Field Validation of the 'Logie' Fish Counter at Forge Weir on the River Lune, 1992.

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1. Summary

1.1 Validation of the Logie Fish Counter was carried out at Forge weir, River Lune between 7th July and 20 November 1992, using video surveillance.

1.2 A total of 1137 hours time lapse and 15 hours real time were used for validation purposes.

1.3 The proportion of upstream migrating fish counted was length dependant, increasing from 24.6% to 90% for fish between 36cm to 65cm. For fish >65cm the proportion counted declined steadily with increasing length. This decline was attributed to a build up of water in front of the fish producing a bow wave.

1.4 For downstream migrants the proportion counted varied from 41.2-100%.

1.5 A total of 88 events were not detected by the Logie; the electrical disturbance produced by the fish was below the threshold setting. Such events were confined, in the main, to fish <35cm in length. At water levels <41cm 6% or less of the events produced no traces. The proportion of 'no trace' events increased to over 80% at water levels between 45cm and 47cm, at higher water levels the proportion declined to 10%, at depths >51cm all fish produced a trace.

1.6 The relationship between peak signal size and fish length Could be described by the equations:

Upstream migrants

$$LOG_{10}PSS = -1.16 + 1.74\ LOG_{10}\ Ln - 0.0067\ Wl + 0.0043\ T \quad (r_{(adj)}^2=0.810)$$

and,

Downstream migrants

$$LOG_{10}PSS = -0.86 + 1.48\ LOG_{10}\ Ln - 0.0035\ Wl \quad (r_{(adj)}^2=0.780)$$

Where PSS = Peak signal strength
Ln = Fish length (cm)
T = Temperature (degrees centigrade)
Wl = Water level (meters).

No significant difference was found between slopes. For both upstream and downstream migrants the model indicated that peak signal size decreases with increasing water depth. The inclusion of water conductivity did not improve the relationship, which suggests that the LF adequately compensates for changes in water conductivity.

1.7 For fish of a given length, no significant difference in signal size was detected across the electrode array.

1.8 The swimming speed of fish between 25cm and 90cm as they traverse the counting zone in an upstream direction was 1.55 ms^{-1} (+/- 0.057 ms^{-1}) and in terms of body lengths per second may be described by the equation:

$$LOG_{10}(BLS) = 2.07 - 0.93\ LOG_{10}(Ln) \quad (R_{(adj)}^2 = 60.0)$$

Where BLS = Body Lengths per second
Ln = Fish Length (cm).

Field Validation of the 'Logie' Fish Counter at Forge Weir on the River Lune, 1992.

1. Introduction

The stock assessment task group report (1991) mentions that fish counters could play a key role in providing data on the size of the adult stock, and in particular the migratory salmonid stock.

Previous studies have shown the Logie fish counter (LF) to be reliable for counting most size classes of fish (Reddin *et al.*, 1992; Dunkley & Shearer, 1982; Nicholson & Aprahamian, 1992), although data for sea trout (in particular that component <35cm) has been limited. However, a comprehensive investigation of the performance of the counter in mixed stock rivers has not previously been evaluated.

The main aims of this study were:

a) To determine the efficiency of the LF in detecting and recording fish above threshold size under different river conditions and with a downstream threshold setting reduced from that used in the 1991 field trials (Nicholson & Aprahamian, 1992).

b) To assess the fish size estimation capability of the LF by investigating the fish size/signal strength relationship at different water levels and conductivities.

2. Materials and Methods

A brief description of the Forge Weir site together with the Logie system and the basic video validation system has been described by Nicholson & Aprahamian (1992). However following the 1991 study a number of changes were made to the validation system and method of recording the data.

Prior to commencement of filming, the floor of the pass containing the electrode array was painted with a white epoxy based anti-fouling paint (available from International Protective Coatings, Birmingham) to facilitate easy cleaning and improve photographic contrast. Also the concrete wall was electrically insulated by fixing a sheet (9mm gauge) of white polypropylex plastic to the wall, and the edges sealed with silicone. The whole procedure required the electrode array to be dry for a period of five days.

The method of operation was basically the same as in 1991 in that, provided the LF's fish algorithm has interpreted a true fish event then the counter outputs, via the printer port, the date, time, conductivity, channel, direction of movement, and peak signal size (text output) together with coded values of electrical resistance sampled at 0.01 s intervals (trace). Should a non fish event be interpreted, then the above information is produced with the exception of the direction of movement which is represented by the character 'E'.

In 1992 however, an IBM PC using software written in house was used to receive the text output and store it to a file on the hard drive fitted to the PC (P. Best pers. comm.).

The data from the counter were analysed in relation to that obtained with a video recording system installed over channel one. In 1992, the system consisted of two cameras (Ikegami ICD-42E CCD); one mounted overhead on a scaffold frame and one situated in a dug out viewing chamber giving a side view. Two infra-red lamps (12 volt DC infra red) were used to illuminate the weir. The outputs from the 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 response (date, time, conductivity, channel, direction of movement, and peak signal size) from the fish counter (via the PC fitted with GENLOCK) and was then recorded on a Panasonic AG6720A video recorder using both time lapse (8 frames sec^{-1}) and real time modes (25 frames sec^{-1}).

A schematic description of the 1992 data acquisition system is shown in Figure 1a.

The threshold settings, which range from 1 to 127, were changed from 20% in the downstream and 10% in the upstream setting to 10% for both settings.

The 'lag period', the time between detection and recording of a fish event, built into the logic circuitry of the LF, was reduced from 1.0 s to 0.5 s.

Information on water level and temperature at Forge weir were recorded at hourly intervals on a Golden River data logger.

For each event a number of parameters taken from the computer and video record were logged, these are presented in Table 1. In addition, the Logie 'trace' data logged for each event was recoded to a standard format, composed of 240 'time units' of constant duration and termed 'product traces'. The duration of 'time units' used to build individual 'product traces' was calculated as:

$$t_u = (n_1/n_2) * 0.01 \text{ seconds}$$

where t_u = 'time unit' (in seconds)
n_1 = number of samples in Logie trace (variable) [Duration/0.01]
n_2 = number of 'time units' in 'product trace'
(constant = 240).

Figure 1a: Data aquisition system (schematic)

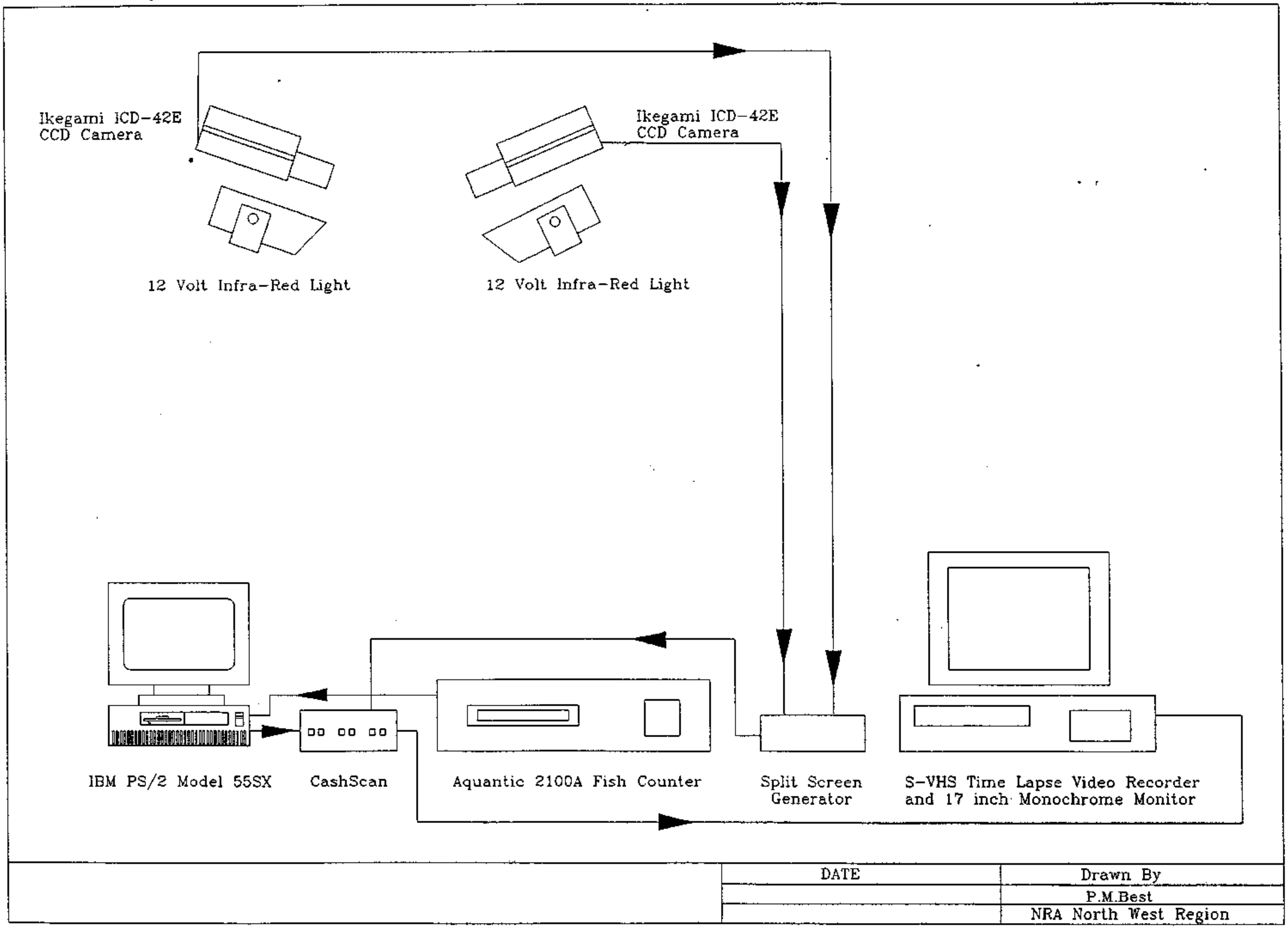


Table 1. Parameters collected for fish events observed on video.

Parameter	Variable	Comment
Event type	1 2 3 4 5 6 7 8 9	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
Date		dd/mm/yy
Date		Day number (scale of 1 - 365)
Time		hh:mm:ss
Time		Minutes (past 00:00 hours)
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	straight pass up down & up down up & down up & down in downstream elec. down & up in upstream electrode up & down down & up staggered
Downstream electrode (viewed downstream)	0-9	position of the fish as it passes over the downstream electrode (DSE). (where 0 = extreme left) (and 9 = extreme right)
Upstream electrode (viewed downstream)	0-9	position of the fish as it passes over the upstream electrode (USE). (where 0 = extreme left) (and 9 = extreme right)

The duration of Logie 'traces' was variable (range 1.7 s to 7.2 s), although the majority were found to be 4.0 s. For traces less than 2.4 s packing was added in order to increase their duration to 2.4 s. Thus 'time units' of different 'product traces' ranged from 0.010 s to 0.030 s. The resulting compression of the majority of 'product traces' served to exaggerate their shape and aid in event interpretation. The positions within the trace, where the fish entered and exited the electrode array were recorded using a computer program (Figure 1b).

Swimming speeds were calculated for upstream migrating fish observed to enter and exit the electrode array cleanly, i.e. minimal variation in orientation or direction whilst in the counting zone, using:

2.i) Swimming speed (ms^{-1}) $= Ss = \left[\dfrac{Ea + Ln}{(t_2 - t_1) * t_u}\right]$

and,

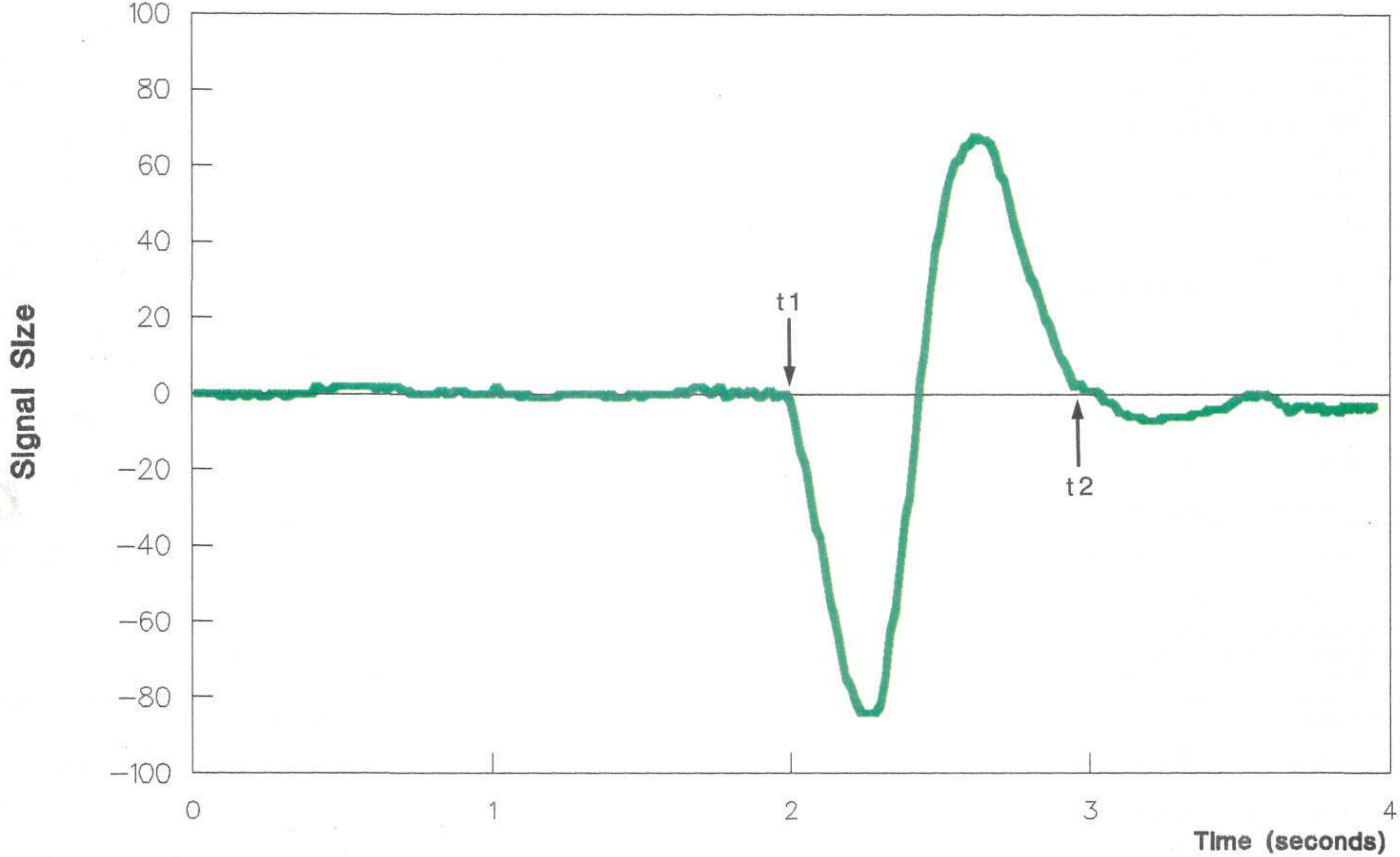
2.ii) Swimming speed (body lengths s^{-1}) $= BLS = \dfrac{Ss}{Ln}$

where:

Ea = distance (in meters) between centre of downstream electrode to centre of upstream electrode (constant, 0.84m)
Ln = fish length (in meters)
t_1 = time at which the head of the fish was recorded (above the downstream electrode) entering the electrode array on the 'product trace'
t_2 = time at which the tail of the fish was recorded (above the upstream electrode) exiting the electrode array on the 'product trace'
t_u = duration of one time unit (in seconds) used in the 'product trace'.

Analysis was carried out using Foxpro (version 2), Minitab (version 7.2) and Systat (version 5.03) computer software packages.

Figure 1b: Upstream fish event showing positions logged to obtain event duration



N.B. t1 = fish entering electrode array
t2 = fish exiting the electrode array

3. Results

Filming was carried out at Forge Weir, River Lune between the 7th July and 20th November 1992.

A total of 2243 hours of time lapse and 22 hours of real time film were recorded of which 1152 hours of film (1137 hours time lapse and 15 hours real time) were suitable for validation purposes. The environmental conditions; water level, temperature and conductivity under which validation was possible are presented in Figures 2a, 2b and 2c respectively.

3.1 Counting Accuracy

The results are summarized in Tables 2a and 2b for upstream and downstream events. Other than fish traversing the electrodes there were two counts generated from other sources; a cardboard box and a log, passing downstream.

There were 14 occasions when a single fish produced more than one count and this was mainly associated with fish lingering over the electrode array. Seven counts were produced by fish not fully traversing the electrode array and three counts were produced for, apparently, no reason.

There were very few instances (four) when more than one fish were traversing the electrode array simultaneously. In all these instances the LF recorded one fish, as expected.

The performance of the LF in relation to the size of fish is shown in Tables 3a and 3b and illustrated in Figures 3a and 3b for upstream and downstream migrating salmonids, respectively.

The proportion of upstream fish counted by the LF increased from 24.6% for fish between 16cm to 25cm to 90% for fish between 36 to 45cm. The proportion of fish counted remains in excess of 90% for fish up to 65cm in length after which there is a steady decline in the proportion counted with size (Figure 3a). This decline may be attributed in part to the fact that a build up of

Figure 2a: Water levels recorded for upstream events

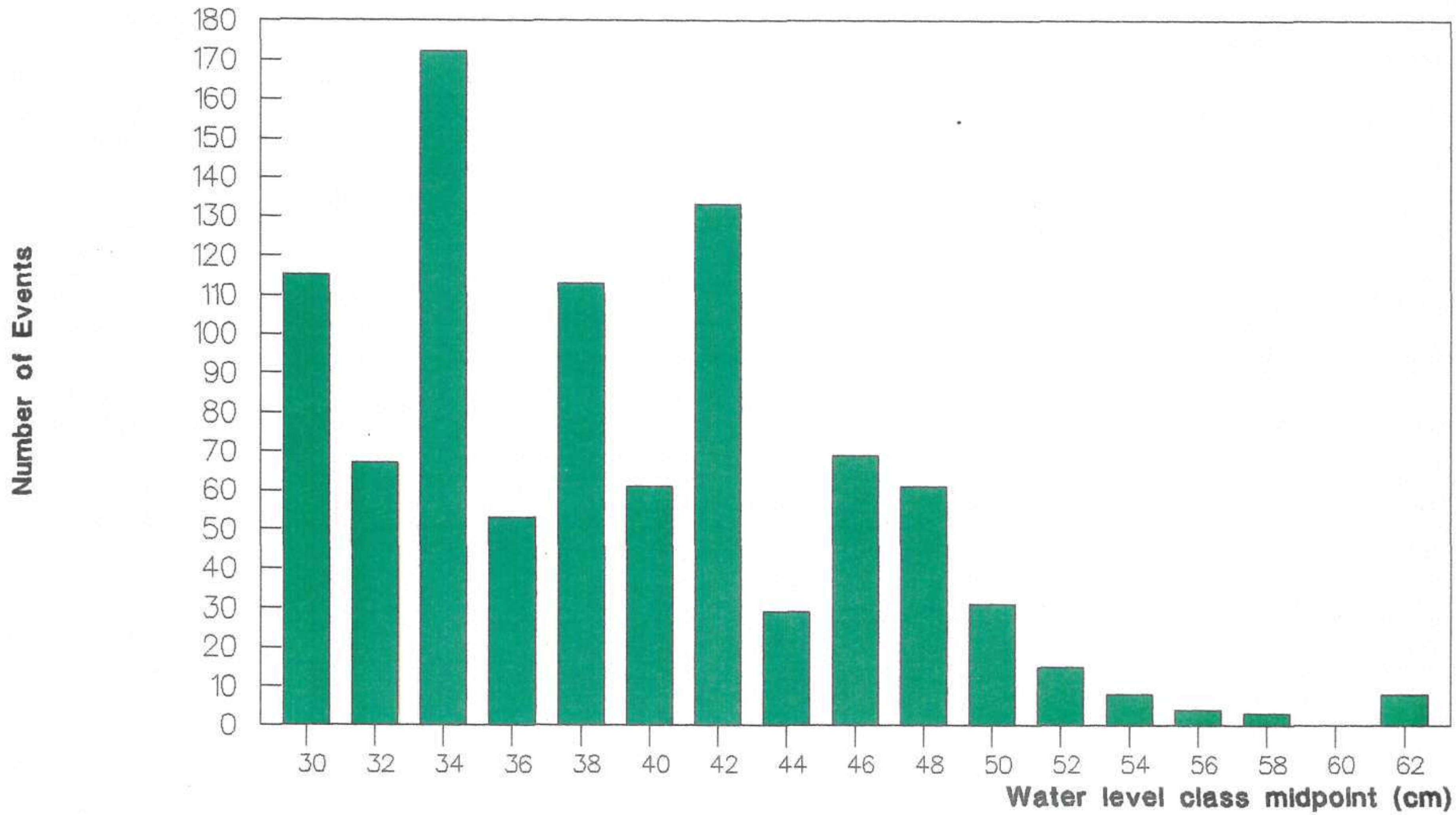


Figure 2b: Water temperatures recorded for upstream events

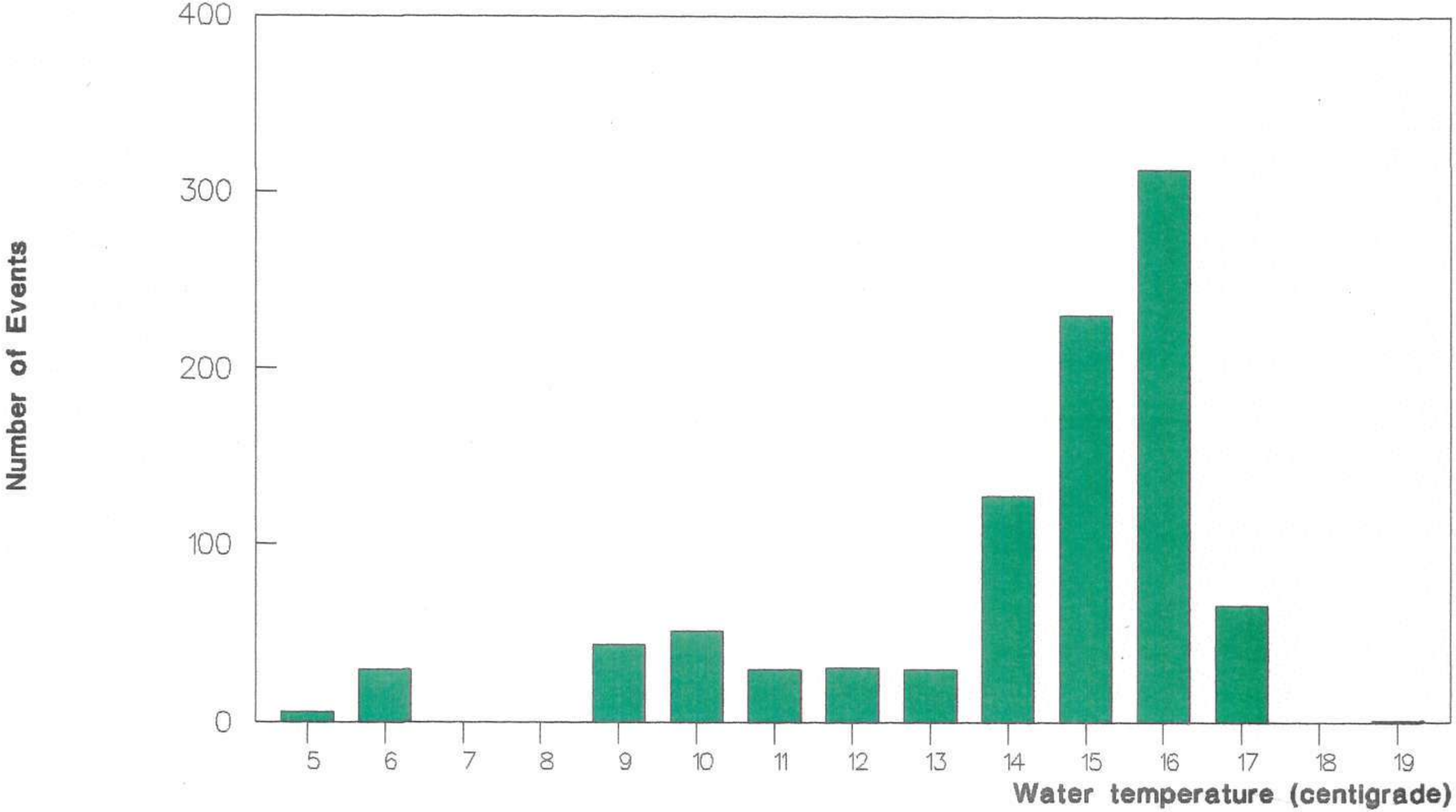


Figure 2c: Water conductivities recorded for upstream events

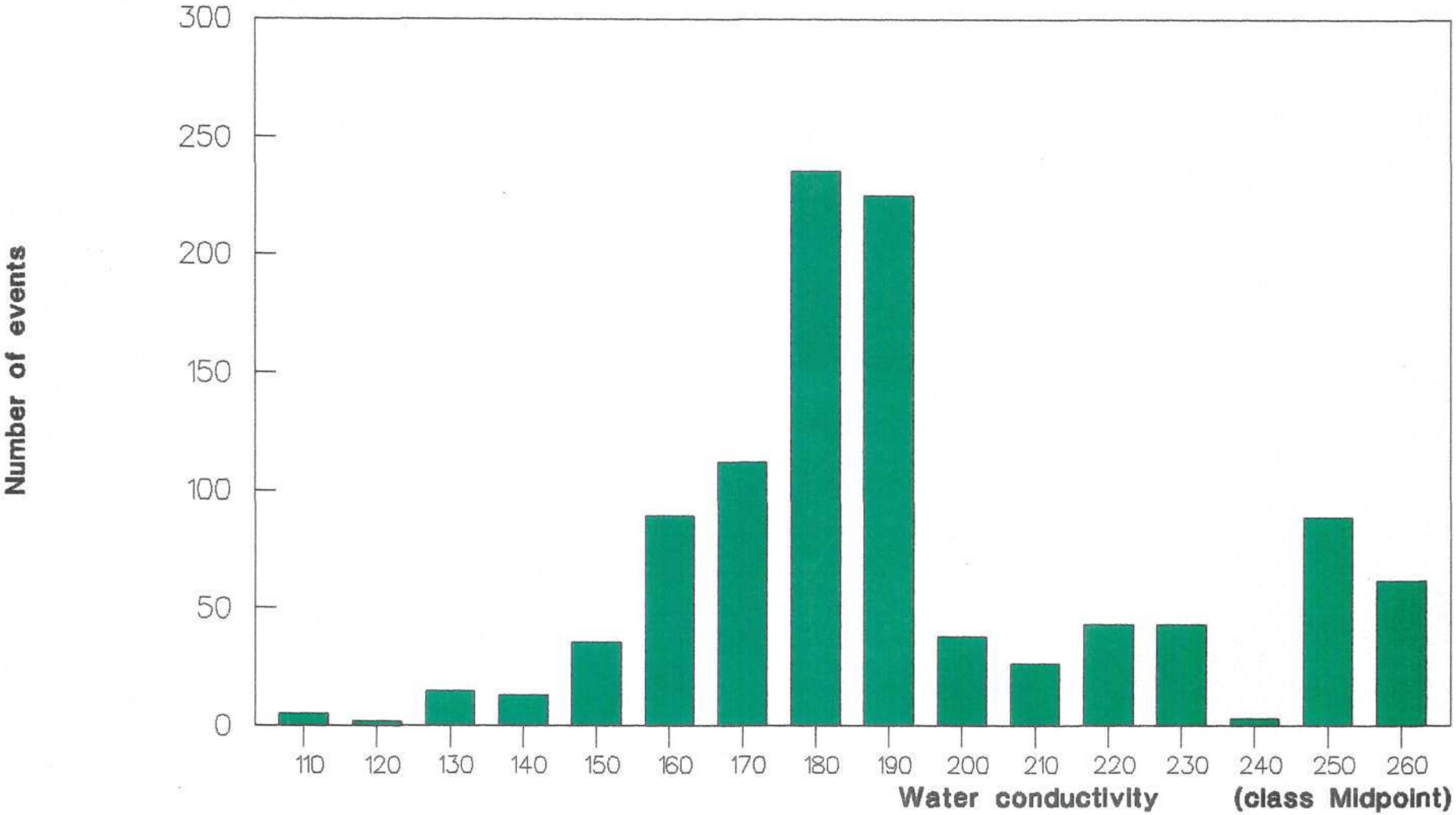


Table 2a: Summary of upstream events recorded by the Logie fish counter

Total Number seen on Video			1010
Total traversing electrode			992
Total not traversing electrode			18
Total number of non fish objects			2

2 Simultaneous fish *	3

Total Number of Counts			766
	fish traversing		740
	fish not traversing		7
		Double Counts **	14
		Non fish objects (insulators)	2
		Counts for no identifiable reason	3

Total not counted			260
		fish traversing - with trace	175
		fish traversing - without trace	74
	fish not traversing - with trace		8
	fish not traversing - without trace		3

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

** 2 events generated by an individual fish moving through the electrode array and counted as 2 fish.

Table 2b: Summary of downstream events recorded by the Logie fish counter

Total Number seen on Video			75
Total traversing electrode			70
Total not traversing electrode			5
Total number of non fish objects			0

2 Simultaneous fish *	1

Total Number of Counts			46
	fish traversing		46
	fish not traversing		0
		Double Counts **	0
		Non fish objects (insulators)	0
		Counts for no identifiable reason	0

Total not counted			27
		fish traversing - with trace	12
		fish traversing - without trace	11
	fish not traversing - with trace		4
	fish not traversing - without trace		1

* 2 fish moving over the electrode array at the same time
** 2 events generated by an individual fish moving through the electrode array and counted as 2 fish.

Table 3a: Response of the counter in relation to fish size
(Upstream events)

	Length Class Mipdpoint											
	0*	20	30	40	50	60	70	80	90	100	110	120
Total Number seen on video	11	74	420	199	88	90	76	35	8	8	0	1
Total traversing electrode	9	73	412	194	88	89	75	35	8	8	0	1
Total not traversing electrode	2	1	8	5	0	1	1	0	0	0	0	0
2 Simultaneous Fish **	0	0	2	1	0	0	0	0	0	0	0	0
Total Counted	7	18	279	185	83	88	69	24	4	4	0	0
fish traversing	7	18	275	176	82	86	64	24	4	4	0	0
fish not traversing	0	0	2	3	0	1	1	0	0	0	0	0
Double Counts ***	0	0	2	6	1	1	4	0	0	0	0	0
Total Not Counted	4	56	141	19	6	3	11	11	4	4	0	1
fish traversing - with trace	2	23	95	15	6	3	11	11	4	4	0	1
fish traversing - without trace	0	32	40	2	0	0	0	0	0	0	0	0
fish not traversing - with trace	1	0	6	1	0	0	0	0	0	0	0	0
fish not traversing - without trace	1	1	0	1	0	0	0	0	0	0	0	0

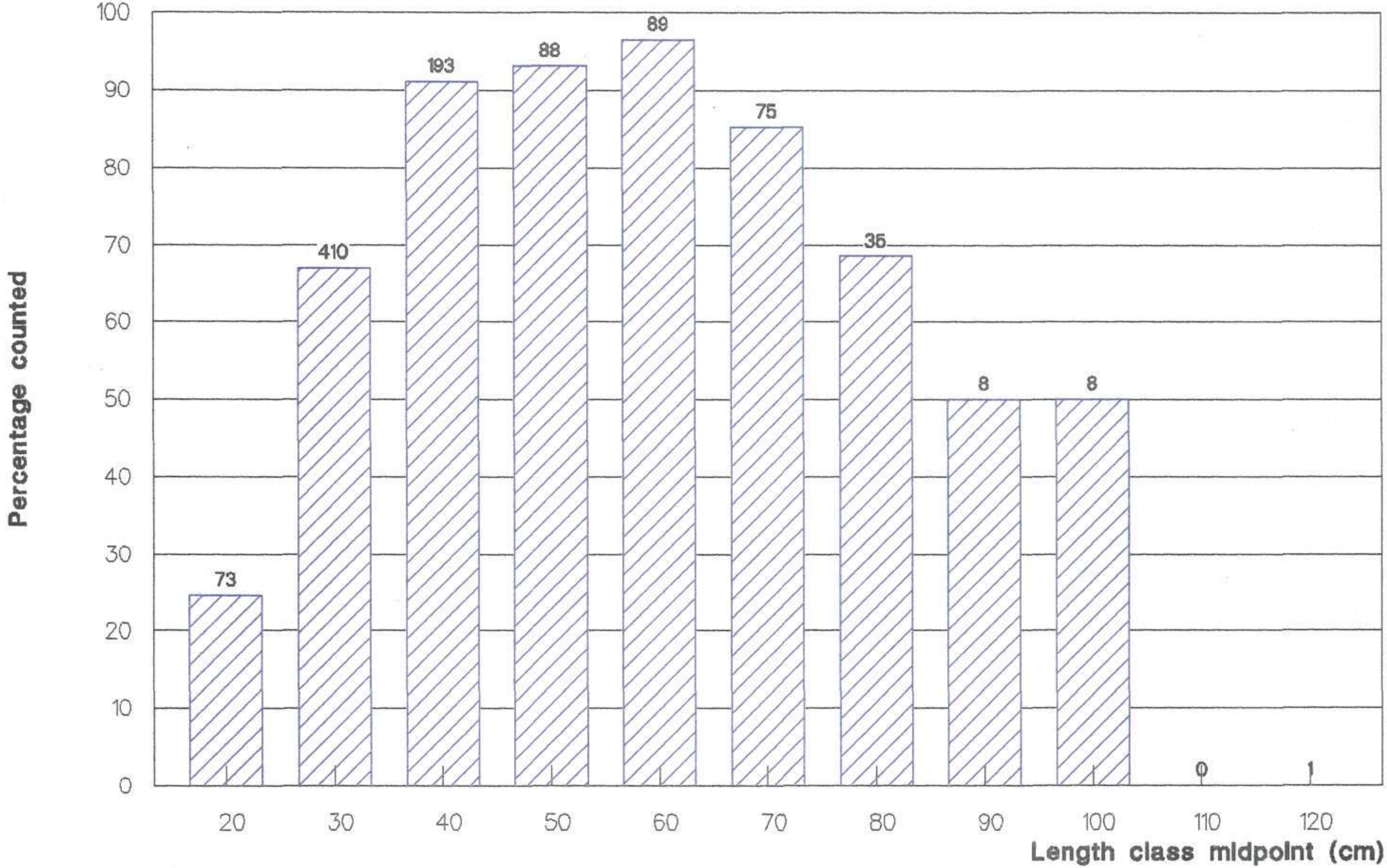
*   no length measurment possible from video
** 2 fish moving over the electrode array at the same time
*** 2 events generated by an individual fish moving through the electrode array and counted as 2 fish.

Table 3b: Response of the counter in relation to fish size
(Downstream Events)

	Length Class Midpoint								
	0*	20	30	40	50	60	70	80	90
Total No seen on video	5	7	17	18	9	9	4	4	2
Total traversing electrode	5	6	17	14	9	9	4	4	2
Total not traversing electrode	0	1	0	4	0	0	0	0	0
2 Simultaneous Fish **	0	1	0	0	0	0	0	0	0
Total Counted	3	1	7	9	9	8	4	3	2
fish traversing	3	1	7	9	9	8	4	3	2
fish not traversing	0	0	0	0	0	0	0	0	0
Double Counts ***	0	0	0	0	0	0	0	0	0
Total Not Counted	2	5	10	9	0	1	0	0	0
fish traversing - with trace	2	1	3	4	0	1	0	1	0
fish traversing - without trace	0	3	7	1	0	0	0	0	0
fish not traversing - with trace	0	1	0	3	0	0	0	0	0
fish not traversing - without trace	0	0	0	1	0	0	0	0	0

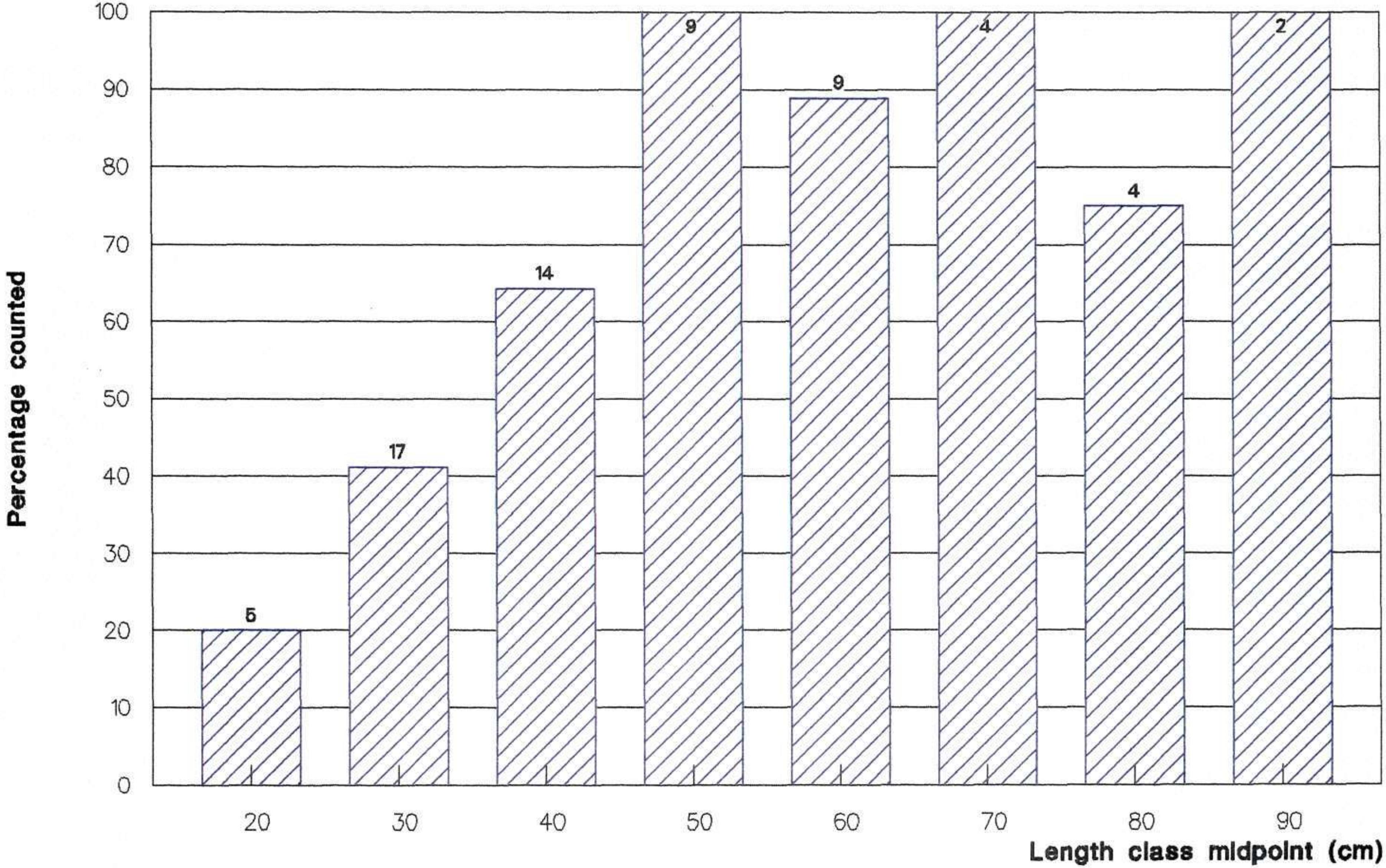
*   no length measurment possible from video
** 2 fish moving over the electrode array at the same time
*** 2 events generated by an individual fish moving through the electrode array and counted as 2 fish.

Figure 3a: Response of the counter in relation to fish size. (Upstream events).



N.B. Numbers given above bars denote the numbers of fish in a given size class moving through the electrode array minus the number of events when more than one fish moved over the electrode array at the same time.

Figure 3b: Response of the counter in relation to fish size (Downstream events)



N.B. Numbers given above bars denote the numbers of fish in a given size class moving through the electrode array minus the number of events when more than one fish moved over the electrode array at the same time water, akin to a 'bow wave', occurs in front of the larger fish as they traverse the electrode array. The effect of this on the pattern of change in electrical resistance is shown in Figure 4.

In comparison to the number of upstream migrants there were relatively few (75) fish migrating downstream. For fish >26cm the proportion counted varied from 41.2% to 100%, though the sample size in most instances were small (Table 3b and Figure 3b).

Tables 3a and 3b also illustrate that a change in electrical disturbance below the threshold level occurred on 77 (upstream) and 11 (downstream) occasions and the pattern of electrical disturbance was not recorded ('no trace'). 'No trace' events were confined, in the main, to fish of less than 35cm in length. The frequency distribution of incidents of upstream 'no trace' events were found to occur between water levels of 30cm and 50cm, modal at 46cm (Figure 5) and water conductivities ranging from 150 $\mu s\ cm^{-1}$ to 250 $\mu s\ cm^{-1}$, modal at 180 $\mu s\ cm^{-1}$ (Figure 6).

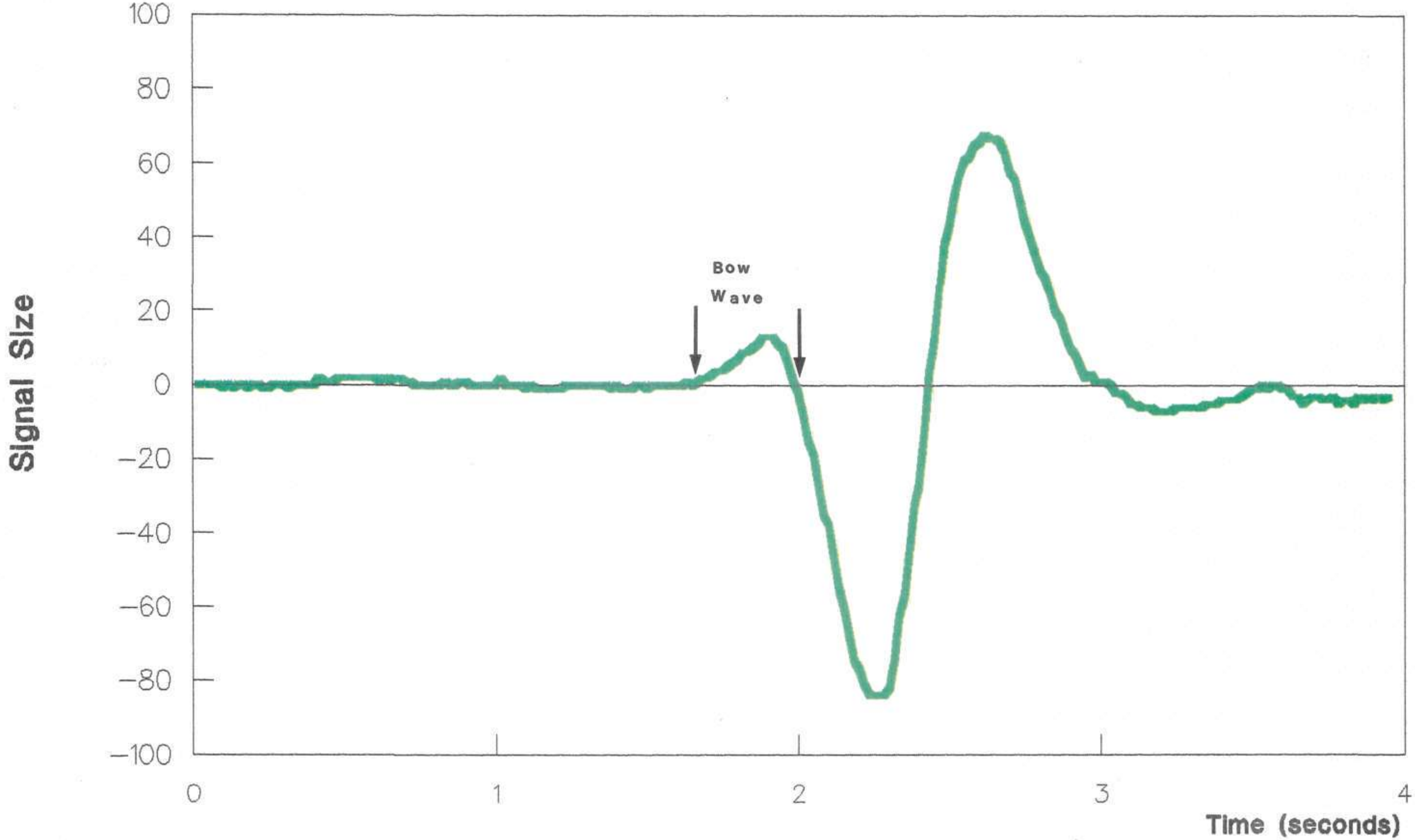
3.2 Sizing ability and environmental conditions

The relationship between fish length and peak signal size is shown in Figures 7 and 8 for upstream and downstream migrants respectively. Confidence limits are illustrated and plateau at the maximum signal size of 127. A t test (Zar 1984) suggested no significant difference between regression coefficients, though regression elevations were significantly different ($p<0.001$, Figure 9).

To assess the similarity between signal size and fish length regressions for upstream migrants in 1991 (Nicholson & Aprahamian, 1992) and the current data, the same techniques were applied. No significant difference was found between regression coefficients though elevations were again found to be significantly different ($p<0.001$ (Figure 10).

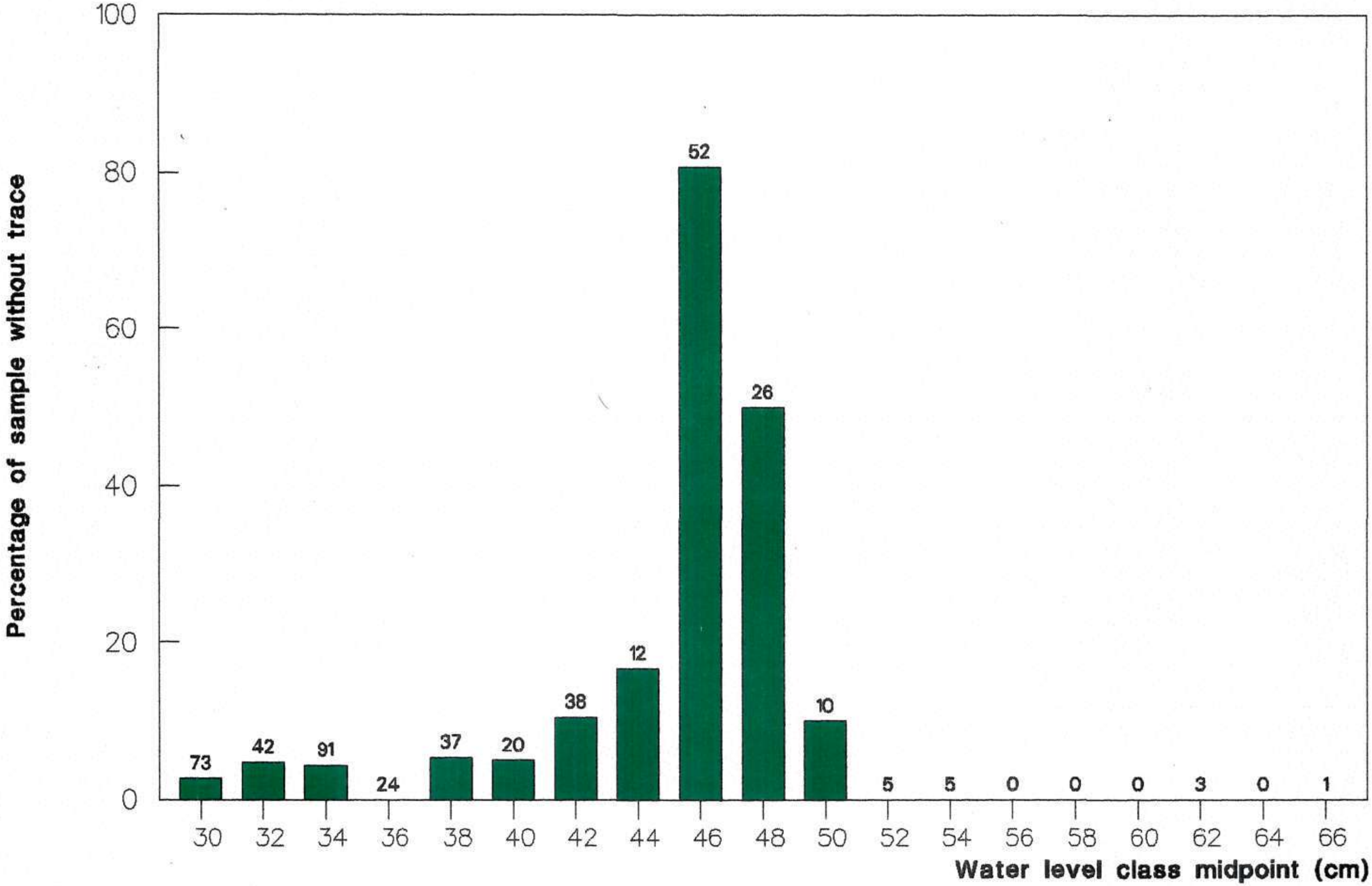
LOG_{10} fish length was found to account for 75.0% and 76.6% of the variability in signal size for upstream and downstream migrants respectively. The inclusion of temperature and water level in a

Figure 4: Bow wave affecting counting efficiency
Fish event 12/08/92 09:20:27



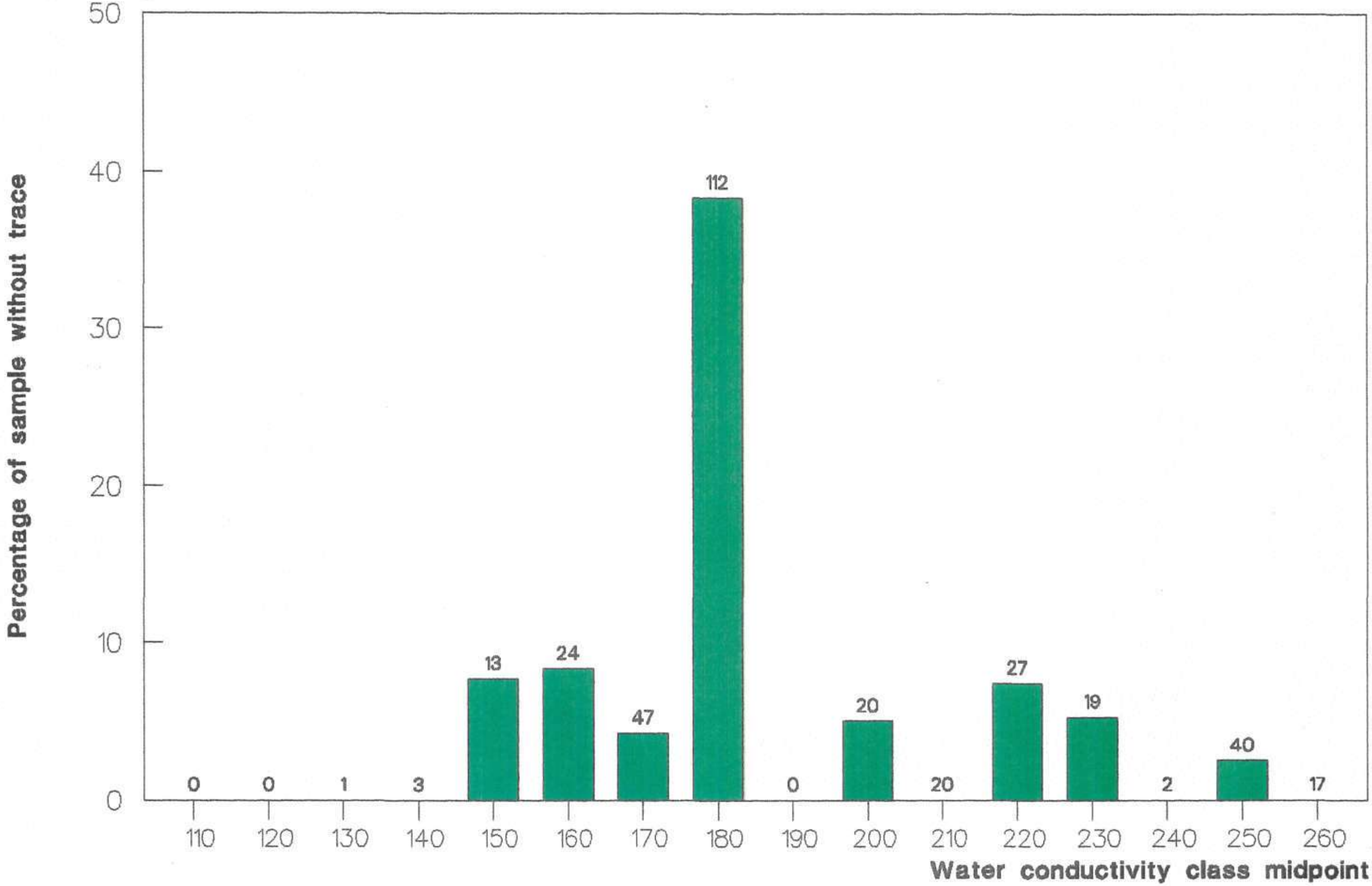
This trace signal was produced by a salmon (89cm) traversing the electrode in 1.2 seconds (normal behaviour) and generated a peak signal size of 99 and was not counted by the fish algorithm (version 8.6 17th April 1992)

Figure 5: The proportion of fish < 35cm traversing the electrode below threshold level related to water level



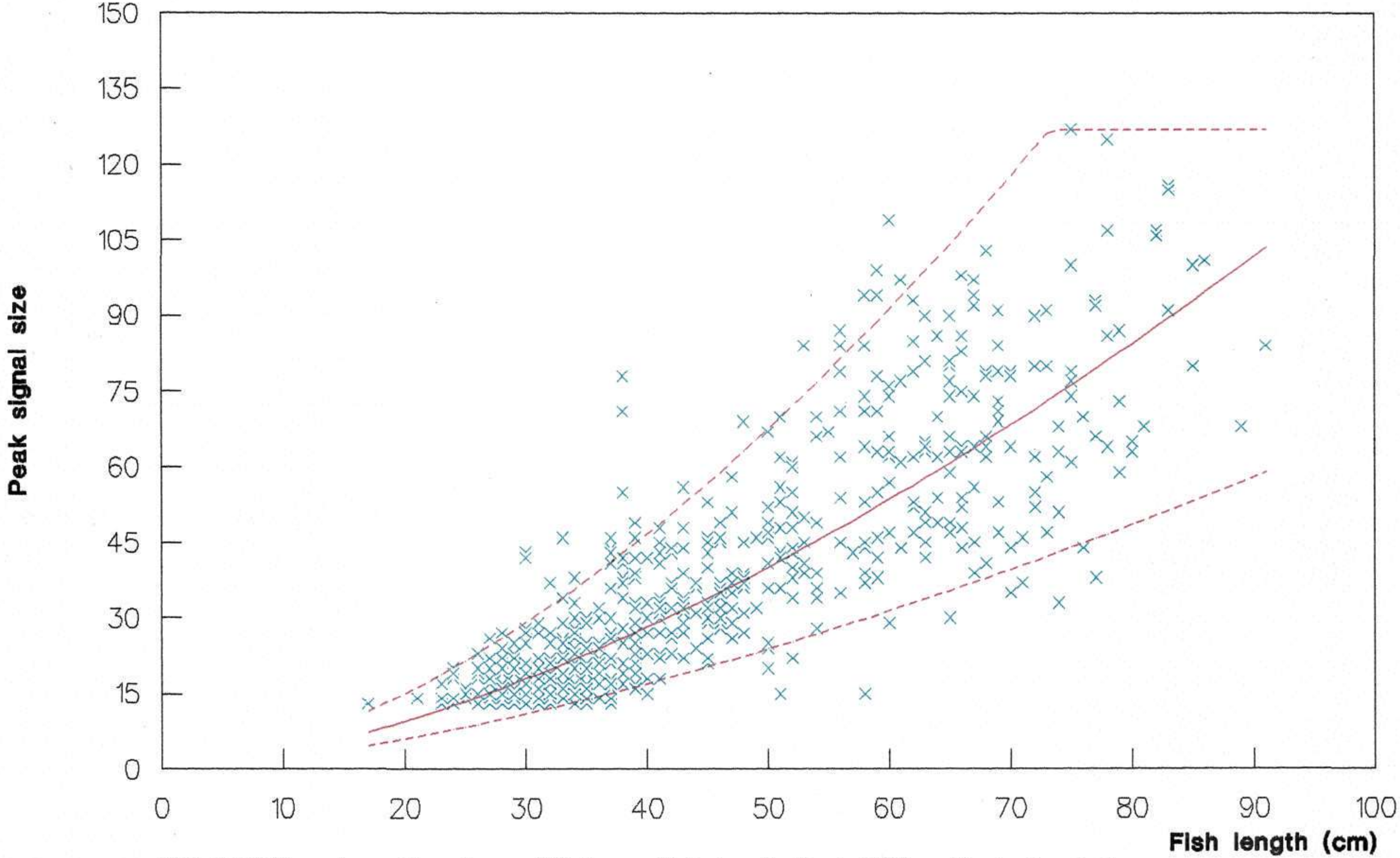
N.B. Numbers given above bars denote the total number of fish < 35cm in length occurring in a water level class.

Figure 6: The proportion of fish < 35cm traversing the electrode below threshold level related to water conductivity



N.B. Numbers given above bars denote the total number of fish < 35cm in length occurring in a water conductivity class.

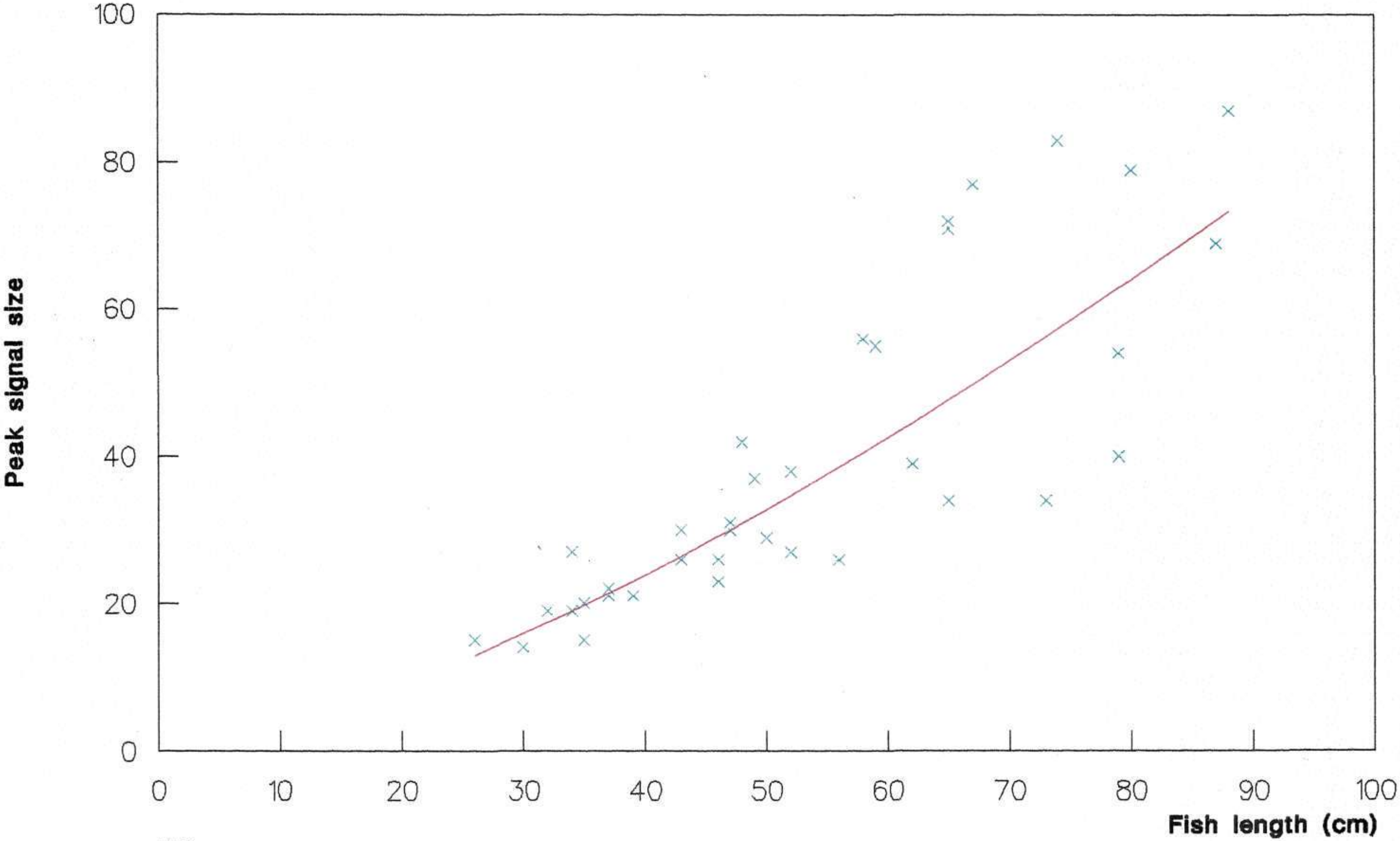
Figure 7: The relationship between signal strength and fish length for upstream migrating salmonids.
LOG10(PSS) = -1.08 (+/- 0.1106) + 1.58 (+/- 0.06803) LOG10(Ln)



N.B. LOG10 = Logarithm (base 10): Ln = Fish length (cm): PSS = Peak signal size
95% Confidence Limits are shown by broken lines.

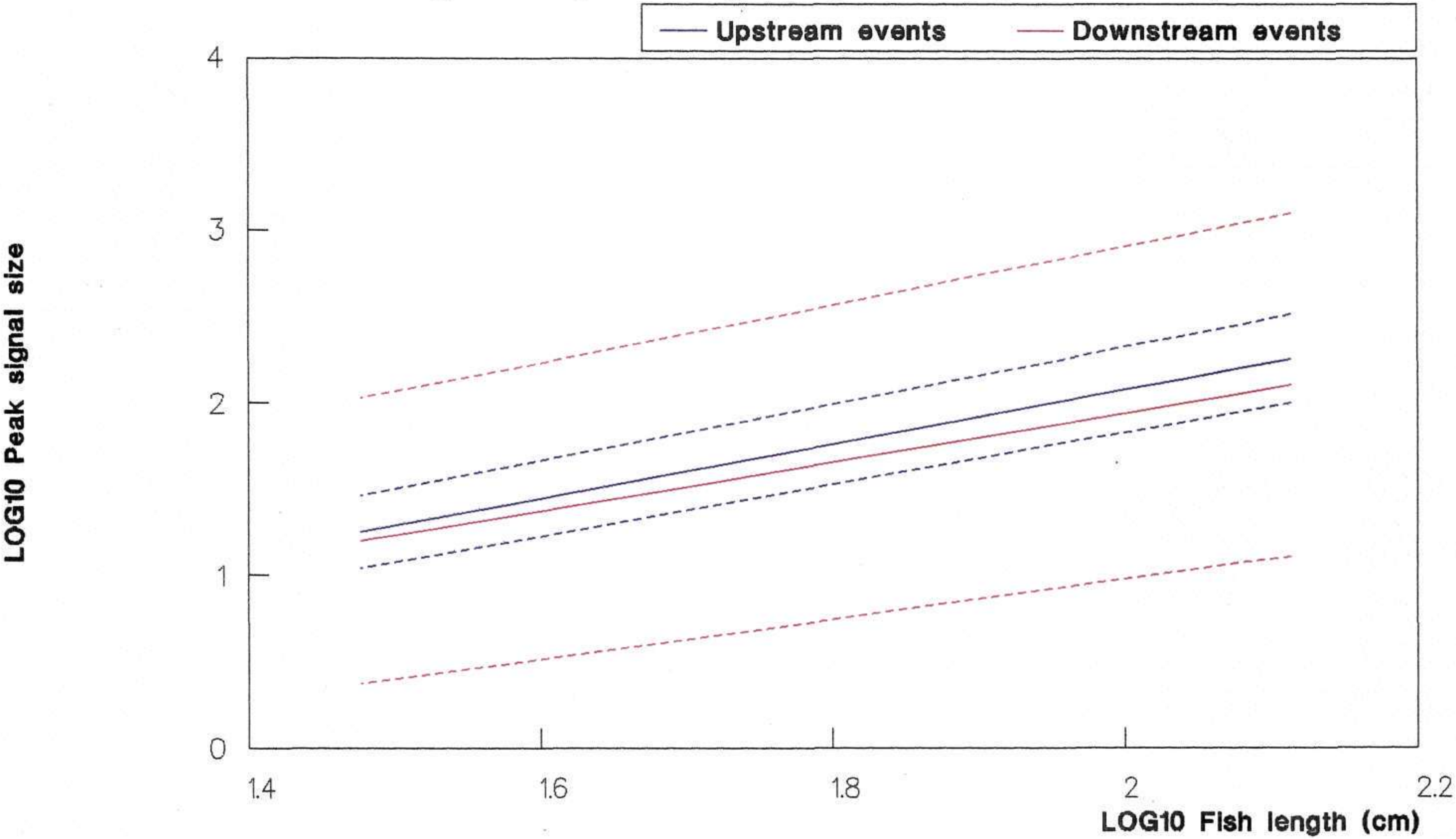
Figure 8: The relationship between signal size and fish length for downstream migrating salmonids.

$$LOG10(PSS) = -0.896\ (+/-\ 0.444) + 1.42\ (+/-\ 0.2597)\ LOG10(Ln)$$



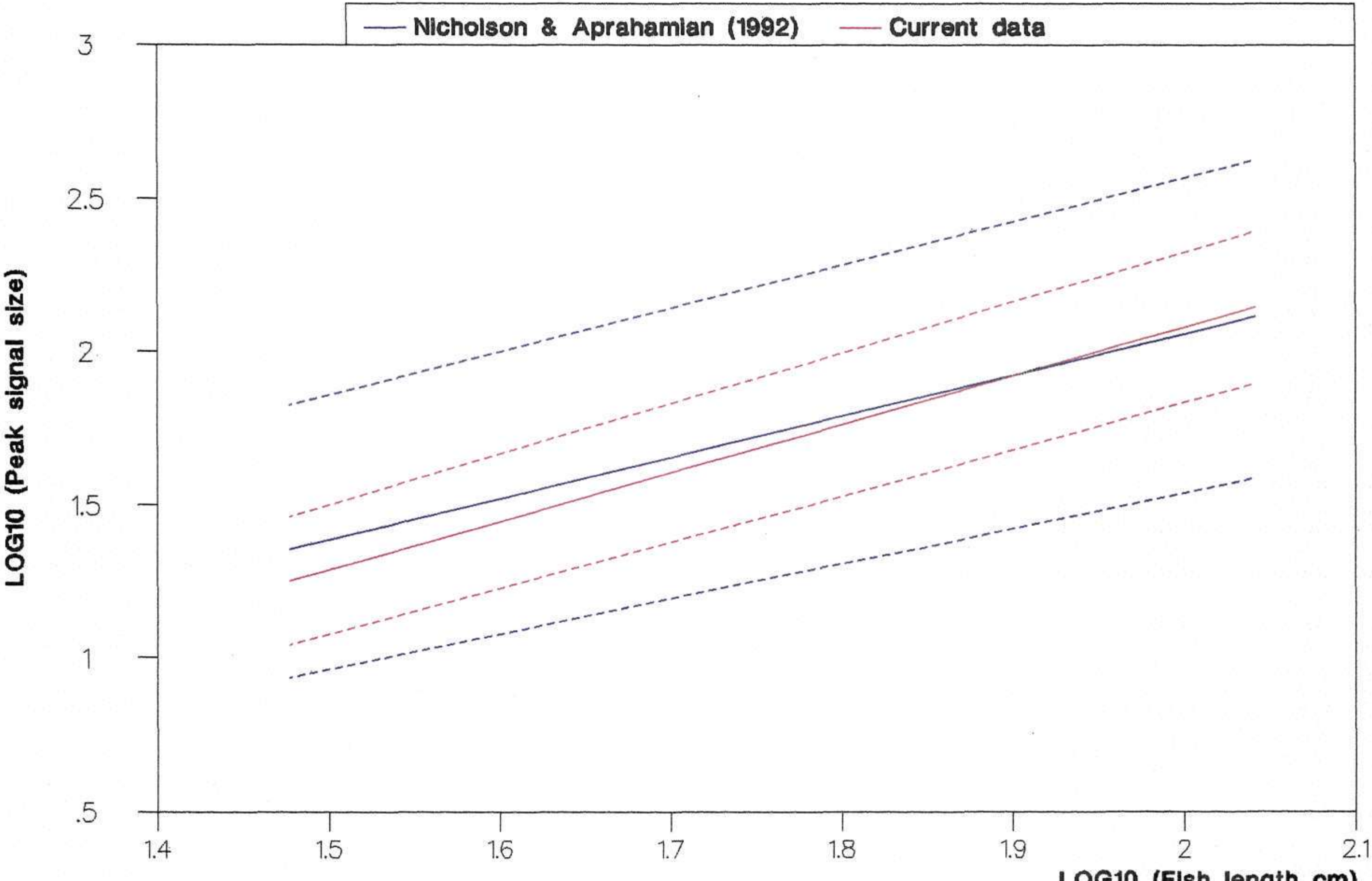
N.B.
LOG10 = Logarithm (Base 10): PSS = Peak signal size: Ln = Fish length (cm)
Large 95% confidence limits are not shown.

Figure 9: Comparison of Upstream and downstream signal size, fish length regressions (current data).



N.B. 95% Confidence limits shown by broken lines

Figure 10: Comparison between signal size and fish length regressions for upstream migrants of Nicholson & Aprahamian (1992) and current data.



N.B. 95% Confidence Limits are shown by broken lines multiple regression accounted for a further 6.0% of the variability for upstream migrants. Though for downstream migrants the inclusion of water level marginally increased the proportion of variability explained by 1.4%, temperature made no significant improvement. The inclusion of water conductivity did not improve the regression equations for both upstream and downstream migrants.

The regression equations were as follows:

Upstream migrants

3(i) $LOG_{10}PSS = -1.03 + 1.72\ LOG_{10}\ Ln - 0.00727\ Wl$

$(r_{(adj)})^2 = 0.807)$

3(ii) $LOG_{10}PSS = -1.16 + 1.74\ LOG_{10}\ Ln - 0.0067\ Wl + 0.0043\ T$

$(r_{(adj)})^2 = 0.810)$

Downstream migrants

3(iii) $LOG_{10}PSS = -0.86 + 1.48\ LOG_{10}\ Ln - 0.0035\ Wl$

$(r_{(adj)})^2 = 0.780)$

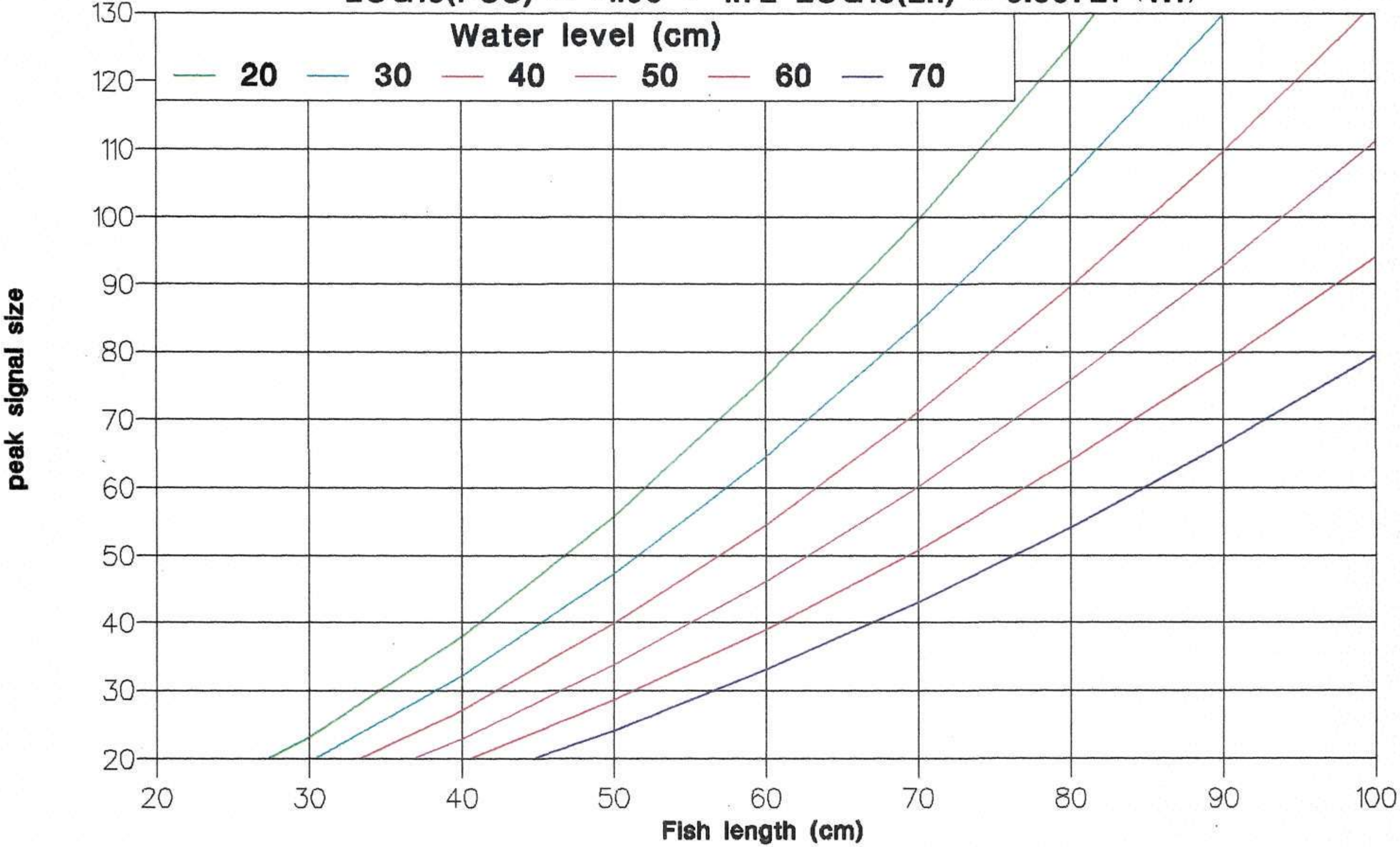
Where PSS = Peak signal strength
Ln = Fish length (cm)
T = Temperature (degrees centigrade)
Wl = Water level (meters).

The influence of water level on the fish length, signal size relationship is illustrated in Figure 11. The model 3(i) implies that signal size decreases with increasing water level, as such small fish may pass the electrode array and not be recorded by the LF.

The impact of water level on fish size estimation was further investigated by examining the mean lengths and generated signal sizes of samples of upstream migrants across a range of water levels (Figure 12, 13). One way analysis of variance revealed a significant difference in the mean lengths of fish across the range of water levels, whilst no significant differences in signal sizes generated by the same samples was identified (Table 4).

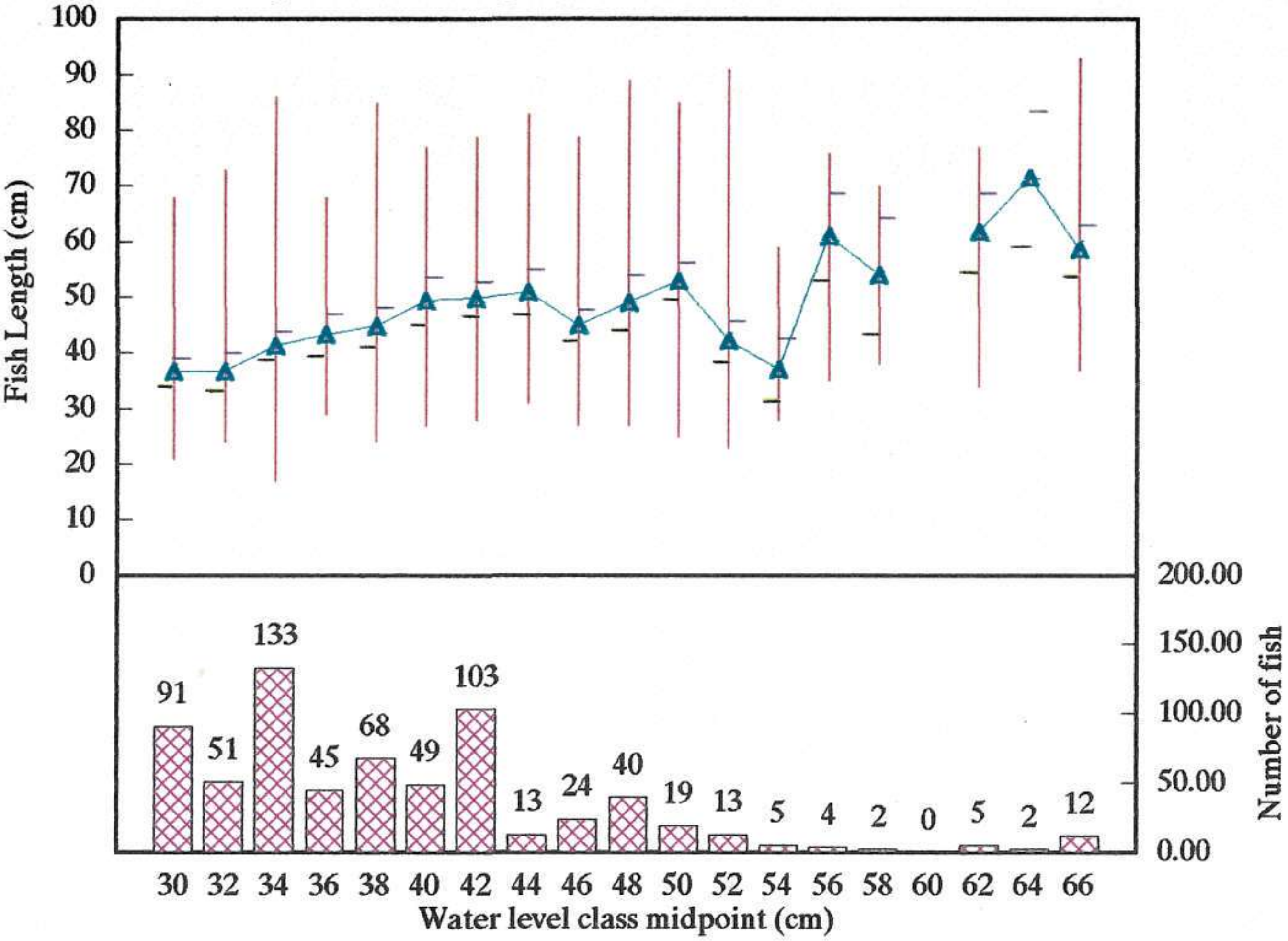
Figure 11: The influence of water level on the relationship between peak signal size and fish length

$$\mathrm{LOG10(PSS)} = -1.03 + 1.72\ \mathrm{LOG10(Ln)} - 0.00727\ \mathrm{(Wl)}$$



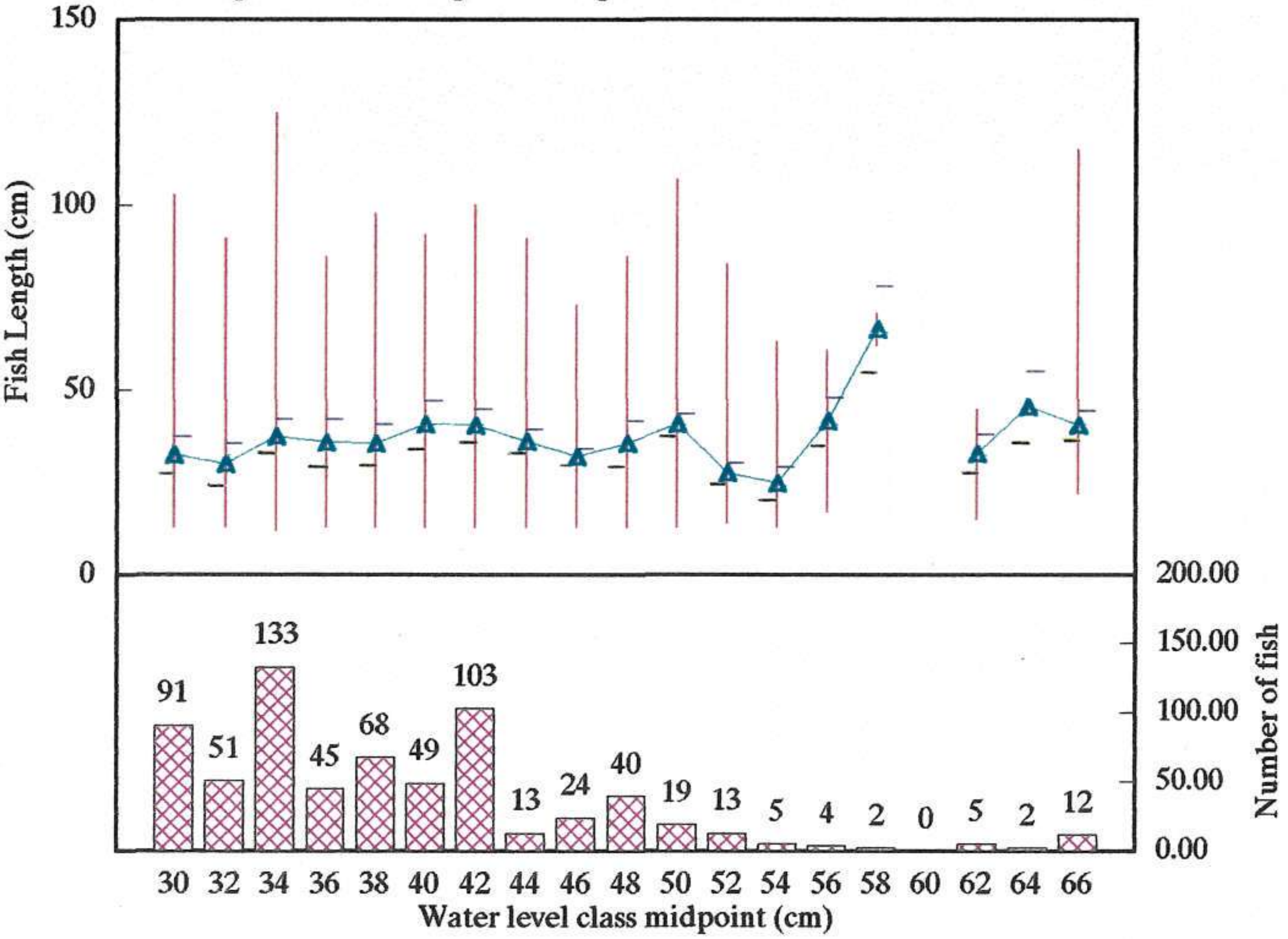
N.B. LOG10 = Logarithm (base 10)
PSS = peak signal size: Ln = fish length (cm): Wl = water level

Figure 12: Fish lengths observed at different water levels



N.B.
Vertical lines denote length range.
Open and closed lines denote 95% confidence limits around the mean.
Connecting line shows mean fish lengths observed at water levels.

Figure 13: Peak signal sizes generated at different water levels



N.B.
Vertical lines denote length range.
Open and closed lines denote 95% confidence limits around the mean.
Connecting line shows mean fish lengths observed at water levels.

Both variables were grouped by 5cm intervals. Only groups containing more than 20 fish were included. Table 6 suggests that except for fish < 25cm, where counting efficiency decreases with increasing water level, no real trend is apparent. However, more data are required to form a more concrete solution.

Table 6: Counting accuracy of small salmonids with reference to water level

	Counting Accuracy (%) Fish Length (cm) class midpoint					
Water level (midpoint cm)	22.5	27	32	37	42	47
32.5	77.8	61.9	86.4	90.3	100.0	91.7
37	50.0	37.5	72.9	85.7	100.0	91.7
42	*	57.1	82.8	84.6	100.0	86.7
47	0.0	57.1	80.0	100.0	88.8	100.0
52	*	50.0	80.0	60.0	100.0	100.0

Where * = no data available

3.3 Performance across the electrode array.

In order to assess the performance of the LF across the electrode array, a sample of upstream migrants of length range 30cm to 40cm, in a water level range of 0.3m to 0.4m and traversing the electrode array exhibiting normal behaviour along one transect were selected. Due to the small sample sizes of fish associated with transects in the centre of the pass, and since the fish rig investigations showed a signal size drop at the extreme sides of the pass (Appendix 1); transects were grouped as follows:

group A - transects 8 & 9 (wall)
group B - transects 2 to 7
group C - transects 0 & 1 (window)

A general description of the fish lengths and signal sizes within these groups are presented in Table 7.

Table 7. Comparison of mean lengths and generated signal sizes across the electrode array.

		Mean Length (cm)		PSS	
Group	Number	Mean	SD	Mean	SD
A	23	34.9	3.2	22.1	6.4
B	25	33.2	3.5	25.8	14.6
C	12	36.0	3.2	23.1	8.3

The larger standard deviation in peak signal size for those fish utilising the centre of the electrode array, may indicate that this group traverses the array with a greater range in height over the electrodes than those traversing the electrode array at the sides of the pass.

A Bonferroni pairwise comparison, (Tables 8a and 8b) indicates that the counter produces a uniform signal size across the width of the electrode array for a given fish passing over it.

Table 8a. Matrix of Bonferroni adjusted pairwise comparison probabilities (Fish length).

Group	A	B	C
A	1.000	-	-
B	0.414 NS	1.000	-
C	0.801 NS	0.059 NS	1.000

Table 8b: Matrix of Bonferroni adjusted pairwise comparison probabilities (Peak signal size).

Group	A	B	C
A	1.000	-	-
B	0.675 NS	1.000	-
C	1.000 NS	1.000 NS	1.000

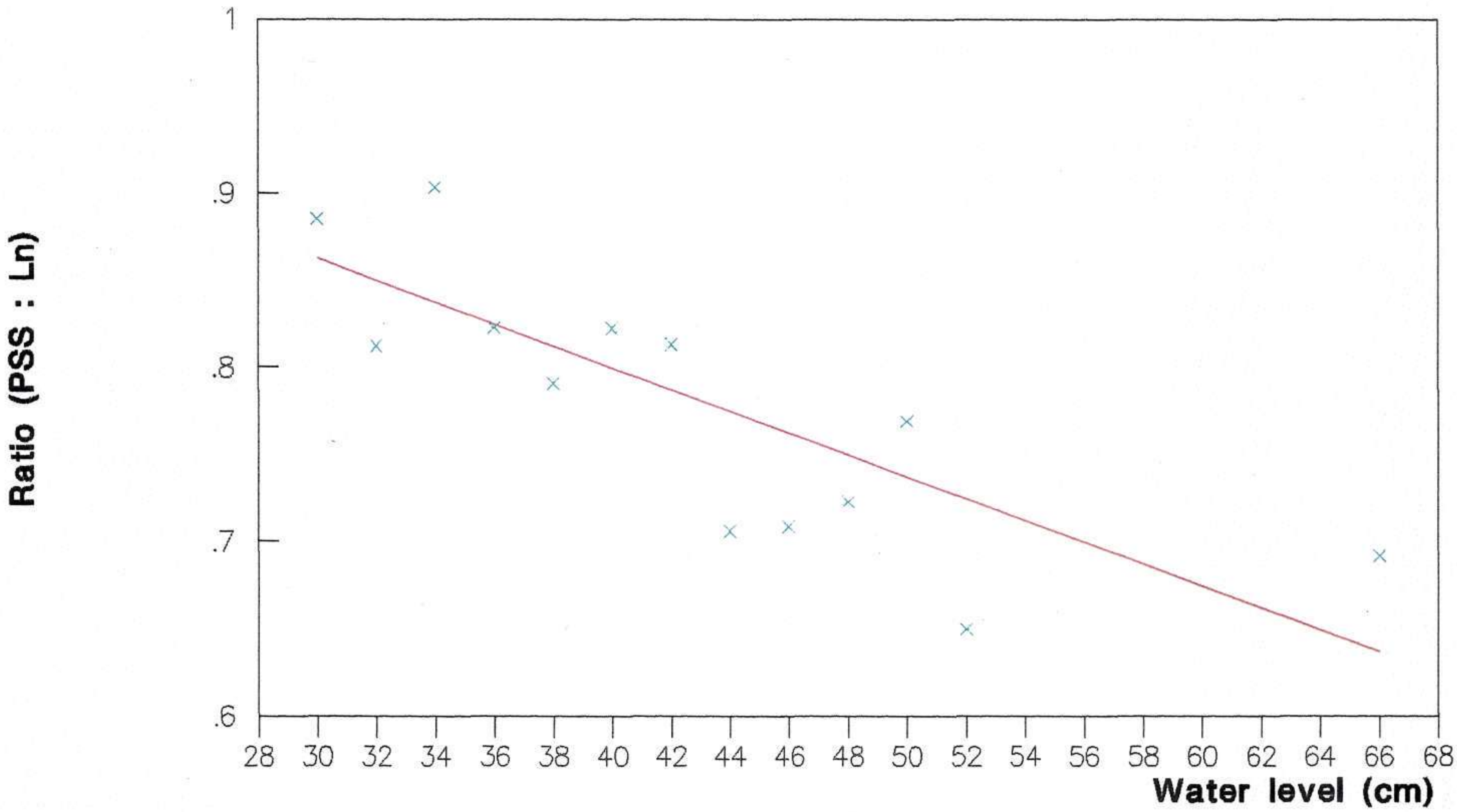
3.4 Swimming speed

Swimming speeds calculated from 'trace' data were verified by comparison with the number of video frames occupied by the event, and are illustrated in Figure 15. Analysis of variance indicated no significant difference ($P > 0.05$) in swimming speed (meters per second) between different length classes of salmonids. The mean swimming speed of the migrants was 1.55 ms^{-1} (+/- 0.057 ms^{-1} [calculated using 1.96 * standard error]). However, swimming speed expressed in terms of body lengths per second exhibited a significant negative curvilinear relationship (Figure 16).

$$LOG_{10}(BLS) = 2.07 - 0.93\ LOG_{10}(Ln) \qquad (R_{(adj)}{}^2 = 60.0)$$

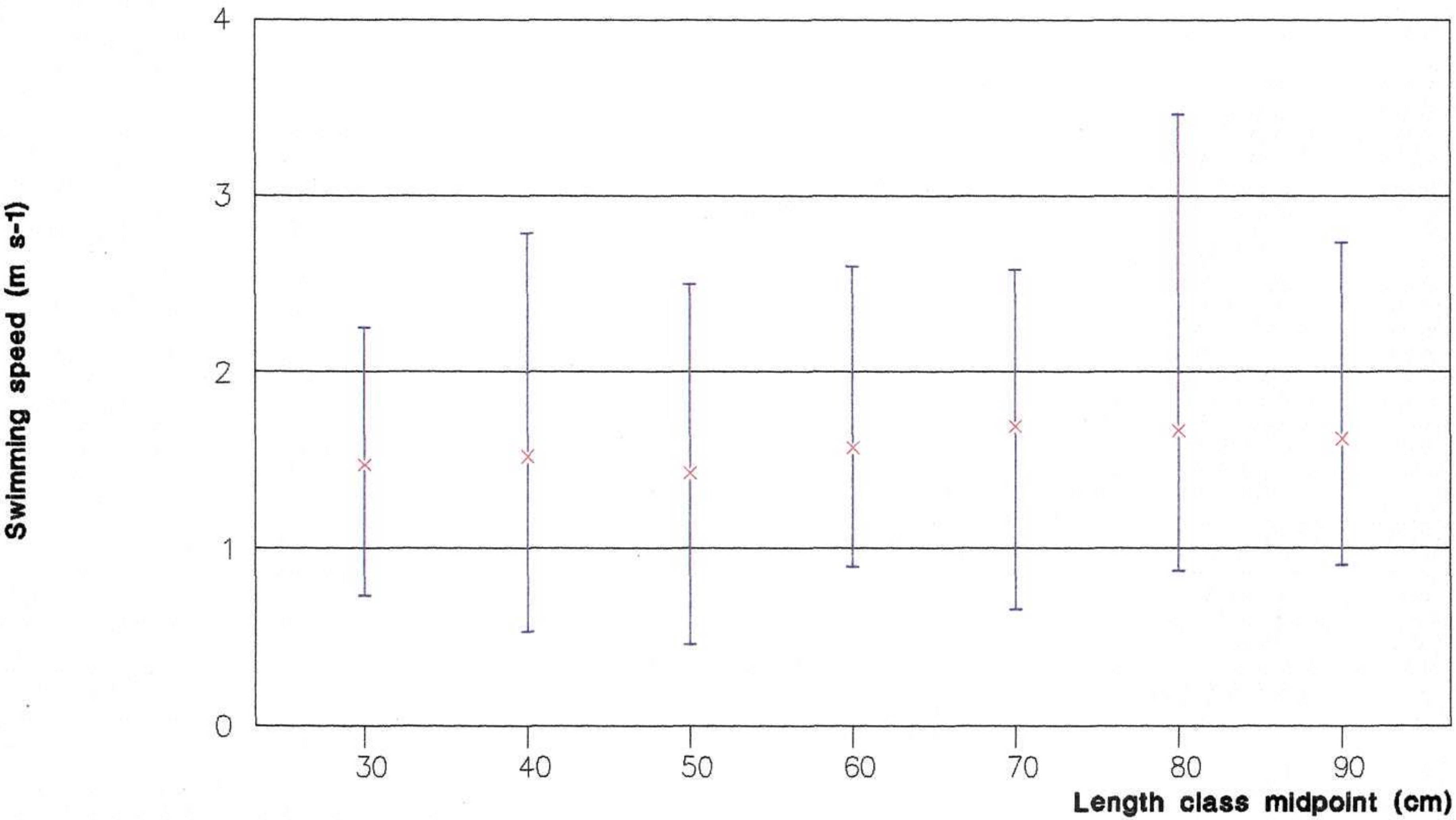
Where BLS = Body Lengths per second
Ln = Fish Length (cm).

Figure 14: Ratio of Signal Size:fish length related to water level
PSS:Ln = 1.05 - 0.00626(Wl)



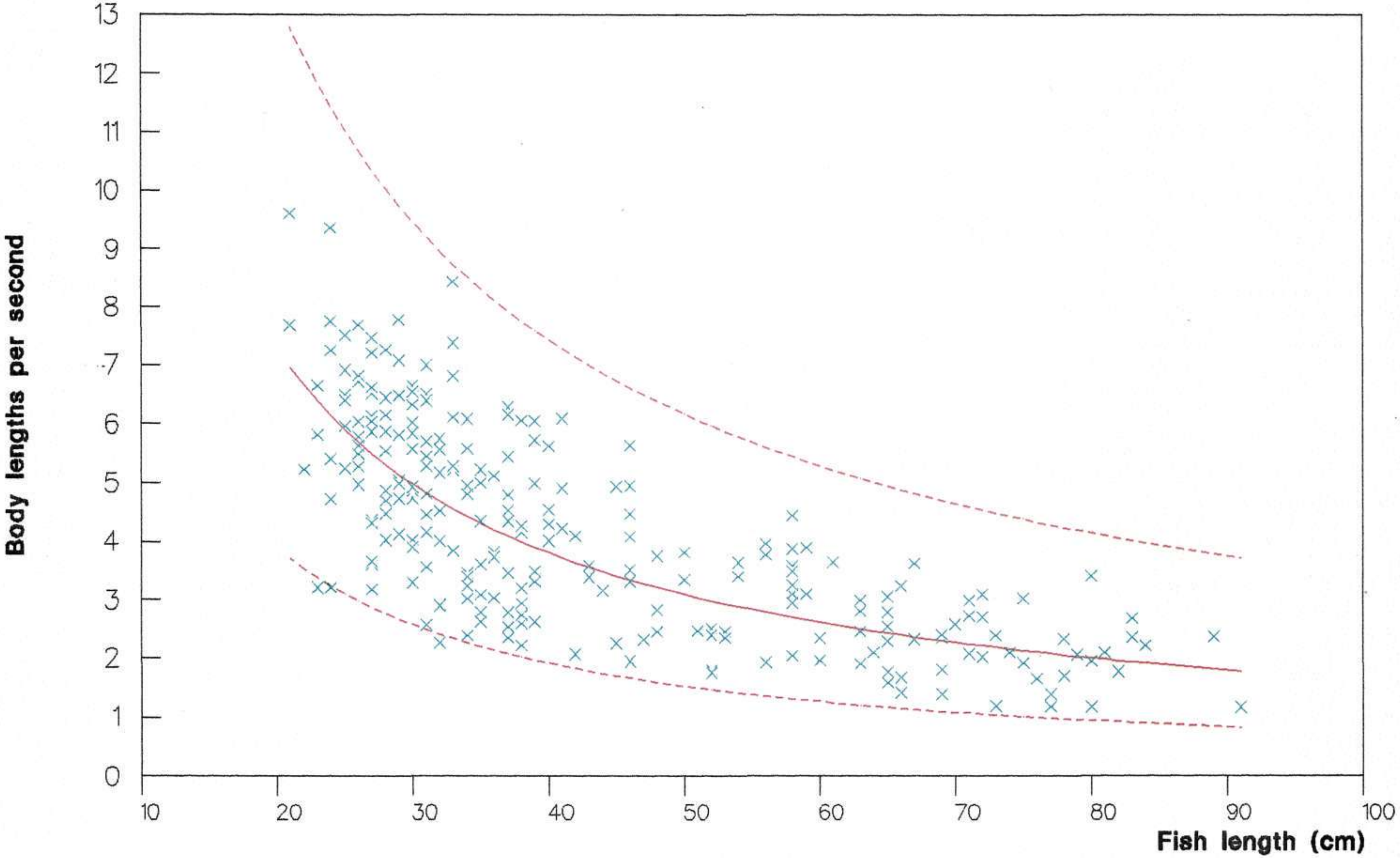
N.B. PSS = peak signal size: Ln = fish length (cm): Wl = water level (cm)

Figure 15: Mean swimming speeds of upstream migrants in relation to fish length.



N.B. Vertical bars denote range in swimming speed for fish length class

Figure 16: Swimming speed of upstream migrants in relation to fish length
LOG10(BLS) = 2.074 (+/- 0.1475) - (0.932 (+/- 0.0918) * LOG10(Ln))



N.B. LOG10 = Logarithm (base 10)
BLS = Body lengths per second: Ln = fish length (cm)
95% confidence limits are shown by broken lines

4. Discussion

Though a total of 2243 hours of video tape were taken 1091 hours of film proved unusable for validation purposes. Various technical problems occurred with peripheral devices used to prepare the video signal prior to recording giving rise to an unusable video record. Also the intensity of the illumination of the electrode array from the two 12 Volt D.C. infra-red lamps was found to be largely insufficient, particularly in spate conditions. As filming progressed through the summer and autumnal flow conditions ensued, it became necessary to incorporate a third lamp of the same specification as the other units into the apparatus. This improved the situation markedly, although, it was felt that the 240 Volt lamps used previously (Nicholson & Aprahamian, 1992) gave better image clarity.

An intermittently malfunctioning conductivity probe was found to produce unreliable conductivity data (lower than expected values) and as a result 21 consecutive days of validation data were removed from the data set. No warning of malfunction is provided with the LF or validation equipment and faults such as this are only detectable on initial analysis of collected data. Analysis of the video record collected at this time revealed that with a conductivity probe producing reduced conductivity readings, the number of 'no trace' events increased, counting efficiency decreased and signal size for a given fish length was reduced. In previous validation work Schofield (1988) suffered undetected faults with the actual fish counter circuitry and stated the operational necessity for error messages to be displayed to prevent the late detection of faults. In this case simple less than and greater than criteria are suggested.

The decline in counting efficiency for upstream migrants >65cm contrasts markedly with the findings in 1991 (Nicholson & Aprahamian, 1992). In 1991 the counting efficiency for these fish was in excess of 90%. This reduced efficiency is likely to reflect the change in the threshold setting from 20% to 10% resulting in greater influence of the 'bow wave' effect. This change in threshold setting is not likely to explain the increased counting efficiencies for fish <35cm migrating upstream, though it may have improved downstream counting efficiency. The number of downstream migrants encountered in this study were small, limiting the extent of analysis. Downstream fish migrations, in the lower reaches of the North Esk, have been observed to be much more prevalent in winter and early spring than at other times (Dunkley & Shearer, 1989) and as such, our seasonal filming activity may not be wholly appropriate for the collection of data on downstream migrants. The operation of the fish trap during November, did not increase the numbers of downstream migrants, contrary to our expectations.

Several upstream migrating fish (7) were observed to produce more than one count, which has not been observed in previous work at the Forge site. This may be due to the reduction in 'lag period' from 1.0 s to 0.5 s. The 'lag period' was originally built into the logic circuitry of the counter to prevent counting those fish which do not fully cross the electrode array (Dunkley & Shearer, 1982). Thus, a fish traversing the electrode array slowly, and erratically may produce a trace which extends over the 0.5 s 'lag period'. If the latter portion of the trace satisfies the criteria of the LF 'fish algorithm' a second count will be generated.

Three counts occurred with no fish visible on the video record, even though river conditions were favourable for filming. Similar 'spurious' counts have also been noted at Invermark (Dunkley & Shearer, 1982). At this stage, no explanation can be offered, though the 'traces', on visual examination, were not of a form envisaged appropriate to the fish algorithm, as a fish.

Downstream passing insulating materials were found to cause upstream counts on 3 isolated occasions, a phenomenon also reported by Dunkley & Shearer (1982) and Schofield (1988). These artifacts were distinguishable from genuine upstream events since all such instances were counted as large fish and related 'traces' did not possess a characteristic 'bow wave'. Quite unlike the 'trace' of a true upstream event of the same magnitude. Indeed, 'trace' data proved a valuable aid for event interpretation, particularly in difficult cases. Further, many small fish (<35cm) not counted, produced traces containing identifiable patterns, typical of a fish, although background noise presumably rendered these 'traces' inappropriate to the LF's fish algorithm. A fish algorithm based on frequency distribution analysis is suggested to improve detection of these identifiable patterns. However, such an algorithm would be unrealistic to incorporate into the logic circuitry of the LF because of the increased processing time, causing saturation of the LF's buffer at times of peak fish migration. Such a method could be office based, particularly since the LF now has the inbuilt ability to output 'trace' samples to intelligent floppy drives physically linked to the operating LF (R. Shaw pers. comm.).

At Invermark fish have been observed to circulate around the electrode array; following upstream movement over the electrodes, the fish migrate downstream before once again migrating upstream over the counter. Since downstream fish are more likely to escape detection than upstream fish an inflated upstream count may be likely where circulation occurs (Dunkley & Shearer, 1982). Fish circulation at invermark was identifiable since individual fish were distinguishable due to recognisable scars and fungal patches. No clear evidence of circulation was observed in this study, though the video record was (for the main part) too weak to gather relevant information. Recent tests on newly available camera equipment have shown that a shutter based system operating at 0.001 s will increase image quality (P. Best pers. comm.) and enable collection of this data, in order to assess any potential population overestimation. Such data could also be obtained through mark recapture or radio tagging exercises.

Downstream migrants were observed to descend the electrode array with the same behaviour as described by Dunkley & Shearer (1982), with the majority orientated tail first as they traversed the electrode array. Some fish were observed to break the water surface, which suggests that downstream migrants traverse the electrode array at a greater range of heights than upstream migrants. The large range in heights over the electrodes may be the reason why the peak signal size for a given fish length is lower for downstream migrating fish when compared to those migrating upstream.

From the investigations into the ability of the LF to accurately size fish it would appear that the LF adequately compensates for fluctuations in water conductivity, since the inclusion of water conductivity into multiple regression equations did not significantly improve the relationship. However, water level was an important variable. The relationship between discharge and water conductivity is not straight forward, water conductivity decreases with increasing discharge, though not instantaneously, there is a lag period dependant on the rate of increase in discharge. Similarly with declining discharge, the rate of increase in conductivity is invariably slower than the rate at which discharge declines, as such a range of water level values have been observed for a particular conductivity value (Dunkley & Shearer, 1982). Further, as water level increases a fish of given length will displace proportionately less water above the electrodes resulting in reduced signal sizes (Schofield, 1988). It therefore follows that if high water levels coincide with low water conductivities, the conductivity compensation may not be adequate in itself to compensate for the change in conditions and stocks may be underestimated in terms of their length frequency and, in the case of the smaller component of the stock (<35cm), their abundance.

Clearly, the sizing ability could be improved if water level compensation could be incorporated into the LF's logic circuitry. This would undoubtedly be worthwhile, particularly since the signal size and fish length regression models between years have been proven to be similar. In order for water level compensation to be incorporated more validation data is required, particularly at water levels ranging from 40cm to 70cm. Filming is already planned for the coming season.

The electrical insulation of the concrete wall of channel 1 was shown to improve the uniformity of signal sizes produced for a 33cm rainbow trout using the 'fish rig' (Appendix 1). Analysis of data from the video record would appear to support this finding, as no significant difference was recorded in signal size or fish length from a selected population of upstream migrants. The improvement in uniformity of signal sizes for a given length of fish across the electrode array could possibly account for the successful increase in counting efficiency (of fish of lengths 25cm to 35cm) from 15% (Nicholson & Aprahamian, 1992) to 67% in this study.

It was not possible to compare mean signal sizes generated with the 'fish rig' with those generated from real data because of the small size of the relevant fish rig data (2 fish). However it is worthy of note that the fish rig fitted with a 33cm rainbow trout appears to generate a larger signal size than a 33cm sea trout (taken from the video record) which could be attributable to the fact that rainbow trout are generally heavier than a sea trout of the same length. Therefore the use of a rainbow trout may not be wholly appropriate if extrapolating the fish length:signal size relationship to that for migrating salmonids.

5. Conclusions

1. At a downstream threshold setting of 10% the 'bow wave' effect seriously impairs the ability of the LF to interpret signals generated by upstream migrating fish >65cm in length.

2. The 'look-up' tables used by the LF to adjust the gain for peak signal size with respect to water conductivity are functioning correctly, and fluctuations in water conductivity are adequately compensated for.

3. The LF is not fully compensating for the change in bulk resistance with water level, and the signal size produced for a given length of fish decreases with increasing water level, resulting in an underestimation of fish size and, in the case of smaller size classes (<35cm), their abundance.

4. No significant differences between peak signal size and fish length were noted across the electrode array, thus the electrical insulation of both the wall and window sides of the pass appear to be successful.

5. No significant differences were found between the swimming speeds of different length classes of upstream migrating salmonids. The average swimming speeds of salmonids in the length range 30 to 90cm was found to be 1.55 $m\ s^{-1}$.

6. Larger upstream migrating sea trout and salmon (<40cm) traverse the electrode array with lesser energetic expenditure than their smaller counterparts.

6. Recommendations

1. To continue with the assessment of the performance of the LF and it's sizing capability under different environmental conditions, particularly flow.

2. At other fish counting sites using the fish algorithm (version 8.6 17/04/92) the downstream threshold setting should be increased to cope with the 'bow wave' problem.

3. Signal strength uniformity should be investigated at other fish counter sites using the fish rig, and electrical insulation of the pass walls should be fitted where appropriate.

4. To inform Aquantic of the need to have water level compensation built into the logic circuitry of the LF to improve length estimates and prevent the occurrence of 'no trace' events at times of high flow and low conductivity.

7. Acknowledgements

Many thanks to Heidi Rhodes for her tireless efforts in data aquisition. To Phil Best, Ron Shaw and Chris Addis for technical work. To Martin Brown, Don McCubbin and Geoff Burton and the South Cumbria fisheries staff for their assistance, advice and tolerance.

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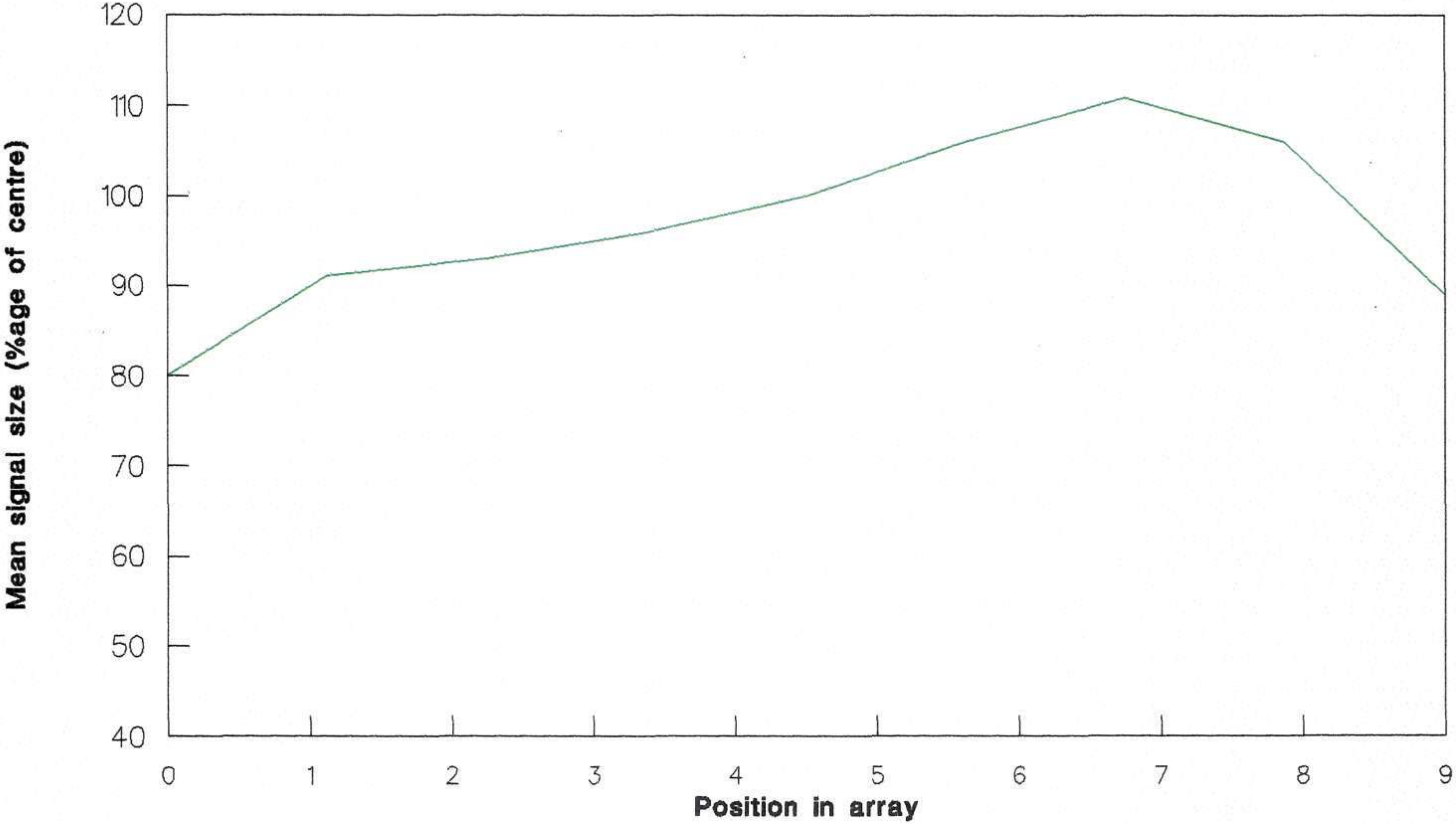
Appendix 1

Investigation into the performance across the electrode array using the 'fish rig'.

		Fish length (cm)								
		33			33			59		
		PSS replicate			PSS replicate			PSS replicate		
	Transect	1	2	3	1	2	3	1	2	3
window	0	34	31	28	32	34	40	98	97	92
	1	*	*	*	*	*	*	*	*	*
	2	31	30	31	40	44	38	*	*	*
	3	44	33	38	45	41	41	102	109	109
	4	37	38	31	40	45	45	103	99	90
	5	36	34	37	46	45	44	121	119	118
	6	33	45	37	49	44	30	121	119	126
	7	42	43	40	54	49	46	110	122	122
	8	45	39	42	61	40	43	116	109	116
wall	9	43	36	34	41	41	38	98	103	90

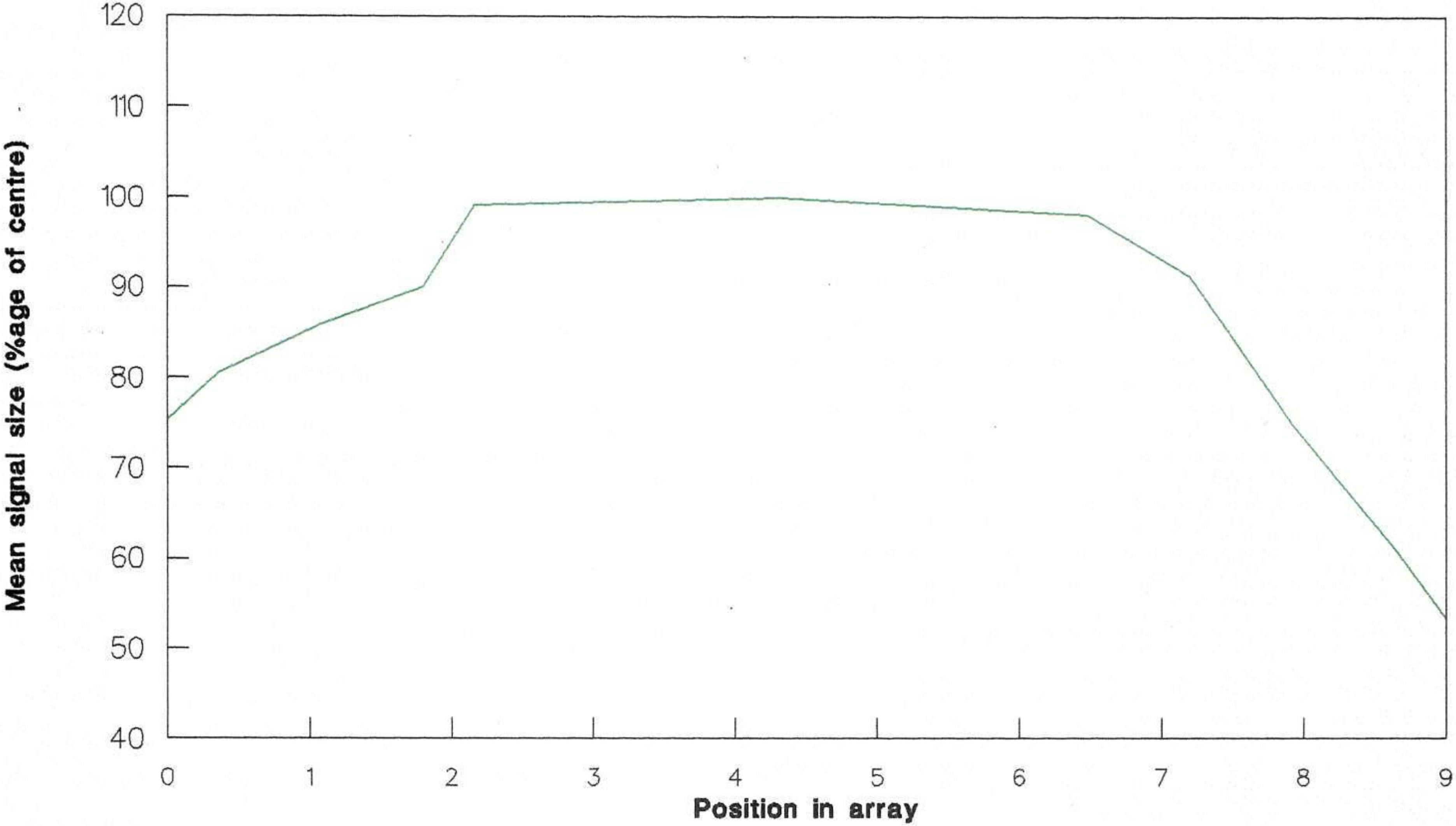
N.B. Fish of 33cm were of the species <u>Onchorynchus mykiss</u>. The 59cm fish was <u>Salmo salar</u>.
* = no data, PSS = Peak signl size.

Appendix 1: Figure B: Mean signal sizes generated using the fish rig at different positions across the electrode array, expressed as a percentage of the mean signal size generated at the centre of the array.
(After electrical insulation).



N.B. Positions in array correspond to positions documented in Table 1.
where 0 = window (extreme left hand side of channel)
and 9 = wall (extreme right left hand side of channel).

Appendix 1: Figure A: Mean signal sizes generated using the fish rig at different positions across the electrode array, expressed as a percentage of the mean signal size generated at the centre of the array.
(Before electrical insulation).



N.B. Positions in array correspond to positions documented in Table 1.
where 0 = window (extreme right hand side of channel)
and 9 = wall (extreme right left hand side of channel).

Appendix 2: Area Fish Counter Work

YEARL COUNTER 1992

Yearl counter on the Derwent at Workington, Cumbria.

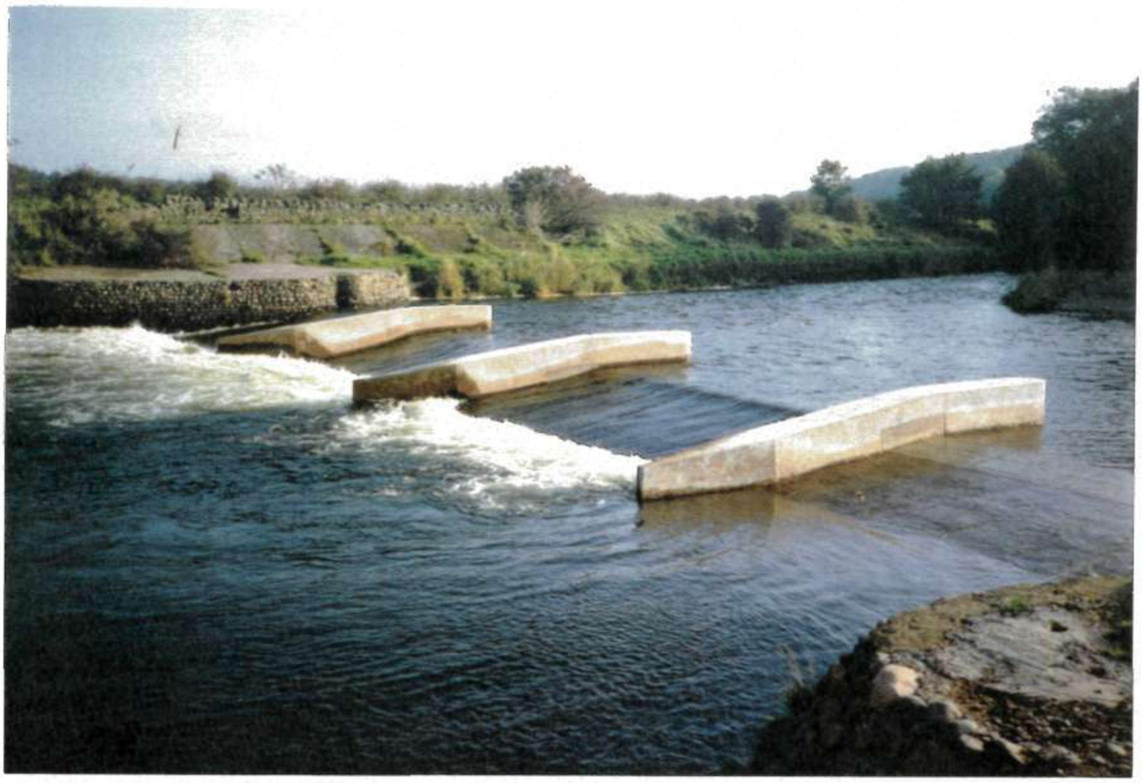
Due to various problems Yearl counter weir required modification and this work was undertaken in 1992.

The counter weir had problems which included electrical leakage and fish jumping the weir especially at higher flows. More channels were also required to cope with the flow variation and cutwaters were needed to increase operational effectiveness.

Work started on 01/06/92 and the in-river works were completed on 01/07/92. The electronics were installed by 20/08/92 and the counter was operational under trial for the remainder of the year. Further modifications to the electronics were carried out during November 1992.

In 1993 the counter will continue to operate under trial and will be subjected to validation work (including filming) and calibration work before becoming operational.

J. Atkins
25/02/93



FORGE WEIR FISH COUNTER - R.Lune

General Assessment

The counter had operational problems in 1991 due to the construction of the British Gas pipeline just upstream of the site. In 1992 less problems were experienced, although several lightning strikes caused channel failures, but over a short time period.

Specific Problems

Fish rigg work carried out in 1992 highlighted a problem with leakage of electrical current into the concrete walls at the sides of counter channel 1. This was over come by adding a sheet of perspex along the concrete wall adjacent to the counter.

Further problems were experienced with false counts when the fish trap upstream of channel 1 was in operation. This was put down to turbulent water conditions and the varying water levels as a result of the use of stop boards to reduce flows for fish trap work.

Channels 3 & 4 (centre weir) experienced problems with water lapping over the crests during low flows and strong winds. This resulted in large numbers of false counts. These were however easily edited out, as they were equal in number (ups and downs) and size of counts.

BROADRAINE FISH COUNTER. R. Lune

General Assessment

The counter generally worked well. Some incidents of false counts occurred when a standing wave formed immediately downstream of the counter, but an alteration in the stop boards in the channel downstream of the counter removed this problem. The counter was put out of action by lightning on a number of occasions.

Specific Problems.

There were comments from Bailiffs that when the fish trap was operated upstream of the counter, large numbers of fish were recorded but not found in the trap. Video validation work was undertaken, and whilst only partially complete has shown that as the flow in the channel is reduced to net trapped fish, false counts are generated.

Video tapes also showed a number of fish ascending the pass, but descending a few minutes latter. It is possible that this is in response to finding the trap inscales.

Further video validation work when the trap is not in operation would seem advisable.

BASSINGHYLL FISH COUNTER. R.Kent

General Assessment.

Bassinghyll was perhaps the most reliable counter with only a few down periods, mainly due to lightning strikes. False counts occur on channel 2 and 3 when levels fall, due to wave action, but these are easily removed.

Specific problems.

Electrical leakage is occurring into the concrete edges of channels 1 and 4 (deep channels). This was found during routine fish rigg calibration work. As yet no remedial action has been taken but this will be followed up.

As no cutwaters were built at Bassinghyll, re are water levels when water dropping from channel 2 onto 1 and 3 onto 4 cause false counts. These are generally easy to spot. Cutwaters were costed up, but funds are as yet unavailable to undertake the work.

BACKBARROW COUNTER. R.Leven

General Assessment.

Backbarrow counter has worked reasonably well in 1992. There were three periods of inoperation due to lightning strikes the longest being about one week.

Specific Problems.

The only problem experienced is that of low water levels causing water to lap over channels 3 and 4 (and very occasionally 1). This whilst a nuisance is easy to rectify in editing data.

At one stage in June the water level was so low, the conductivity and level probe were out of the water. This resulted in many false counts, and a method of overcoming this is being sought.

CENTRAL AREA FISH COUNTERS.

1. Waddow Weir.

The fish pass and counter at Waddow were re-built in 1992 with a trapping facility incorporated in the new structure. Initially problems were encountered with flow rates in the counter channel. These have now been solved by adjusting the water depth in the first pool of the fish pass below the counter. The counter is now fully operational and counter validation and fine tuning of the new pass to optimise counter accuracy will take place in 1993.

2. Winkley Hall.

The fish counter at Winkley Hall was replaced with a new Logie Counter in 1992. The new counter is already proving to be an improvement over the older equipment and the problem of high numbers of false counts which used to exist at this site seems to have been solved.

3. Locks Weir.

A Logie counter was installed at Locks Weir in 1992. The new counter is continuing to generate false counts from turbulence at both high and extreem low flows . This problem is to be addressed through structural alterations to the pass in 1993. In general this site is continuing to provide good quality data but validation needs to be carried out.

4. Garstang.

The counter at Grastang has major problems with false counts which are associated with the design of the counter strip. Only a very limited data set was generated at this site in 1992 as a result of these problems. The counter only functions at certain high flow levels and the accuracy of the counter is in doubt even when it is functioning. There are no plans to invest resources in solving the problems at this site until the problems at the other three sites have been addressed.