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Validation of the performance of the Aquantic 2100A fish counter.

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Summary

Validation of the performance of the Logie 2100A fish counter was carried out at Forge Weir (River Lune) and Gunnislake Fish Pass (River Tamar), using a video recording system.

At Forge Weir the efficiency, of counting upstream migrating salmonids, was 86.9% and downstream migrants, 79.9%. At Gunnislake the efficiency, of counting upstream migrating salmonids, was 90.4% and downstream migrants, 26.32% although the sample size for the latter was small. At Forge Weir the efficiency of the counter was size dependent, increasing for upstream migrants, from 40% for fish between 16-25cm in length to approximately 90% for those between 36-75cm. There was a decline in the proportion of fish greater than 75cm counted, reasons for this are discussed. The pattern for those moving downstream was broadly similar. At Gunnislake no such decline in the performance of counting large upstream migrants was observed, however the performance of the counter at this site may be overestimated, reasons for this are discussed.

At Forge Weir, the amount of variability in peak signal size that could be accounted for was 79% for upstream and 61% for downstream migrants. The majority of the variability was explained by fish length. However, depending on the direction of movement, water level, conductivity and temperature were also significant. At Gunnislake 57% of the variability in peak signal size could be accounted for by fish length for upstream migrants. The inclusion of water conductivity in a multiple regression did not improve the relationship for this site. Further work is planned to investigate the effects of water level at this site.

Further work has been carried out on systems for the detection of fish using different construction materials and techniques to attempt to eliminate problems of symmetry, albeit with little success. The only system identified as able to detect fish presence with close spaced electrodes requires constant adjustment to offset system drift.

The research project has provided an insight into the problems faced by fish counters using resistive techniques and as a result will enable currently available systems to be improved.

1. Introduction

The main aims of the 1993 work programme were to:

a) Evaluate the new 'fish algorithm' on counter performance. The algorithm had been modified by Aquantic following the results of the investigations in 1992.

b) Assess the performance of the recently installed Aquantic 'Logie' Counter at Gunnislake Fish Pass on the River Tamar.

c) Continue with the development of the multiple electrode array.

2. Validation of the Logie counter at Forge Weir (River Lune) and Gunnislake Fish Pass (River Tamar).

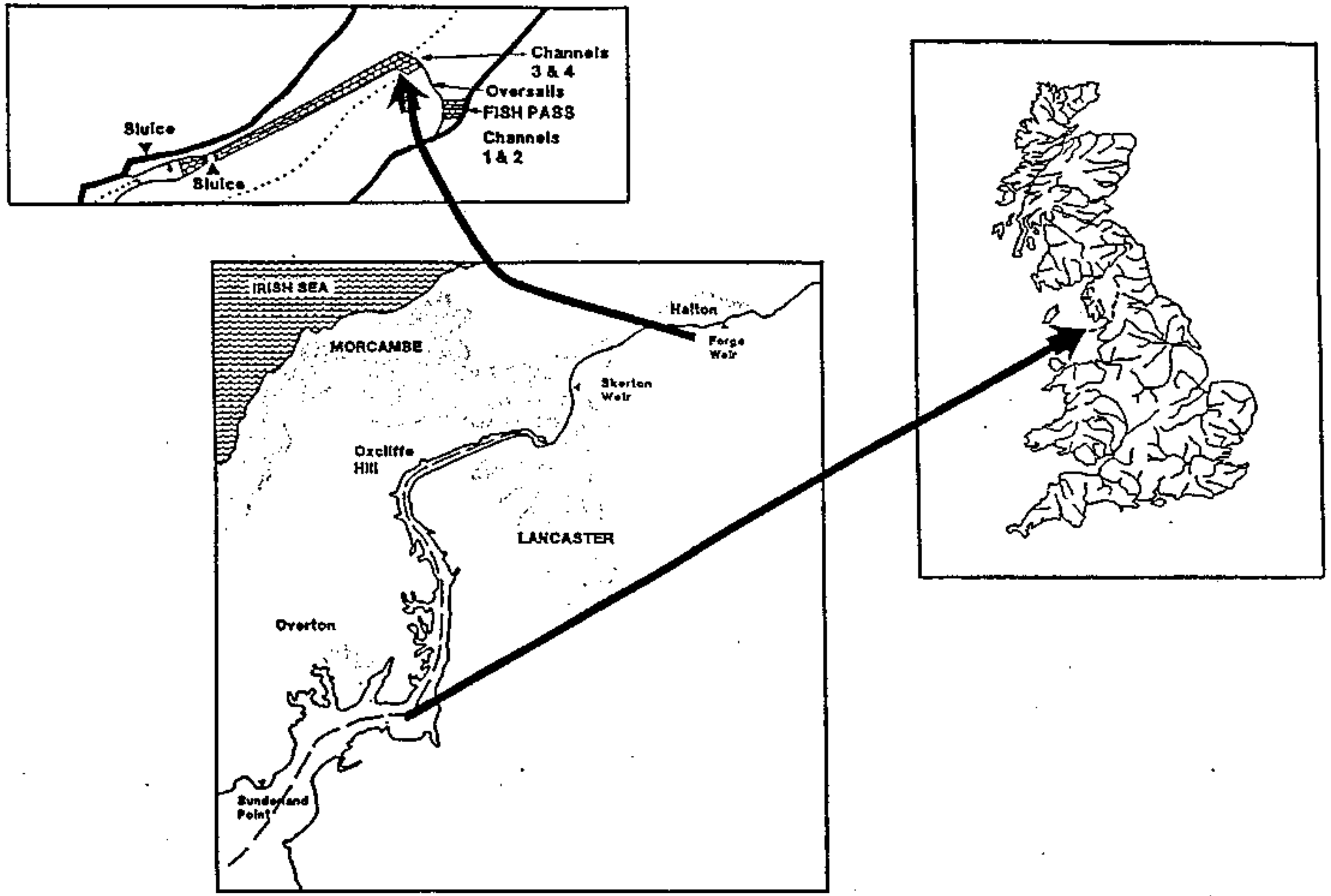
2.1 Site Descriptions.

2.1.1 Forge Weir

Forge Weir is located on the River Lune, situated approximately 4km upstream of the tidal limit (Figure 1). At this point the river is spanned by an oblique facing weir on which are situated four counting channels; two in the fish pass (channels 1 and 2) and two on the weir itself (channels 3 and 4). Part of the weir, not covered by electrodes, has been fitted with oversails to prevent fish ascending at these positions. A length of weir does remain where it is possible for fish to ascend. This is considered unlikely because of the position of the weir in relation to the flow.

Channel 1 was used for validation purposes. The counting zone consists of three electrodes (12 x 12mm stainless steel) installed in Nitomortar, mixed with aggregate, blocks on the downstream face of the weir (slope 1:7.5) and stretching the full width of the channel (2.0m). The distance between the crest and the midpoint of the upstream electrode was 12cm, between the upstream and the centre electrode 38cm and between

Figure 1: Location and site layout of Forge Weir, River Lune, Lancaster.



the centre and downstream electrode 46cm. To ensure that the concrete wall on the right hand side of the pass was electrically insulated, a sheet of white polypropylex plastic (9mm gauge) was fitted and the edges sealed with silicone. A perspex viewing window is positioned on the left hand side of the pass, to aid with species identification and determination of the presence or absence of an adipose fin.

2.1.2 Gunnislake Fish Pass

Gunnislake fish pass is situated on the River Tamar at the head of the tidal limit (Grid Ref: SX 437 713), where one fish counting channel is situated. The electrode array is installed and insulated similarly to Forge Weir. The downstream slope over the crest was 1:7 and the width of the channel 1.60 metres. The distance between the midpoint of the centre and upstream electrode was 40cm and the distance between the downstream and the centre electrode 45cm.

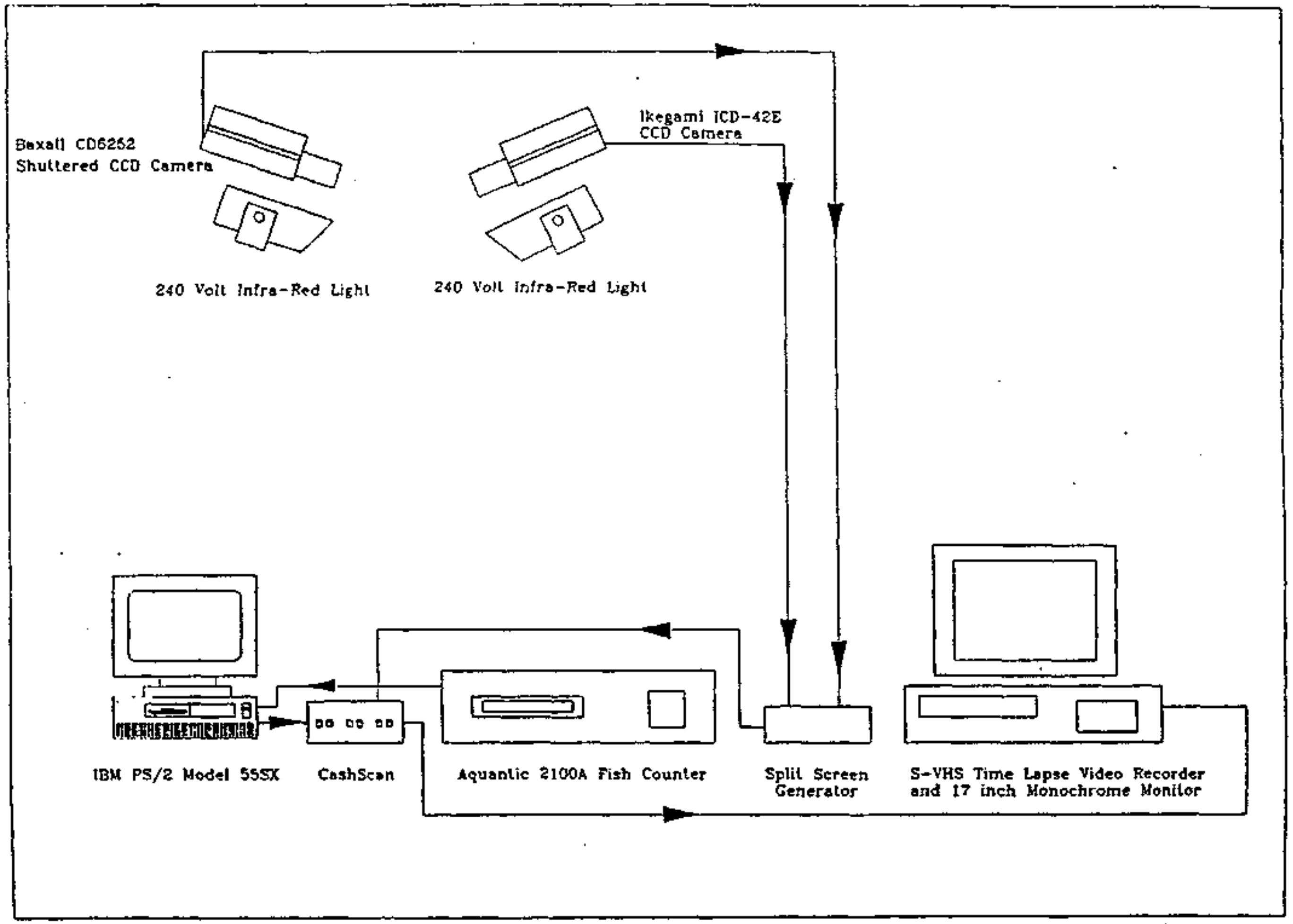
2.2 Materials and methods

At both Forge Weir and Gunnislake Fish Pass the Logie 2100A fish counter was used to interpret any change in electrical resistance between the electrodes. At both sites, information was recorded by the counter when a change in electrical resistance, above the threshold setting, had been detected and the Logie's fish algorithm had interpreted a true fish event: the date, time, conductivity, channel, direction of movement and peak signal size together with coded values of electrical resistance sampled at 0.01s intervals (trace data). On detection of a non-fish event at Forge Weir the above information was recorded with the exception of the direction of movement which was represented by the character "E". These data were then stored on the hard drive of an IBM PC (PS/2 model 55SX). This latter data was not recorded at Gunnislake.

The counters at both Gunnislake and Forge had the thresholds set at 12.7, on a scale of 1-127, for both the upstream and downstream sections of the counter and the "lag period" (the time between detection and recording of a fish event) at 0.5s.

The data from the Logie fish counters (LF) were analysed in relation to that obtained using a video recording system (Figure 2) installed over channel 1. The system consisted of a camera mounted overhead on a scaffold frame (Baxall CD6252 shuttered CCD) and at Forge Weir a second camera (Ikegami ICD-42E CCD) situated in the dug out viewing chamber on the left hand side of channel 1, giving a side view. Two infra-red lamps (240 volts, 500 watts) were used to illuminate the weir. The outputs from the

Figure 2: Schematic representation of the data acquisition system at Forge Weir



two cameras were assimilated using a split screen generator, an on line display of date and time was added using a "cashscan". The resultant video signal was then combined with the counter output: date, time, conductivity, channel, direction of movement and peak signal size, via the PC which had been fitted with GENLOCK. The product was then recorded on a Panasonic AG6720A video recorder, using both time lapse (8 frames sec^{-1}) and real time (25 frames sec^{-1}).

At Gunnislake fish pass various time lapse speeds (0.90, 1.2, 2.0 and 5.50 frames s^{-1}) were employed. An electronic alarm was used to initialise real time filming of actual fish events.

At Forge Weir water level, measured at the weir crest on channel 1, and water temperature were recorded at hourly intervals on a Golden River data logger.

In order to estimate fish size the video screen image was divided into 3 distinct screen measuring areas which were defined as:

area 1: between the downstream and the centre electrodes
area 2: between the centre and upstream electrodes
area 3: between the downstream and upstream electrodes

A measurement conversion factor was calculated for each of the screen measuring areas using:

$$Cf_i = D_i / S_i$$

where Cf_i = conversion factor for area i
D_i = measurement (cm) between electrodes defining fish measuring area i
S_i = mean of three screen measurements of distance between electrodes for measuring area i in mm, taken at extreme left, right and centre of the counting channel

and i = measuring area 1, 2 or 3.

Fish length was calculated as follows:

$$FL = Ls_i * Cf_i$$

where FL = fish length (cm).
Ls_i = length from snout to tail (mm) taken from screen measuring area i
Cf_i = conversion factor for $zone_i$

The efficiency of the counter was defined as:

$$Eff = FC / (Ftrav - Fsim)*100\%$$

Where :

Eff = Efficiency (expressed as a percentage).
FC = Total number of fish counted which traversed the electrode array.
Ftrav = Total number of fish traversing the electrode array.
Fsim = Fish moving simultaneously over the counting zone.

For each event a number of parameters taken from the computer and video record were logged, these are presented in Table 1.

Analysis was carried out using the statistical package MINITAB (Ryan, *et al.* 1985). Where appropriate 95% confidence limits were calculated and are presented within brackets.

2.3 Results

2.3.1 Forge Weir

2.3.1.1 Conditions under which validation was carried out.

Validation was carried out over a range of different water levels from 28 to 66cm, the level at which each individual fish was recorded is shown in Figure 3. Few observations were possible at high water levels partly because of their relatively infrequent occurrence and partly because the high turbidity at levels in excess of 0.54m, measured at the weir crest. The range in water conductivity and temperature are displayed in Figures 4 and 5, respectively.

2.3.1.2 Evaluation of counter performance

A) Upstream migrants.

A summary of the findings is presented in Table 2. A total of 2,769 salmonids were recorded on video migrating over the electrodes, on 32 occasions two fish passed simultaneously upstream over the counter. As the counter is not designed to count more than one fish at a time, this reduces the expected count to 2,737 fish.

Of the events counted by the counter 2,378 were from fish traversing the electrodes, giving an accuracy of 86.88% (95% C.L. 86.85 - 86.89%). However 125 fish did not

Table 1: Parameters collected for fish events observed on video.

Parameter	Variable	Comment
Event type	1 2 3 4 5 6 7 8 9 10	Fish event counted correctly Fish event counted incorrectly Fish event missed correctly Fish event missed incorrectly No body on video record No trace Test Fish River Noise 2 Fish Events Double count
Date		dd/mm/yy
Time		hh:mm:ss
Channel number	1	channel 1-4
Direction	U D	Upstream event Downstream event
Peak signal size		
Species	1 2 3 4 5 6 7 8 9 10 11	salmon sea trout salmonid eel other fish log other insulator weed/bags human dogs unknown
Behaviour	1 2 3 4 5 6 7 8 9	straight pass up down & up down up & down up & down in downstream electrode down & up in upstream electrode up & down down & up staggered swimming stalled swimming
Downstream electrode (viewed downstream)	0-9	position of the fish as it traverses the downstream electrode. where 0 = extreme left where 9 = extreme right
Upstream electrode (viewed downstream)	0-9	position of the fish as it traverses the downstream electrode. where 0 = extreme left where 9 = extreme right

Table 2. Summary of events recorded by the Logie fish counter at Forge Weir.

		Upstream	Downstream
Total number seen on video		2946	471
Total traversing electrode		2769	365
Total not traversing electrode		177	106
Total number of non fish objects		0	0
2 simultaneous fish *		32	31
Total number of counts		2445	308
Fish traversing		2378	267
Fish not traversing		35	29
Double counts		3	2
Non fish objects		0	0
Counts for no identifiable reason		29	10
Total not counted		501	144
	Fish traversing - with trace	234	50
	Fish traversing - without trace	125	17
	Fish not traversing - with trace	141	75
	Fish not traversing - without trace	1	2

* 2 fish moving over the electrode array at the same time.

Figure 3: Water levels at which each event was recorded at Forge Weir.

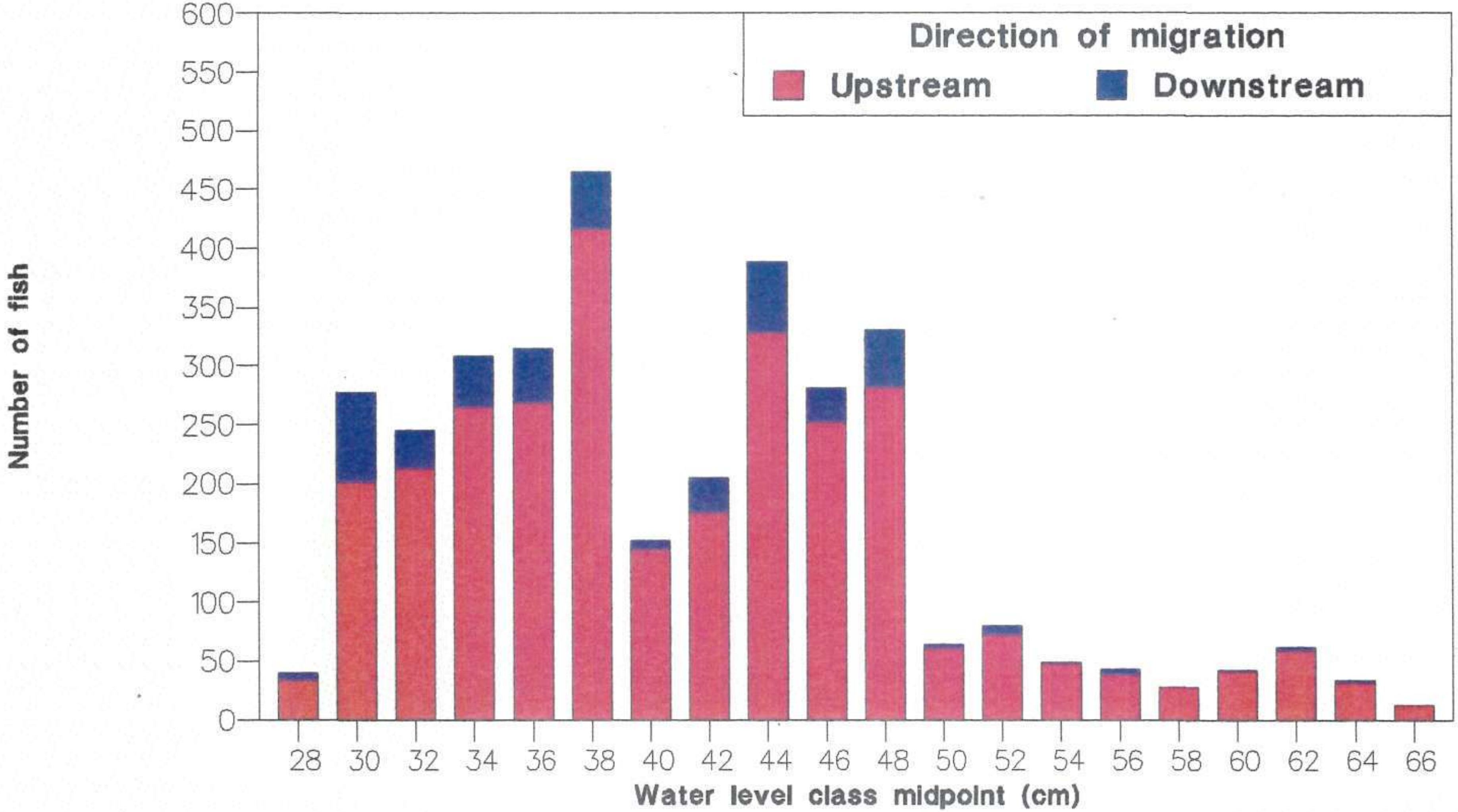


Figure 4: Water conductivities at which each event was recorded at Forge Weir.

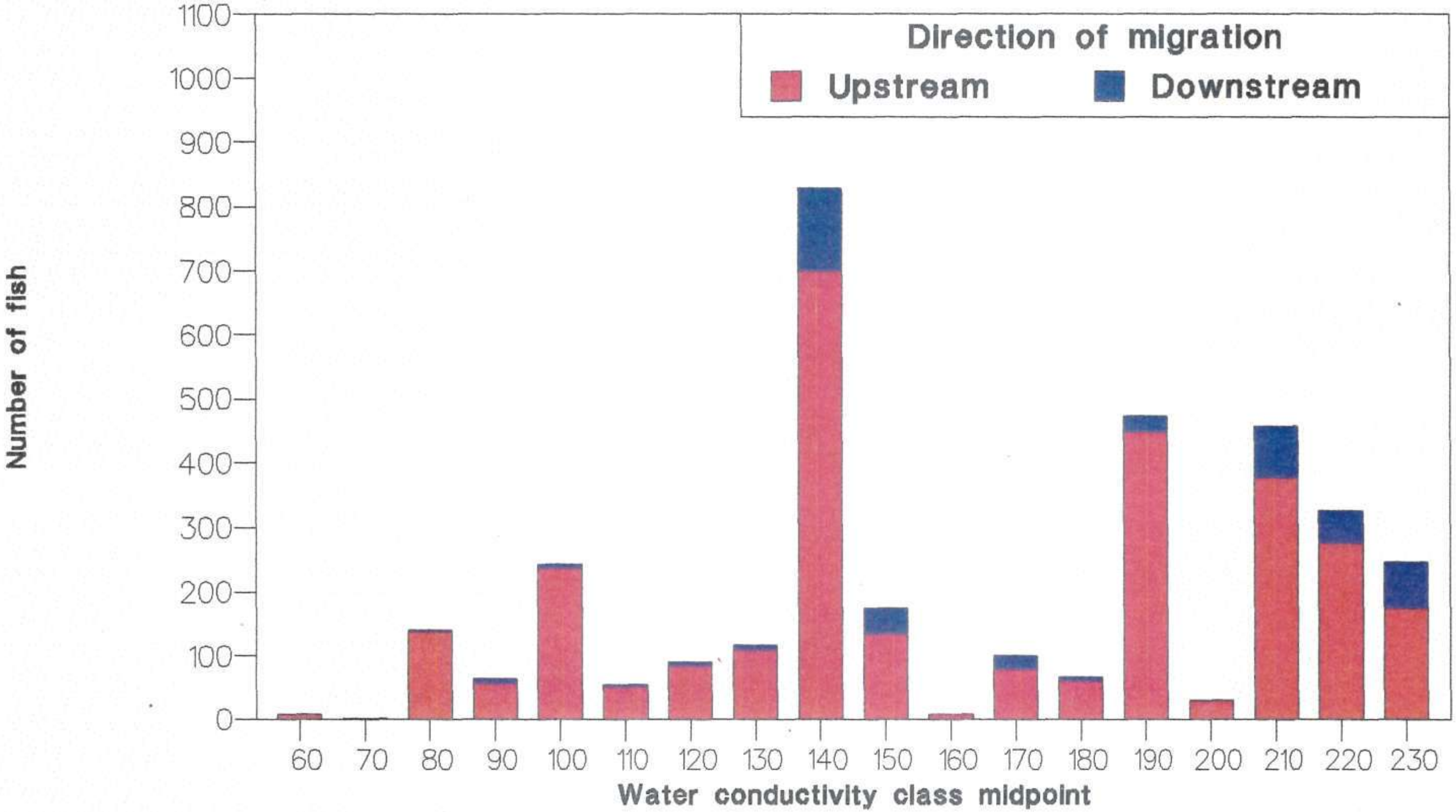
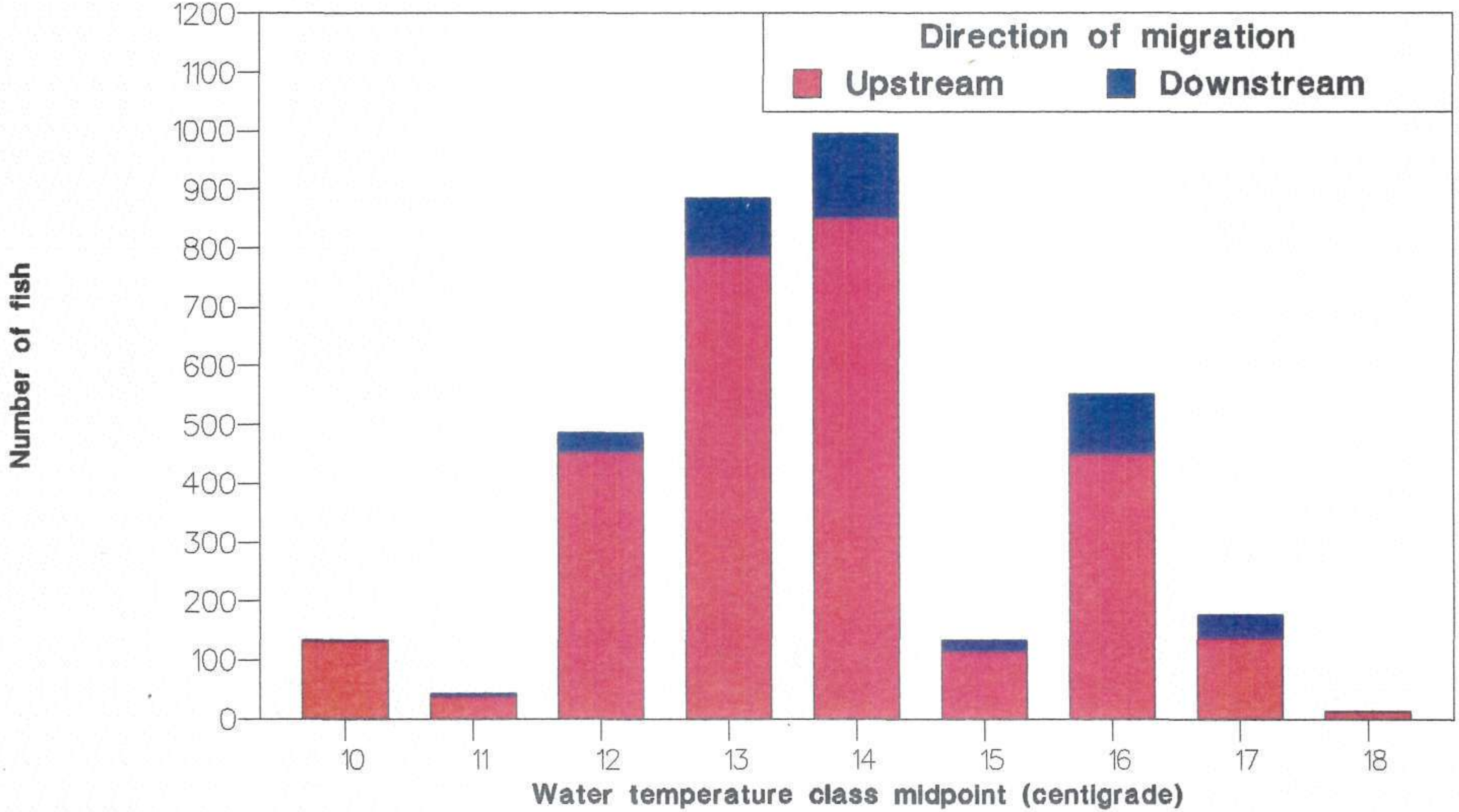


Figure 5: Water temperatures at which each event was recorded at Forge Weir.



produce a change in electrical resistance above the threshold setting, as such no trace information was recorded. If those fish events below threshold size are excluded, the efficiency of the counter at counting fish, which had generated a signal above the threshold setting is 91.04% (89.87 - 92.06%).

Of the total count 97.26% (96.57 - 97.83%) were from fish passing upstream over the counting electrodes. The counter recorded relatively few (2.74% (2.15 - 3.45%)) false counts. Of the 67 false counts it was not possible to identify the reason the counter had recorded an event on 29 occasions. From the trace information it was suspected that fish had generated these events, although no fish were seen on video. This situation may arise when a small fish passes close to the side of the counter when visibility is poor. Of the 38 where a reason could be identified; 35 were from fish dropping back downstream having not fully migrated upstream over and away from the counting area and from three fish which lingered over the electrodes on their upstream passage, producing a double count. In any case the false counts being a small percentage of the overall count, their inclusion increases only slightly the proportion of the upstream migrants accounted for, from 86.85% to 88.3% (88.27 - 88.30%). If the events below threshold are excluded , the proportion accounted for increases to 93.61% (93.57 - 93.61%).

B) Downstream migrants.

There were 365 salmonids recorded on video migrating downstream, of which there were 31 occasions when two fish passed over the electrodes simultaneously (Table 2). Of the potential 334 fish events 79.94% (75.56 - 83.66%) were counted. Though of the 365 events, 17 did not exceed the threshold setting. Thus for fish exceeding the threshold value 84.23% (79.62 - 87.86%) were counted.

Of the total count 86.69% (81.95 - 89.95%) were generated by fish traversing the electrodes. The 41 false counts were mainly generated by fish not fully crossing the electrodes. There were 10 counts for no identifiable reason.

Of the 317 fish which had produced a trace and had traversed the electrodes 84.23% (79.62 - 87.86%) were counted by the counter. The 50 occasions when no count was produced can be attributed to the fact that the migrants did not produce a trace recognisable as a true fish event by the counter's fish algorithm. This can arise through aberrant swimming behaviour as opposed to the more typical straight passage exhibited by the majority of the migrants.

2.3.1.3 Influence of fish size on counter performance

A) Upstream migrants.

Counter performance increased gradually from 40% (34 - 47%) for the 16 - 25cm size group to close to 90% for 95% of the time , for fish ranging in size from 36 - 75cm (lower 95% confidence limits ranged from 87.5 - 96.0%) (Figure 6). Fish greater than 75cm showed a steady decline in the proportion of fish counted, though the sample size was small for this size group.

This decline in performance is considered attributable to a build up of water in front of the larger fish as they migrate upstream over the counter, and is particularly prevalent under low flow conditions. The effect is to produce a signal characteristic of a fish moving downstream followed by an upstream movement (Figure 7), and is thus rejected by the counter.

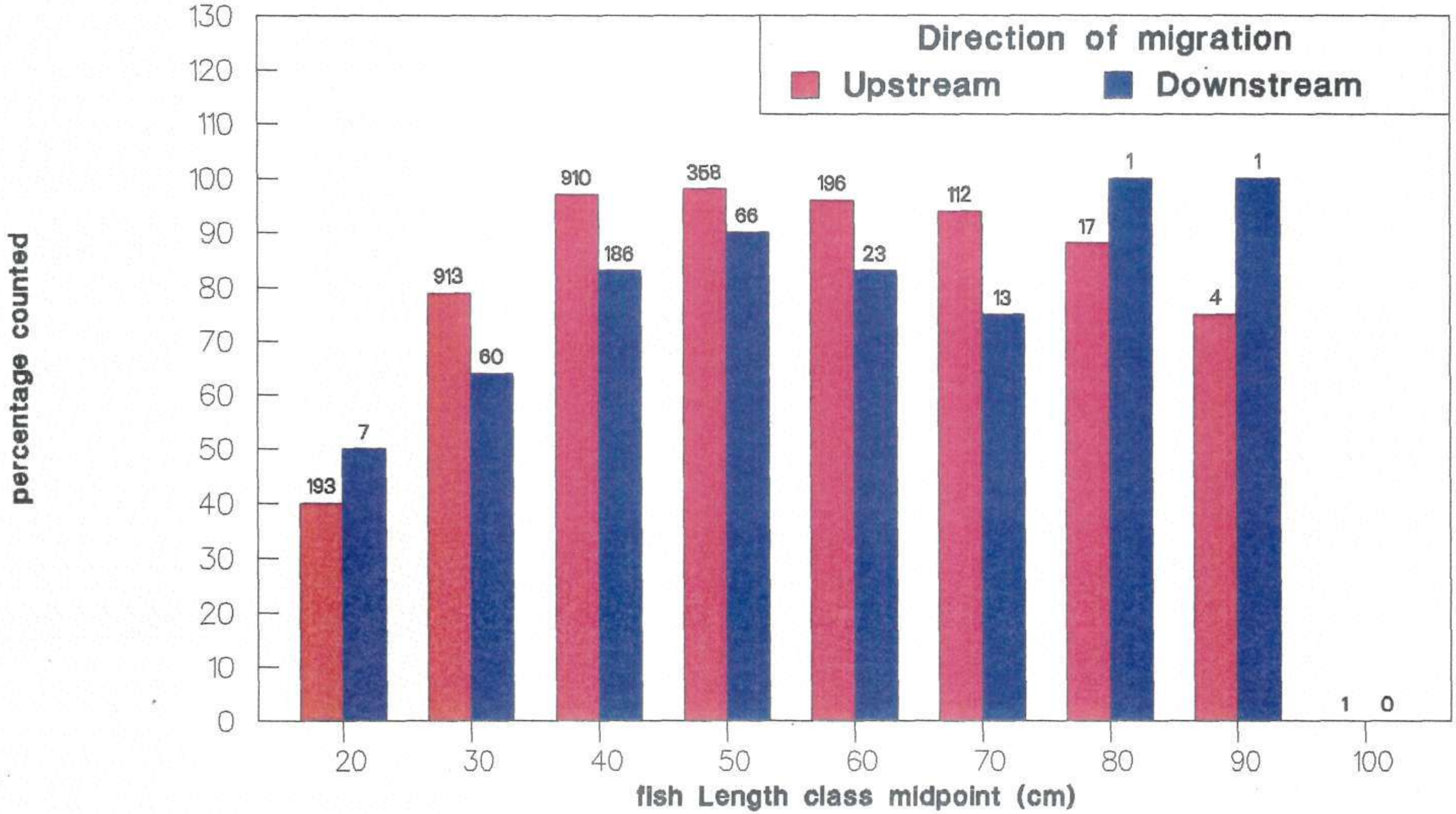
B) Downstream migrants.

The pattern for the downstream migrants was broadly similar to that evident for the salmonids migrating upstream; an increase in the percentage counted with increasing size, followed by a subsequent decline (Figure 6). However because of the small sample and associated large confidence limits, for a number of the size classes, the pattern can not be regarded as definitive.

2.3.1.4 Relationship between peak signal size and fish length.

The majority of the variability in signal size could be accounted for by fish size, with log fish length explaining 69.5% and 57.6% of the variability in log peak signal size for upstream and downstream migrants, respectively (Figures 8 & 9). For those fish migrating upstream the inclusion of water level, water temperature and conductivity accounted for an additional 7.4%, 2.6% and 0.08% of the total variability, respectively. For the downstream migrants the inclusion of conductivity accounted for a 3.3% of the variability while the addition of water level, temperature and conductivity did not significantly improve the relationship.

Figure 6: Response of the counter in relation to fish size at Forge Weir.



N.B. Numbers above bars indicate sample size

Figure 7: Typical trace of a fish exhibiting the 'bow wave' affect.

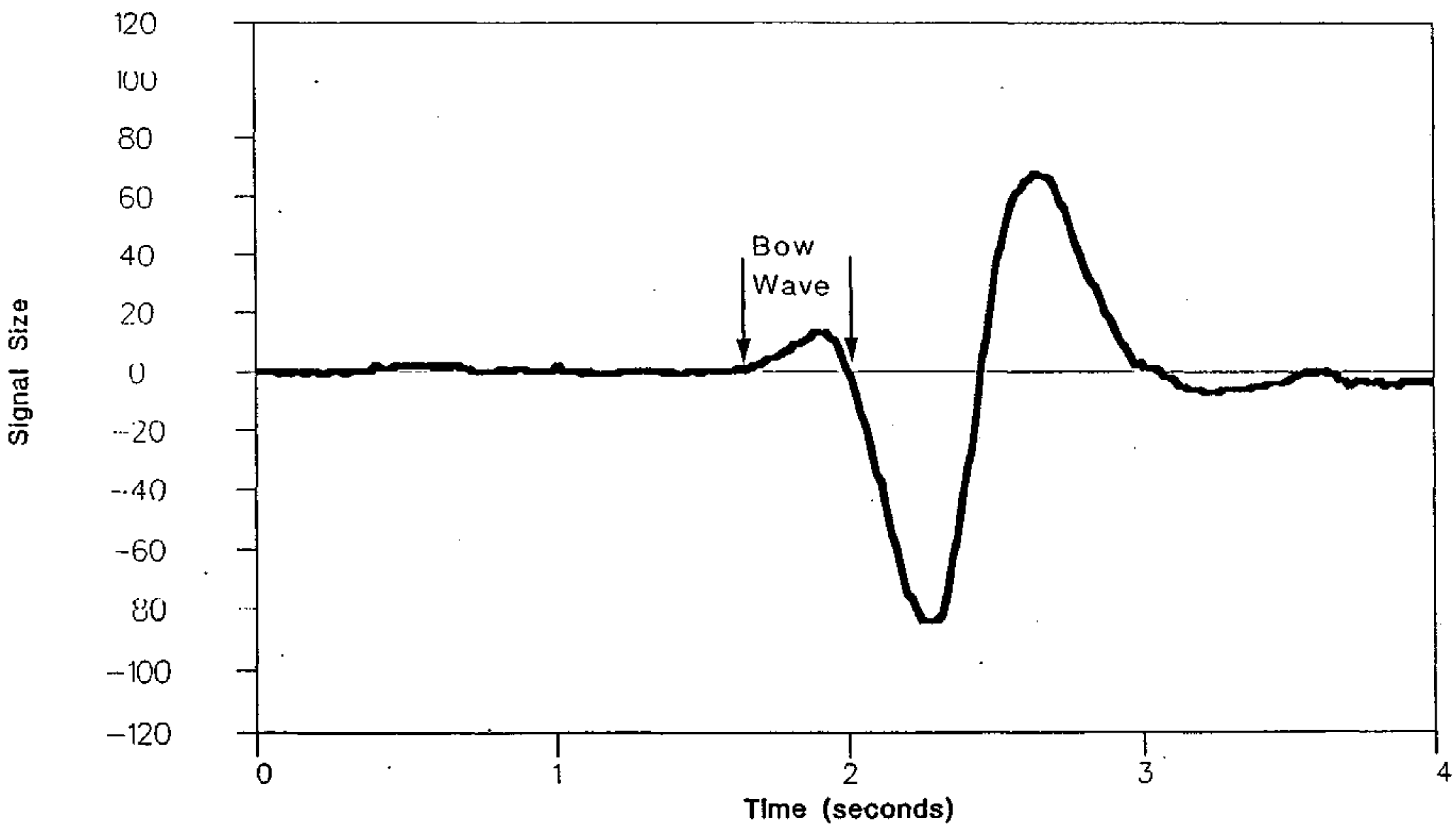
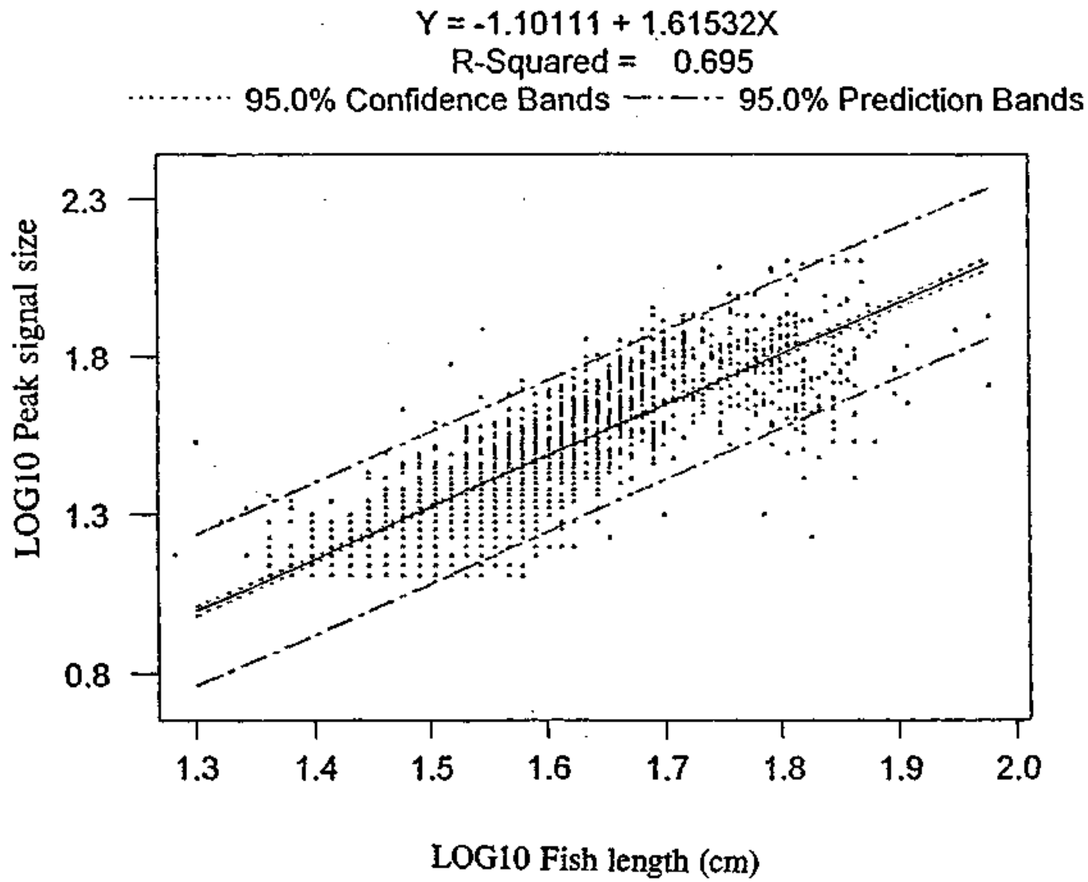
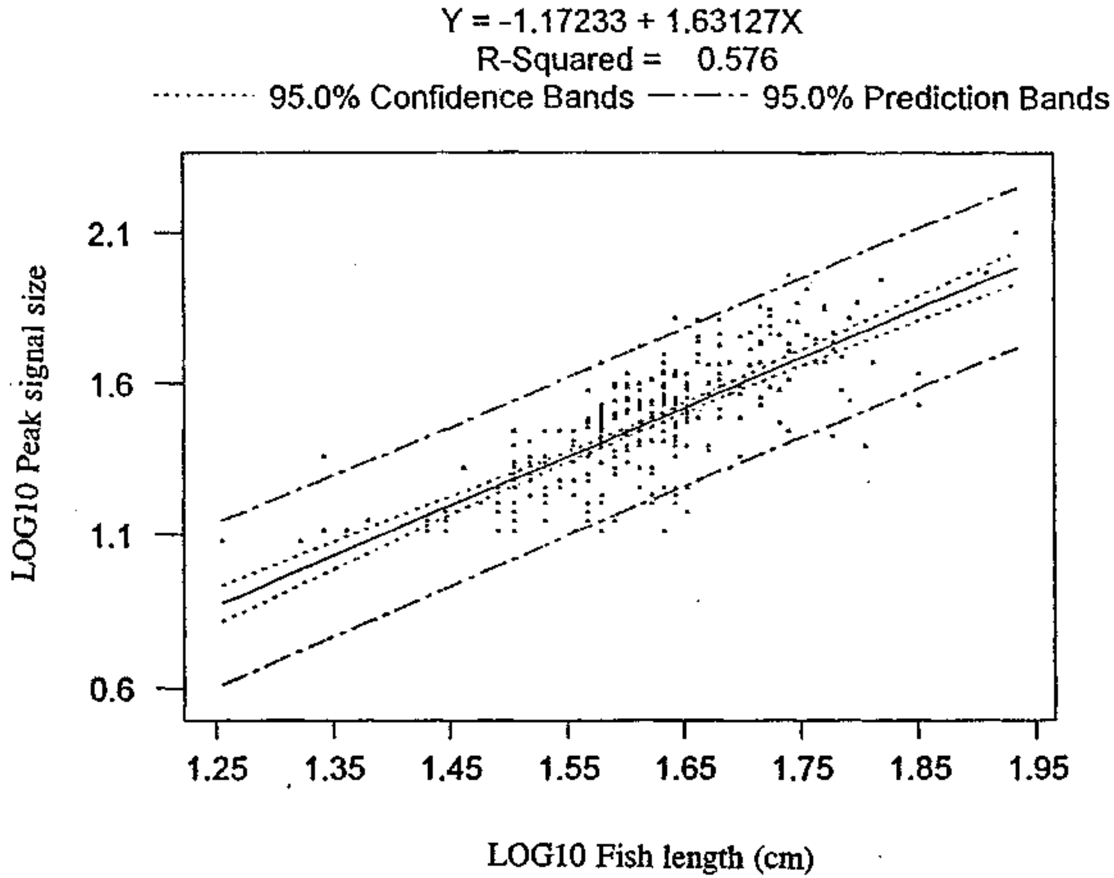


Figure 8: The relationship between signal size and fish length for upstream migrants at Forge Weir



N.B. LOG10 = Logarithm (base 10)

Figure 9: The relationship between signal size and fish length for downstream migrants at Forge Weir



N.B. LOG10 = Logarithm (base 10)

The relationship between peak signal size and fish length and certain environmental variables was as follows:

Upstream migrants ($n = 1954$), $r^2 = 0.79$, $p < 0.001$.

$$\log_{10}PSS = -1.39(0.087) + 1.74(0.041)\log_{10}Ln - 0.557(0.07)Wl + 0.0248(0.003)T - 0.00019(0.0001)C$$

Downstream migrants ($n = 302$), $r^2 = 0.61$, $p < 0.001$.

$$\log_{10}PSS = -1.31(0.252) + 1.62(0.152)\log_{10}Ln + 0.00095(0.00036)C$$

where PSS = peak signal size,
Ln = fork length (cm),
Wl = water level (m),
T = temperature (^{o}C)
C = conductivity ($\mu s/cm$)

The small proportion of the variability accounted for by conductivity indicates that the LF adequately compensates for changes in bulk resistance (resistance between the electrodes) resulting from changes in conductivity. As conductivity is inversely related to river flow and thus water depth (Dunkley & Shearer, 1982) changes in bulk resistance resulting from changes in water depth will in part be compensated for by conductivity compensation. However, as a lag period inevitably exists between a change in river flow and conductivity, it is thus not possible for the LF to fully compensate for changes in river flow through conductivity compensation only. This explains why peak signal size decreases with increasing water depth for fish of a given size. The consequence of this is that under high flow conditions there is a higher probability that a small fish will be missed by the counter because the resultant signal is less likely to exceed the threshold value.

2.3.2 Gunnislake Fish Pass

The water conductivity at which each fish was recorded migrating over the electrodes is illustrated in Figure 10.

2.3.2.1 Counting Accuracy

A summary of the findings are given in Table 3.

Figure 10: Water conductivities at which each event was recorded at Gunnislake Fish Pass.

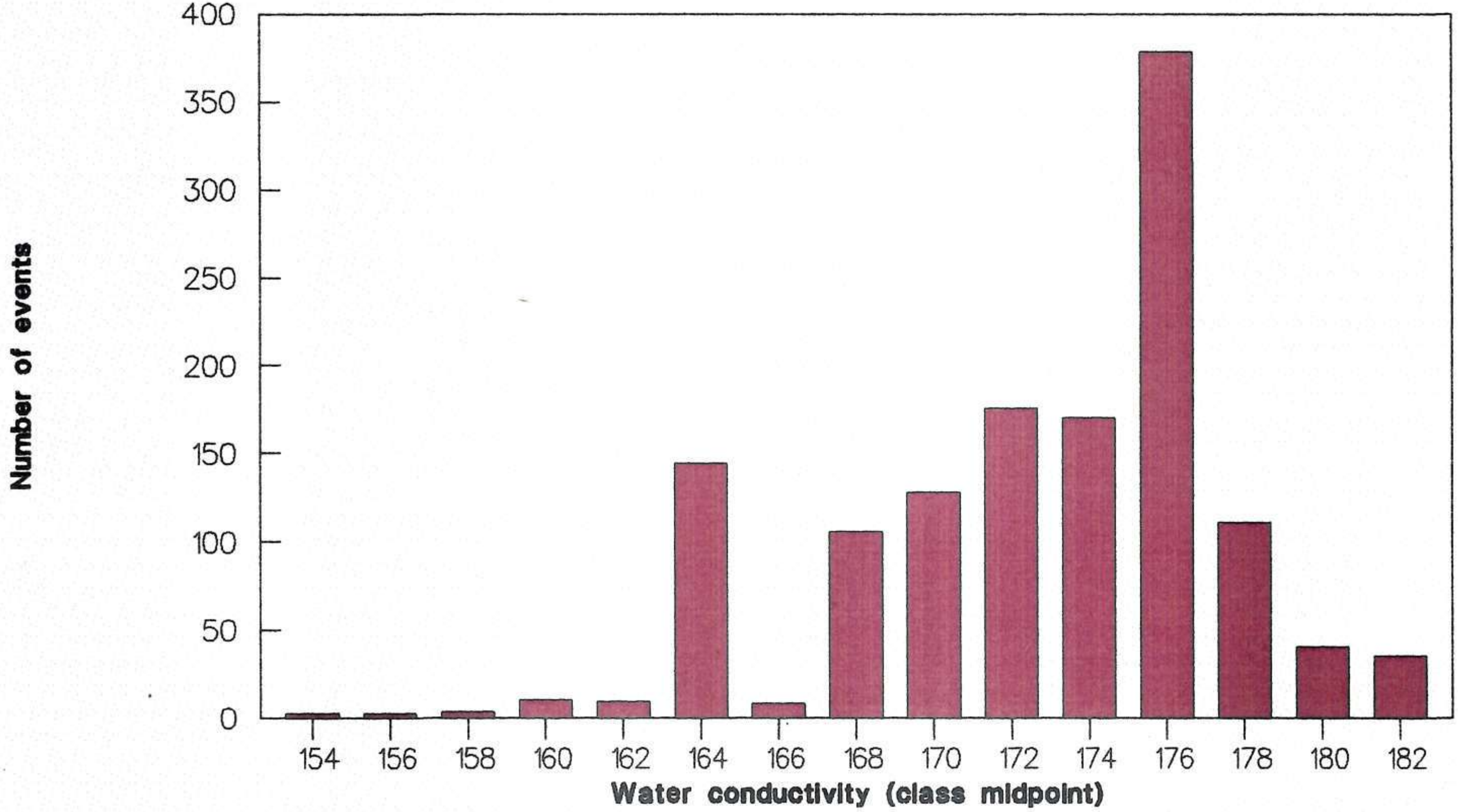


Table 3. Summary of events recorded by the 'Logie' fish counter at Gunnislake Fish Pass.

	Upstream	Downstream
Total number seen on video	1388	22
Total traversing electrode	1362	20
Total not traversing electrode	26	2
Total number of non fish objects	0	0
2 simultaneous fish *	13	1
Total number of counts	1230	5
Fish traversing	1219	5
Fish not traversing	11	0
Double counts	0	0
Non fish objects	0	0
Counts for no identifiable reason	0	0
Total not counted	145	16
Fish traversing - with trace	0	0
Fish traversing - without trace	130	14
Fish not traversing - with trace	0	0
Fish not traversing - without trace	15	2

* 2 fish moving over the electrode array at the same time.

A) Upstream migrants

A total of 1362 salmonids were recorded on video migrating over the electrodes, on 13 occasions two fish passed simultaneously over the counter. As the counter is not designed to count more than one fish at a time, this reduces the expected count to 1349 fish.

Of the events counted by the counter 1219 were from fish traversing the electrodes, giving an accuracy of 90.36% (88.49 - 91.72). However 130 fish did not produce a change in electrical resistance above the threshold setting. Excluding these events the efficiency of the counter at counting fish, which had generated a signal above threshold setting is 100% (lower C.L. 99.7%).

Of the total count 99.11% (98.41 - 99.55%) were from fish traversing the electrodes. The counter recorded 11 (0.89% (0.45 - 1.6%)) false counts, which were all associated with fish which dropped back downstream having not fully migrated upstream and away from the counting zone. Inclusion of the false counts slightly increases the proportion of the upstream migrants accounted for, from 90.36% to 91.18% (89.44 - 92.71%).

B) Downstream migrants

A total of 20 fish were recorded migrating over the electrodes, on 1 occasion two fish passed simultaneously downstream over the electrodes. Excluding this event the expected count is reduced to 19 fish.

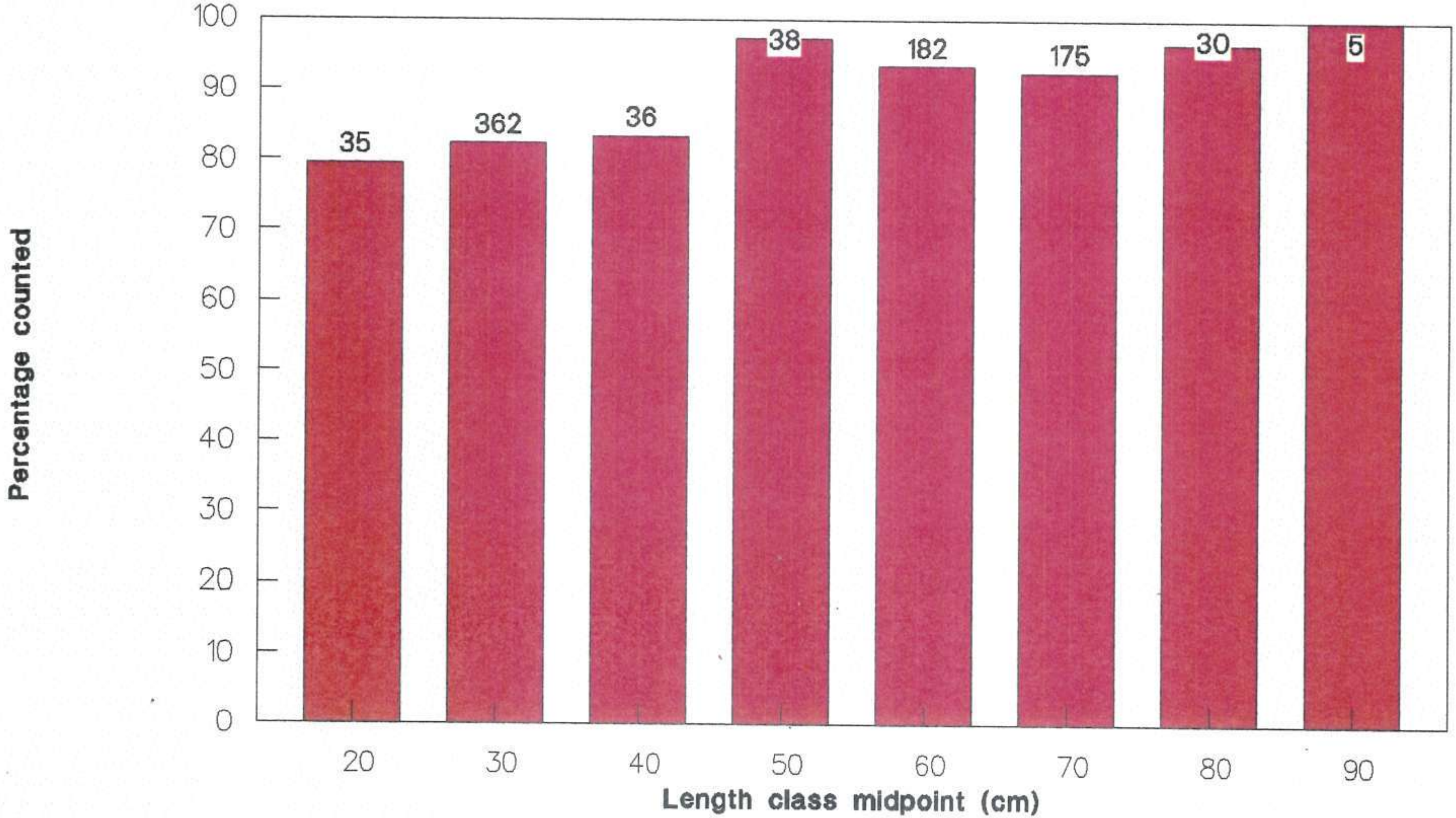
All of the events (5) counted by the counter were generated by fish migrating downstream over the electrodes giving an accuracy of 26.32% (13.11 - 51.22%). However 14 fish passed over the electrodes and did not exceed threshold settings. If these events are excluded, the efficiency of the counter at counting fish, which had generated a signal above threshold setting is 100%. No false counts were produced by downstream migrants.

2.3.2.2 Influence of fish size on counter performance

A) Upstream migrants

Counter performance increased gradually from 79.4% (61.9 - 91.3%) for the 16 - 25cm size group to over 90% for fish ranging in size from 46 - 85cm (Figure 11). All fish >85cm were counted by the counter. However, non fish events were not logged by the

Figure 11: Response of the counter in relation to fish size at Gunnislake Fish Pass (upstream migrants only).



N.B. Numbers above bars indicate sample size counter and slow time lapse speeds were employed which increases the likelihood of fish not being recorded or accidentally overlooked in the validation procedure.

B) Downstream migrants

No pattern could be identified for downstream migrants due to the small numbers encountered. The counter was found to count 10% (0.3 - 44.5%) of those fish ranging from 25 - 36cm in length. Only three other downstream migrating fish were observed. Of these and 2 fish of length 39 and 61cm were not recorded by the counter and one fish of length 89cm was counted.

2.3.2.3 Sizing accuracy

The relationship between fish length and peak signal size is illustrated in Figure 12 for upstream migrants only.

The regression equation for upstream migrants was as follows :

$n = 397$, $R^2 = 0.57$, $p < 0.001$

$$Log_{10} (PSS) = 0.111 + 0.930 \, Log_{10} (Ln)$$

where:

PSS = peak signal strength
Ln = fish Length (cm)

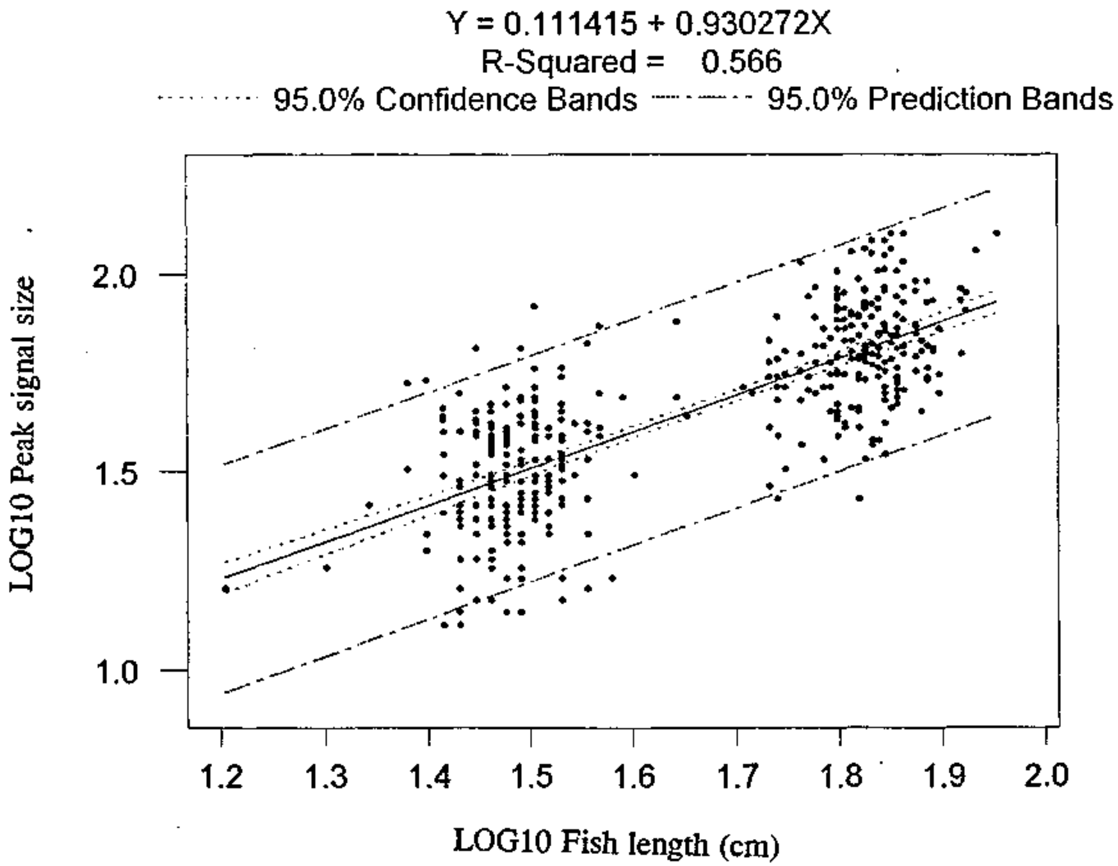
The regression equations describing the relationship between signal size and fish length (for upstream migrants) identified for both Forge and Gunnislake sites were compared using a t test (Zar 1984) and regressions were found to be significantly different ($p<0.001$).

2.3.2.4 Size Frequency Distribution, Gunnislake

The length frequency distribution of upstream migrants ranged from 15cm to 95cm and exhibited two modes at 30cm and 70cm (Figure 13) which suggests two distinct groups. Data collected from an upstream trap revealed that the two modes represent sea trout and salmon separable at 50cm (Broad, 1994 pers. comm.).

In order to assess the usefulness of signal size for species separation for Gunnislake Fish Pass the frequency of signal sizes generated by upstream migrants were investigated by separating the total number of fish into classes of fish > 50cm and fish < 50cm. The extent of overlap of PSS between the two fish populations is illustrated in Figure 14.

Figure 12: The relationship between signal size and fish length for upstream migrants at Gunnislake Fish Pass



N.B. LOG10 = Logarithm (base 10)

Figure 13: Length frequency distribution of salmonids derived from the video record.

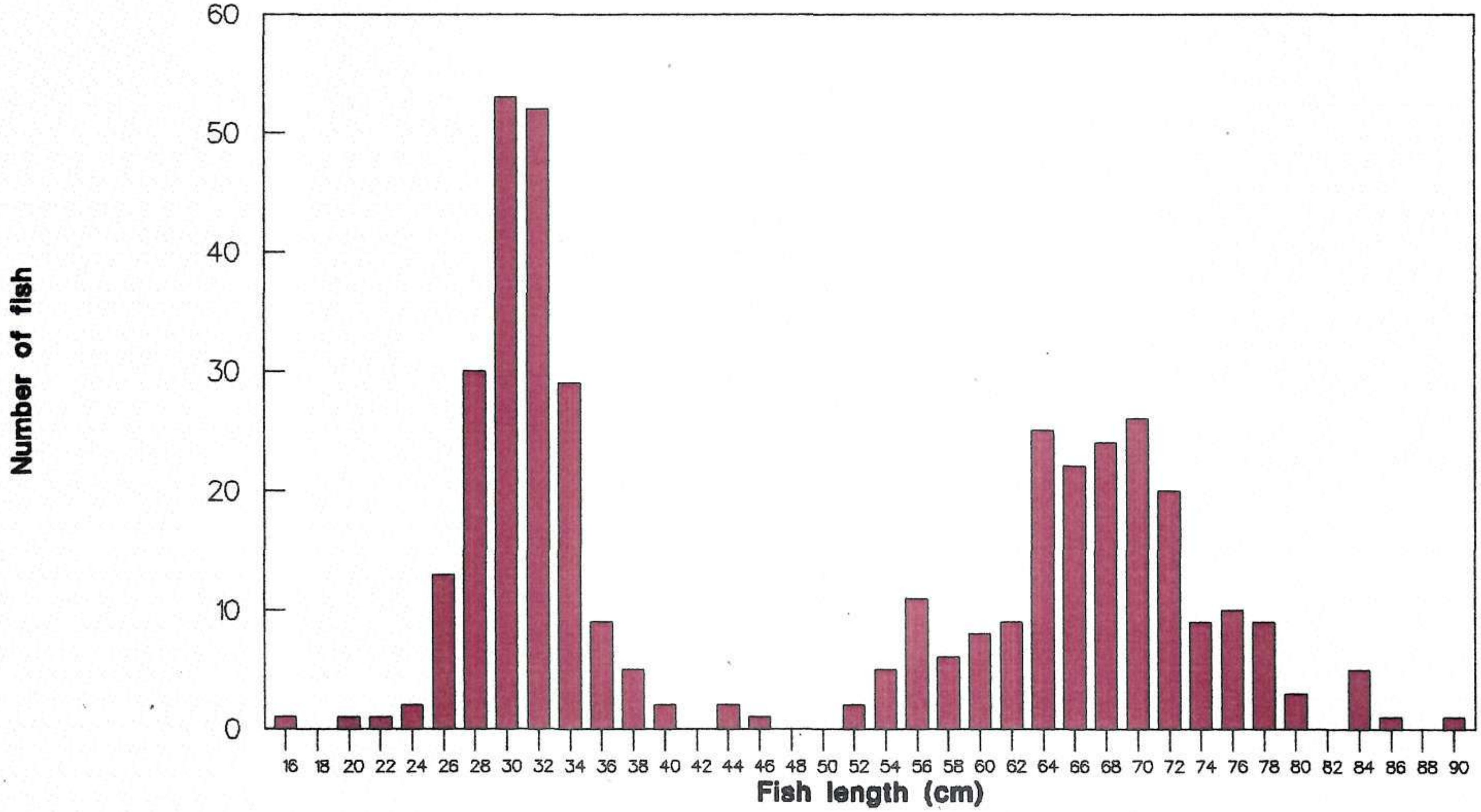
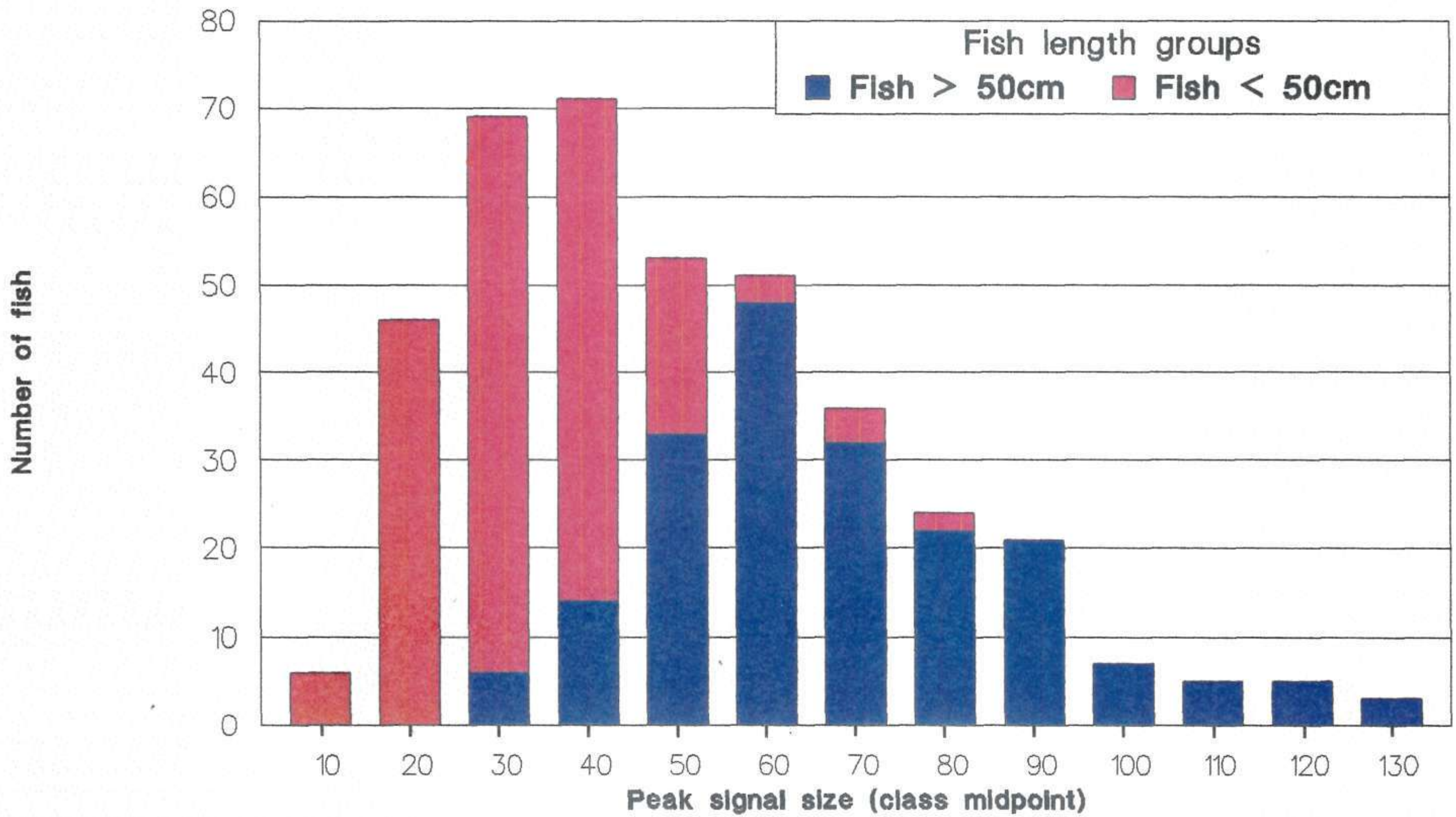


Figure 14: **Frequency of signal sizes generated by upstream migrants**



A degree of error is associated with separation of sea trout and salmon using a signal size of 50, with 22% of sea trout generating a signal size of >50, and 14% of salmon generating a signal size <50.

2.4 Discussion

At Forge Weir there were few counts generated by non-migratory salmonids. The main problem, other than the effect of water depth on the counting efficiency of the larger fish, was when two fish traversed the electrodes at the same time. This is likely to remain a problem as it is unlikely that the algorithm used to analyse the pattern of electrical disturbance (trace data) could be modified in such a way that it could detect two fish events from noise or aberrant fish behaviour. At Forge Weir and Gunnislake Fish Pass these particular events occurred relatively infrequently, their exclusion resulting in an under count of 1.1 - 6.6% and 1.0 - 5.0% respectively. This may not be the case at other locations, however a similar low occurrence of two fish events was also reported by Dunkley and Shearer (1982).

Forge Weir exhibits a decrease in counting performance of upstream migrants >75cm. This problem was attributed to the production of 'bow wave' traces in low water conditions. The impact of the 'bow wave' problem appears to be reduced from that reported in earlier work (Nicholson & Aprahamian 1993) following the provision of an improved algorithm by Aquantic. This problem was not observed at Gunnislake Fish Pass and we attribute the fault at Forge Weir to the fact that the height of the water above the weir crest is less than optimum for the operation of the counter.

The regression equations describing the relationship between signal size and fish length generated from Forge and Gunnislake proved significantly different which is most probably a consequence of site design. In order to best determine the most effective design for a counting channel it may prove worthwhile to compare relationships generated at other sites, when data becomes available.

Problems with fish visibility and screen length measurement were experienced with the video record at Gunnislake Fish Pass due to the 'time lapse' speeds employed. In general 'time lapse' speeds of <8 frames s^{-1} should not be used, as too few frames of individual fish events are obtained. There is thus particular concern that fish could be missed between frames, there is also uncertainty on direction because in certain cases only one frame was obtained. This latter problem also reduces the accuracy of the length measurement and may explain the lower coefficient of variability of the signal size relationship at Gunnislake compared to Forge. The use of the electronic 'alarm' to instigate real time filming of fish events proved detrimental to the quality of the video record, producing electrical interference and impairing data quality.

On those river systems where it is important to partition the count into salmon and migratory trout it is essential that the counter has some sizing capability. It is also important if salmon are to be separated into their various sea age-classes. At Forge Weir it was possible to explain a considerable portion of the variability in peak signal size, 21 - 39% remained unexplained for upstream and downstream migrants respectively, and in the case of Gunnislake 43% remained unexplained for upstream migrants. In the case of Gunnislake the higher proportion of variance remaining unexplained may be due to the fact that no information on water depth were available. The small number of downstream migrants encountered at Gunnislake limited the extent of the analysis.

Part of the unexplained variance may be accounted for by variation in swimming height above the electrodes. This not only directly effects the size of the signal, but also the measurement of the fish taken from the video. The effect of an increase in swimming height will be a reduction in signal size and the estimate of fish length. Fewings (1987) estimated a 0.5% reduction in fish size per centimetre increase in swimming height above the electrodes. It is considered unlikely that peak signal size will decrease at the same rate. There will also be some error associated with the fish length measurement itself and Beach (1978) estimated this at the 95% level of confidence to be +/- 5.2cm, similar to that reported by Dunkley and Shearer (1982). Another variable, not measured, which may account for a significant portion of the variance was the weight of the fish. Though weight was closely correlated with length (r^2 = 0.96 Aprahamian *et al*, 1994) it will be mass which more directly influences the size of the signal.

At Forge Weir attempts were made to identify to species those fish which were visible using the side window. Only 4.4% of the total sample could be identified due to poor visibility, which indicates that the window is in need of replacement.

2.5 Conclusions

2.5.1 Counters at both Forge and Gunnislake both exhibit an ability to count and size fish with an acceptable level of accuracy and fulfil the specifications set out for a fish counter by Beach and Potter (1987).

2.5.2 Small numbers of false counts were generated at both sites, although not at such incidence as to over estimate numbers of returning salmonids.

2.5.3 The 'Bow wave' problem identified at Forge Weir does not affect Gunnislake Fish Pass and is probably attributable to the fact that the height of water above the weir crest is less than the optimum for the performance of the counter.

3. References

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4.1 Multiple Electrode Array Fish Counter - Progress at 31st May 1994

From the detection systems described in the previous report, it was decided to concentrate development effort on the 'Four Electrode Cell' system. This decision was due to the fact that this system was the only one offering a simple method of amplification of the detected signal.

Once set up the cell provided the following signals:

i) Zero amplitude output for no fish present.
ii) Progressive increase in signal amplitude as fish moves over array, maximum amplitude when array is completely covered.
iii) Progressive decrease in amplitude, null and phase inversion as the fish leaves the array.

Although this signal was extremely small it exhibits good noise immunity and therefore can be amplified using a high gain amplifier.

The principle of detection however presented problems that had not previously been noticed. The sinusoidal excitation voltage, used to eliminate any dc component and associated problems, is affected by circuit parameters of resistance, capacitance and inductance. All components may affect the amplitude, Capacitance (C) and Inductance (L) also affect the phase of the signal. L appears to be insignificant, but stray C must be balanced by capacitors added to the detection circuitry. This in simple terms would involve fine tuning of each cell during calibration of the counter to remove errors generated as a result of stray capacitance. Using a microprocessor it may be possible to adjust this value automatically although integrated circuits capable of varying capacitance under microprocessor control have not been identified. A further observation was that the apparent capacitance, or resultant phase, varied over time, this was attributed to changes in water depth, conductivity and temperature. This renders the system inherently unstable and requiring constant adjustment for physical and environmental variations.

Testing continued to assess the effectiveness of the system, if the problems detailed above could be surmounted. Three different physical constructions of the array were used in an attempt to reduce the effects of stray capacitance. No significant advantage of any one method could be indentified.

Once the cell had been balanced a repeatable result could be obtained. Primarily the detected signal was viewed directly via the differential mode on an oscilloscope (CRO) and subsequently the signal was monitored after processing by a high gain differential amplifier.
Further studies allowed the principle of operation to be understood more fully, but also highlighted potential problems. Concern was expressed over the nature of the output signal. The two extremes of completely covered and completely uncovered provided signals of maximum and null respectively, however when the array was partially covered it was possible to achieve null and a phase inversion. The phase inversion could be detected with the use of extra components, but the secondary null, if encountered would suggest that no fish was present. The scanning principle suggested would however allow several 'shots' of any one fish travelling across the array, the chances of every 'shot' to include a secondary null would be slight, meaning the processor analysing detected signals could ignore such occurrences.

Some experimentation has been carried out to determine the detection range, that is the maximum height an object can be above the electrodes before it escapes detection. At this time it is not known whether the detection range will be adequate when using close spaced electrodes.

4.2 Conclusions

Research to date has investigated ways of detecting fish in rivers using closely spaced electrode arrays. Resistive sensing has produced the most favourable results but is far from satisfactory. Errors resulting from stray capacitance must be accurately compensated for in addition to the variations caused by physical and environmental changes. Further work effort is required to overcome difficulties identified thus far, and it is unlikely that this will be possible within the scope of this project. However the findings will be useful in the continued development of existing fish counters.