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## South West Region.

# A preliminary assessment of the ability of Restormel fish counter to enumerate the passage of migratory salmonids on the River Fowey.

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**September 1998.**

# Table of Contents.

## A preliminary assessment of the ability of Restormel fish counter to enumerate the passage of migratory salmonids on the River Fowey.

### 1. Aim.

The following report presents the results of the validation study performed on Restormel fish counter (SX 107 613) in 1997. The aim of this work was to assess the counter's ability to accurately count migrating adult salmon (***Salmo salar, L***) and sea trout (***Salmo trutta, L***) and establish a means by which to distinguish between the two species. The validation of Restormel fish counter is necessary for three principle reasons: -

- To obtain an estimate of the counter's current and historical operating efficiency that will enable accurate interpretation of counter data collected over the last four years.
- To enable modifications, if necessary, to the current operational set-up of the counter to improve the level of counting efficiency.
- To provide an independent, accurate assessment of the salmon and sea trout runs on the River Fowey to support fishery management decisions.

### 2. Introduction.

The current fish counter at Restormel was installed in 1994 following the purchase of a Logie 2100 A resistivity based fish counter manufactured by Aquantic Ltd. This form of counter is at present only used on a few selected salmonid rivers throughout England, Wales and Scotland. The counter at Restormel is the second resistivity based counter system to be operated by the Cornwall Area fisheries science team. The other counter is located on the River Tamar at Gunnislake.

The Logie 2100 A counter has proven to be reliable and efficiencies at counting salmonids have been reported to approach 100% for fish greater than 45 cm in length. The counter is therefore capable of providing a fully independent, accurate assessment of migratory salmonid runs.

In 1997, the requirement for a quantitative assessment of the counter's efficiency (validation) using CCTV cameras and infrared lighting systems was established. This equipment would enable 24 hour non-intrusive monitoring of the passage of migratory salmonids ascending Restormel weir. The subsequent comparison of video data to the counter's output will enable the determination of counter efficiency. In addition, this will consequently assist in establishing a means by which to partition the migratory salmonid counts between salmon and sea trout.

The results of the 1997 validation study can be used in the interpretation of counter data collected since 1995. In 1994, an electrical fault resulted in the collection of only a limited amount of data. The monthly summary data obtained from the counter for the years 1995, 1996, 1997 and 1998 are presented in Appendix (2).

## 3.0 Restormel fish counter validation methodology.

The means of operation of the resistivity fish counter at Restormel is described in Appendix (1)

The River Fowey at Restormel has a total width of 17 metres and the gauging weir at this point is divided into 3 separate channels. The two side channels (Channels 2 and 3) both have a width of 6.5 metres. The centre channel (Channel 1) has a width of 3.5 metres.

Following a preliminary review of historical counter data, it was apparent that channel 1 recorded the highest number of upstream counts, especially under low flow conditions. It was therefore considered that the validation of data collected from this channel was of the highest priority. This was to be undertaken using a high quality, light sensitive CCTV camera system and infrared lights.

The additional width of channels 2 and 3 made it necessary to install wide-angle CCTV cameras for validation purposes. In the absence of infrared lighting, video data was only available during daylight hours on these channels. Analysis of historic data indicated that the side channels were infrequently used by migratory salmonids. However, it was still considered necessary to attempt to investigate their operating efficiency.

Owing to the overall width of the river at Restormel and the potential for high river flows (2.9 metres in 1979), careful design of the structure to support the validation equipment was necessary. Following the approval and subsequent installation of the validation gantry, video cameras were positioned over the weir in June 1997.

The intention of the validation was to gather the maximum amount of fish passage video data and to compare this to the fish counter data output. Video footage for each channel was recorded using a time lapse video recorder in recording modes ranging from 6 to 48 hours. It was considered that the 24-hour mode provided the best practical compromise between the collection of sufficient data for each fish ascending the weir and the volume of video material collected per visit to the site. Infrared lights were installed in mid July and this enabled the passage of fish to be monitored in complete darkness on channel 1.

Video footage was collected from 1 July 1997 until 31 December 1997. It was considered important to gather information on fish passage under as wide a range of flows as possible. However, under high and prolonged spate events, this was not always possible owing to excessive water turbidity. This proved to be the case in the autumn and early winter of 1997.

Video footage collected during the study was reviewed manually. Migrating fish were identified (where possible) and the date, time of fish passage and screen length measurements (tip of snout to tip of tail) recorded. Screen measurements required correction for CCTV camera parallax error and image distortion. The calculation of a suitable calibrated conversion ratio (Nicholson et al, 1995) enabled these lengths to be converted into a "real" length measurement. The distortion to the video image by the wide-angle cameras positioned over the side channels prevented the accurate collection of fish measurement data. However some indication of size was provided by classifying observed fish as either brown trout, sea trout or salmon / sea trout (> 45 cm). In addition to migratory salmonid passage events, other notable objects observed traversing the electrode array were recorded. These events included tree branches, unidentifiable debris, non-salmonid fish (Eels) and Otters. The occurrence of these latter events and their impact upon the salmonid count has been discussed.

Following the initial review of the video data, an audit was performed to ensure that all fish present on the videotapes had been recorded and processed. This identified that very few fish had been missed and enabled a high level of confidence to be placed on this data.

All of the objects recorded from the video analysis, including their time of passage and where possible, length measurements, were entered onto an MS Excel spreadsheet for data processing.

A comparison was made between video data and the fish counter data output. Fish and other objects that are detected by the counter are registered as either upstream (U), downstream (D) or as a non-directional event (E). For each of these occurrences there is also an associated counter deflection signal recorded. The magnitude of this signal is related to fish length. Fish that were present on the video data but absent on the counter output were recorded as missed on the validation summary spreadsheet.

The comparison of the video and counter data was used to identify the following: -

- The efficiency of the counter in enumerating the different size classes of fish observed ascending the river Fowey at Restormel.
- The relationship that exists between fish length and counter deflection signal size.
- Required improvement in the counters operation.

## 4.0 Results.

A summary of the counter and video data recorded for upstream migrating fish observed on Channel 1 in 1997 is summarised in Table 1 (Appendix 2). The corresponding data observed for downstream migrating fish is presented in Table 2 (Appendix 2).

This data has been presented as the number of fish recorded in various size (length) classes. This has been further subdivided between those fish that were assigned by the counter as being an upstream fish (U), fish "events" without direction (E) or missed. In addition, those upstream fish that ascended the weir face together (a simultaneous passage event) have been separated on the basis of whether they were recorded by the counter as being a non-directional event, an upstream fish or missed. None of the downstream fish movements observed were simultaneous.

In total, 871 upstream migrating salmonids were recorded ascending Channel 1 of Restormel weir on 680 hours of video data covering 109 days. 33 downstream fish passage events were observed during the same period.

Tables 3 and 4 (Appendix 2) summarise the data collected from channels 2 and 3 respectively. The use of wide-angle cameras prevented the accurate collection of specific length measurements on these channels. However, some indication of fish size has been provided in the identification (based upon comparative fish length) of the fish species concerned.

In total 22 migratory salmonids were recorded ascending channels 2 and 3 from 62 and 281 hours of video footage respectively. All of the observed fish were upstream movements with only 1 eel observed moving downstream. The low numbers of fish recorded on the side channels reflect their low usage by salmonids and the fact that infra red lighting was not used to monitor passage in darkness.

All fish that were observed migrating upstream and that were detected by the counter were assigned as either an upstream fish or as a non-directional event. The validation of Channel 1 did not identify any occurrences of false event counting. This was however not found to be the case on channels 2 and 3.

The data presented in Tables 1, 2, 3 and 4 (Appendix 2) have been used to estimate the current and historic level of efficiency of the counter in enumerating the passage of migratory salmonids. The results have been used to highlight areas of potential improvement in counter operation.

Fish that were recorded as upstream or downstream movements by the counter and for which length measurements were available have been used to establish the relationship that exists between counter deflection size and fish length. The results of this analysis are presented graphically in Figures 1 and 2 respectively.

**5.0 Discussion.**

**5.1 Efficiency of the counter for upstream fish of less than 45 cm on Channel 1.**

The majority of upstream migrating fish observed (818 / 871) were school sea trout in the size range of 26 to 45 cm. The density of fish in July was such that on 129 occasions two or more fish (upto 5) were observed ascending the weir at any one time. This involved a total of 303 fish, which had a length of less than 45 cm. Nicholson et al (1995) state that simultaneous fish passage events should be removed from validation efficiency calculations as the counter is essentially designed to count single fish passage events. The counter has a requirement for a two-second delay between fish events in order to process the electrical signals received. It is therefore apparent that simultaneous fish events have the potential to inflate the number of fish that are missed by the counter.

Excluding simultaneous fish from the calculation, the counter's efficiency for fish ***of less than*** 45 cm was determined to be: -

- Fish detected as "Upstream" (U) by the counter - 36.7%.
- Fish detected as an "Event" (E) by the counter- 23.2%.
- Fish missed – 40.1%.

The observed lack of efficiency for fish less than 45 cm may be related to the following factors: -

- The electrical signal obtained by the counter as the fish ascended the weir was below the pre-set threshold.
- The swimming velocity of the fish was erratic and as such confused the counter's ability to determine a "real" fish passage event.
- The spacing of the electrode array is too great (maximum of 45 cm) to enable an adequate electrical signal to be generated by smaller fish.
- The height of fish swimming over the electrodes. The higher fish swim over the electrodes the lower the electrical signal received by the counter.
- Counter operating set up (Conductivity gain table settings).
- The high number of multiple (simultaneous) fish passage events.

Reduced efficiency for smaller fish has been observed on other resistivity counters and this reflects the counter's main requirement to accurately enumerate the passage of salmon and not sea trout. It may however be possible to correct or improve the current situation through discussion with the systems manufacturer.

In the short term, a better estimate of the sea trout count can be obtained by using the non-directional fish "events" as a means of detecting fish passage. Analysis of the July fish counter data identified that close to 100% of the non-directional "events" with a deflection of less than 40 on channel 1 could be attributed to an upstream moving sea trout. Therefore, by using these events in addition to the upstream count, the efficiency for detecting sea trout passage (based upon 1997 video data and counter data including simultaneous fish) was found to be 59.9%. Events registered by the counter that generated a deflection greater than 40 could generally be related to unsuccessful ascent attempts by larger fish or downstream moving Otters

### 5.2 Counter efficiency for upstream fish greater than 45 cm on Channel 1.

Counter efficiency for fish in excess of 45 cm was determined to be 90% and indicates that without further modification the counter is capable of providing an accurate assessment of large sea trout and salmon runs. Only 1 fish greater than 45 cm was associated with a simultaneous passage event. Other validation studies (Nicholson et al, 1995) have shown a similar level of efficiency for fish in excess of 45 cm. This result was encouraging considering the wide range of flows encountered at the site in 1997.

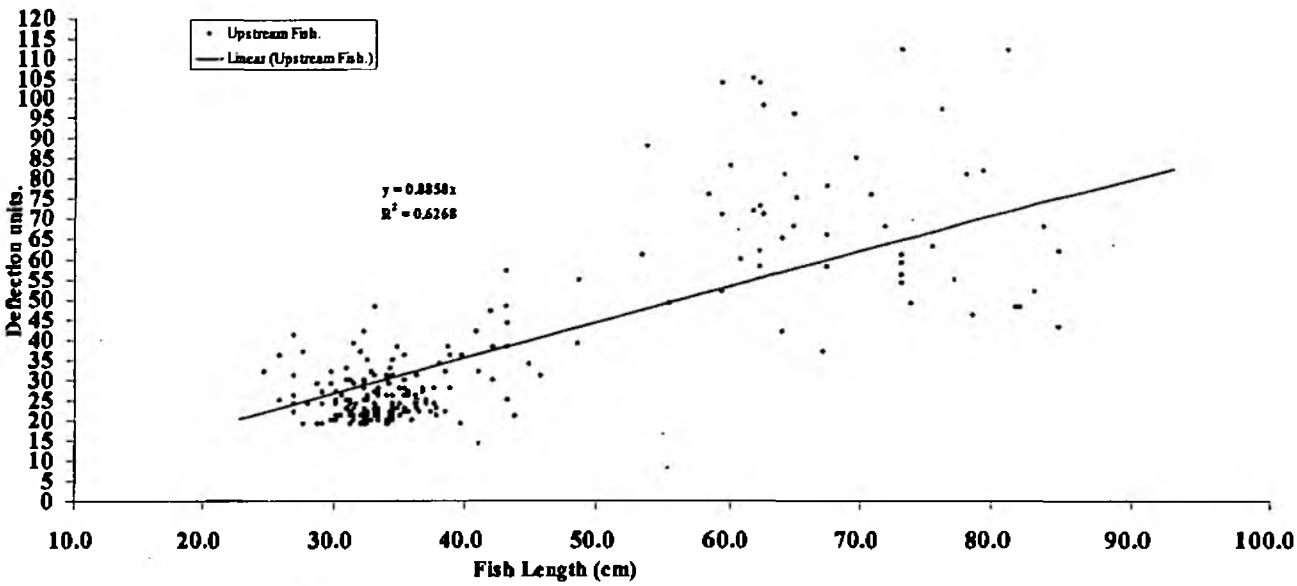
### 5.3 Relationship between upstream fish length and counter deflection strength on Channel 1.

The relationship that exists between fish size and deflection strength is presented in Figure 1. The graph indicates that a statistically significant linear relationship ($R^2 = 0.657$, $t = 21.41$, $P < 0.0001$) exists between fish length and counter signal output.

A deflection of 50 would appear to effectively differentiate between the majority of salmon and sea trout although there is still some evidence of overlap in both directions. Of the 50 fish recorded that were in excess of 50 cm, 44 (88%) attained a deflection in excess of 50.

The counter is therefore capable of distinguishing between fish on the basis of body length. However, a large sea trout with a comparable length to that of a salmon will still attain a similar deflection, i.e. in excess of 50. However, at present there is no better method to distinguish between salmon and sea trout.

**Figure (2) Relationship between fish length and deflection size for upstream fish at Restormel Weir.**




Rod catches provide a means to identify the run pattern of large sea trout and salmon. Data from the past few years indicates that larger sea trout run into the river from the end of April until the end of June, with only a small number of larger sea trout ascending the river from July. Therefore, to eliminate as many sea trout from the salmon count in the period April to June, a deflection of 70 would serve to select only the largest sea trout or salmon. For the rest of the year, when there were only small sea trout migrating, a deflection of 50 would serve to select specifically for salmon.

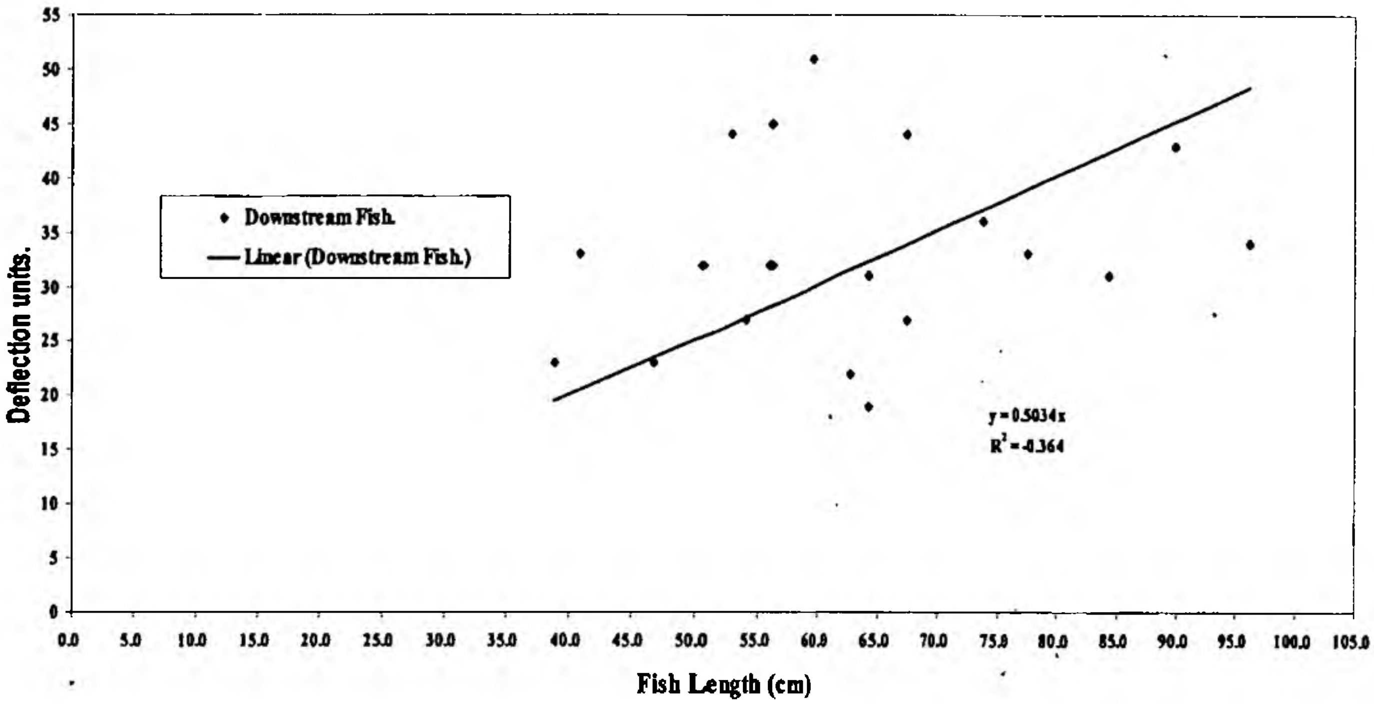
### 5.4 Counter efficiency for downstream migrating fish on Channel 1.

The efficiency of the counter at detecting the passage of downstream moving fish observed on channel 1 is presented in Table 2. This indicates that the counter was 64% efficient at detecting all downstream fish. As observed for upstream fish, the efficiency of detection increases for larger fish and the efficiency for fish greater than 45 cm was 76%.

Figure (2) presents the relationship that exists between the length of downstream moving fish and counter deflection size. Regression analysis indicates that this relationship is not significant ($R^2 = 0.064$, $t = 1.14$, $P > 0.20$). This result may reflect the fact that downstream migrating fish are not actively swimming against the flow and are therefore not forced to swim in close proximity to the electrode array. This will have the net effect of reducing deflection size for any given size of fish.

The results indicate the potential difficulties of providing a net upstream movement of salmonids at Restormel based upon upstream and downstream counts. This is clearly not practical and, would tend to be further confused by downstream migrating sea trout kelts when salmon were still entering the river to spawn in December and January.

**Figure (2) Relationship between fish length and deflection size for downstream migrating fish – Channel 1.**




**5.5 Use of Channels 2 and 3 at Restormel weir by migratory salmonids.**

It is apparent that in the summer months under low flow conditions, the volume of water passing over the side channels will not support migratory salmonid movements. On 11 August, which coincided with a flow of 1.104 Cumecs, sea trout were actively seen jumping at the weir face of channel 2 but were unable to fully ascend the weir. Sambrook (1978), following trials of a fish counting system, identified that a minimum flow of 1.16 cumecs, which equated to a depth of approximately 5-cm over the weir crest, was required by migratory salmonids to successfully ascend the side channels.

In addition to low flows impacting upon upstream salmonid migration on channel 2, video and counter data identified that under low flows channel 2 is subject to counting non-fish related events which is typified by counter deflections typically ranging from 15 to 30. When this occurs false event counts can be found to extend for several hours at a time with each count separated by only 2 or 3 seconds. Analysis of video data identified that this was due to the action of water running at a low depth over the face of the weir. Adjustment for this false counting may be possible by altering the counter's set up and will be discussed with the system's manufacturer. Channel 3 is prone to the same problem although on a less regular basis.

The impact of false counting due to low flows on the side channels could occur at any time of the year when suitably low flows are present. Analysis of the 1997 video and counter data identified that these false counts could be excluded from the side channel salmonid count by only selecting counter deflection signals in excess of 30. It is inevitable that the analysis of data in this manner may remove some sea trout from the count for the side channels. However, this loss can be considered to be minimal in terms of the numbers of sea trout that ascend channel 1 and the potential impact of leaving the false data within the count. The application of this data filtering will have no impact upon the count for salmon. Further work using flow data may enable the establishment of a data handling protocol whereby filtering of side channel data is only initiated when the flow level falls below a certain point.

It was evident that at the end of August 1997, flows began to increase and the occurrence of false event counting on the side channels diminished. The 1997 counter and video data indicated that salmonids used channel 1 almost exclusively at times of low to medium flow. However, under higher flow conditions, they increasingly use the side channels for migration purposes. This was particularly evident in the high flows experienced in November and December 1997. Sea trout were still observed to be ascending the river at this time although in very low numbers.

Tables 3 and 4 provide a summary of the fish movements recorded on Channels 2 and 3 respectively.

Only two salmon were observed ascending Channel 2 under elevated flow conditions. Both of these fish were detected as upstream movements by the counter and each of the counter deflection signals generated were in excess of 50.

On channel 3, a total of 20 fish were observed ascending the weir face. 6 of these fish were small brown trout, which were not detected. 11 sea trout sized fish were observed and of these, four were detected as upstream fish by the counter. This resulted in an efficiency for these fish of 36.6%. 2 salmon were observed both of which were detected as upstream movements. This provided a level of efficiency of 100% for these fish.

On each of the side channels the deflection obtained from each upstream fish enabled them to be correctly categorised between salmon and sea trout. However, a larger sample of fish is required to enable a high level of statistical confidence to be placed in this assessment. At present it would appear that channels 2 and 3 share a similar working efficiency to that of channel 1.

**5.6 The impact of non-salmonid fish events on the interpretation of counter output.**

All of the fish observed migrating upstream at Restormel weir were identified as migratory salmonids. Following heavy rainfall in October and November, 3 Eels were observed migrating downstream. Only one of these fish was recorded as a downstream fish with the other two registering as a non-directional event. All inert debris observed passing downstream (which included tree branches) was not detected by the counter.

The greatest potential impact upon the counter's performance from non-fish passage was found to be due to Otters. It was apparent from video observations that a regularly used Holt is located within the near vicinity of the Weir. In total, Otters were recorded on 11 occasions using both Channels 1 and 3. They were never observed using Channel 2 (the channel nearest to the water treatment works). Channel 1 was used by Otters for downstream movement only with channel 3 being used in both directions. The upstream or downstream movement of an Otter over the electrode array never produced an upstream or downstream count but a non-directional event. The size of the associated deflection varied although on 9 (82%) occasions it was found to be in excess of 40. It is apparent that the presence of Otters at Restormel is unlikely to have a significant impact upon the migratory salmonid count if "upstream" counts are used. The potential for error therefore exists if "events" are used to increase the detection efficiency of sea trout. However, as only events with a deflection of less than 40 would be selected in the period of maximum sea trout movement (June / July) the impact on the count data is likely to be minimal.

### 5.7. Historical River Fowey migratory salmonid count data.

The results of the 1997 validation study have been used to assist in the interpretation of Restormel fish counter data collected since 1995.

The validation of Channel 1 indicated that upstream counts recorded by the fish counter can be attributed to actual fish passage events. The counter detected 90% of migratory salmonids that were in excess of 45 cm in length. The counter data can therefore be considered to be accurate in assessing the upstream migration of these fish.

The validation identified that 36% of sea trout (the majority of which were under 36 cm) were detected by the counter as an upstream fish. This must be borne in mind when interpreting the counter data provided.

Preliminary assessment of the efficiency of channels 2 and 3 identified that they are subject to false event counting at times of low flows. Analysis of video and counter data identified that the false counts could be eliminated from the migratory salmonid count by only selecting deflections in excess of 30. This may result in the loss of some sea trout count data. However, this loss is offset by the following factors: -

- The lack of sea trout using these channels in the summer months for migration purposes.

- The potential size of the over counting error by including false upstream counts within the data.

The sea trout count will currently only provide a minimum estimate of the sea trout run on the river Fowey owing to the current inefficiency for fish less than 45 cm in length and the data filtering protocol for the side channels.

The 1997 validation of Restormel fish counter has identified the relationship that exists between counter deflection signal size and fish length. It is therefore apparent that a sea trout with a comparable length to that of a salmon will attain a similar deflection signal.

A counter deflection size of 50 has been identified as being capable of separating the majority of salmon and sea trout on the River Fowey (88% of all fish greater than 50 cm attained a counter deflection greater than 50). However, in April, May and June a large number of salmon sized sea trout are known to enter the river. An attempt has therefore been made to exclude these fish from the salmon count through the selection of deflections in excess of 70 within the period March to June. At all other times a deflection of 50 has been applied so as to separate salmon and sea trout.

**5.7.1 Salmon / large Sea trout counts recorded on the river Fowey - 1995 to 1998.**

Figure 3 presents the salmon counts obtained between January 1995 and September 1998. This has been based upon the division of counter deflection signals recorded as described above.

Despite the selection of deflections in excess of 70 in March, April, May and June, it is apparent that very good numbers of salmon sized fish are migrating into the river at this time. Although unproven, it is very likely that the majority of these fish are in fact large sea trout. Both rod and net catch data and anecdotal evidence support this. The counter data indicates that there has been a general increase in the numbers of these fish over the last four years, particularly in June. The lower numbers of fish recorded in 1995 may reflect the fact that this was a drought year.

Salmon (predominantly 1 sea winter fish) are traditionally known to enter the Fowey from the end of June. The counter data implies that over the last four years consistent numbers have entered the river in July, August and September. A notable increase in the salmon run is evident in November and October 1995 and 1996 respectively. This is likely to be associated with increasing river flow. However despite this general pattern, only a slight increase in the salmon run was observed in November 1997 despite the presence of suitable river flows. Unlike the runs in 1995 and 1996, the 1997 run was not supported by a run of fish in January. The late run in January 1998 was the lowest recorded over the last four years. The peak monthly salmon run in 1997 (between August and December) was approximately 50% of that achieved in 1996 and 1995.

It is apparent from the counter data that the predominant late salmon run on the river Fowey has declined between 1995 and 1997. The run in 1997 would appear to have been particularly poor.

**5.7.2 Sea trout runs recorded on the River Fowey - 1995 to 1998.**

Figure 4 presents the sea trout count data recorded from the river Fowey between 1995 and 1998.

The graph indicates that over the last four years the sea trout run has predominantly been concentrated within the months of June and July, with smaller runs evident in April, May and August. The runs outside of this period in 1996 and 1997 were generally negligible in comparison to the runs recorded in June and July. However, in 1995 it was evident that larger numbers of sea trout were migrating upstream until December. This may again reflect the impact of low flows that restricted earlier upstream movements.

The sea trout run in July 1996 was particularly large and twice the count achieved in 1995 and 1997. However, this abundance of sea trout did not result in a large increase in the sea trout rod catch (1995: 561, 1996:581). This may reflect unsuitable conditions for angling when the fish entered the river or limited fishing effort.

In 1998, the counter data indicated that the main run of sea trout began earlier than usual in May. This resulted in the May 1998 sea trout count being twice the size of that recorded in May 1995, 1996 and 1997. The run in July 1998 was the lowest recorded over the last four years and this may reflect the fact that the fish migrated upstream earlier than usual. This situation may partly be due to the high river flows experienced in the spring of 1998.

**6.0 Conclusions.**

1. The efficiency of Restormel fish counter for upstream migrating fish of less than 45 cm on Channel 1 was determined to be 36.7%. The counter detected a further 23.2% of these fish as a non-directional event. The counter missed 40% of these fish. This result identified the need to seek improvement in the operating set-up of the counter to increase the level of efficiency for these fish.

2. Under low flow conditions, close to 100% of fish "events" recorded by the counter with a deflection of less than 40 could be attributed to the upstream passage of a fish (sea trout) over the electrode array. The use of recorded fish "events" was found to increase the efficiency for sea trout detection to 59.9%.

3. The efficiency of the counter for upstream fish in excess of 45 cm was determined to be 90%. This therefore indicates that Restormel fish counter provides an accurate assessment of these fish entering the river Fowey without further modification.

4. A highly significant relationship ($P<0.0001$) was found to exist between the deflection signal generated by the counter for an upstream fish and the length of the upstream migrating fish. Regression analysis indicated that the length of a fish could explain 66% of the observed variability within the counter deflection size data.

5. 88% of all fish with a length in excess of 50 cm attained a deflection in excess of 50. This indicated that a counter deflection signal of 50 would serve to effectively separate the majority of salmon and sea trout.

6. The validation study indicated that non-fish passage events were unlikely to cause any significant error in the interpretation of the data. Otters and Eels were the only non-salmonid species to register as an "Event" on the counter data. Neither of these species registered as an upstream count on the counter data output.

7. The counter was efficient at detecting the downstream passage of migratory salmonids. However, the deflection size of descending fish was found to be unrelated to the size of the fish.

8. Analysis of Restormel fish counter data recorded from 1995 to 1998 indicates that the late running salmon stock on the River Fowey has declined significantly. The counter data highlighted the very poor run of salmon into the River Fowey in 1997.

## 7.0 Recommendations.

1. To continue the validation process to gather more information and assess changes in counter operation following adjustments to the current counter set-up.

2. Initiate full validation of the side channels to assess their individual efficiency.

3. Restormel fish counter data provides an independent, quantified assessment of the River Fowey migratory salmonid runs. The counter data produced should be used to actively manage the migratory salmonid stock resource and the water resources that these fish are dependent upon.

4. To provide Restormel fish counter data to interested parties with a view to managing the River Fowey salmon stock.

## 8. References.

Nicholson et al (1995) Design and use of resistivity fish counters. National Rivers Authority.

Sambrook (1981) Upstream migration of salmonids over Restormel Weir into the River Fowey catchment in 1977 and 1978. South West Water Authority.

**Appendix (1).**

## Operating protocol of a resistivity based fish counter.

The operation of the Logie 2100 A resistivity fish counter is dependent upon 3 stainless steel electrodes, which are attached to the downstream face of Restormel hydrometric gauging weir. This weir is crump sectioned and is essential in ensuring the establishment and maintenance of a stable flow regime over the electrodes. This also ensures that fish ascend the weir in close proximity to the electrode array. The electrodes have been mounted in polyethylene sheeting so as to insulate the applied electrical signals and avoid unwanted electrical interference.

The counter unit applies a low voltage (5 volts) high frequency current to both the upper and lower electrodes respectively. That applied to the upper electrode is positive and that to the lower electrode is negative. Owing to the applied positive and negative voltages, the net voltage received at the central electrode is virtually zero as the two signals effectively cancel each other out. The body of a fish acts as a weak electrical conductor and as it passes over the bottom electrode, the amount of electricity passing to the central electrode increases resulting in a subsequent increase in negative voltage at the central electrode. As the fish passes between the upper and central electrode the counter receives a higher positive signal. The net result of a passing fish over the electrode array is a typical sine wave signal of a given magnitude that is related to the length of the fish.

The counter processes the magnitude of the electrical disturbance and velocity criteria and compares it to known fish criteria within its Central processing unit (CPU). If the two halves of the signal are similar the counter recognises the "event" as a fish and as such records it as either upstream or downstream. In addition, the date, time of passage, direction of travel, water conductivity and a signal strength unit (deflection) are stored within the counter. If the deflection signal received does not conform to that of a "typical" fish, the data is either assigned as a near fish event, which infers that some aspects of the trace met that of a "typical" fish. If none of the required criteria are met the event is discarded. In this way the counter can exclude inanimate objects such as leaves twigs and other river debris from the count.

**Appendix (2).**

## Table 1. Restormel Fish Counter – Upstream migratory salmonids – Channel 1 – 1997.

| | Fish Length Classes (cm). | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Restormel Video Validation.** | **0-15** | **16-25** | **26-35** | **36-45** | **46-55** | **56-65** | **66-75** | **76-85** | **Totals.** |
| | | | | | | | | | |
| **Expected total count.** | 1 | 13 | 730 | 74 | 6 | 19 | 16 | 12 | 871 |
| Missed Fish. | 1 | 6 | 194 | 6 | 1 | 1 | 2 | 0 | 211 |
| Upstream count. | 0 | 2 | 118 | 31 | 5 | 16 | 14 | 12 | 198 |
| Event Counts. | 0 | 1 | 142 | 14 | 0 | 1 | 0 | 0 | 158 |
| | | | | | | | | | |
| | | | | | | | | | |
| **Simultaneous Fish (Total).** | 0 | 4 | 275 | 24 | 0 | 1 | 0 | 0 | 304 |
| Upstream counts | 0 | 1 | 34 | 8 | 0 | 1 | 0 | 0 | 44 |
| Event counts | 0 | 1 | 74 | 6 | 0 | 0 | 0 | 0 | 81 |
| Missed | 0 | 2 | 167 | 10 | 0 | 0 | 0 | 0 | 179 |
| | | | | | | | | | |
| Efficiency (%) (Nicholson et al, 1995) | 0 | 22.2 | 25.9 | 62.00 | 83.33 | 88.89 | 87.5 | 100 | |

**Appendix (2) (Contd.).**

## Table 2. Restormel Fish Counter – Downstream migratory salmonids – Channel 1 – 1997.

| | Fish Length Classes (cm). | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Restormel Video Validation.** | **0 – 15** | **16 – 25** | **26 – 35** | **36 – 45** | **46 – 55** | **56 – 65** | **66 – 75** | **76 – 85** | **86 – 95** | **96 – 105** | **Totals.** |
| | | | | | | | | | | | |
| **Expected Downstream count.** | 0 | 0 | 3 | 5 | 8 | 9 | 3 | 2 | 2 | 1 | 33 |
| Missed Fish. | 0 | 0 | 2 | 2 | 1 | 3 | 0 | 0 | 0 | 0 | 8 |
| Downstream Count. | 0 | 0 | 0 | 2 | 6 | 6 | 3 | 2 | 1 | 1 | 21 |
| Event Counts. | 0 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 1 | 0 | 4 |
| | | | | | | | | | | | |
| **Simultaneous Fish (Total).** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | | | | | | | | | | |
| Efficiency (%) (Nicholson et al, 1995) | N/A | N/A | 0 | 40.00 | 75.00 | 67.00 | 100 | 100 | 50 | 100 | |

**Appendix (2) (Contd.).**

**Table 3. Restormel Fish Counter – Upstream migratory salmonids – Channel 2.**

| | Brown Trout. | Sea Trout | Salmon. |
|---|---|---|---|
| **Expected Upstream count.** | 0 | 0 | 2 |
| **Missed.** | 0 | 0 | 0 |
| **Events.** | 0 | 0 | 0 |
| **Upstream.** | 0 | 0 | 2 |
| **Efficiency(%)** | N/A | N/A | 100 |

**Table 4. Restormel Fish Counter – Upstream migratory salmonids – Channel 3.**

| | Brown Trout. | Sea Trout | Salmon. |
|---|---|---|---|
| **Expected Upstream count.** | 6 | 11 | 3 |
| **Missed.** | 6 | 5 | 0 |
| **Events.** | 0 | 2 | 0 |
| **Upstream.** | 0 | 4 | 3 |
| **Efficiency (%).** | 0 | 36.36 | 100.00 |

**Appendix (3)**

**Table (5).**

**Restormel Fish counter monthly data summary – Salmon / large Sea trout counts – 1995 to September 1998.**

| | 1995 | 1996 | 1997 | 1998 |
|---|---|---|---|---|
| January | 108 | 143 | 62 | 40 |
| February | 26 | 9 | 66 | 26 |
| March | 12 | 9 | 5 | 8 |
| April | 47 | 103 | 80 | 56 |
| May | 78 | 207 | 264 | 206 |
| June | 35 | 153 | 183 | 316 |
| July | 94 | 129 | 90 | 105 |
| August | 23 | 66 | 63 | 49 |
| September | 50 | 53 | 49 | 64 |
| October | 97 | 159 | 46 | |
| November | 198 | 101 | 85 | |
| December | 122 | 55 | 82 | |
| | | | | |
| **Totals: -** | **890** | **1187** | **1075** | **870** |

**Table (6).** **Restormel Fish counter monthly data summary – Sea Trout counts – 1995 to September 1998.**

| | 1995 | 1996 | 1997 | 1998 |
|---|---|---|---|---|
| January | 52 | 156 | 13 | 46 |
| February | 8 | 10 | 4 | 27 |
| March | 47 | 18 | 1 | 35 |
| April | 274 | 303 | 264 | 256 |
| May | 446 | 573 | 388 | 948 |
| June | 1759 | 1065 | 1454 | 1369 |
| July | 1513 | 2578 | 1237 | 770 |
| August | 368 | 489 | 116 | 210 |
| September | 263 | 92 | 21 | 30 |
| October | 310 | 125 | 36 | |
| November | 368 | 84 | 113 | |
| December | 98 | 18 | 30 | |
| | | | | |
| **Totals :-** | **5506** | **5511** | **3677** | **3691** |

**Figure (3).** **Restormel fish counter data – River Fowey – Salmon / large Sea trout – 1995 to September 1998.**

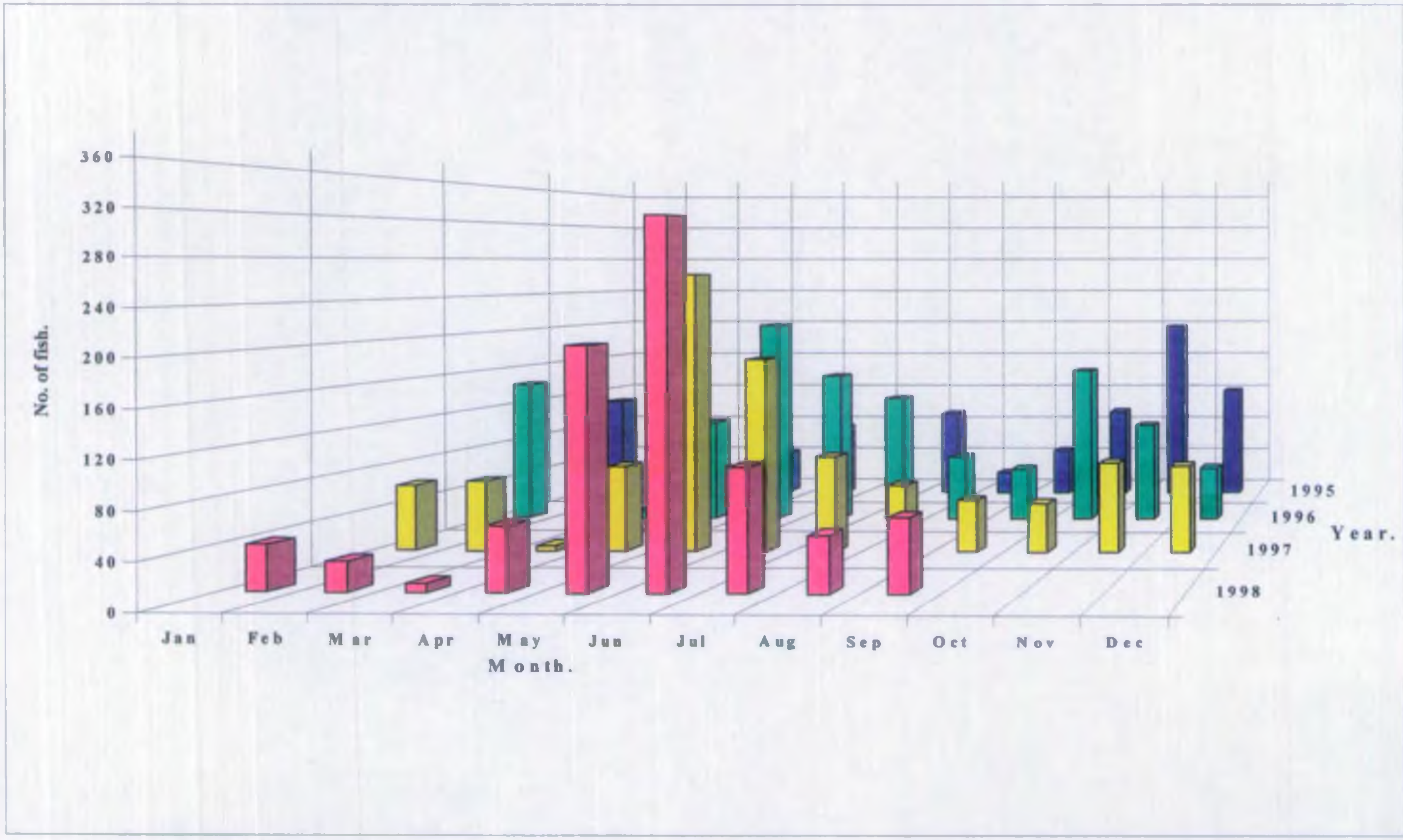


**Figure (4).** **Restormel fish counter data – River Fowey – Sea trout – 1995 to September 1998.**