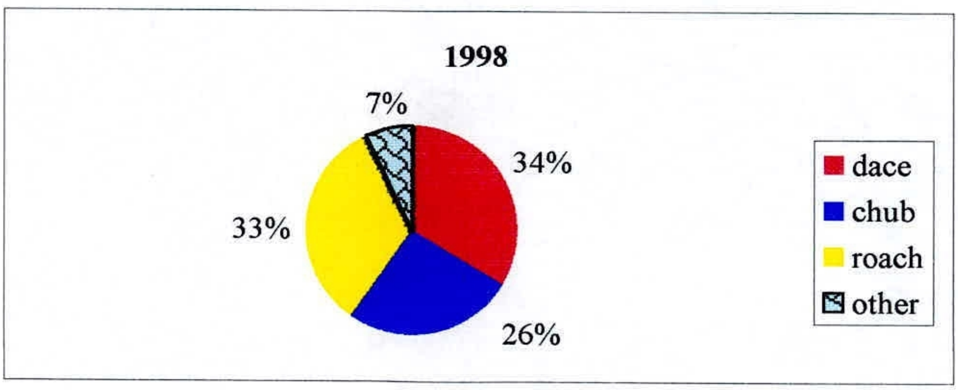


Figure 16. Mean density of dace in each section in pre- and post-barrage September surveys. Sections have been combined into four reaches.

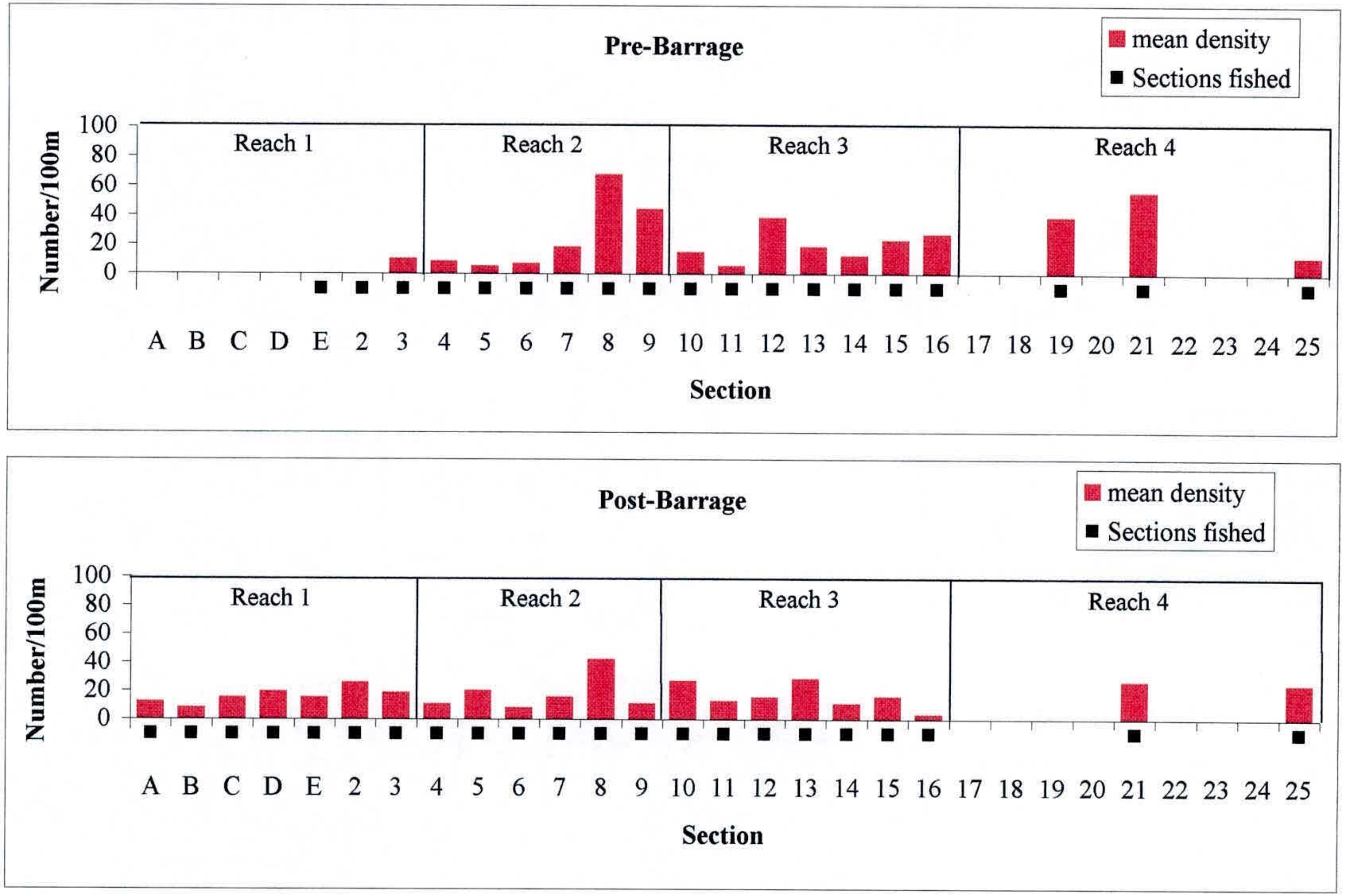
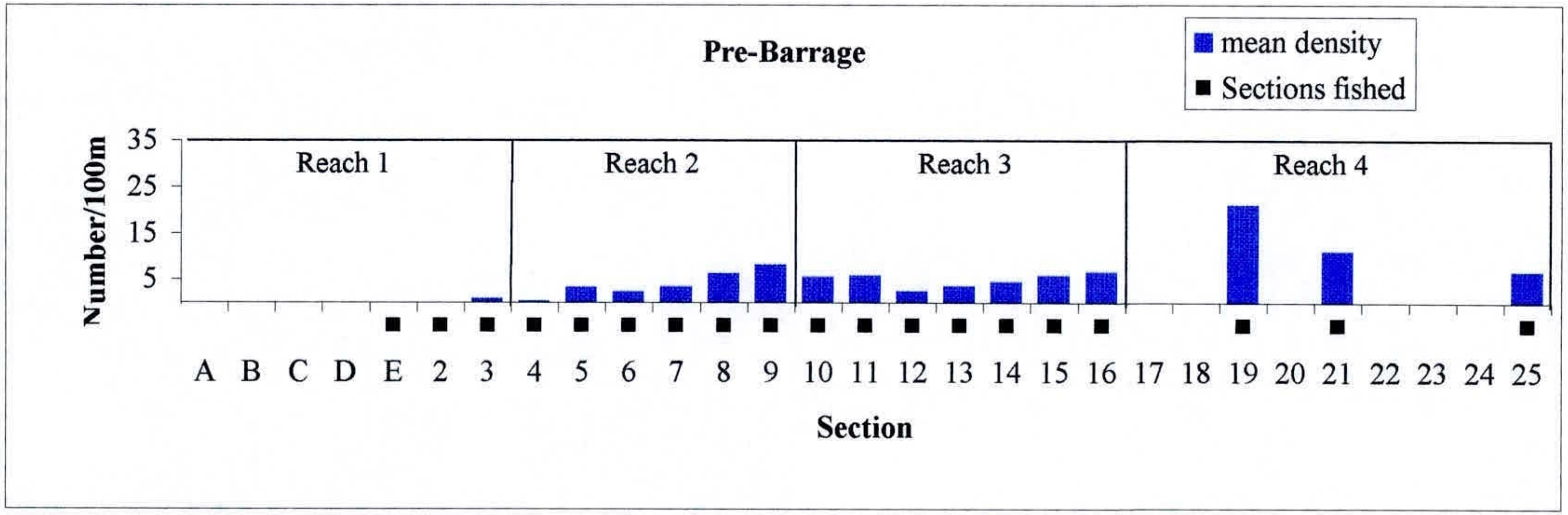


Figure 17. Mean density of chub in each section in pre- and post-barrage years
Sections have been combined into four reaches.



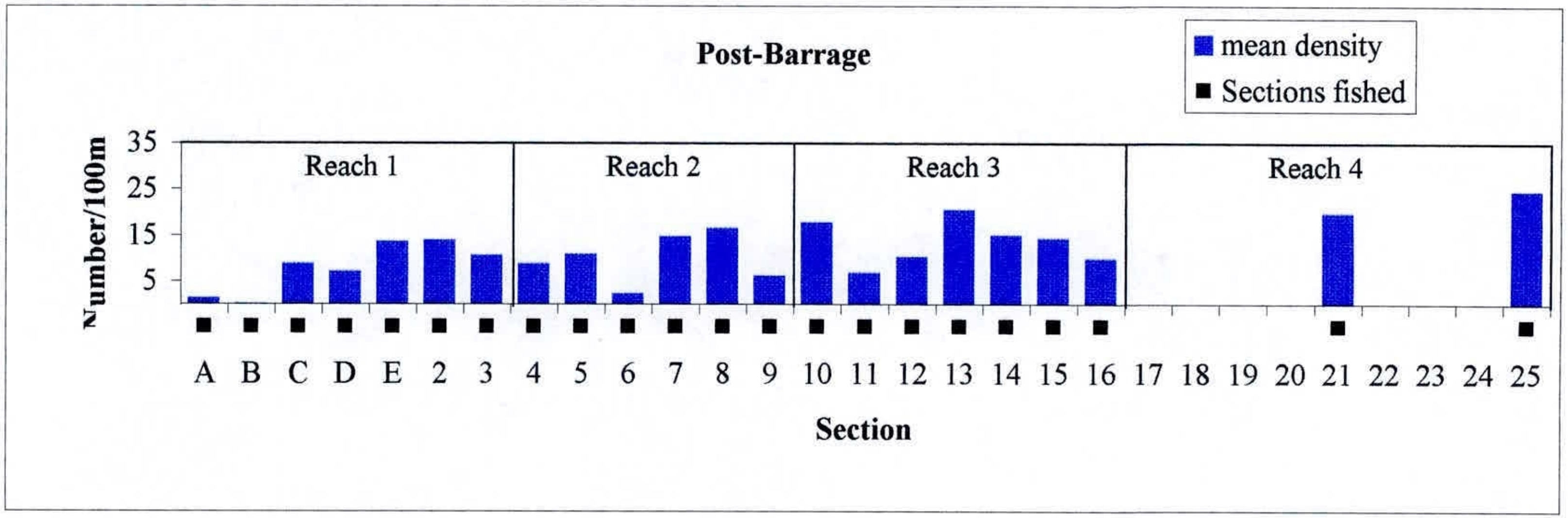


**Figure 18. Mean density of roach in each section in pre- and post-barrage years
Sections have been combined into four reaches.**

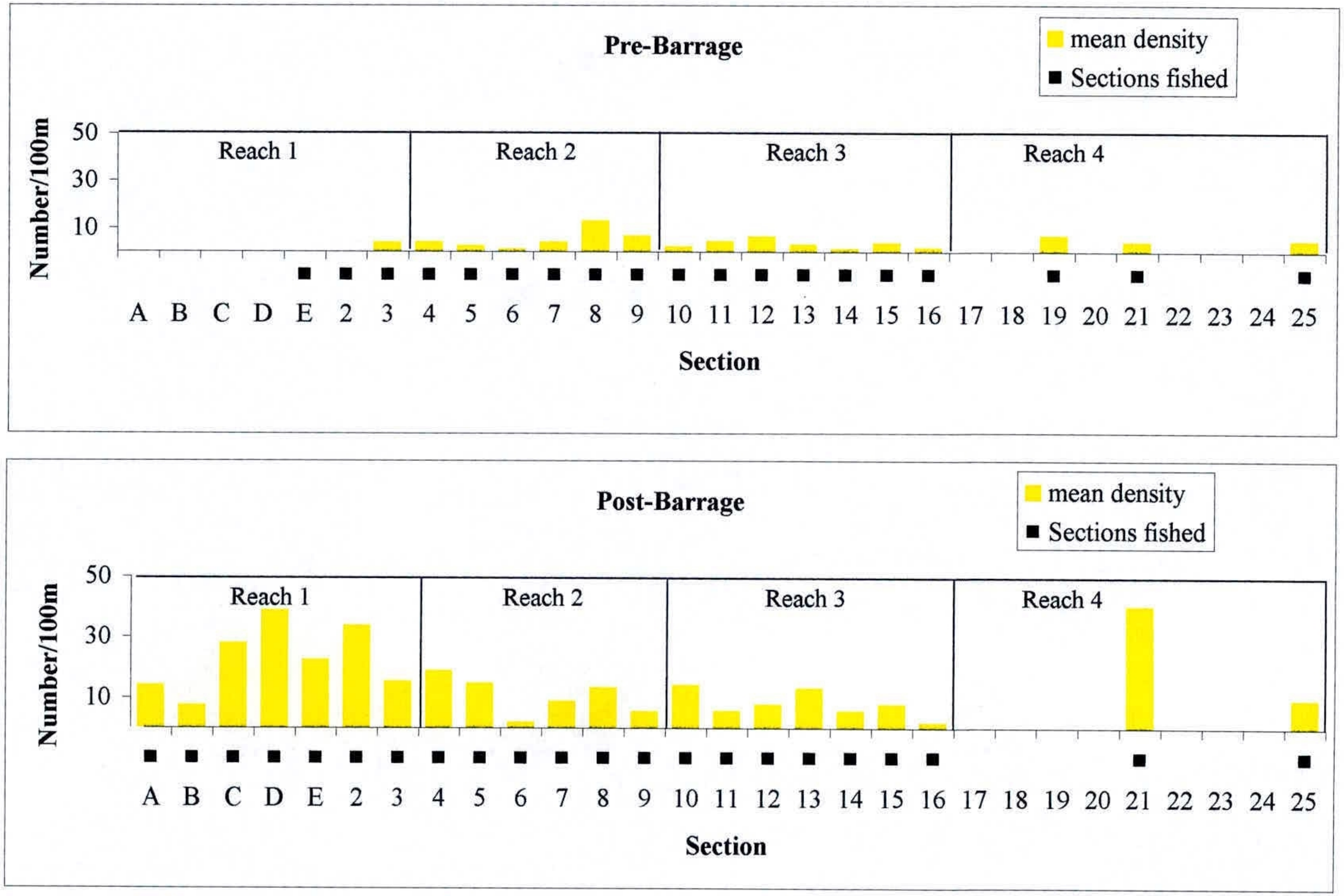


Figure 19. Length frequency distributions of all dace from pre- and post-barrage September surveys

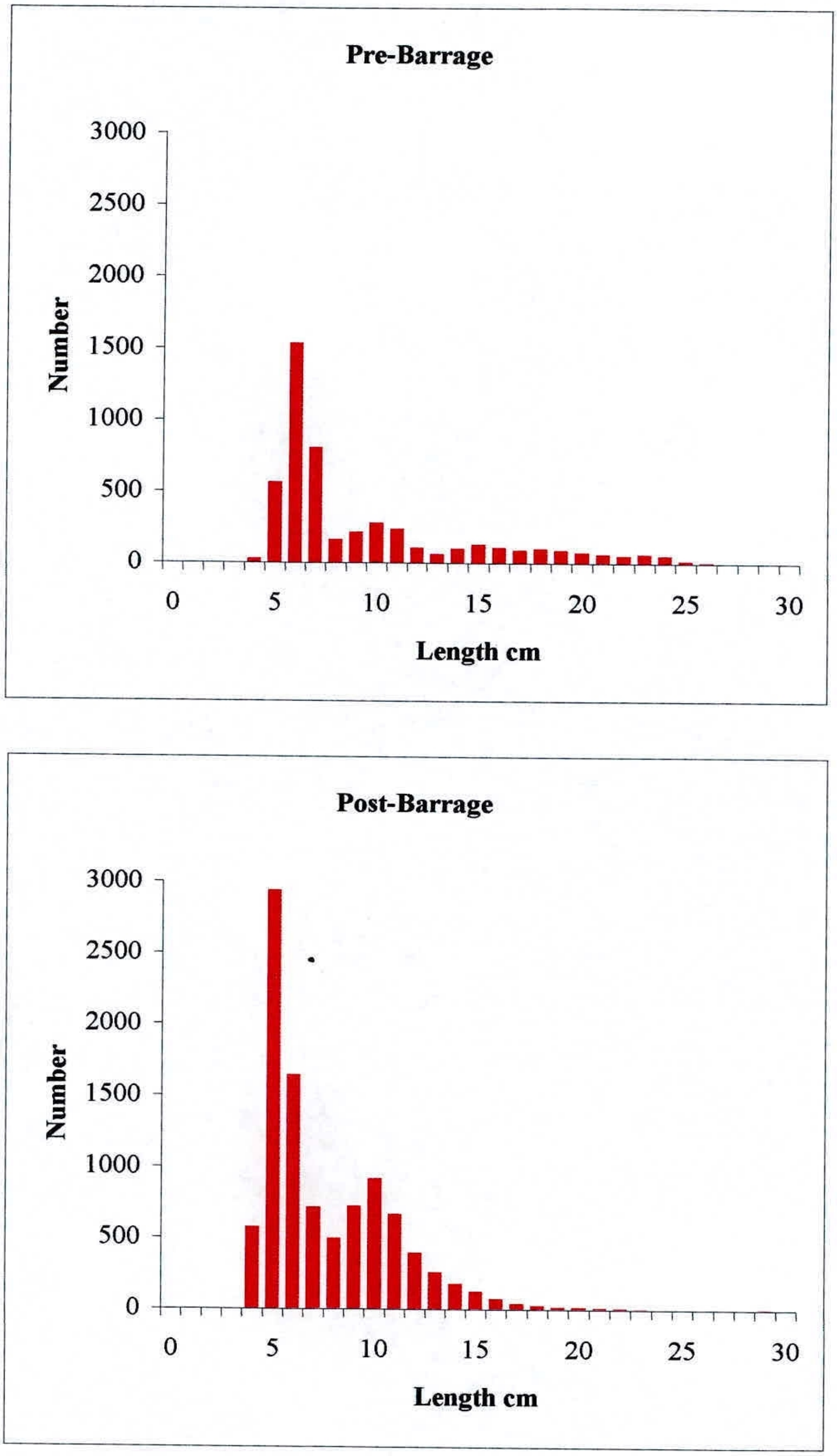
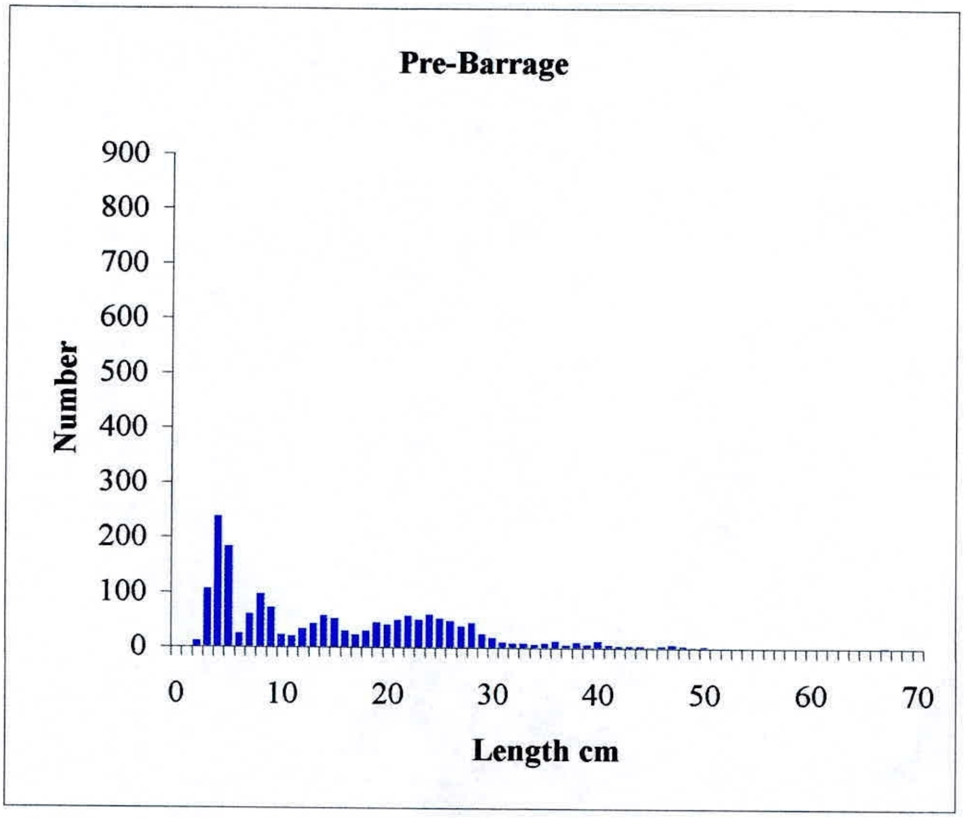


Figure 20. Length frequency distributions of all chub from pre- and post-barrage September surveys



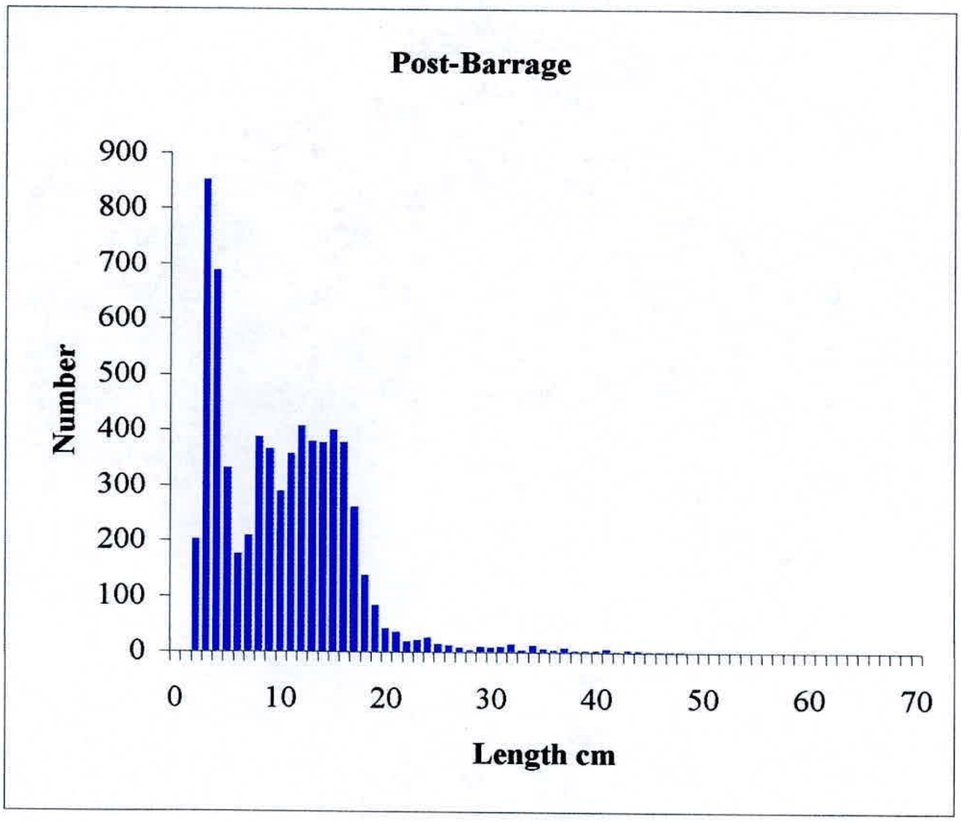
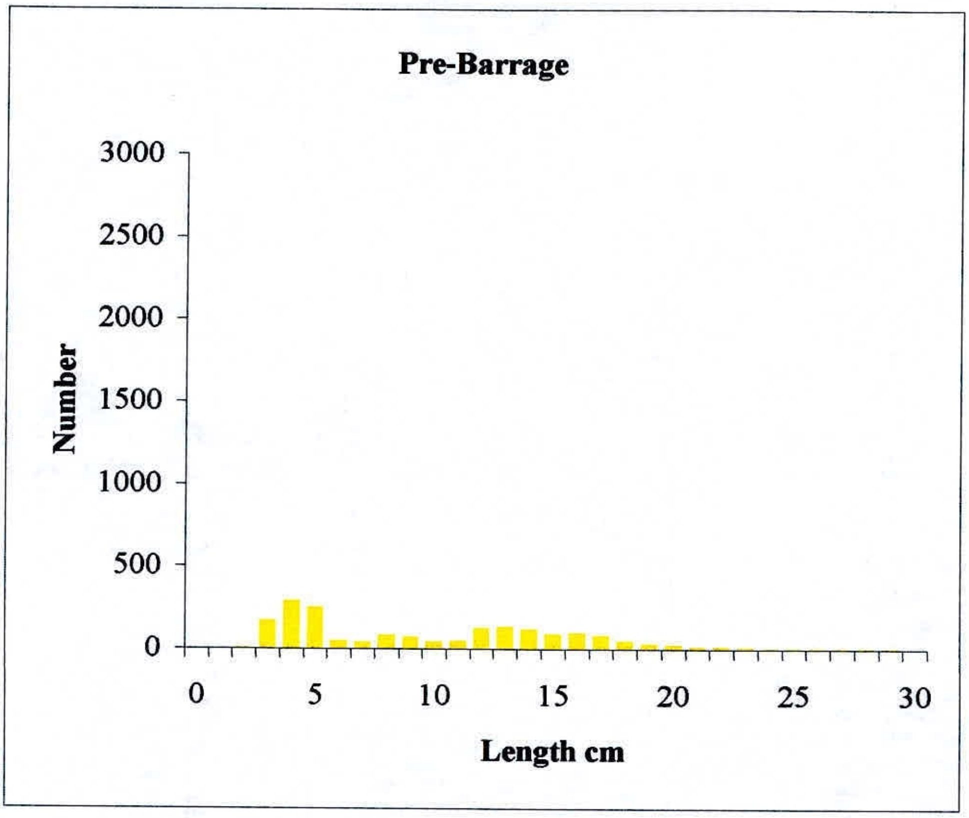


Figure 21. Length frequency distributions of all roach from pre- and post-barrage September surveys



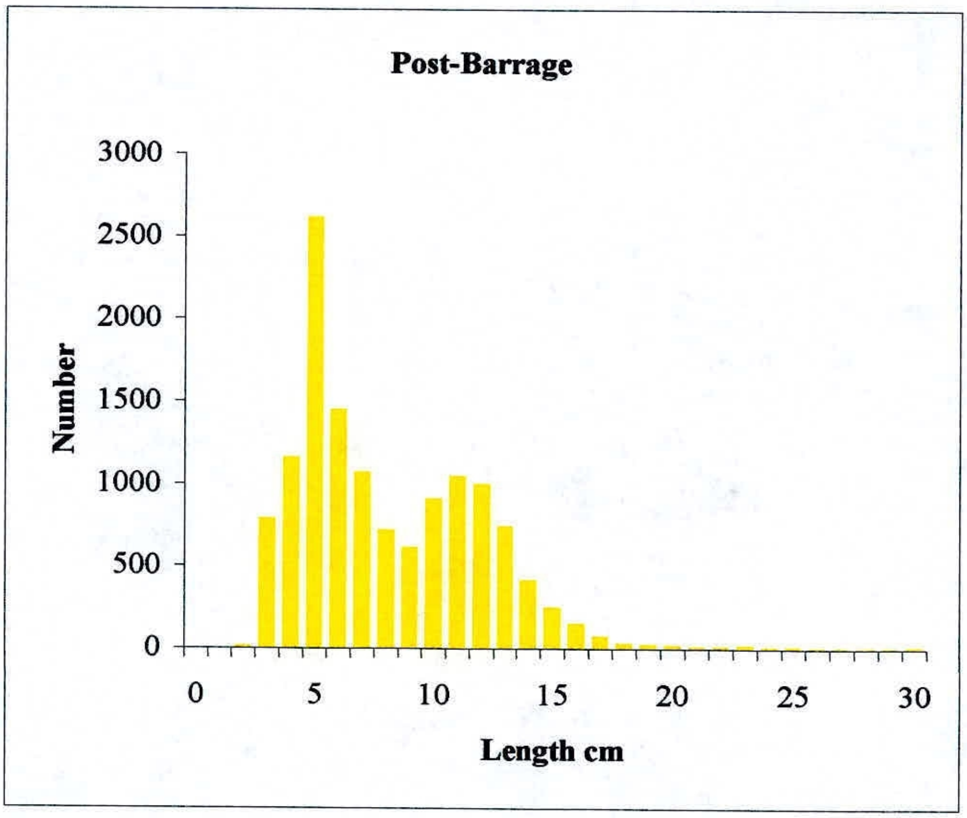
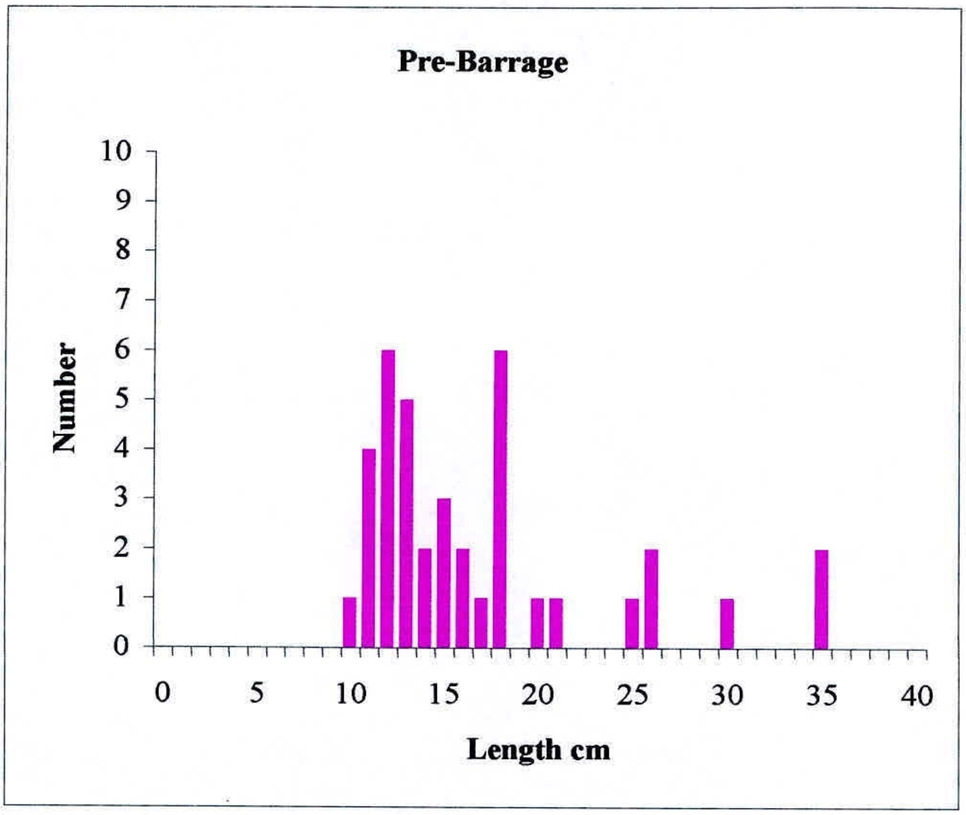


Figure 22. The length frequency distributions of all flounder from pre- and post-barrage September surveys (Section 21 only).



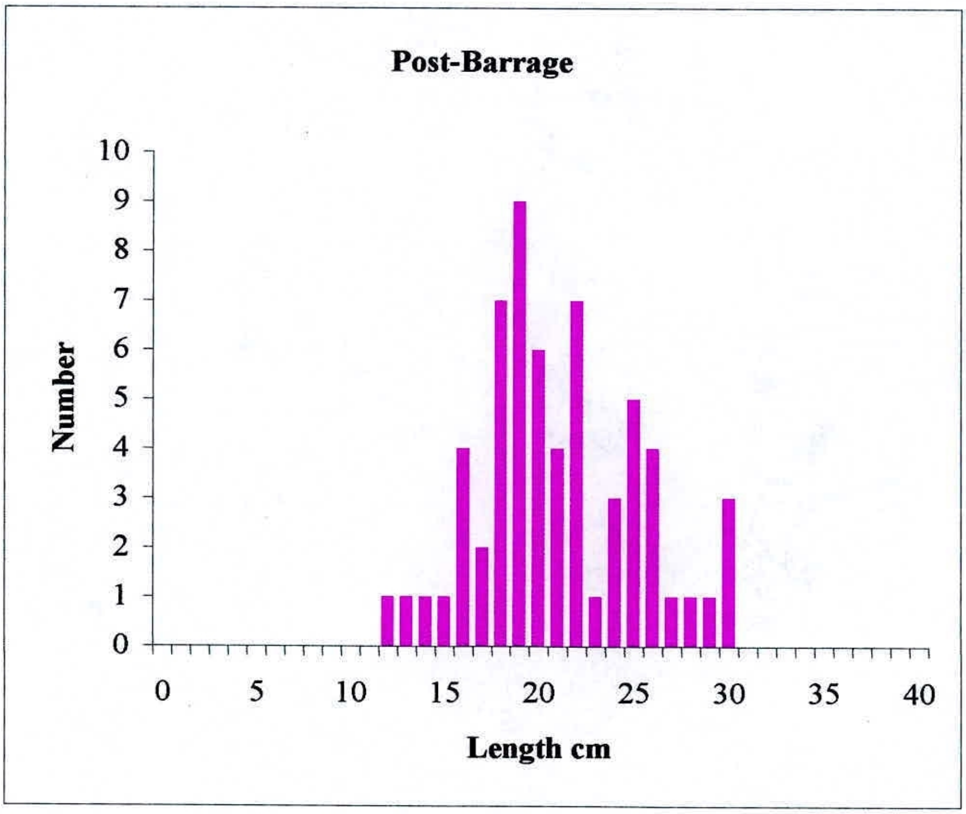
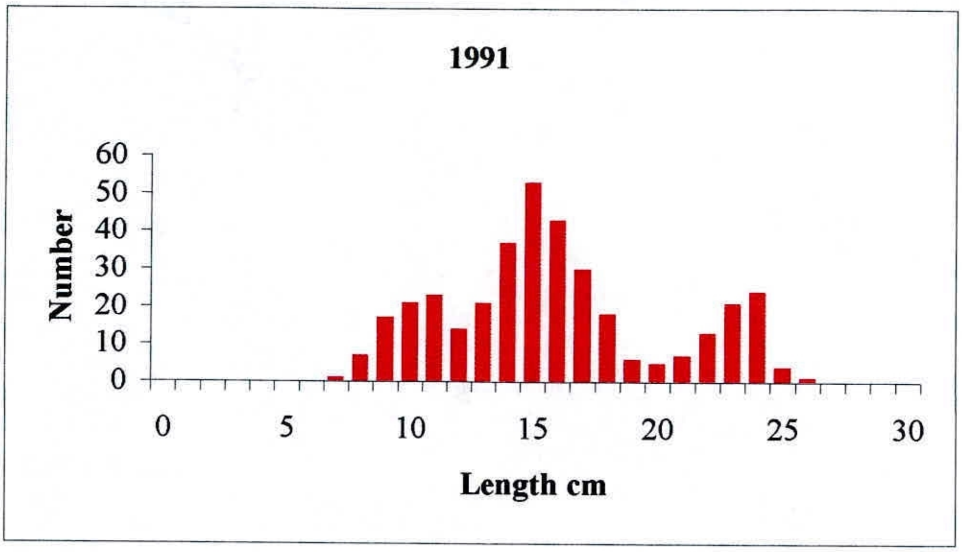
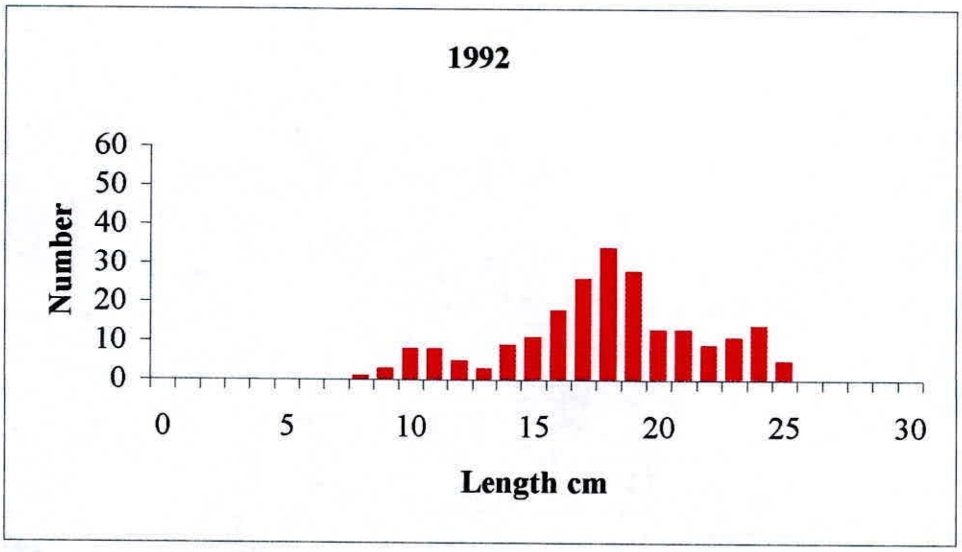


Figure 23. Length-frequency distributions of weighed Tees dace in each September survey.





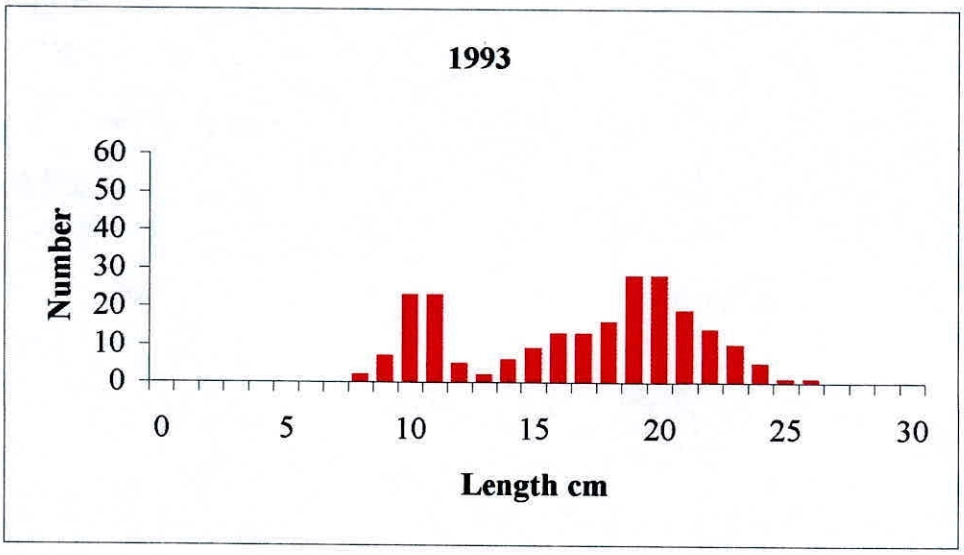
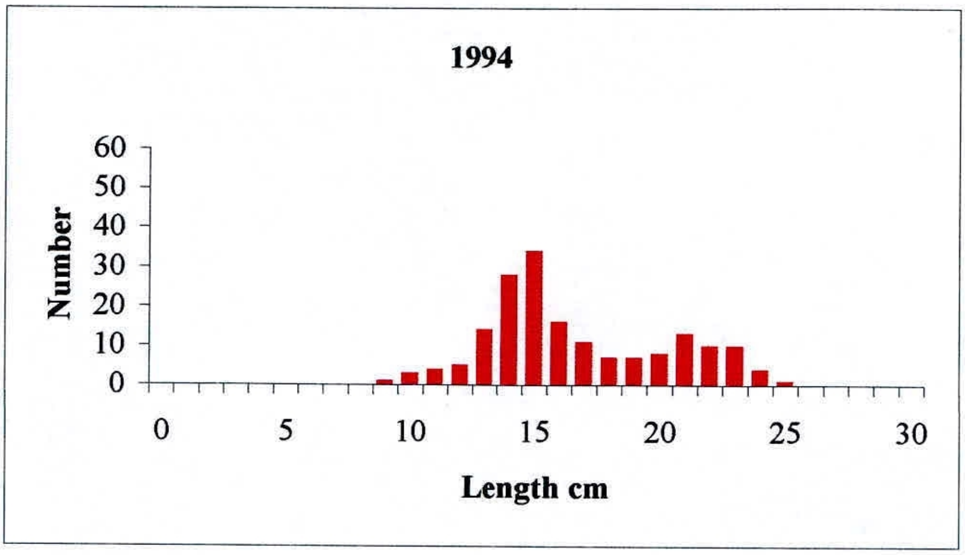
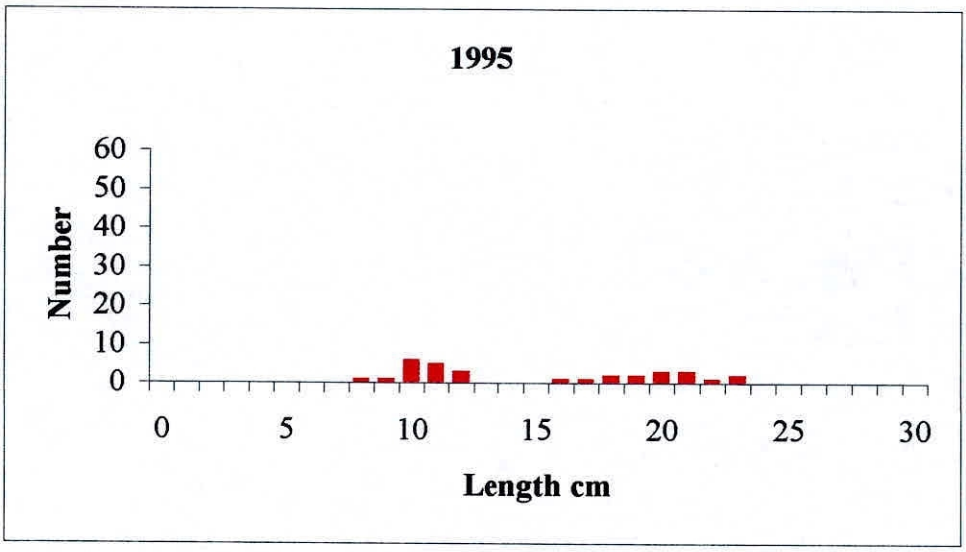


Figure 23. Continued





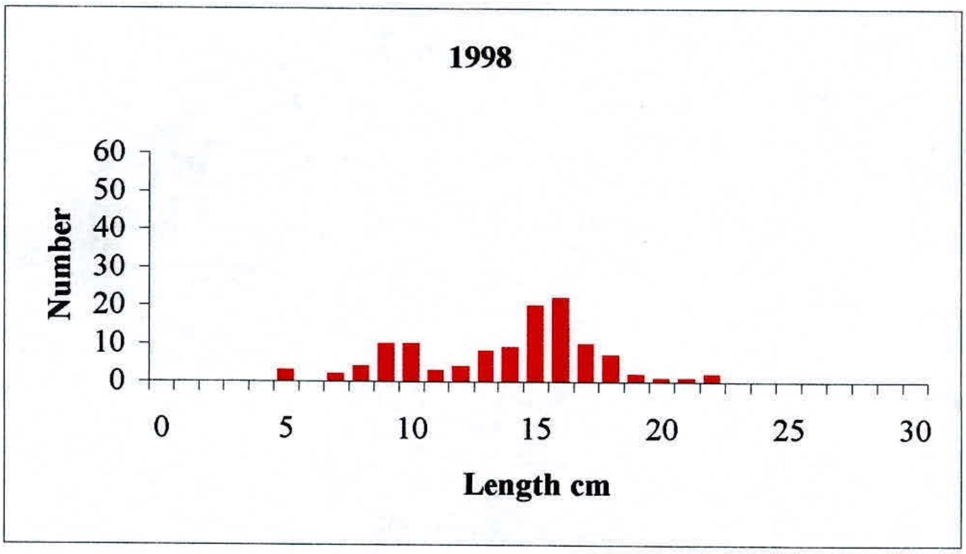


Figure 24. Length-frequency distributions of weighed Tees chub in each September survey.

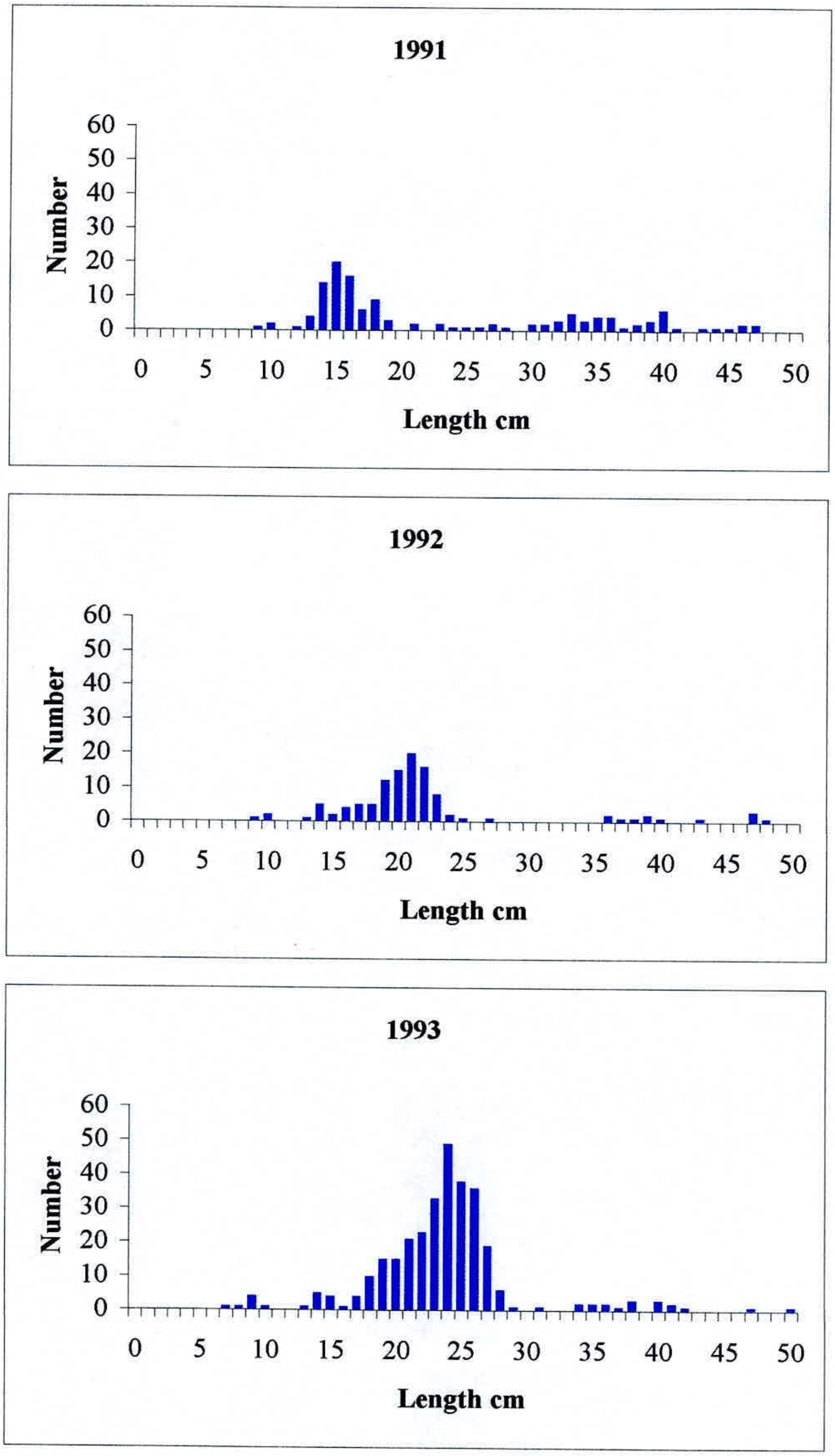
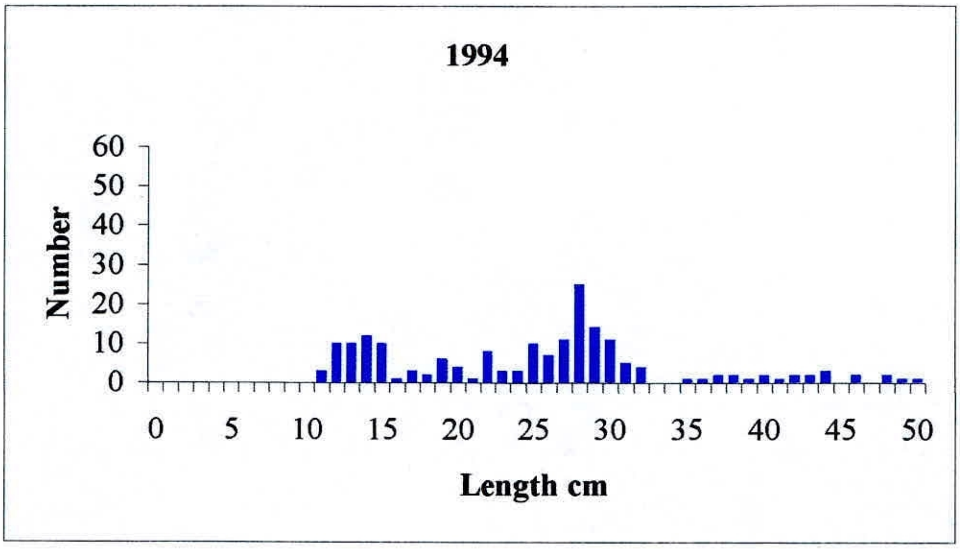
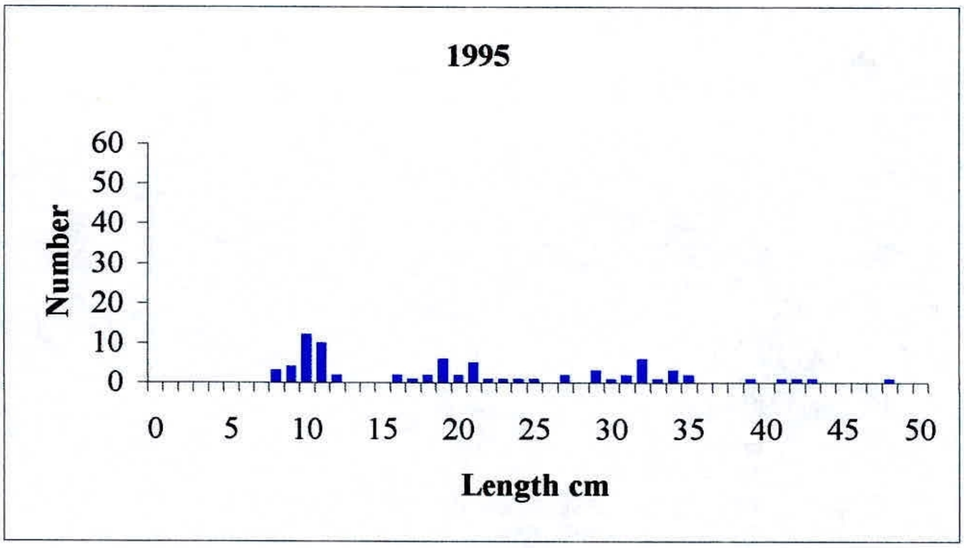


Figure 24. Continued





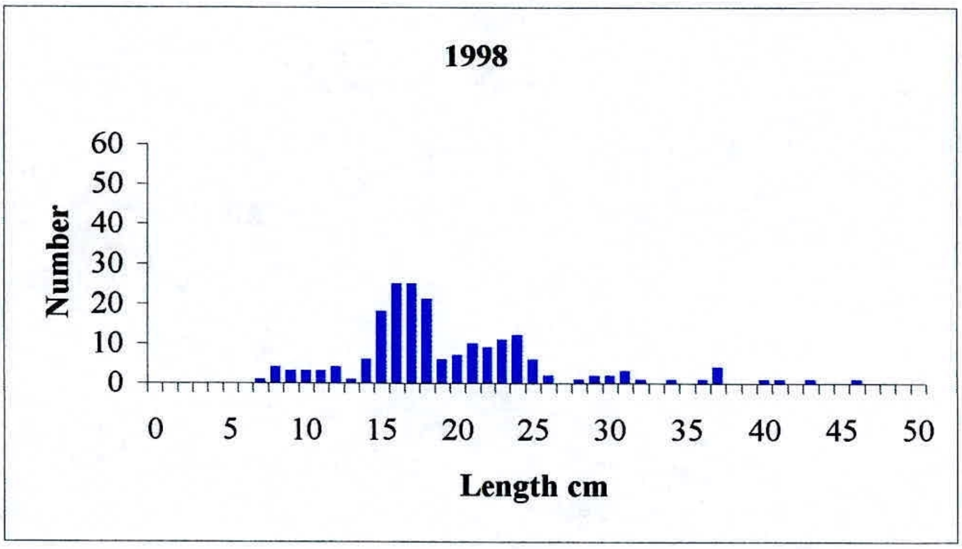


Figure 25. Length-frequency distributions of weighed Tees roach in each September survey.

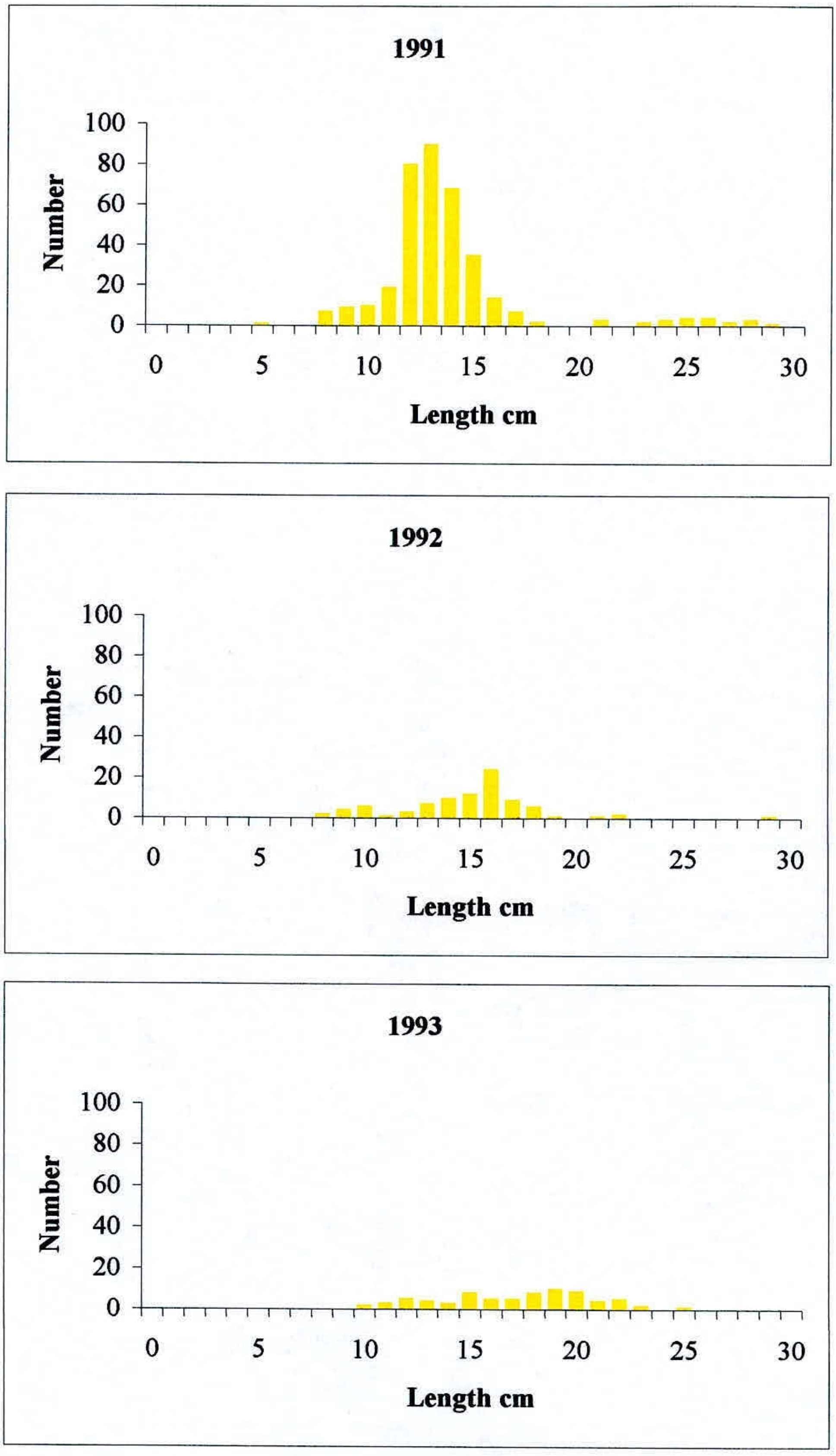
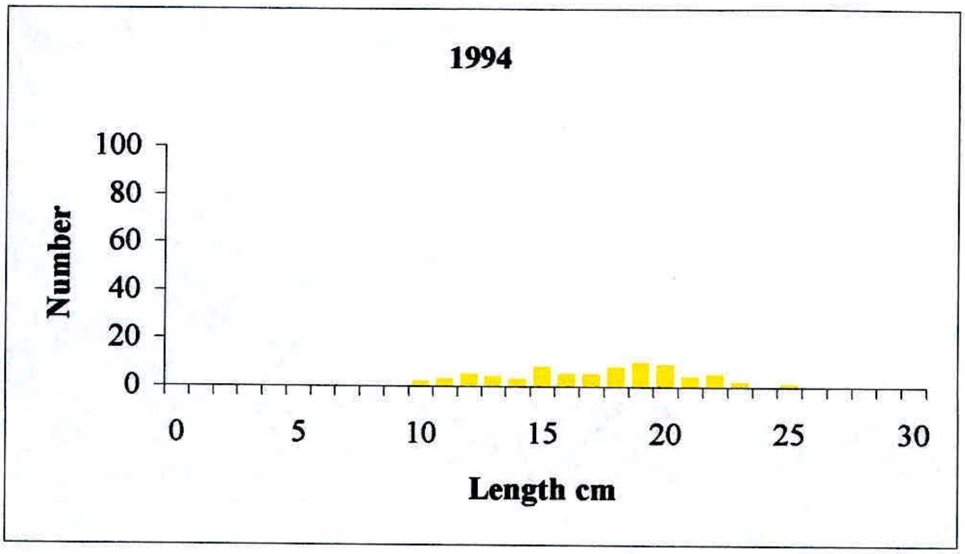
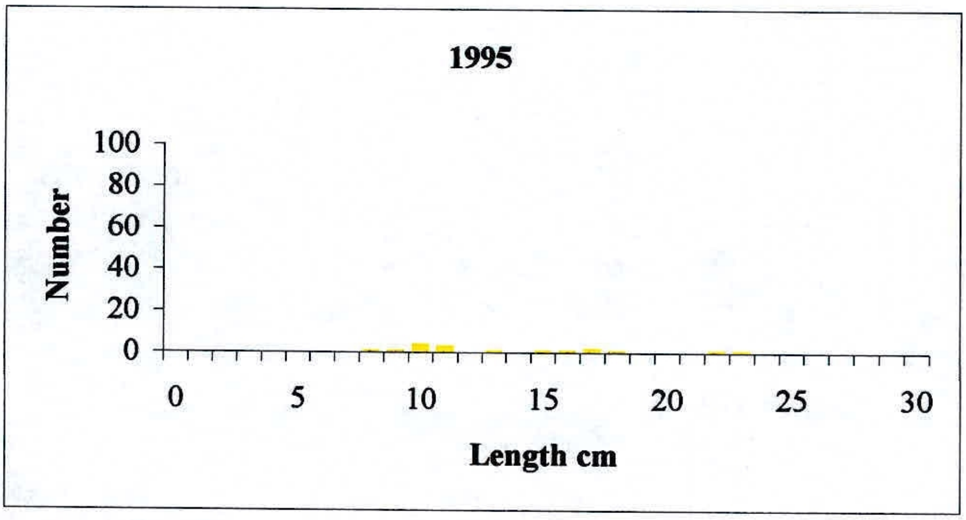


Figure 25. Continued





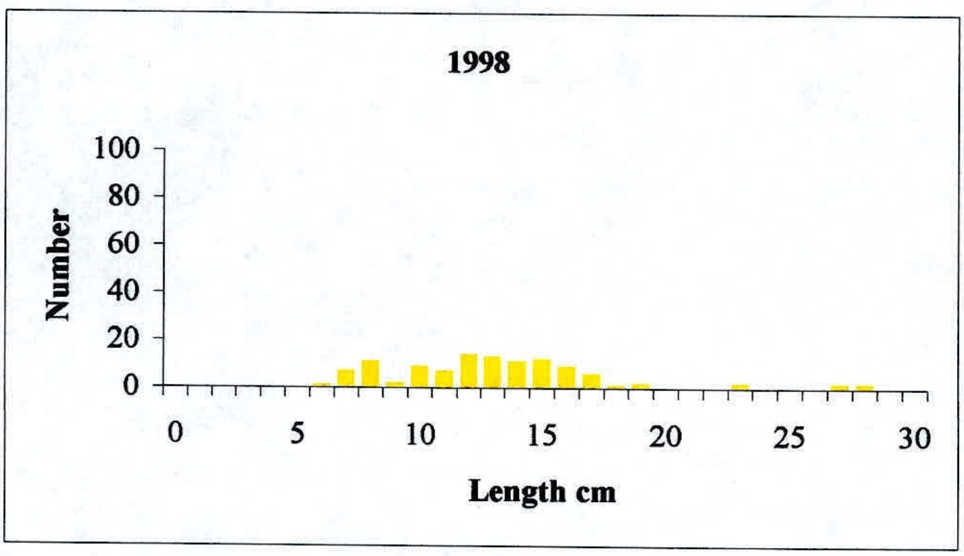
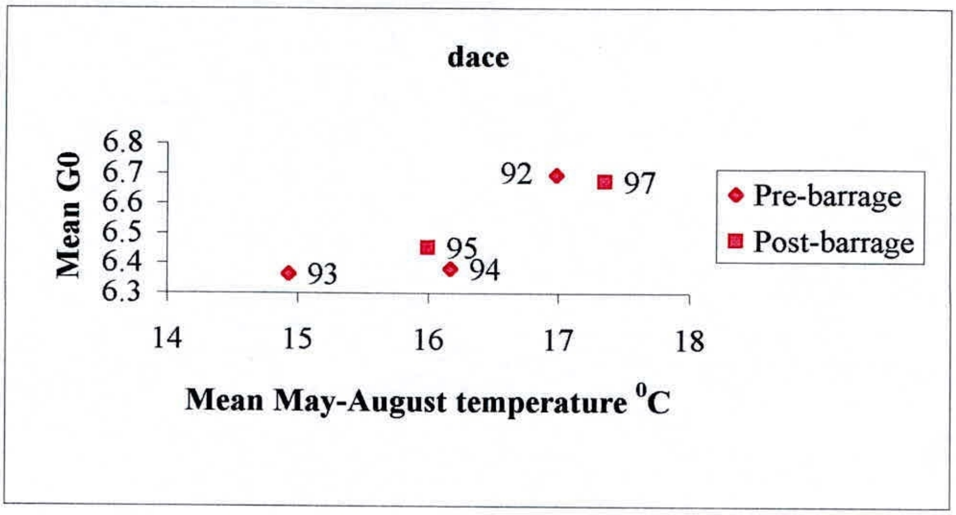
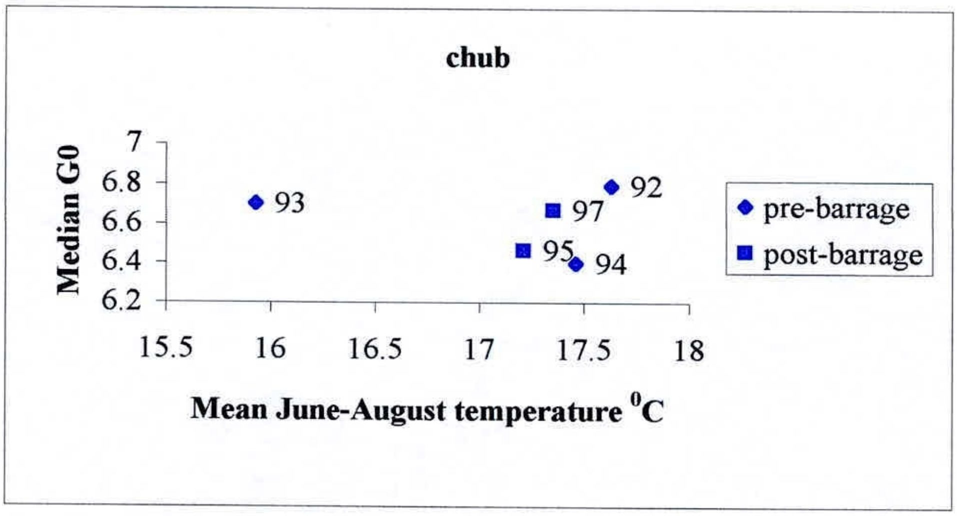


Figure 26. Mean G0 in pre- and post-barrage years plotted against mean May-August temperature or mean June-August temperature for dace, chub and roach.





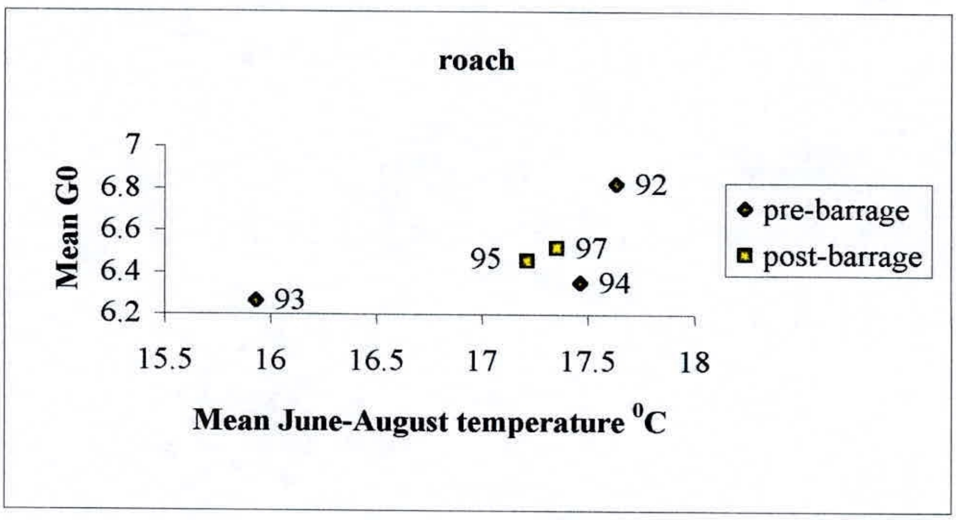


Figure 27. Mann Relative Year Class Strengths (Ma) for Tees dace, chub and roach. 100 = average year class strength

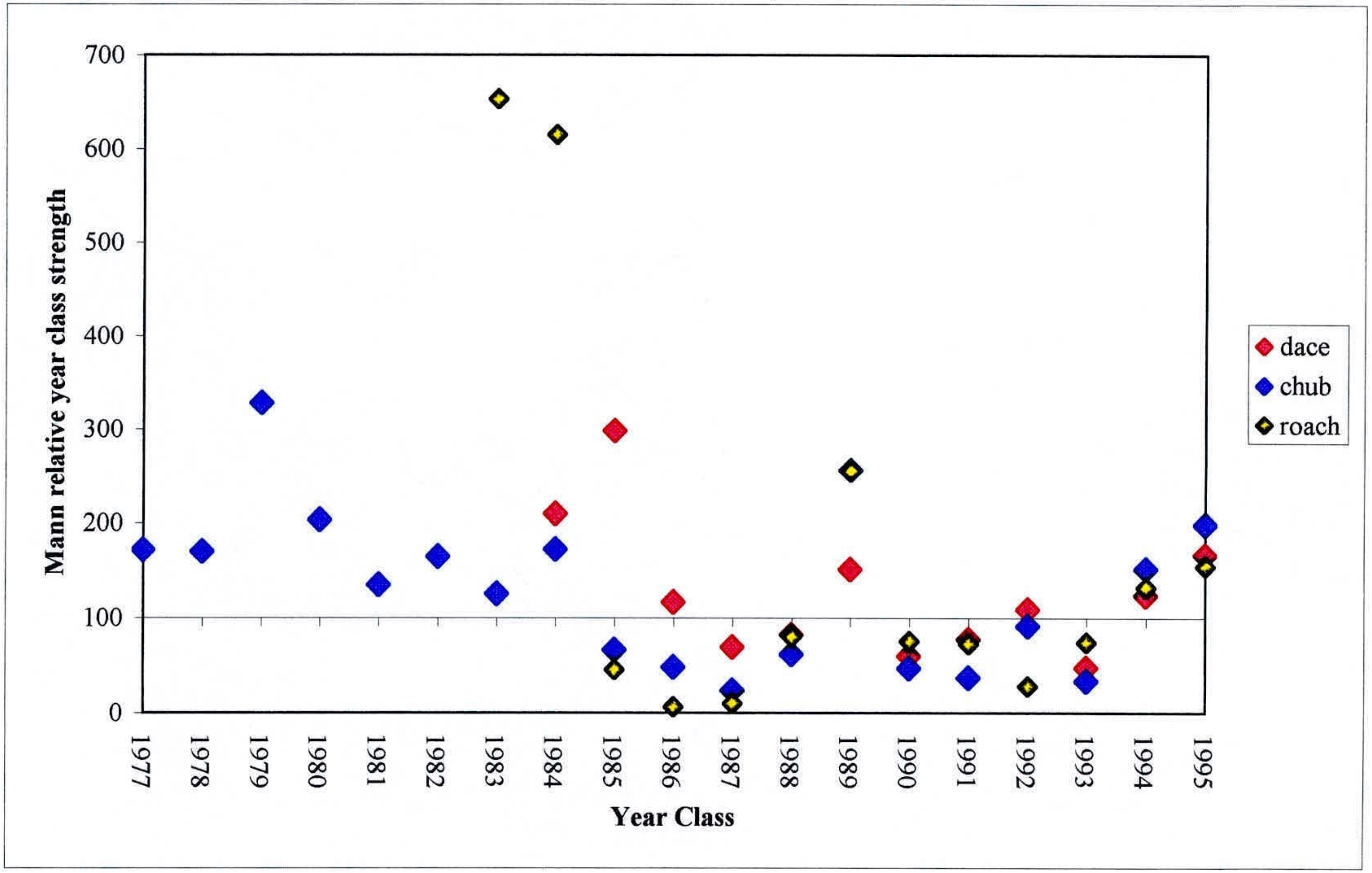
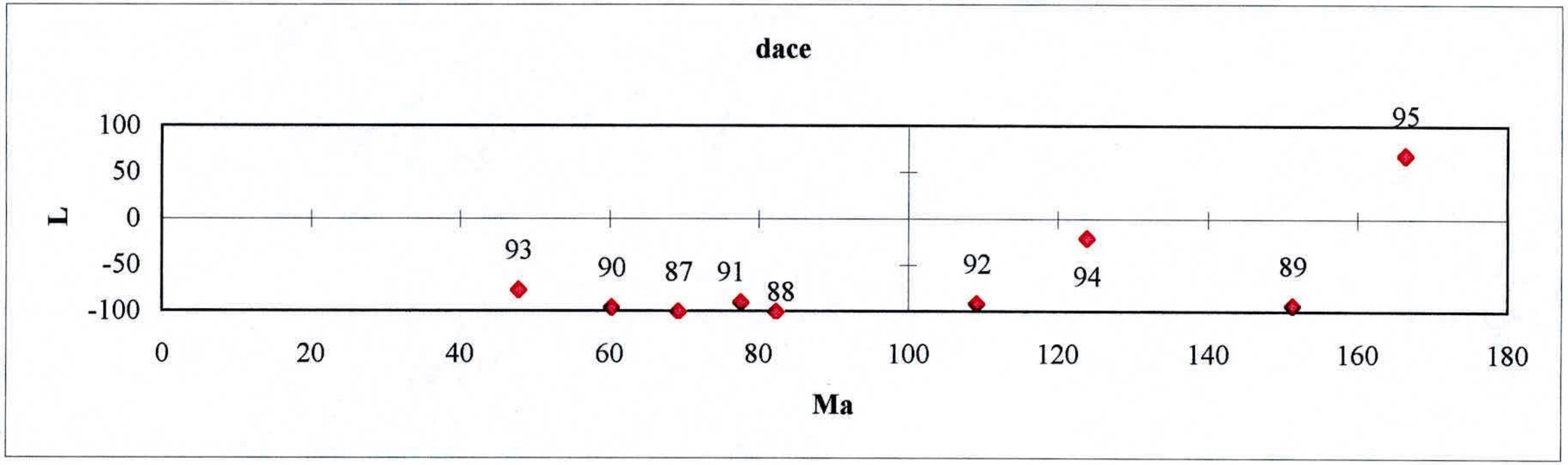


Figure 28 Linfield (L) relative year class strengths plotted against Mann (Ma) relative year class strengths.



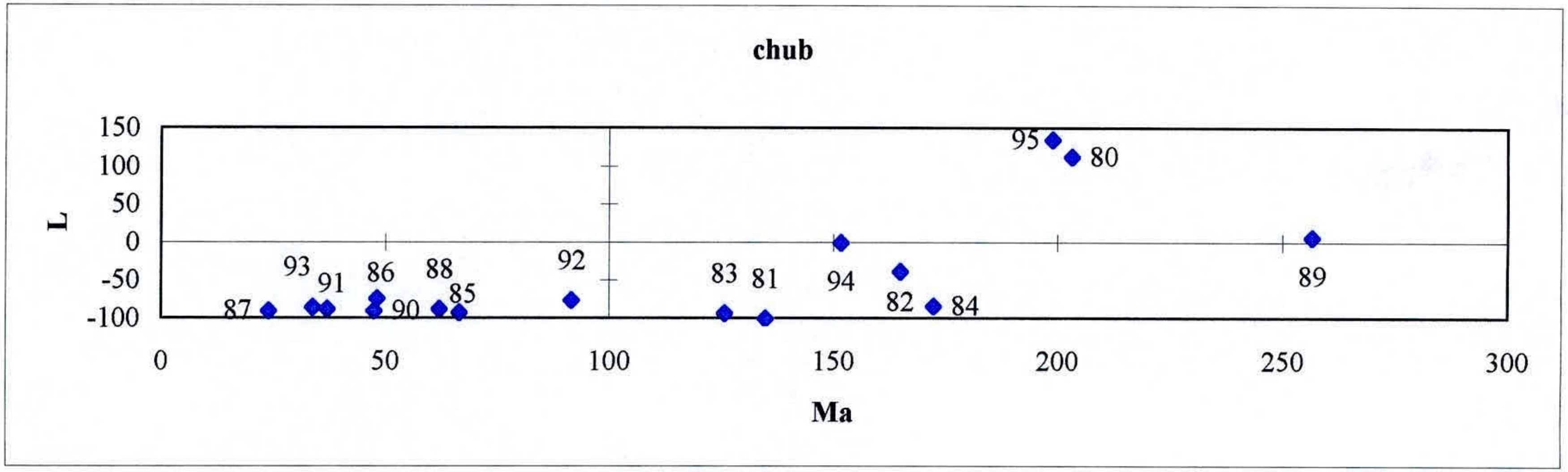


Figure 28. Continued

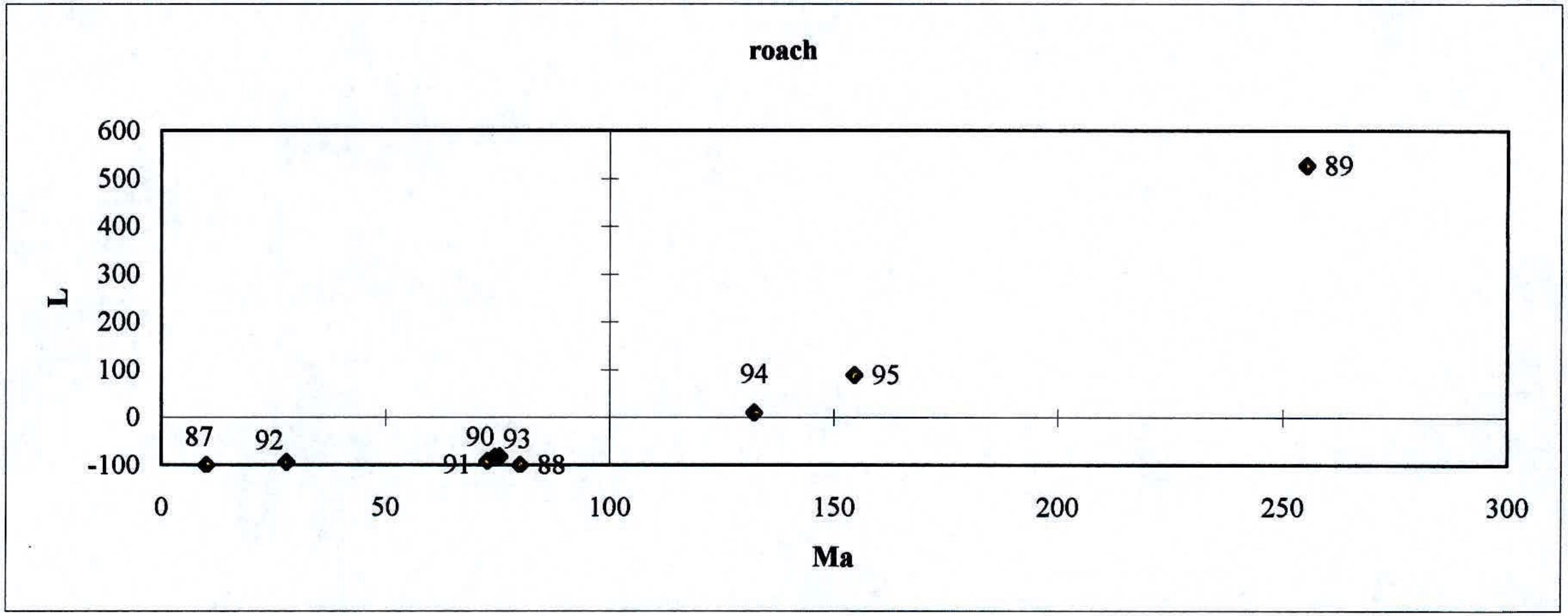


Figure 29. Number of 0+ dace, chub and roach caught during September surveys against Mann relative year class strength.

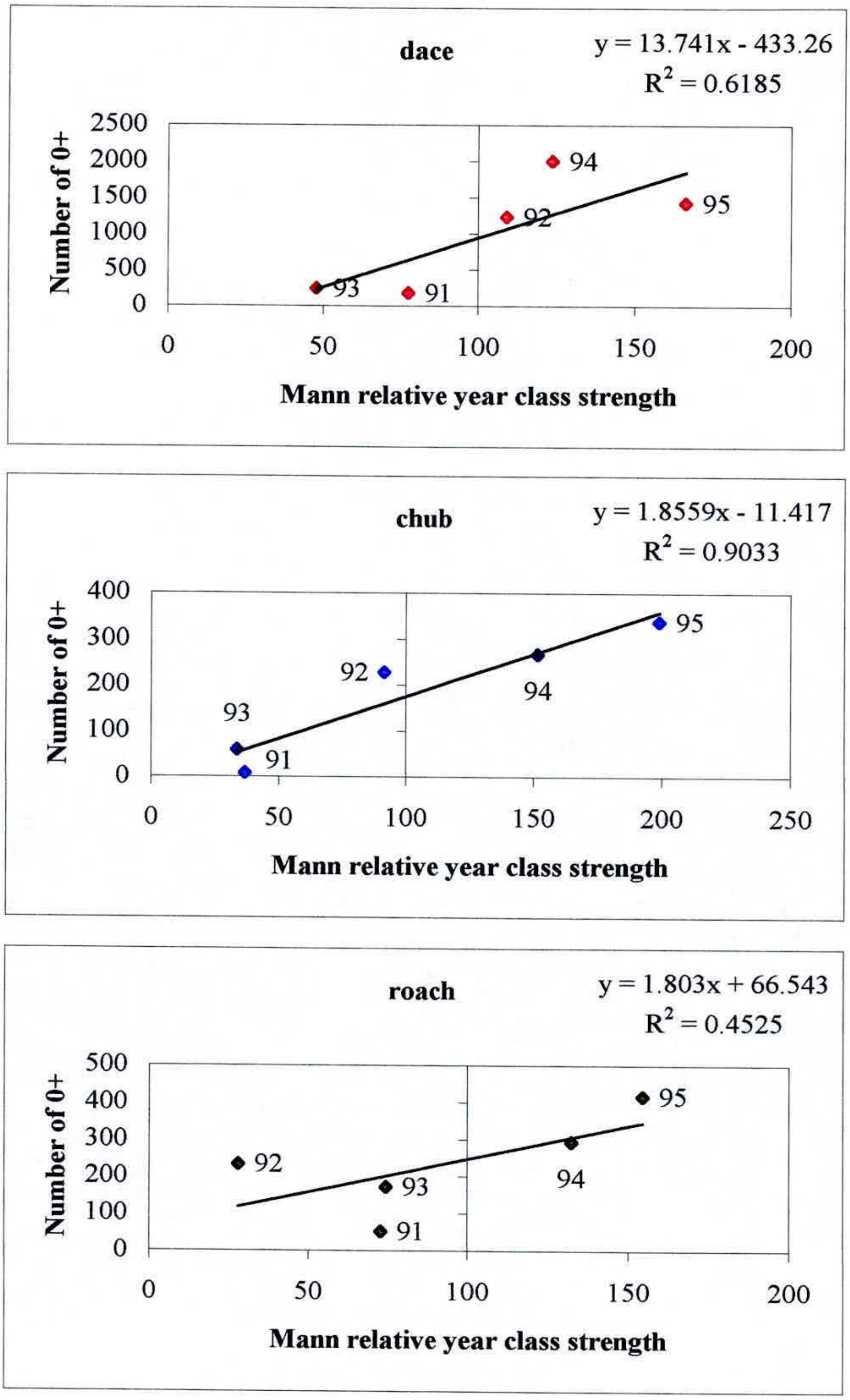


Figure 30. Distribution of scaled dace with copepods in the R.Tees in September 1992, 1996, 1997 and 1998.

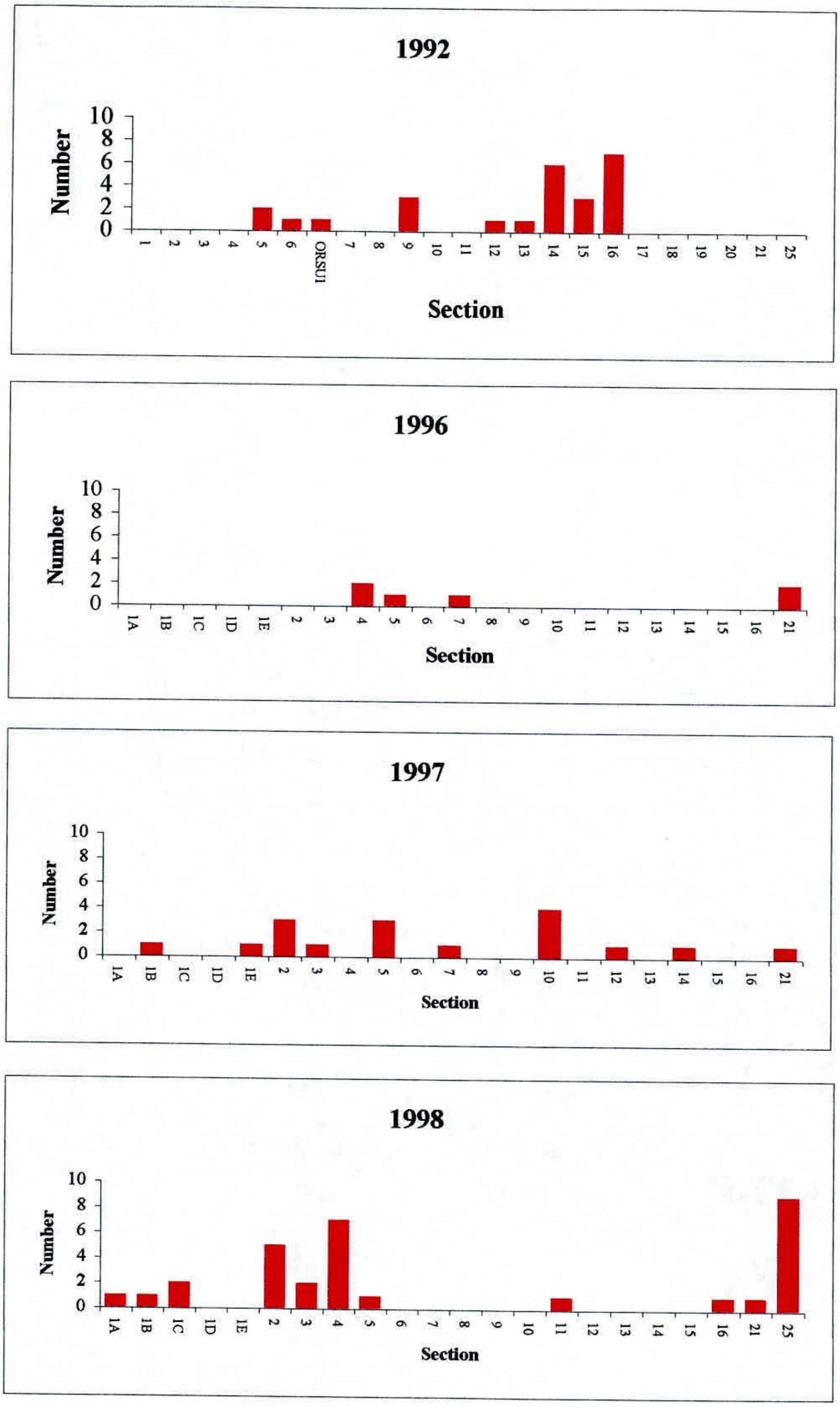


Figure 31. Mean (± 95% CL) catch weight per angler per match for each season in the study period

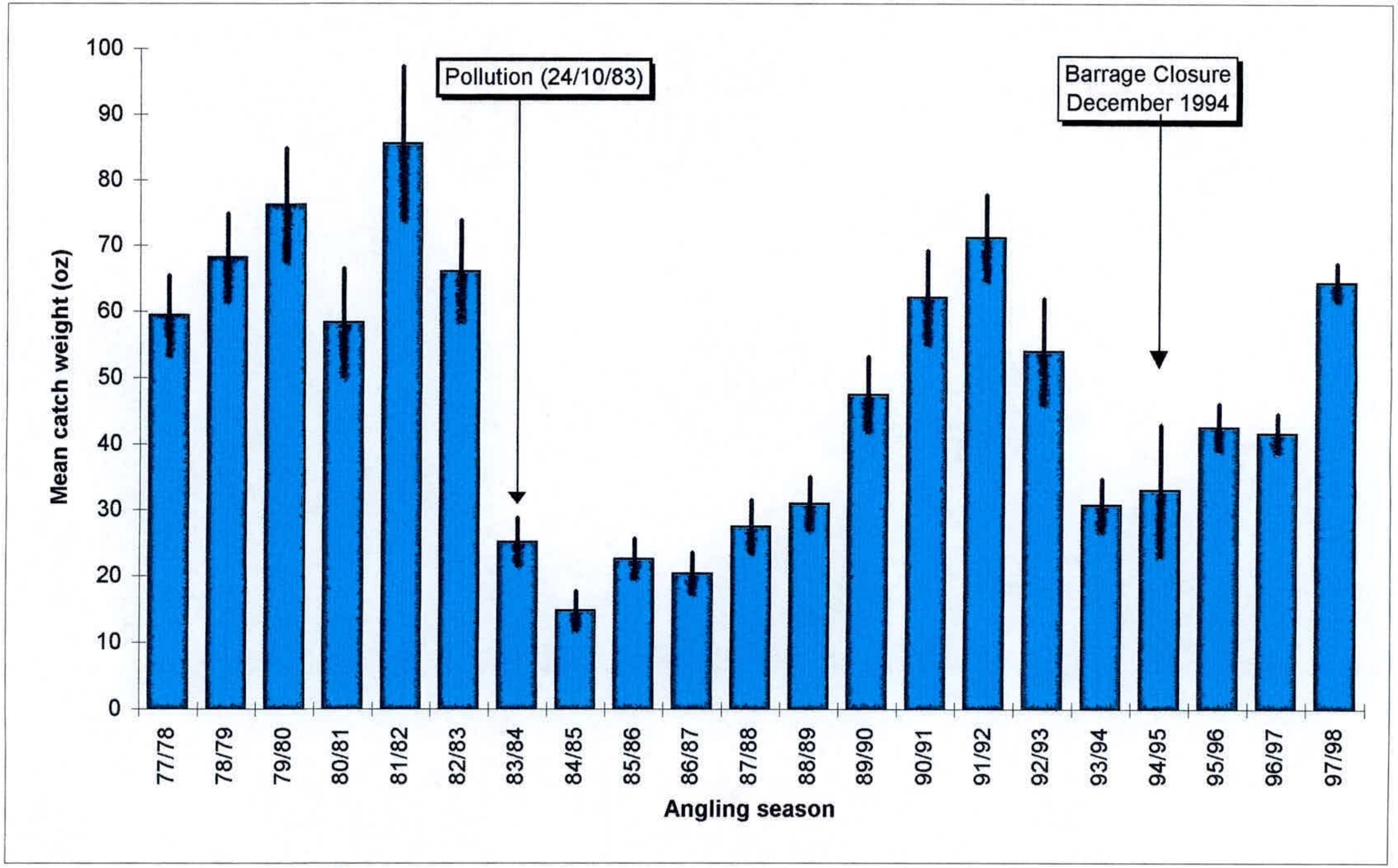


Figure 32. Mean (± 95% CL) catch weight per top ten angler per match for each season in the study period

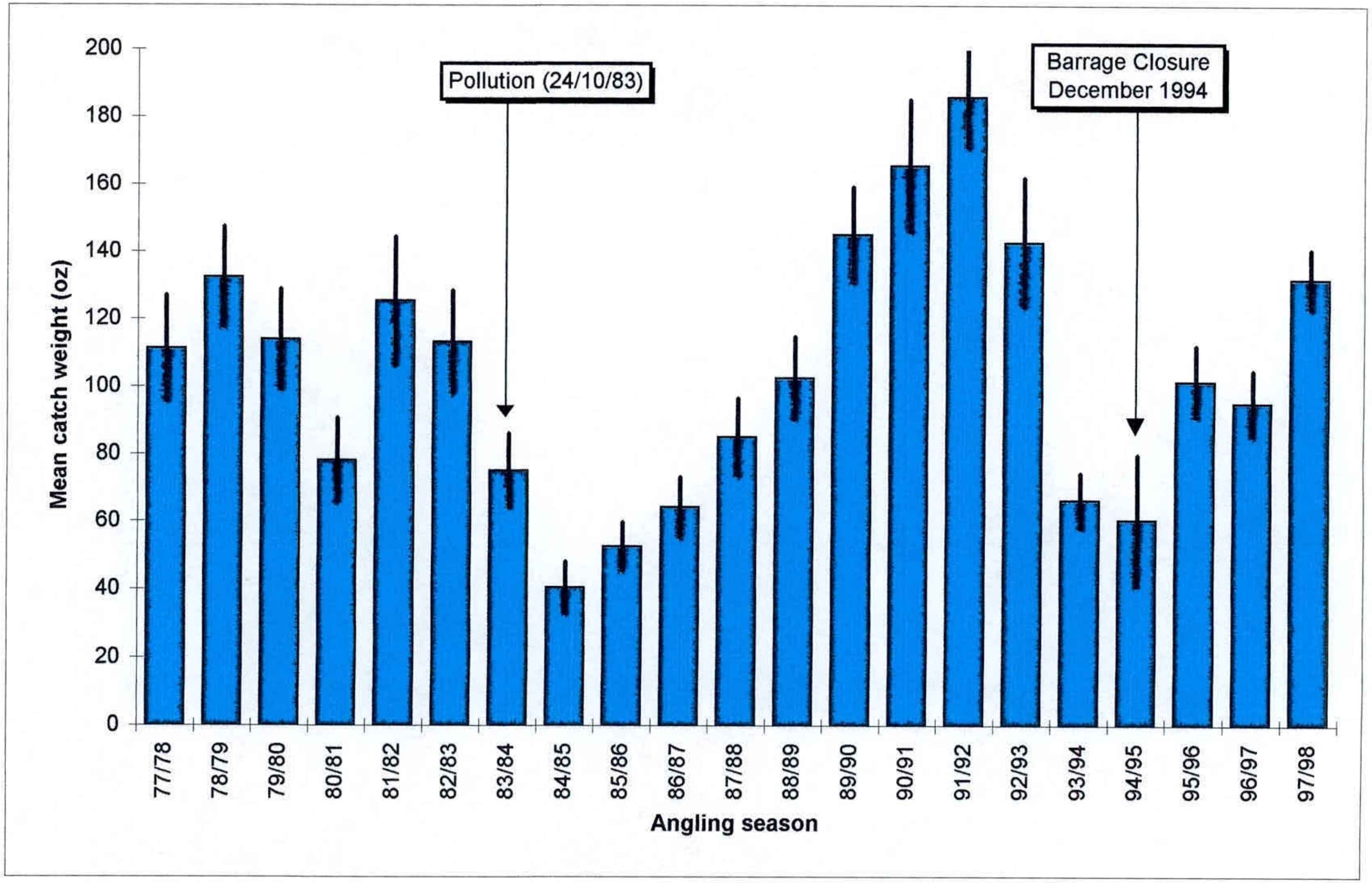
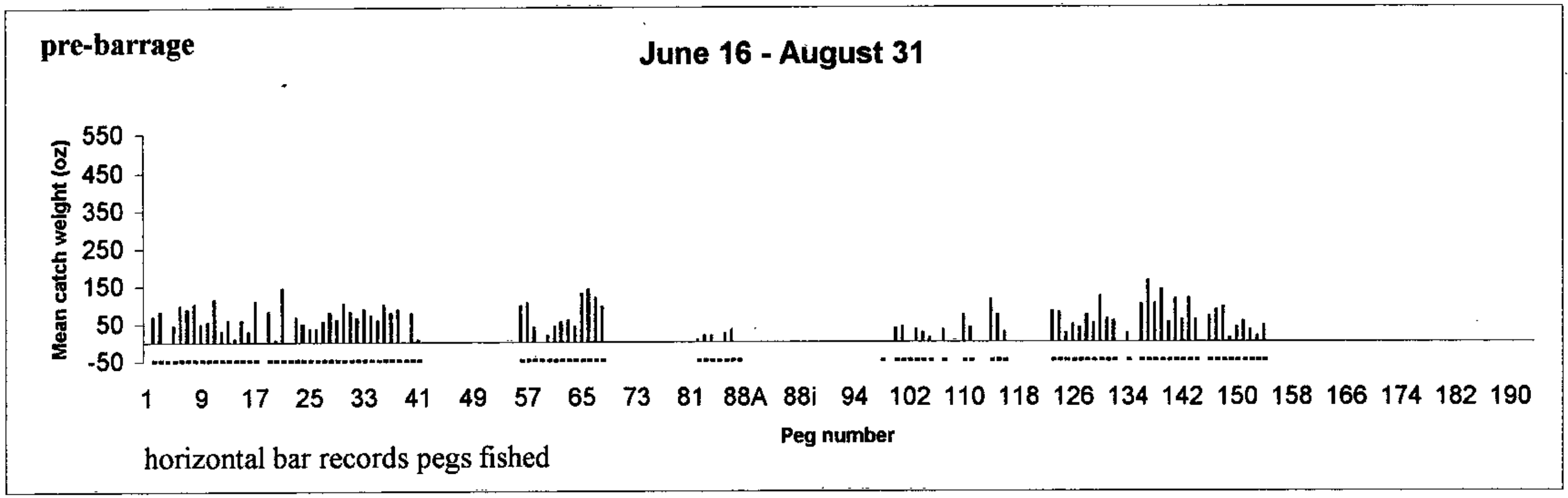


Figure 33 Pre- and post-barrage distribution of catch weights in the River Tees



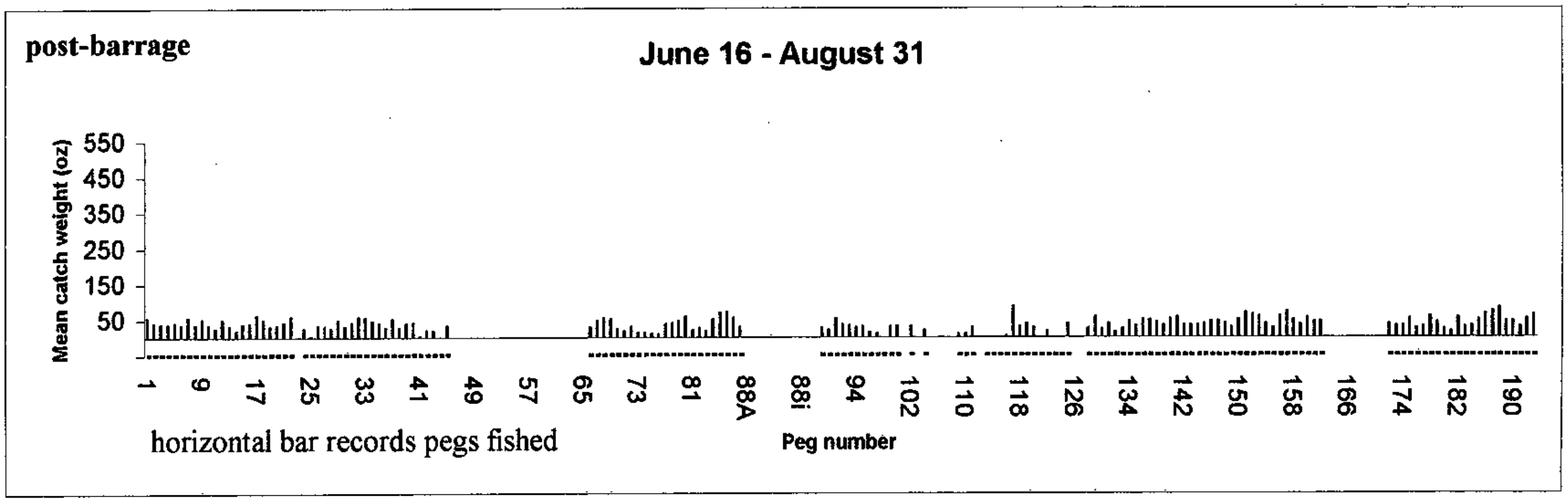
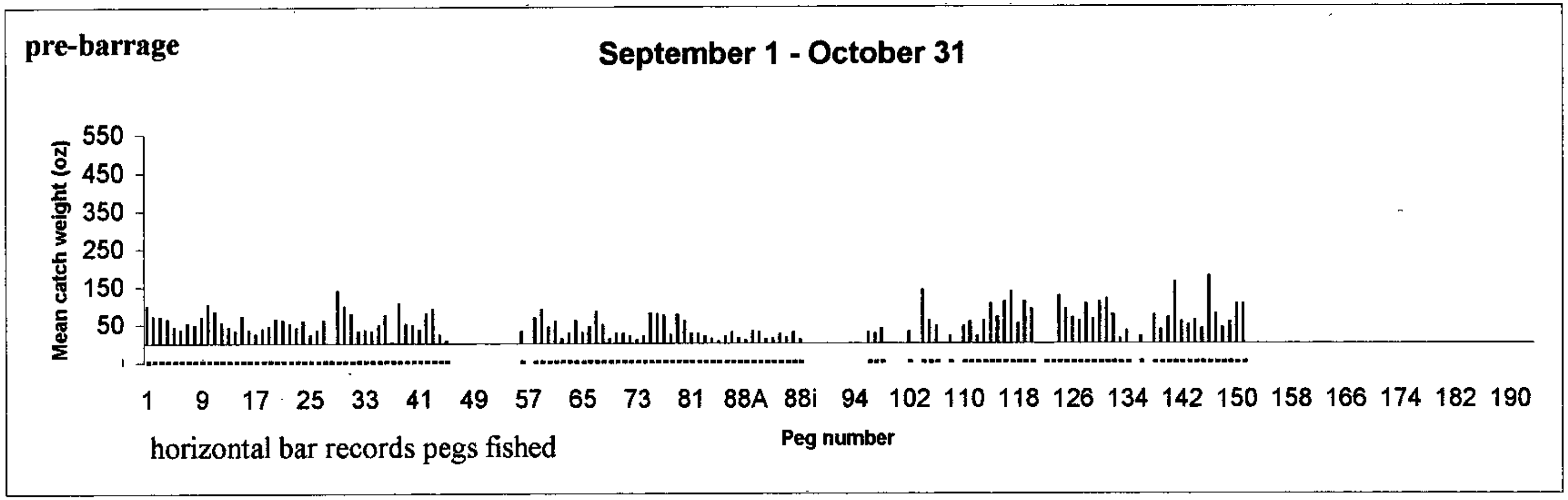


Figure 33. Continued



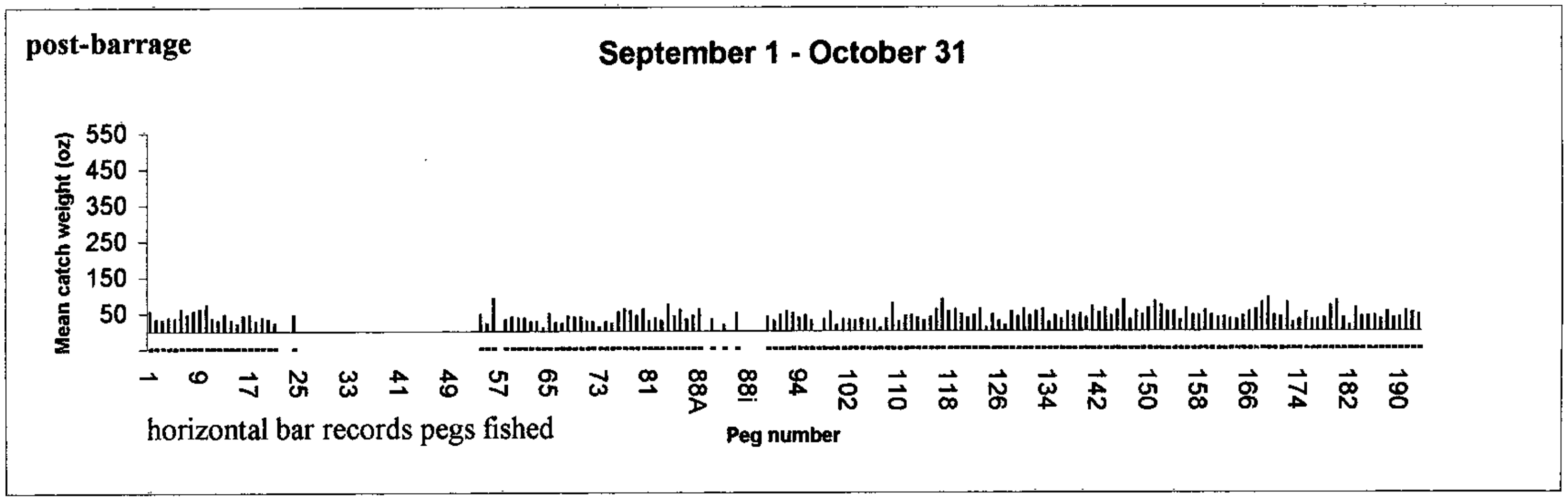


Figure 33. Continued

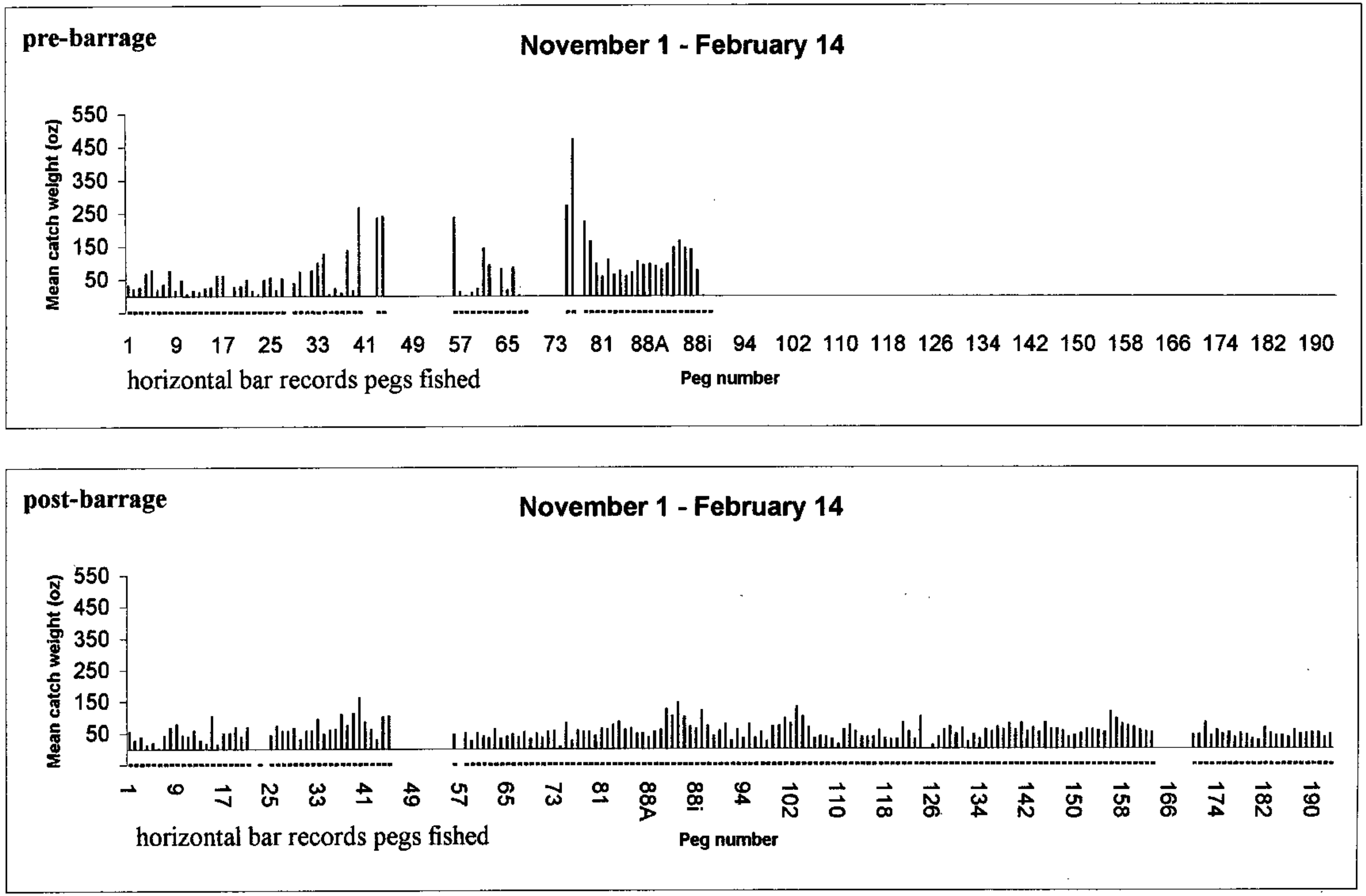
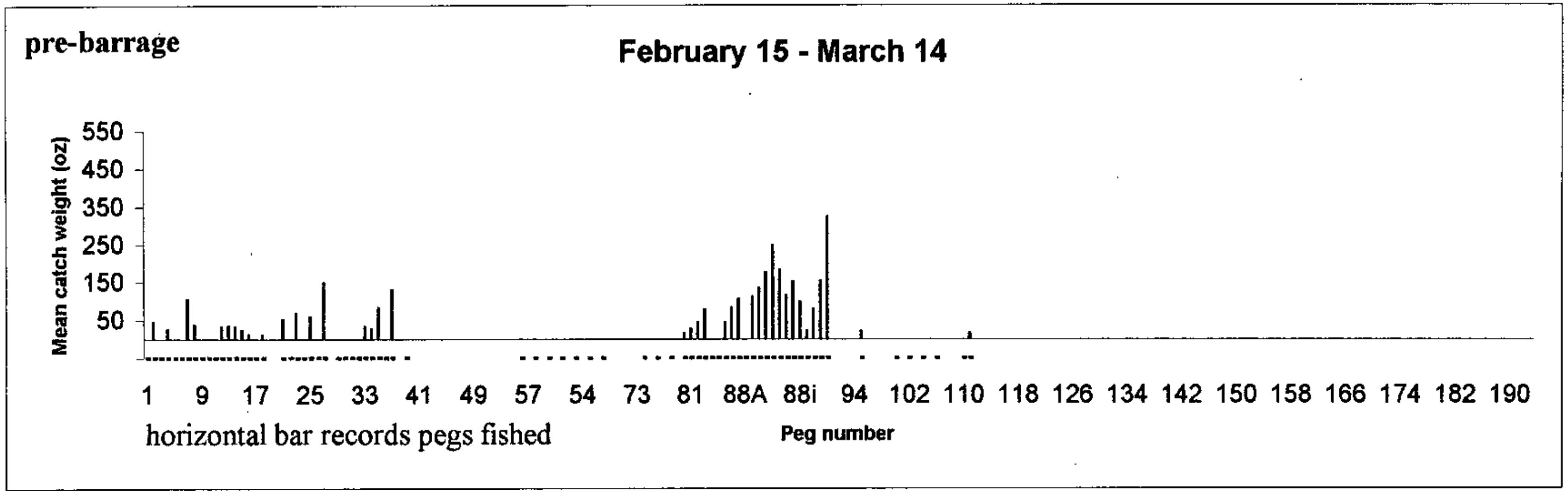


Figure 33. Continued



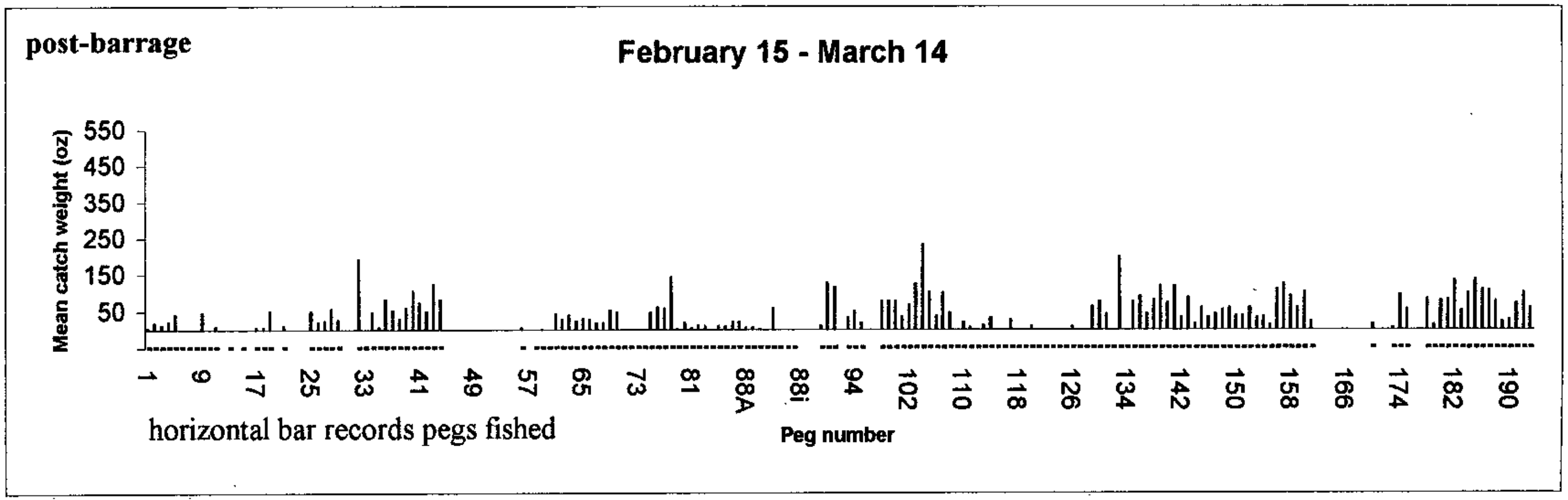
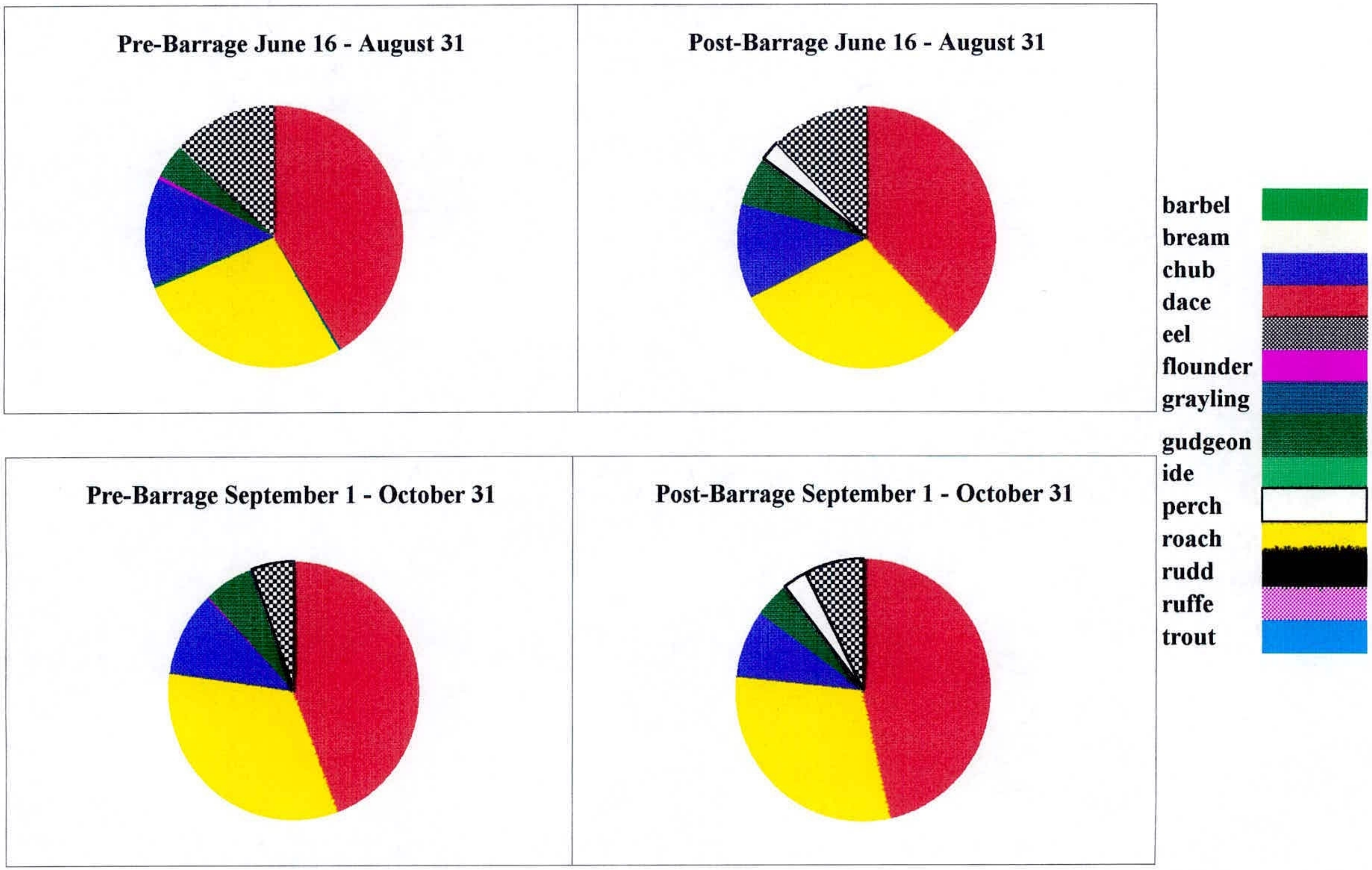


Figure 34. Species composition of anglers catch in pre- and post-barrage years



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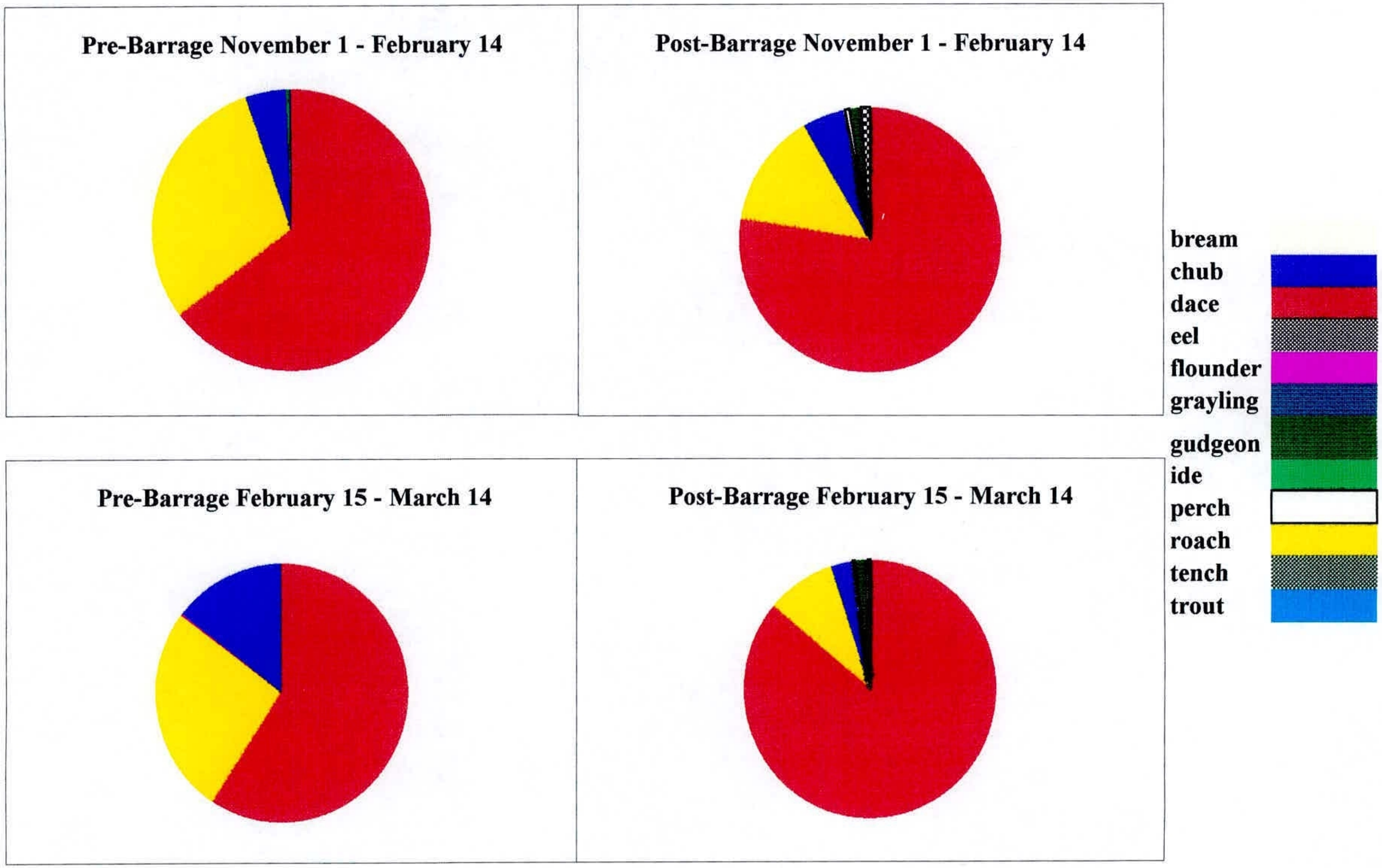


Figure 35. Percentage of dace, chub and roach in the total catch, in each season (A = Jun 16 - Aug 31, B = Sep 1 - Oct 31, C = Nov 1 - Feb 14, D = Feb 15 - Mar 14)

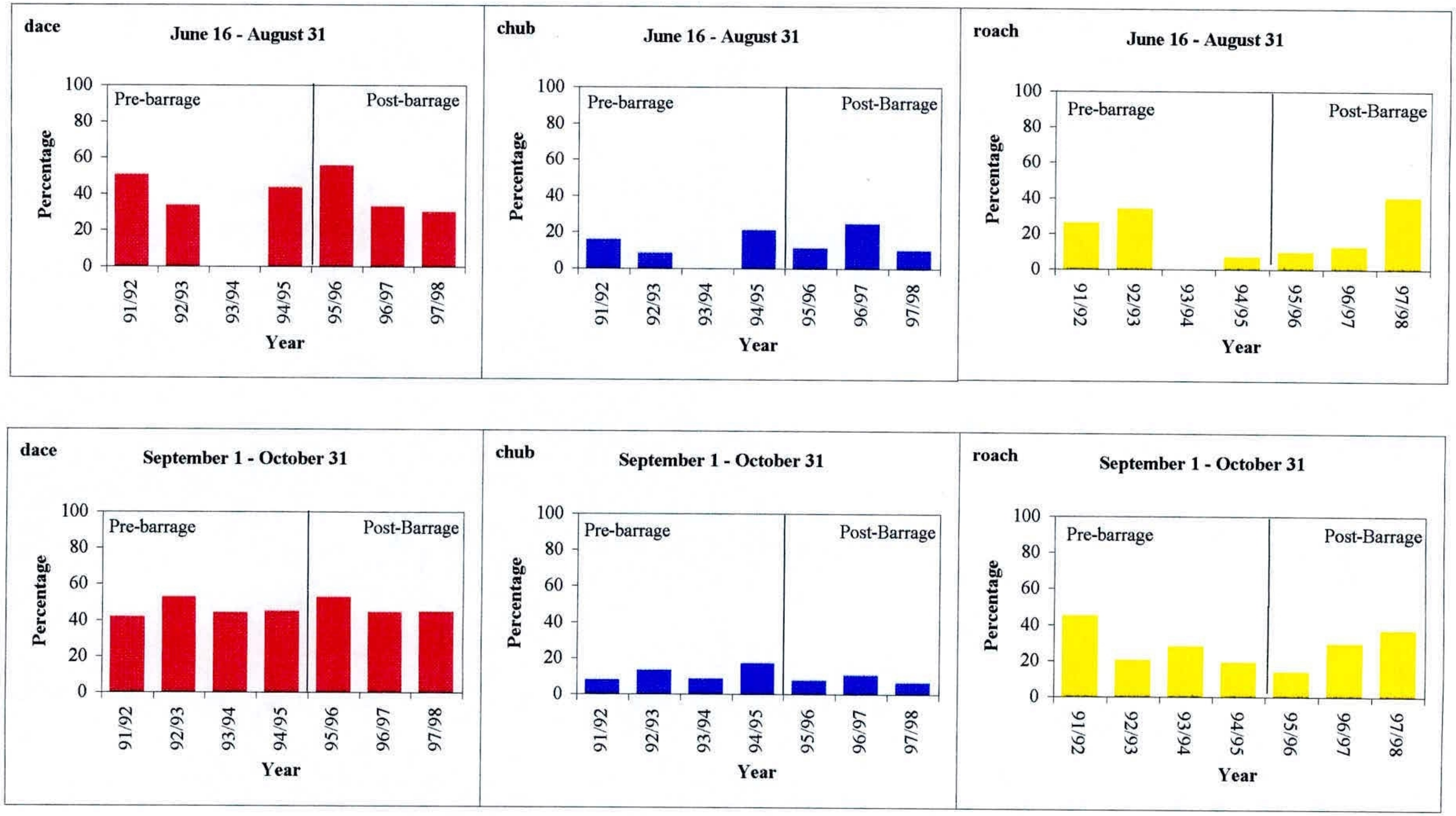


Figure 35. Continued

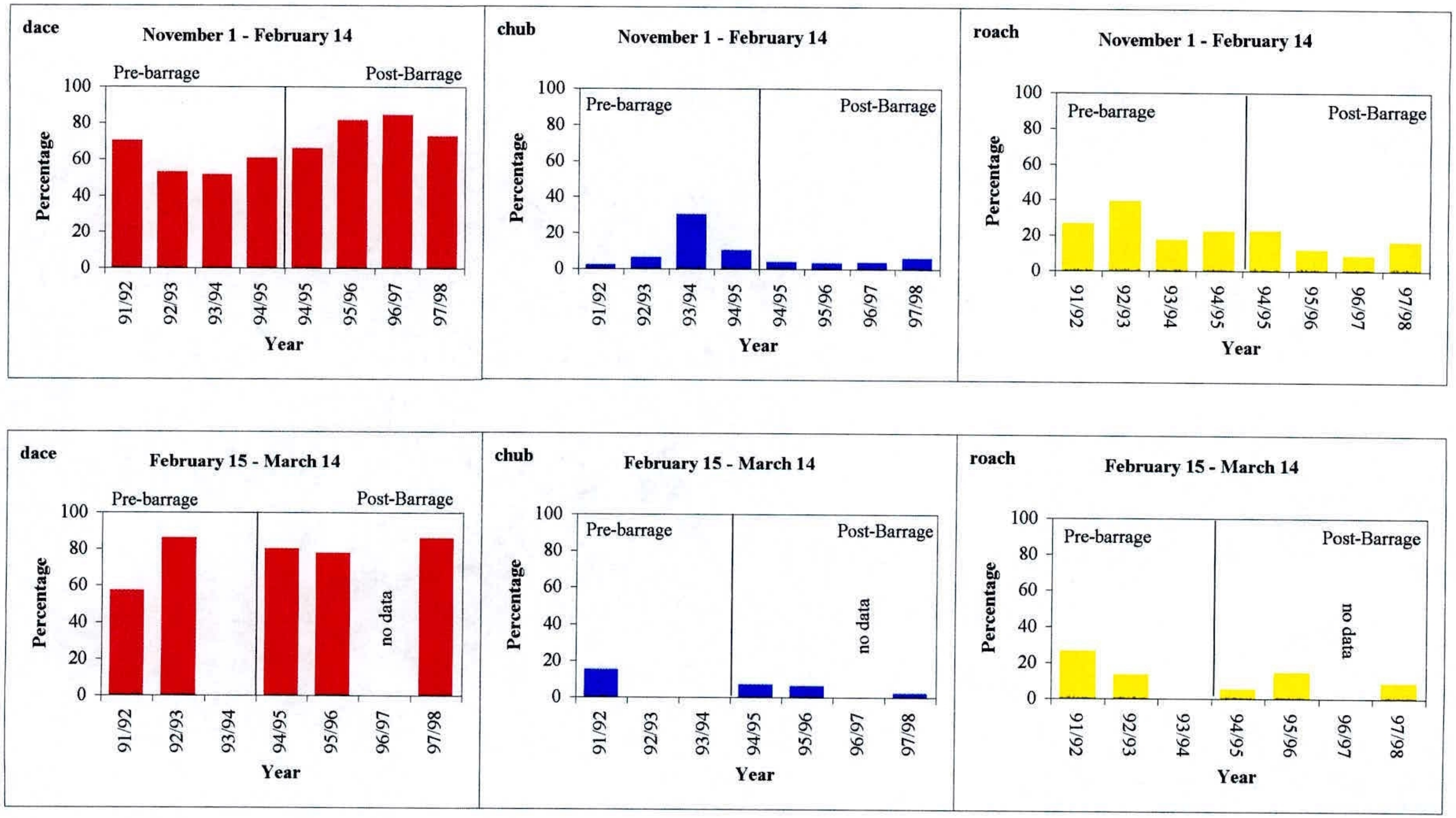


Figure 36. Proportions of large and small dace, chub and roach caught by anglers pre- and post-barrage

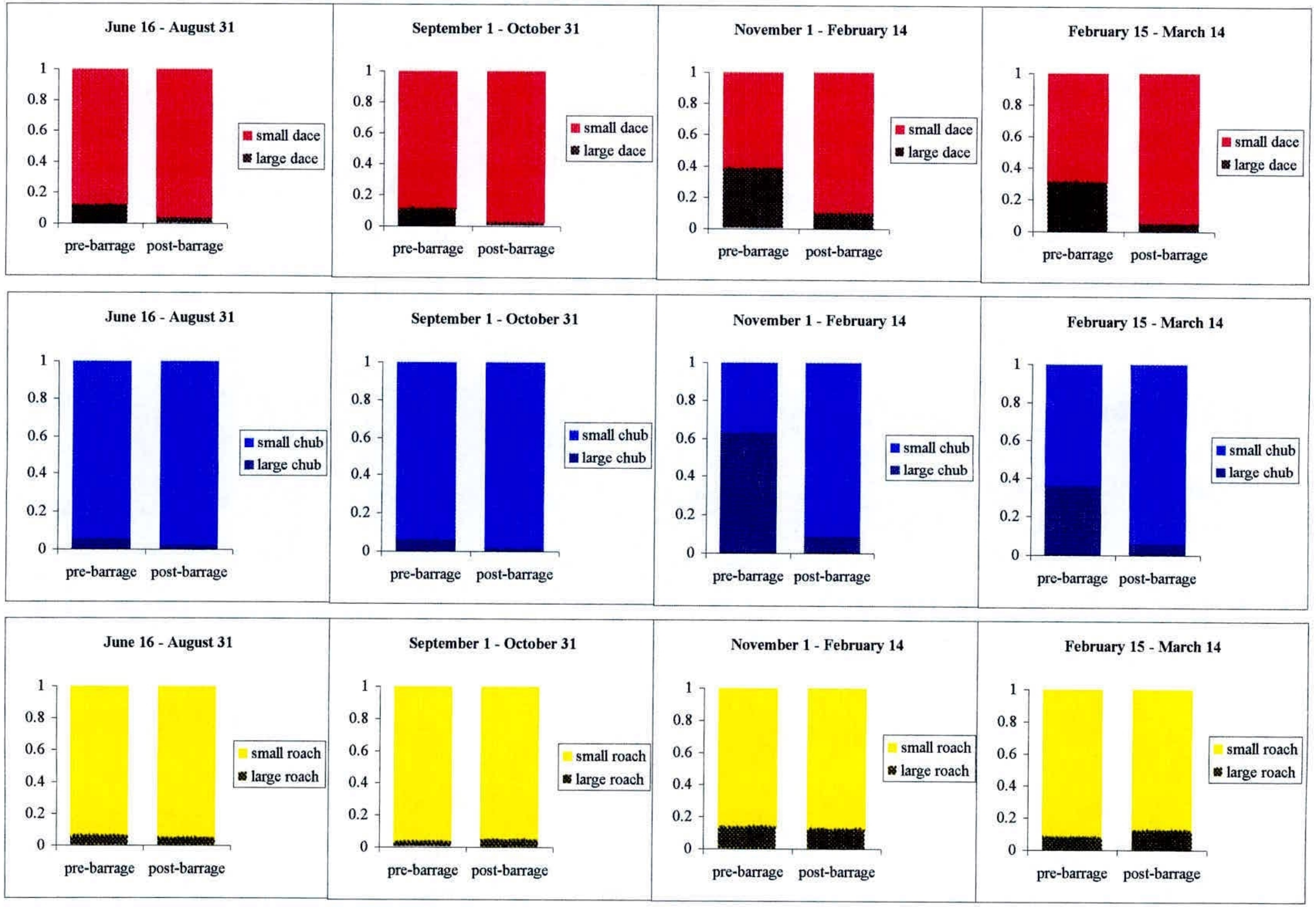


Figure 37. **The proportion of large and small dace, chub and roach caught by anglers in pre- and post-barrage Years**

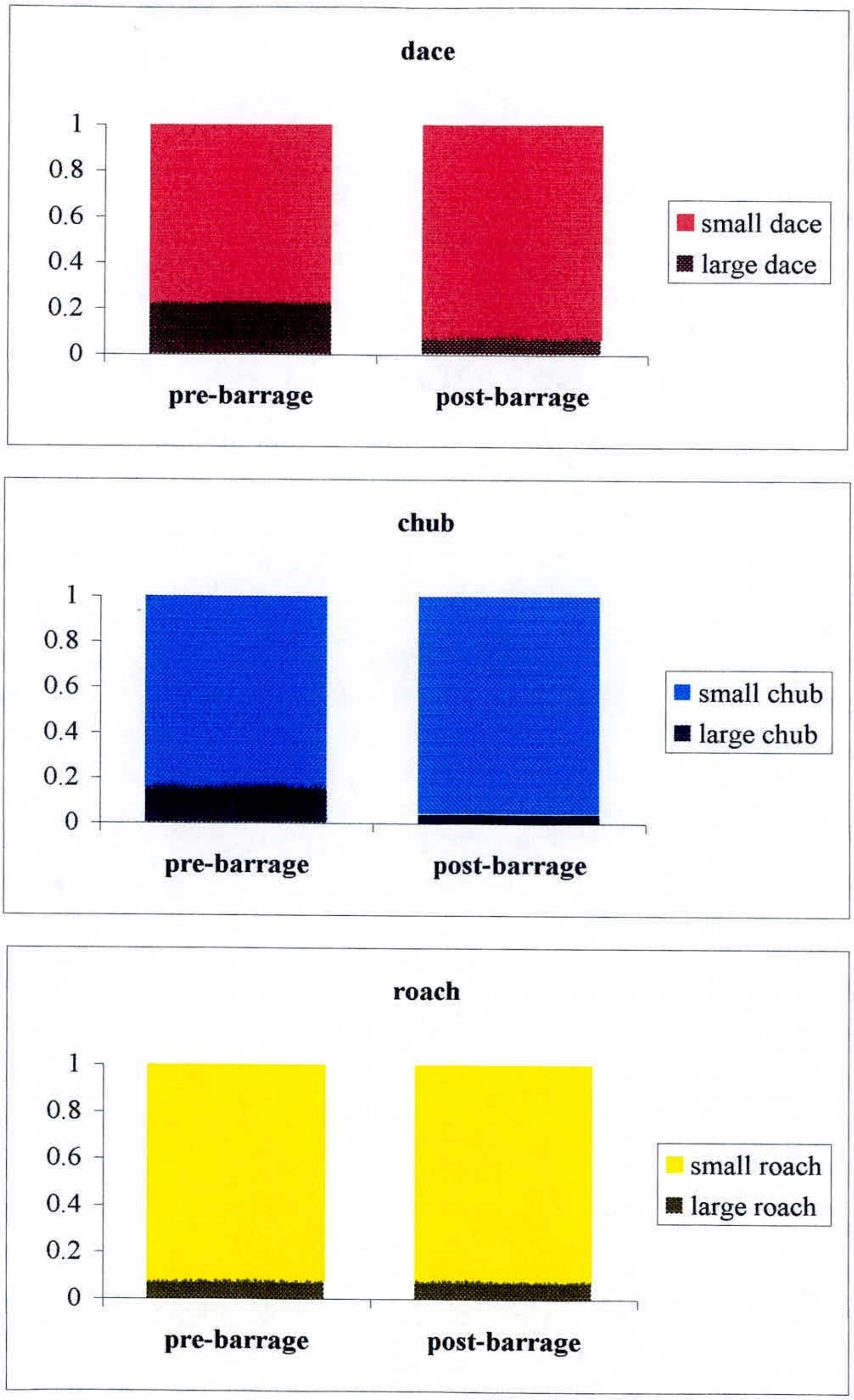
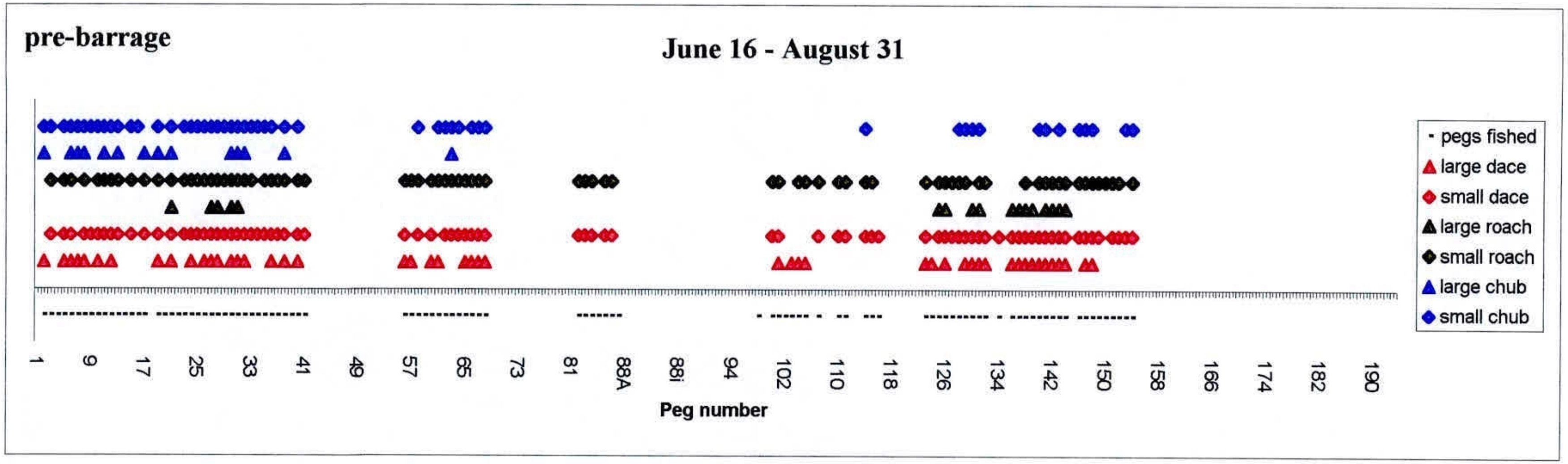


Figure 38. The distribution of large and small dace, chub and roach caught by anglers pre- and post-barrage



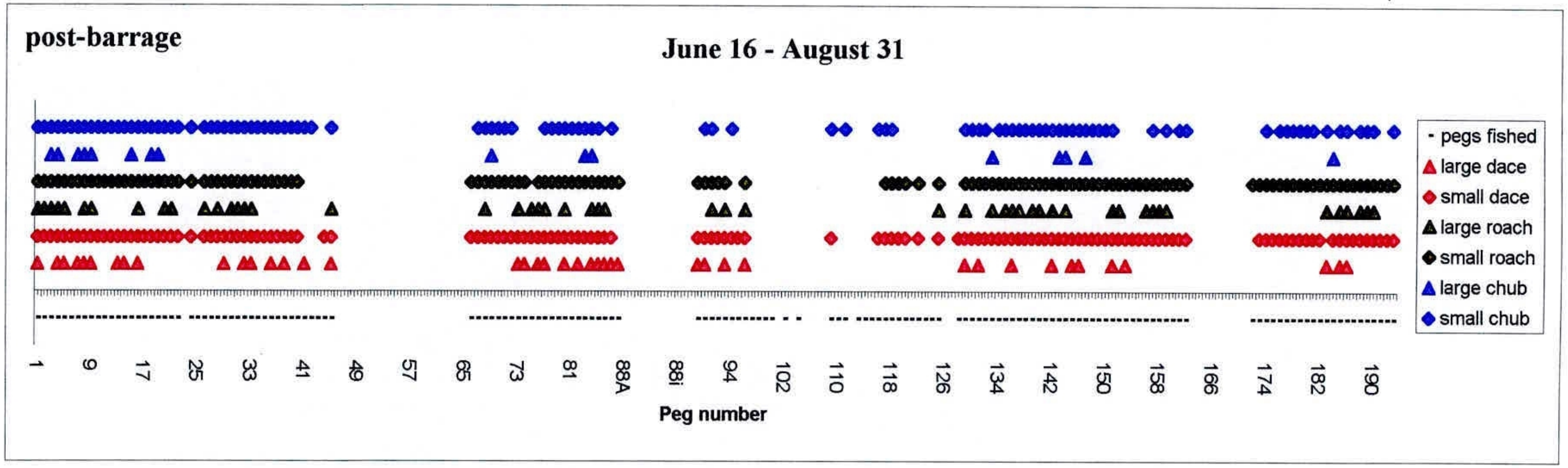


Figure 38. Continued

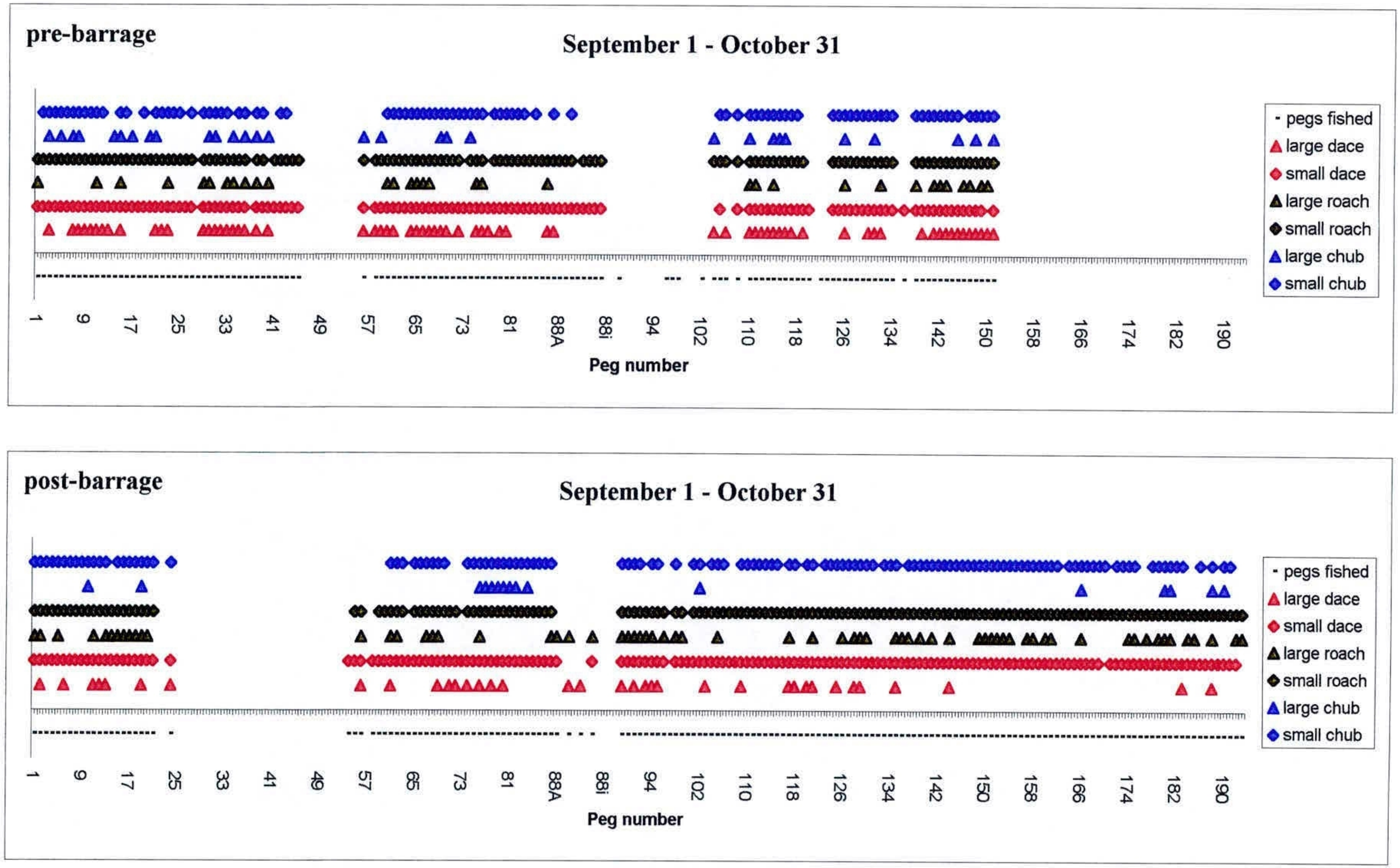
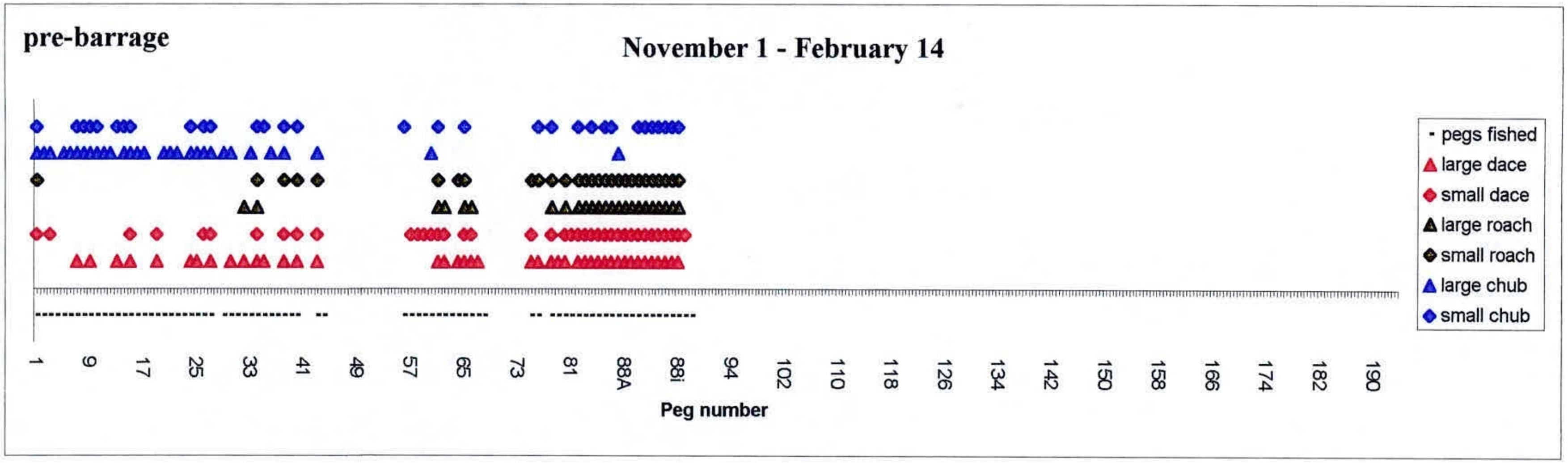


Figure 38. Continued



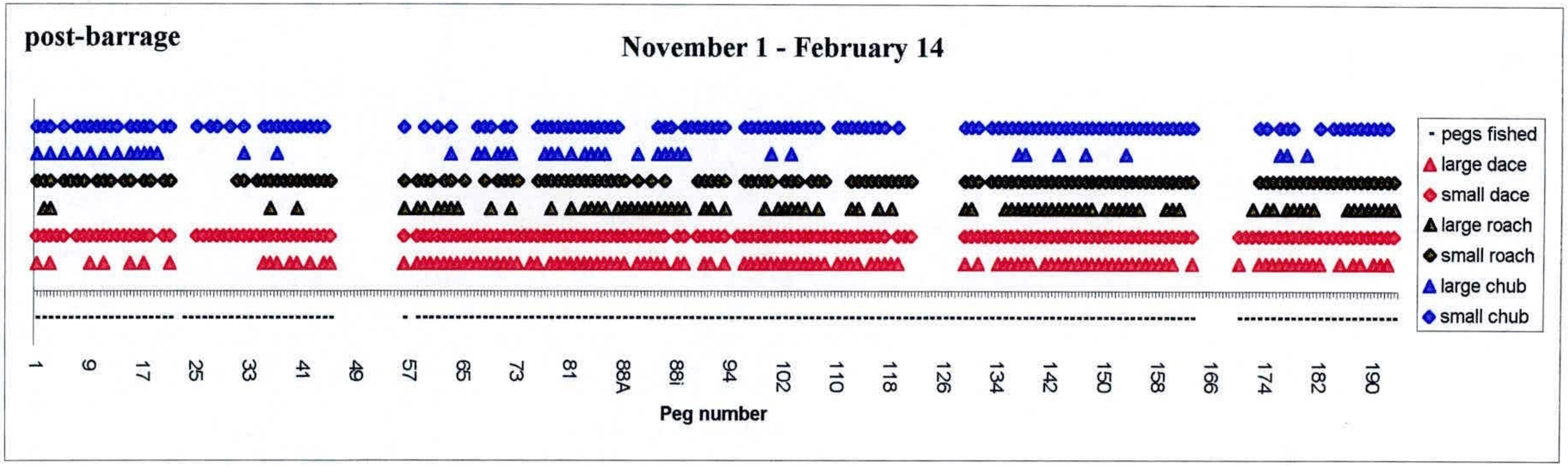
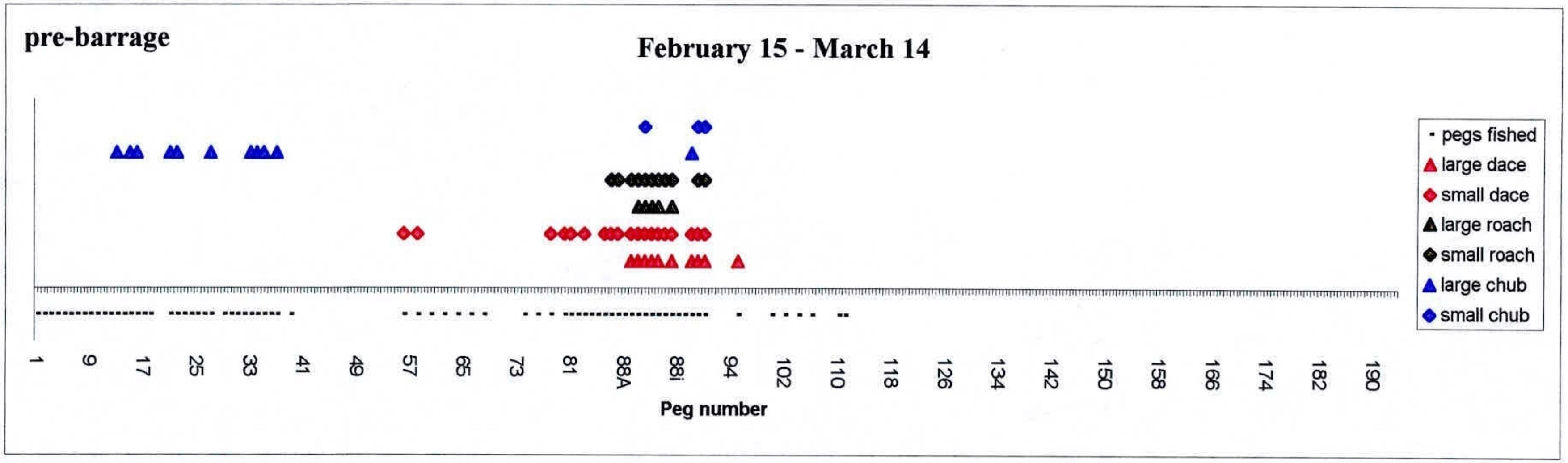


Figure 38. Continued



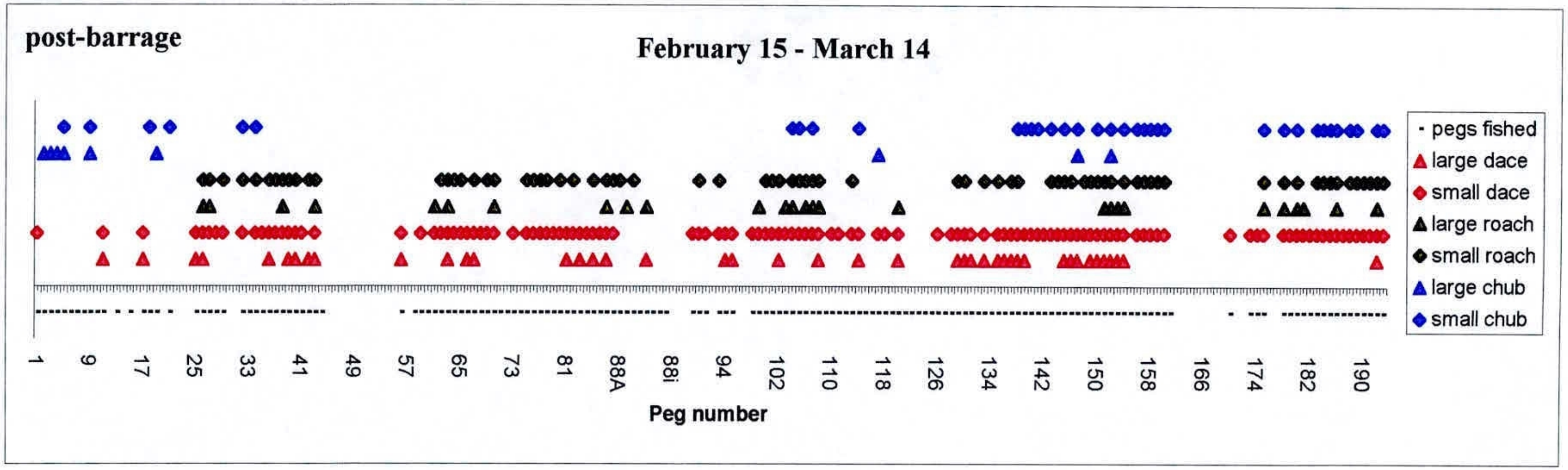


Figure 39. Pre- and post-barrage mean density of dace, chub and roach in Sections 1E and 4, representative of the lower impounded reaches of the R.Tees

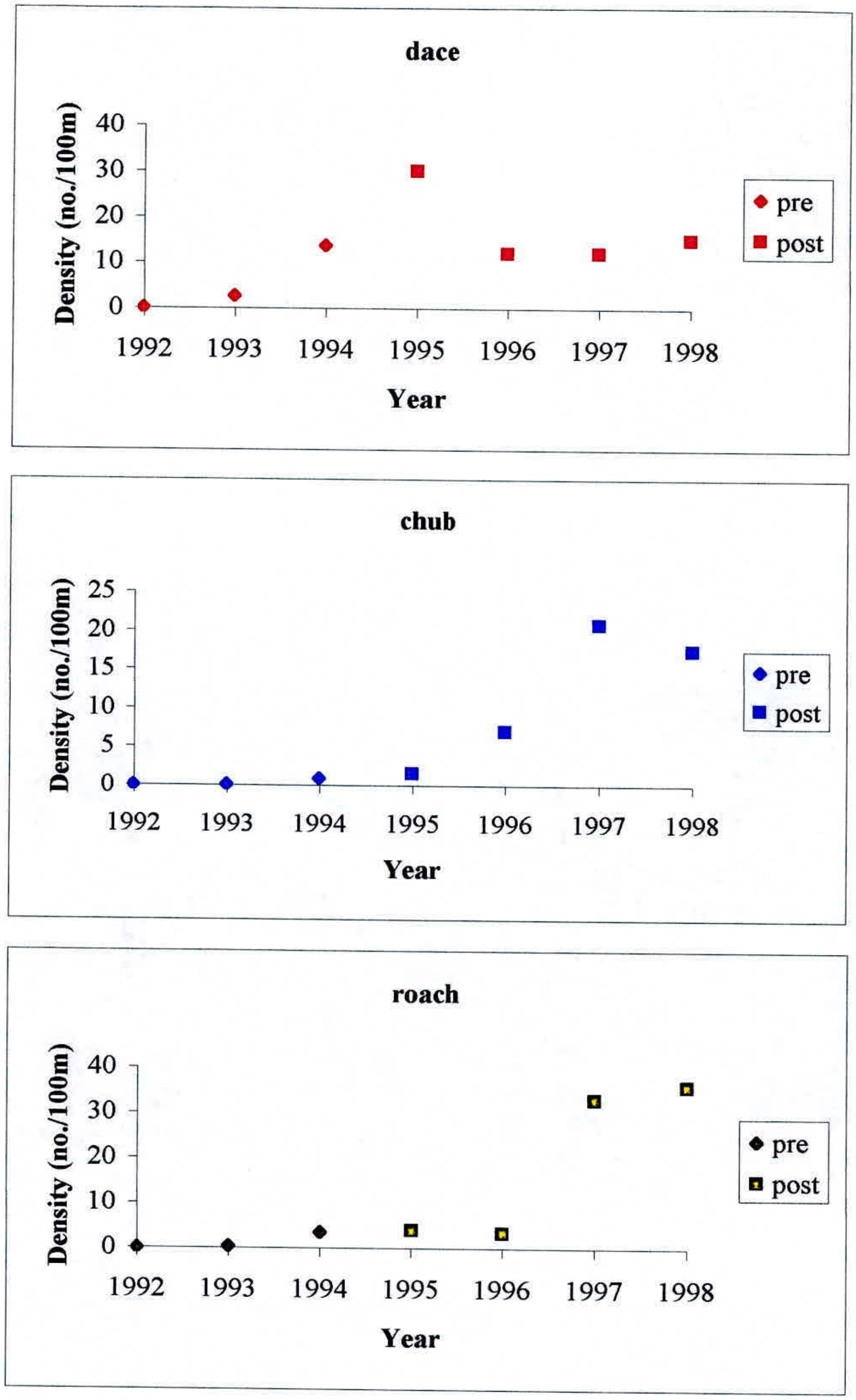


Figure 40. Pre- and post-barrage mean density of dace, chub and roach in Sections 5 and 7, representative of the middle impounded reaches of the R.Tees

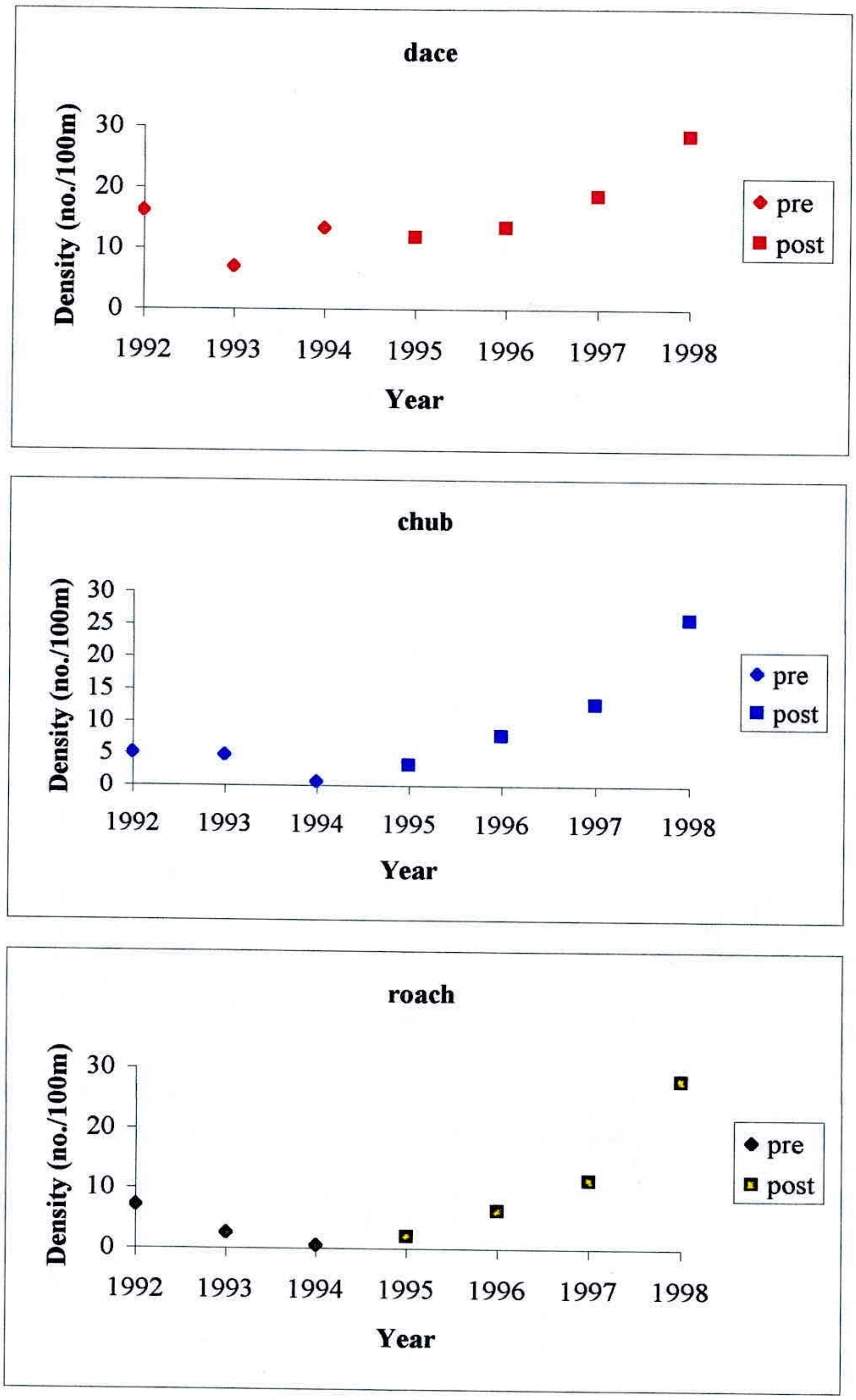
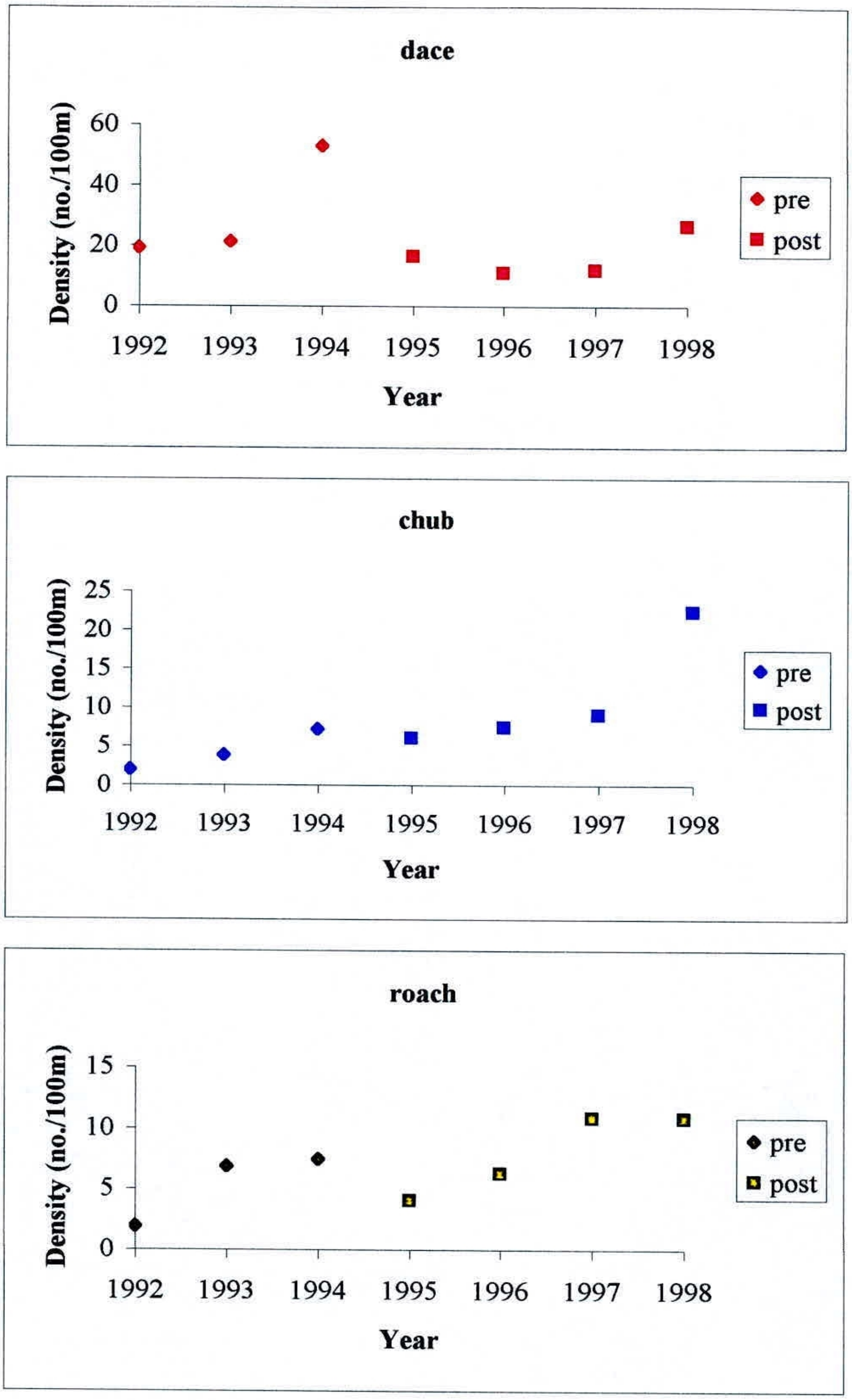


Figure 41. Pre- and post-barrage mean density of dace, chub and roach in Sections 12 and 15, representative of the upper impounded reaches of the R.Tees



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