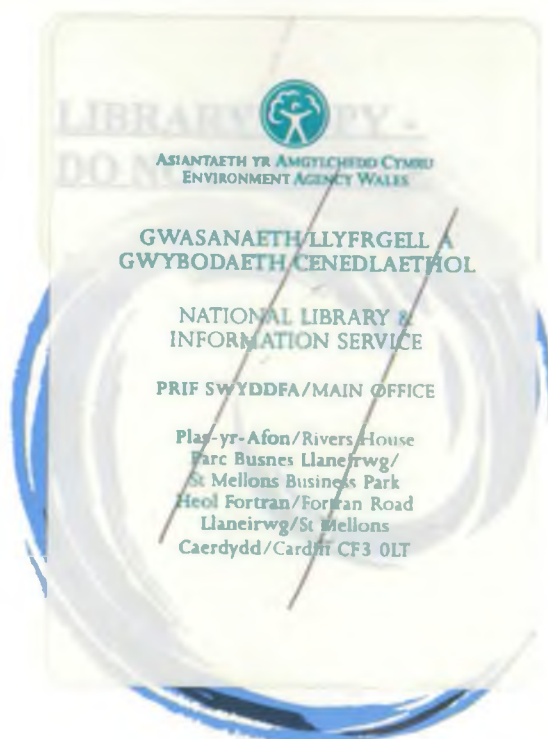


NATIONAL RIVERS AUTHORITY
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WELSH REGION
RHANBARTH CYMRU



NRA

Guardians of the Water Environment
Diogelwyr Amgylchedd Dŵr

**Cardiff Bay Barrage - Assessment of Impact
on Salmonid Fisheries**

Annual Report 1990 : Year One Pre-Barrage Construction

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ENVIRONMENT AGENCY



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1. SUMMARY

1. This report describes work undertaken in 1990, Year One of the period pre-construction of the Cardiff Bay Barrage in which base-line data on the salmonid fisheries of the River Taff were collected.
2. The total known return of salmon to the Taff this year was 195, the highest total yet recorded since the recovery of the river from industrial pollution. The majority of these were caught by electrofishing late in the year (100 fish) or by angling (72 fish), and the remainder were caught by trapping (25 fish).

The total known return of sea trout was 169 of which 22 were electrofished, 85 were caught by angling and the remaining 62 by trapping.
3. In the adjacent River Ely which will also be impounded, 51 salmon (35 by electrofishing and 16 mortalities) and 73 sea trout (56 by electrofishing and 17 mortalities) were recorded.
4. A total of 71 of the Taff salmon and 8 of the Ely salmon were adipose fin-clipped, and all but 3 of those scanned proved to be microtagged. Over two-thirds of the tags were inspected, and fish derived from smolt releases in the rivers Rhymney, Usk, Ebbw and Tywi in addition to the Taff itself were identified. Fish bearing unexamined microtags were allocated proportionally to specific sources, and overall only 54% of the tagged salmon were of Taff origin. This is an indication of the degree of straying between local rivers.
5. Trapping of adult salmonids during their upstream migration was started in late September at the newly commissioned pass and trap at Radyr Weir. 9 of the 25 salmon captured were microtagged and these were all subsequently radiotagged and released: 2 of these were used to investigate trap retention, and the remaining 7 were re-located to the Bristol Channel at Penarth.
6. All of the re-located salmon returned to the Taff within 39 days and 4 within 2 days at ground-speeds of 0.14 to 0.26 km/hr. All of the fish were also detected leaving the river after residence of 17 to 98 days.
7. The rate of return of microtagged salmon smolts to the Taff and Ely as grilse was estimated to be 0.33%, a figure lower than most published data but in the range expected for hatchery fish. The rate of return of microtagged sea trout was estimated to be 0.11%.
8. A total of 135 salmon were caught by electrofishing and 67 of these were retained as broodstock to produce future generations of stock fish for the Taff. The remaining salmon were released into the middle reaches of the river.
9. Initial design work on a trap for downstream migrant salmonids at Llandaff has been undertaken.
10. The results are discussed in terms of progress against the four stated objectives.

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2. INTRODUCTION

The proposed construction of a tidal-exclusion barrage across the mouth of Cardiff Bay will impound the flows of the Rivers Taff and Ely, creating a large freshwater lake. This will have an impact on the migrations of diadromous fish and could compromise the full recovery of the migratory salmonid populations. The River Taff used to support an important commercial salmon fishery, however the stock became extinct and has only recently begun to recover after approximately 200 years of industrial pollution (Mawle et al, 1986). Both salmon and sea trout are now returning to the river each year in increasing numbers, and some successful reproduction by both species is known to have occurred.

The NRA has a statutory duty under the provisions of the Salmon and Freshwater Fisheries Act 1975 (amended by the Water Act 1989) to maintain, improve and develop fisheries for salmon, trout, freshwater fish and eels. In carrying out this duty on the River Taff it will be necessary to gain full understanding of the mechanism and degree of impact of the barrage development. The situation is complicated by the fact that the catchment is still very much in the recovery process, and the potential for improvement in the absence of a barrage can only be estimated. Considerable investment in terms of both fish pass construction and fish stocking programmes have been undertaken in the past by Welsh Water Authority, and more recently the NRA, in anticipation of such a recovery.

To assess the impact of the proposed barrage on migratory salmonids, a monitoring programme was designed to examine current and future stock characteristics. The salmonid monitoring programme was proposed initially by the Water Authority and latterly by the NRA to study the implications of the development and the magnitude of any impact. The outline and aims of the programme are presented as Appendix 1. Further, the programme was designed to assess the efficacy of the proposals for mitigation by the stocking of salmon smolts and hence the potential for adequate protection of the potentially valuable fishery resource. A document proposing the basis for calculation of mitigation costs is presented as Appendix 2.

The proposed programme was accepted by the promoters of the Barrage Bill and subsequently implemented in 1990. Briefly it consists of the monitoring prior to, during, and following construction of the barrage of:

- (i) the migration of adult salmonids into the river, their time of entry, and survival
- (ii) the emigration and survival of smolts as adults
- (iii) the emigration and survival of kelts
- (iv) the mechanism of any impact

In particular the experimental design includes an examination of the rates of return of stocked smolts and previously tagged sea trout, and the examination of migratory behaviour of adult salmon using biotelemetric techniques (Solomon and Storeton-West, 1983; Solomon and Potter, 1988).

The monitoring programme has been designed in accordance with section 23(2)(d) of the Cardiff Bay Barrage Bill. The experimental protocol will be followed for an anticipated three year period prior to barrage construction, and then for periods of two and five years during and following construction respectively.

This report describes the work carried out in Year One (ending March 31st 1991) of the pre-construction period.

3. METHODS

Implementation of the monitoring programme prior to the commencement of barrage construction has the specific objective of establishing base-line data to describe current aspects of the Taff fishery and stock. Practical work this year has consisted of the assessment of adult salmonid abundance in the river, the release of tagged salmon smolts and adult sea trout, and the radio tracking of adult salmon.

3.1 SALMONID STOCK ASSESSMENT

Stocks have been monitored to date by the examination of declared angling catch returns, and by the catch of fish during electrofishing operations. Although such minimum estimates have been valuable, they are not sufficient as base-line data for future impact assessment. To complement them therefore, further monitoring techniques as proposed in the salmonid monitoring programme have been initiated this year.

3.1.1 Trapping

Trapping of migrant salmonids is a technique widely employed to study the timing of movements of fish, responses to environmental cues, and to provide minimum estimates of stock abundance. In this study an upstream trap at Radyr weir to catch adult fish ascending the river, and a downstream trap at Llandaff weir to catch descending migrants are proposed.

3.1.1.1 Radyr Trap

The impassable weir at Radyr (fig. 1) was renovated from its state of disrepair in 1988/89, and the opportunity was taken to renew the upstream trapping facility and construct a permanent and secure building to house the trap itself. The trapping compartment is situated at the top of a conventional denil-type fish pass designed to allow fish to bypass the weir on their upstream migration (fig. 2). Fish are attracted to the pass entrance and hence into the trap by adjustment of the water flow, both in the pass and in the attraction water channel. A penstock located at the upstream end of the trap regulates the water flow through the pass, whilst the flow over the attraction channel is regulated with stop boards. The flow through the trap is kept relatively constant compared to river flow which fluctuates widely.

Following completion of the building works on 18.9.90, the trap was operated virtually continually for a total of 86 days in three periods. It was inspected up to four times per day to check for the presence of fish and to clean screens. Experience quickly showed that trapping efficiency could be reduced, sometimes to the extent that operation ceased, by clogging of the grids covering the trap entrance. Large amounts of Cladophora sp. in spring and early summer and water-bourne leaves in the autumn were most problematical. Regular inspection of the trap and cleaning of these grids was therefore essential to ensure trapping efficiency was maintained.

Fish ascending the two components of the pass move through an inscale and enter a mesh cage. During inspection the water flow through the trap is stopped by closing the penstock, and the cage lifted for examination. Entrapped fish were moved to a large holding tank (approximately 1.5m x 0.8m x 0.8m) containing river water prior to examination.

Fish were moved from the holding tank in a polythene tube to avoid excessive abrasion and the loss of mucus and skin, and transferred to a smaller tank (1m x 0.4m x 0.2m) in which they were anaesthetised in a solution of 150 ppm 2-phenoxyethanol. Plastic gloves were worn to further minimise mucus loss and reduce the possibility of infection of the fish. The fish were then measured to the nearest centimetre and tagged according to their size and species. Juvenile salmon and sea trout less than 40cm in length were measured only, whereas all adult salmon and larger sea trout were tagged. All fish were then transferred (in the plastic tube) to a transporting tank (1.5m x 1m x 1m, containing 1500 litres of river water) and delivered to their respective release locations.

Fish escapement from the trapping cage back downstream through the pass was assessed by the return of two radio tagged salmon to the trap.

3.1.1.2 Llandaff Trap

Designs for the downstream migrant trap at Llandaff weir are at an advanced stage and are currently being reviewed. During the year a trap of similar design on the River Wear, Northumbria, was visited and discussions held on its design and operation and the significance of these to the proposed structure at Llandaff. It is envisaged that construction will commence in the summer of 1991 prior to the first season of operation later that year.

The trap will be used to capture descending salmonids and thus provide both salmon and sea trout kelts for tagging. It is intended that up to forty of the salmon kelts will be radio-tagged and their continued emigration from the catchment studied. The remaining salmon and all of the sea trout kelts will be floy-tagged to permit subsequent identification of the fish should they return to the river and be captured. The trap will also permit the enumeration of migrant smolts.

3.1.2 Angling Returns

It is a statutory duty for all anglers fishing for salmon or sea trout to submit details of all catches, and also all blank angling days to enable an examination of angling success and effort to be made. In the absence of a voluntary return at the end of the season, up to two reminders are automatically sent to anglers.

Analysis of these returns for the River Taff will be undertaken to produce annual catch data, however experience shows that this will be both incomplete (Gregory et al 1990) and not necessarily representative of stock abundance. Nevertheless it will provide an index of the salmonid stock and an indication of fishery performance.

3.1.3 Electrofishing

Electrofishing has been carried out in the lower Taff on a number of occasions in recent years largely on an opportunistic basis to examine the distribution of fish and their accumulation downstream of obstructions, and to collect broodstock for subsequent rearing of stock fish.

The weirs at Blackweir and Llandaff on the River Taff were fished on three occasions (December 4th, 7th and 13th) and at Wiggins Teape on the adjacent River Ely (Fig. 1) on four occasions in 1990 (November 7th, 11th and 28th, and December 10th) using pulsed D.C. electrofishing equipment. Captured fish were examined for the presence of batch marks and then either released in the middle reaches of the Taff (fig. 1) or retained to be used as broodstock at the NRA Cynrig hatchery.

3.1.4 Release of Tagged Fish

The tagging and release of both hatchery-reared smolts and trapped adult sea trout to investigate any future reductions in the ability of these fish to emigrate from and return to the Taff was recommended in the original monitoring proposal (Appendix 1). Although the rates of return can vary considerably, they are independent of stock size and will provide an indication of survival.

3.1.4.1 Release of Salmon Smolts

The stocking of tagged salmon smolts in the Taff catchment commenced in 1986, and since 1989 this has formed a part of the monitoring programme (table 1). The fish have been derived in the past from wild River Usk parents although the one year old smolts this year were derived from Taff adults (table 1). In future greater use will be made of broodstock taken from the Taff itself. The smolts are reared at the NRA hatchery at Cynrig and are usually two years old when released. The majority of them are batch-marked by microtagging: these tags are lengths of magnetised stainless steel wire about 2mm long carrying a code which distinguishes batches of fish stocked in different sites or at different times. The smolts are further marked by clipping of the adipose fin, and returning adults marked in this way are then examined for presence of a tag. Anglers are encouraged by the offer of a reward to report full details of the capture of such fish and retain the head for tag extraction.

A total of 10,800 smolts, two-thirds of which were microtagged two year old fish, were stocked into the River Taff in 1990 (table 1). The fish were transported by road to the release site at Radyr weir-pool (fig. 1), a journey of approximately one hour, and then introduced into the river via a length of tubing to minimise the stress of excessive netting and handling.

3.1.4.2 Release of Adult Sea Trout

Information on the rates of return of sea trout will be acquired by the tagging and release of adult fish. Sea trout can return to freshwater to spawn several times, and it will therefore be important to monitor this following barrage construction.

Sea trout for the marking programme were captured at the Radyr trap, and those considered to be large enough (more than 40cm) were floy-tagged with brown tags and transported to the middle reaches of the river at Quakers Yard (ST 092967), or Pontygwaith Bridge (ST 080976) where they were released. The transfer time for the fish was approximately 20 minutes. Further adult fish will be trapped at Llandaff during their descent of the river and tagged.

3.2 MIGRATION OF ADULT SALMON

To study the current patterns of migration of adult salmon within the catchment, and how these might be influenced in the future by the barrage, a radio-tracking programme has been implemented. The technology and procedures for such a study are well established and have been used successfully in several British rivers (see Milner, 1989 for review).

3.2.1 Capture, Tagging and Release of Salmon

Adult salmon were captured during routine operation of the Radyr trap and, following measurement, microtagged salmon were selected for radio-tagging. Such fish were expected to be derived from batches of smolts released into the River Taff, and thus to behave as natural Taff fish. Unmarked adults are thought to be mainly strays from adjacent catchments and may not behave as native fish in their home catchment. The fish were floy-tagged using orange tags, and then a standard radio tag (4cm long x 1.5cm diameter) was gently inserted into the stomach of the fish using a plastic tube and plunger. After this operation the fish were transported to the release point at Penarth (fig. 1), outside the mouth of the Taff estuary, a journey of approximately 20 minutes or sometimes 75 minutes if other fish were released in the middle river first. The fish were then acclimatised to the sea water over a period of about one hour by gradual pumping and exchange of the tank water. After this the fish were removed from the tank, again in the plastic tube, and released into knee-depth water.

3.2.2 Radio Tracking of Salmon

To monitor the return of radio-tagged relocated salmon to the Taff and their subsequent behavioural movements in the river, a network of seven automatic listening stations (ALS) was deployed in the lower freshwater river (fig. 1).

Automatic Listening Station	NGR	Distance from Release Point (km)
Sophia	ST 174772	6.6
Blackweir	ST 171781	7.8
British Telecom	ST 163783	8.6
Llandaff	ST 152784	9.7

Each listening station scanned the range of expected frequencies every five minutes, recording any signals received from passing fish. The tags used each had a unique combination of radio frequency and pulse rate, thus permitting the discrimination of individual fish. The approximate range of each ALS was 150-250 metres up and downstream, depending on environmental conditions such as flow, and a hand-held portable receiver was used to locate fish believed to be residing between them.

This system was used this year to examine the movements of upstream migrants and will continue to be used, supplemented by sonar buoys and buoy listening stations in the impoundment, following barrage construction. Salmon and sea trout kelts will similarly be tracked on their downstream migration following their capture, tagging and release at the proposed Llandaff trap.

3.3 ENVIRONMENTAL MONITORING

3.3.1 Flow

Freshwater flow is gauged at a number of locations in the catchment. The furthest downstream of these is at Pontypridd, and it is principally data from this site which will be used to interpolate the effect of flow on fish behaviour.

3.3.2 Water Quality

Relatively little data on dissolved oxygen levels and temperature, the two principle aspects of water quality which influence the migratory performance and success of salmonids, exist for the Cardiff Bay area. The rivers Taff and Ely are both sampled approximately monthly at a number of points and these data are available from the NRA Technical Data Information Bank.

4. RESULTS

4.1 SALMONID STOCK ASSESSMENT

The total known return of adult salmon to the River Taff this year was 195 (table 2), the highest since the recovery of the river from pollution began. The majority of these were caught by electrofishing the weirs at Blackweir and Llandaff where salmon were confined by low flows (100 salmon, including one recapture of a fish first recorded at the Radyr trap and released), and the remainder were caught by angling (72 salmon, including one recapture) and trapping (25 salmon). Similarly on the River Ely, fish were deterred in their migration by the impassable obstruction at Wiggins Teape, and here 35 salmon were captured by electrofishing. Amongst the 195 Taff salmon were 71 microtagged fish, the majority of which were grilse, and another 8 microtagged fish were included in the total of 51 salmon reported on the River Ely (table 2). Sixteen of the Ely salmon were recovered dead following a pollution incident in June.

The total known run of sea trout was 169 fish, over half of which were captured by anglers (table 2). This total was higher than that of 1989, but considerably less than those of the preceeding two years. On the Ely 73 sea trout were recorded, 56 of them by electrofishing and the remainder during the pollution incident mentioned above.

4.1.1 Trapping

4.1.1.1 Radyr Trap

The first salmonids were captured on September 20th, two days after trap operation commenced. Two of the first salmon caught were radio-tagged and returned to the trap to examine the retention of fish. Both successfully escaped downstream and trapping was therefore terminated while the trap inscale was modified to prevent escape. One of the two escaped fish was subsequently captured by an angler downstream at Blackweir whilst the other was not encountered again and was presumed to have left the Taff system. Fish capture resumed immediately after the re-opening of the trap on October 8th.

During the season, totals of 25 salmon, 9 of which were microtagged, and 62 sea trout, 5 of which were microtagged, were captured (table 3). The daily catch of all salmonids in relation to flow (fig. 3) shows a tendency for captures to occur shortly after peaks in the hydrograph and the individual plots for each species shows that this tends to be more clear for salmon (fig. 4) compared to sea trout (fig. 5).

An evaluation of the length-frequency (fig. 6) shows that all of the salmon were probably grilse (1 sea-winter), whereas the catch of sea trout apparently contained two distinct sea ages.

4.1.1.2 Llandaff Trap

Initial plans for the construction of this trap were produced and following detailed appraisal returned for modification. It is anticipated that work will commence in 1991 prior to the first trapping season later that year.

4.1.2 Angling Returns

The final total rod catches of salmon and sea trout for the 1990 season on the Taff (72 and 85 respectively) were considerably larger than the corresponding reported catches for 1989, but less than the recorded values of 114 salmon in 1988 and 227 sea trout in 1987 (table 2). The monthly breakdown of these catches (table 4) shows that about half of the total catch of each species were taken in the first seventeen days of October before the angling season finished. This is probably a reflection in part of the extremely low summer flows and also the preponderance in the stock of relatively late-running grilse. The majority of fish were captured using spinning tackle downstream of the weirs at Blackweir at Llandaff.

4.1.3 Electrofishing

During the three electrofishing operations on the River Taff at Blackweir and Llandaff a total of 100 adult salmon were captured. This catch included the recapture of one of the radio-tagged fish, which had been re-located to the sea, and 41 of the fish proved to be microtagged. All of the fish were removed, and 54 of them were taken to Cynrig as broodstock whilst the other 46 were released in the middle reaches of the river at Quakers Yard. All microtagged males were killed, as they were not to be used for propagation, and the tags extracted for identification. Twenty two sea trout were also captured and these were released (at Quakers Yard) together with the salmon.

The River Ely was electrofished on four occasions and a total of 35 salmon, 7 of which were microtagged, were captured. These fish were also removed with 13 being delivered to the hatchery as broodstock and the remaining 22 being released at Quakers Yard. A higher catch of sea trout was taken here, and the 56 fish were all released into the River Taff.

The details of these movements are given in table 5: it is anticipated that the fish released into the Taff would have moved on to find potential spawning sites. No fish were released into the Ely because of the unsuitability of much of the catchment for salmonid spawning.

4.1.4 Release of Tagged Fish

4.1.4.1 Salmon Smolts

Included in the total count of 195 Taff salmon this year were 71 adipose clipped fish derived from previous releases of smolts. All but one of those scanned bore microtags (table 2) and it was assumed that all unscanned fish had also been tagged. Seven more clipped salmon were captured in the Ely by electrofishing and 2 of these which were scanned did not have microtags. A further clipped and microtagged fish was

found dead in the upper Ely. In the absence of any information on releases of salmon which had been clipped but not microtagged, it was assumed that the 3 clipped fish captured this year represented tag losses.

Fifty one of the adipose-clipped salmon were available for examination and the origin of the 48 which contained microtags is shown in table 6. Only 8 of the 20 microtagged fish caught by rod in the Taff and made available for examination proved to have been stocked in the river with 7 of the others being derived from a release of juveniles in the River Rhymney.

In contrast to this 61% of the tagged salmon captured by electrofishing were of Taff origin, whilst again a considerable number (19%) were of Rhymney origin. Of the 27 salmon known to be derived from Taff releases 7 were two sea-winter fish (2SW) and the remaining 20 were 1SW (grilse).

The remaining 17 microtagged fish which were captured were released alive into the Taff following examination and scanning, and their tag codes are therefore unknown. All of the 9 microtagged fish captured in the Radyr trap were presumed from their lengths to be grilse (fig. 5) although their stock origin was unknown (but might be presumed to be Taff as they chose to enter the river a second time). These fish, together with the 3 fish which had lost their microtags were therefore among the 31 which were allocated to specific stocks on a proportional basis:

Stock Source	Number of Salmon		Total
	Microtag Read	Proportional Allocation	
Taff 1988 2SW	7	3	10
Taff 1989 1SW	20	13	33
Others	21	15	36
TOTAL	48	31	79

The catch of Taff grilse this year therefore represents an interim rate of return of 0.33% which will be revised following the capture of marked 2SW salmon from the same source in 1991.

Several more salmon derived from releases of smolts in the River Taff were reported from other fisheries during the year. Single grilse from the 1989 stocking were captured in the Usk commercial nets and by rod in the River Ogmore, and a larger total of 7 2SW salmon derived from the 1988 release were also reported. Four of these were captured by netsmen in the Severn Estuary, 2 by anglers in the River Wye and the last by an angler in the River Tywi.

4.1.4.2 Adult Sea Trout

A total of 62 of the 169 sea trout recorded this year were captured in the Radyr trap: 5 of these were microtagged and therefore derived from a release of 4,434 smolts in 1988. This represents a minimum estimate of the rate of return of 0.11%. Thirty one of the trapped fish were greater than 40cm in length (fig. 5) and these were therefore floy-tagged prior to their release.

4.2 MIGRATION OF ADULT SALMON

4.2.1 Upstream Migration

The 9 microtagged salmon caught in the Radyr trap were all radio-tagged. Seven of these were relocated to the sea near Penarth Pier, outside the proposed barrage line (fig. 1) whilst the other 2 were reintroduced to the trap to determine trap retention efficiency.

All 7 of the relocated fish returned to the freshwater Taff. They reached the most seaward of the listening stations, positioned 6.6 km from the release point, within a range of 1 to 39 days (average 6.5 days) with 4 of them doing so within 2 days at ground speeds of 0.14 to 0.26 km/hour (table 7). The patterns of re-entry behaviour in relation to freshwater flow (fig. 7) show no clear relationship and similarly the time of first detection at the lower ALS showed no distinct pattern.

All of the fish continued their ascent to Blackweir, 5 of them reaching this station within 30 hours and the quickest in only 1.4 hours at a groundspeed of 0.85 km/hour. In contrast the other 2 salmon took more than 16 days to cover the distance of just 1.2 km, probably reflecting the decision of these fish to lie within this reach.

Only one of the salmon which re-entered the river ascended the obstruction of Blackweir despite the presence of an operational fish pass. The 6 fish which failed to do so were all detected by fixed listening stations or portable receiver in the stretch of river between Blackweir and Sophia Gardens. The one successful migrant ascended to Llandaff where it remained below the weir for 10 days prior to its capture by electrofishing. It was then transported to the middle reaches of the river where it was released with several other salmon.

4.2.2 Downstream Migration

All of the 7 radio-tagged fish were detected leaving the river. The 6 fish which remained below Blackweir left the river between December 25th and January 16th having spent 17-98 days in freshwater (table 7). The other fish was detected during its descent from the middle reaches by 2 listening stations prior to its exit from the river on December 25th during elevated river flows. The rate of descent of this fish was estimated from the recordings to be 2.4 km/hour.

4.3 ENVIRONMENTAL MONITORING

4.3.1 Flow

River flows during the summer and early autumn proved to be relatively low with a minimum value of 3 cumecs (16% of the 1990 average daily mean flow) being recorded in mid-September. Flows started to increase at the end of that month and during the remainder of the year a series of higher flow events interspersed with periods of low flow occurred (table 8).

4.3.2 Water Quality

Data from the Technical Data Information Bank reveals minimum dissolved oxygen (D.O.) levels in the River Taff at Clarence Road and in the River Ely at Penarth Road (fig. 1) in the period 1987 to 1990 of 6.0 and 4.9 mg/l respectively. During 1990 D.O.'s of 8.4-13.1 mg/l and 5.9-12.5 mg/l were recorded at these sites in the Taff and Ely respectively. Maximum temperatures of 22°C and 20°C were recorded during August.

Other than these routinely collected data, no information was collected specifically for this programme.

5. DISCUSSION

The largest recorded run of salmon since the recent improvements in water quality was reported in the Taff this year. This demonstrates the improving status and current performance of the catchment but it does not necessarily reflect the true future potential. Further improvements in water quality, continued stocking, the opening of the catchment by construction of fish passes and proposed new byelaws to control estuarial fishing pressure should all result in increased abundance of salmon and rates of salmon entry to the river.

The Radyr trap appeared to work satisfactorily, catching both salmon and sea trout principally on rising or falling flows but only rarely during low flow conditions. Similar flow-related behaviour has frequently been observed elsewhere (e.g. Alabaster, 1970). Much of the run of migratory fish failed to reach the weir at Radyr however, principally because of the low flows but also because of apparent problems with fish passage at both Blackweir and Llandaff weir. The pass at Blackweir was opened late in the year, and the use of it might have been restricted by the relatively low water temperature at that time. Over 120 adult salmon and sea trout were caught by electrofishing below these obstructions in the winter, principally at Llandaff, clearly demonstrating that access upriver was severely restricted. Although passage during higher flows and warmer temperatures during the summer and autumn would probably be much easier, it is clear that attention must be given to the effectiveness of these passes. Potential modifications will therefore be considered during the 1991 season. Although the accumulation of fish below the weir greatly assists the collection of broodstock, it is undesirable because of the restricted distribution of the spawning stocks and the increased vulnerability of the fish to capture. It also restricts the numbers of fish reaching Radyr which are then available for tagging and relocation.

A relatively low proportion of the 20 microtagged salmon caught by anglers for which we have information proved to be fish originally stocked into the Taff. Five of these were 2SW salmon derived from the release of smolts in the Taff in 1988 and only 3 were grilse derived from the 1989 release. The proportion of Taff fish is thus only 40% and this contrasts with the corresponding figure of 55% for electrofished salmon (excluding 2 further grilse caught in the River Ely). The different proportions is perhaps a reflection of the time of year when electrofishing took place: many more strays from other rivers were reported by anglers during the summer and autumn and relatively few from the electrofishing operations in November and December. The straying of salmon between rivers entering the Severn Estuary is a well known phenomenon (Swain, 1982), and the extent of this is becoming clearer with recent returns from microtagging. Whether such vagrants remain in a non-natal stream and ultimately spawn there, or choose to leave and enter their correct river of origin is unknown.

There is some evidence that the penetration of non-Taff salmon into the river this year and perhaps also their residence in the river was influenced by the partially impassable structure of Blackweir. Only 2 of the 17 salmon caught by angling above Blackweir prior to completion of the fish pass were vagrants, whereas 8 of the 25 caught after the pass opened were strays. Perhaps therefore physical obstructions deter straying fish from residing and therefore spawning in a non-native river. This would clearly be of significance regarding the recolonisation of the Taff by such fish in the presence of the proposed barrage.

The rate of return of grilse from the 1989 stocking of tagged hatchery reared smolts is, at 0.33%, lower than the range of return rates observed on the River Bush in Northern Ireland (0.45-4.3%, C.D. Strange - pers. comm.), the Burrishoole system in the Republic of Ireland (0.80-7.0%, Salmon Research Trust of Ireland Inc., 1966-1987), and the River Lagan in Sweden (5-10%, Carlin, 1955). Hatchery reared smolts were used in all these studies. However whereas their fish were derived from native wild parents and reared within the catchment where they were released, the Taff smolts were derived from wild Usk parents and were reared at the Cynrig hatchery, outside the Taff catchment. Lower return rates from smolts transplanted to other catchments might be expected: such data is sparse, however on the Thames, observations on the rate of return of reared smolts over the past nine years is available. Many of these smolts were transported a considerable distance and yet rates of return as grilse of up to 1.7% were recorded, although some zero returns were also reported (P.J. Gough - personal observations). These catches represented large proportions of the whole run of fish however, whereas the proportion of the Taff run captured is unknown. 1990 has been widely recognised to be a poor year in terms of the abundance of grilse entering many rivers and a low return of Thames grilse (less than 0.3%) was recorded. The reasons for this are unclear, however the very low flows widely experienced at the time when most grilse were expected to enter their home rivers is probably significant. Returns during 1991 of 2SW salmon derived from the same smolt release will increase the overall percentage return rate but the scale of their contribution is likely to be rather small.

Relocation of trapped salmon to the release point in the Bristol Channel requires the fish to re-adapt rapidly both osmotically and behaviourally to marine conditions after having spent an unknown time in the freshwater environment. The earlier migration from the sea to freshwater will have placed demands on their ability to adapt, however relocation and the enforced repeat of this transition might have been expected to debilitate the fish. The successful return of all the relocated salmon showed however that the fish were able to make the adjustments required of them, and has therefore justified the use of the re-location technique for this study.

The passage speeds between the release point and the freshwater stations represent minimum estimates, as the behaviour of the fish during passage is unknown. The most rapid re-entry of 25.4 hours at a speed of 0.26 km/hour might represent near continuous swimming and is within the range of annual median migratory velocities recently reported in the Usk estuary (0.15-0.71 km/hour, Mills et al 1991). It is considerably slower than the rate of 1.0 km/hr reported in the Tywi estuary (Clarke and Purvis, 1989) and the 3 most rapid Usk migrants which moved at about 1.3 km/hour (Mills et al 1991). The more rapid velocity of 0.85 km/hour shown by the quickest fish in its ascent to Blackweir is more in line with these reports, however this was achieved in freshwater against a uni-directional current over a relatively short distance.

The movements on the Taff were observed principally in December when swimming ability, and hence performance, might be expected to be more limited and current velocities relatively high. In contrast the observations for the Usk and Tywi were made during summer months.

There was some suggestion that fish moved upriver during periods of relatively high flow (fig. 6), however this was probably more related to the time of capture and release of the fish. Salmon are likely to be less discriminating in their decision to move as their maturation advances and the urgency to reach spawning grounds increases.

The sparse water quality data available suggests that neither D.O. or temperature would have limited the ability of salmon or sea trout to ascend the river. In the absence of data from continuous quality monitors however, it remains unclear whether any episodic pollution occurred during the year. It is also unclear whether any current aspect of water quality in the bay or lower river is limiting the success of migration of salmonids into the river.

The period of residence of the radio-tagged fish in the river extended over the period when the fish might have been expected to spawn, and they all were detected leaving the catchment within a relatively discrete period of 22 days. All but one of the relocated salmon remained below Blackweir, and it is unclear whether any spawning here would be productive.

5.1 PROGRESS AGAINST OBJECTIVES

5.1.1 Adult Salmonids: Migration into the River. Time of Entry and Survival

The method of relocating salmon trapped at Radyr to the sea and the study by radio telemetry of their subsequent return to the freshwater Taff has proved to be a viable technique. Each of the seven fish treated in this way returned to freshwater within 39 days (average 6.5 days), showing no clear preference for time of day or freshwater flow at entry to freshwater. Although the data-set is small, a valuable precedent for the relocation method is now set and it is anticipated that considerably more data will be collected next year.

The delay of salmon below the weirs at Blackweir and Llandaff is of concern, particularly because this has limited the availability of fish at Radyr and hence restricted the numbers radio-tagged. In addition to modification of the passes consideration will be given to the trapping of adults at Blackweir. If a trap here proves successful it will yield more fish for tagging and permit the selection of the freshest fish which are likely to adapt to relocation best.

5.1.2 Emigration and Survival of Smolts

Information on both the emigration and survival of smolts has been obtained this year in the form of the percentage rate of return of tagged smolts as grilse. The capture of older 2SW salmon during 1991 will complete the total return from this batch of fish, assuming that no salmon older than these return in following years. The estimate of return rate is a minimum one, the recorded catch being an unknown proportion of the whole run of fish for the year. It is relatively low compared with rates observed on other rivers, however 1990 was widely perceived to be a poor year for grilse.

The migratory behaviour of smolts following construction of the barrage will almost certainly change and this might affect their rate of survival. Continued monitoring of the return rate of tagged smolts as adult fish will provide information on the scale of this, and in particular indicate if the negative impact of the development exceeds 37%. The ability of the monitoring methods to detect and quantify statistically significance impact of less than 37% is unlikely to be sufficiently good for management purposes. This premise has lead to the current approach to minimum mitigation (appendix 2).

It is hoped that the technology for radio-tracking of migrant smolts will become available over the next couple of years and permit the more detailed examination of their migratory patterns.

5.1.3 Emigration and Survival of Kelts

No information on this stage of the life cycle was obtained this year. The trapping and tagging of kelts should commence in 1991 and radio telemetry should provide information on their migratory behaviour.

5.1.4 Mechanism of Impact

Adequate understanding of the mechanism of any impact on the migratory salmonid stocks of the Taff will be essential if appropriate mitigation is to be recommended. This mitigation might be in the form of revised barrage operation and management, or compensation for fish excluded from the river or damaged so that they are unable to contribute to the stock.

Data will be collected to assess the impact of construction, and later the effect of the barrage. The rates of return of marked fish and the behaviour of radio-tagged adults will be compared with corresponding data from the pre-construction period, whereas localised telemetric studies of both smolts and adults will enable investigation of the impact of the structure on behaviour.

Once the scale of impact is assessed in this way, the data will provide the basis for recommendation of appropriate mitigation for the barrage in an attempt to compensate adequately for any perceived adverse effect.

6. STAFF

The following staff were in post during 1990:

N.R.A. Management

Senior Environmental Martin J. Mills
Appraisal Officer

Miran Aprahamian (until Oct. '90)

Environmental Appraisal Peter J. Gough
Officer - Fisheries (Miran Aprahamian until Oct. '90)

Cardiff Bay Barrage Fisheries
Project

Project Officer Gary O. Jones

Assistant Project James Gregory
Officer

Technical Assistants Paul Edwards
and William Blacklidge

7. FINANCE

A summary of the project expenditure for 1990/91 is given below and shows that the total revenue costs were kept well within the agreed budget for the year (which was set at 1989/90 prices) although some adjustment between areas of expenditure was required. For example, Office Equipment was overspent because of the purchase of software for handling the fish tracking data. Capital costs for Radyr fish pass and trap exceeded the annual budget for 1990/91 because the bulk of the construction work was carried forward from 1989/90. However, the total cost of the Radyr pass and trap was within 3.3% of the total budget (again set at 1989/90 prices) and therefore well within acceptable inflationary limits.

No significant progress was made with the construction of the Llandaff trap during 1990/91 so this capital expenditure should be carried forward into 1991/92.

CARDIFF BAY BARRAGE FISHERIES STUDY

FINANCIAL SUMMARY - YEAR ENDING 31/3/91

<u>DESCRIPTION</u>	Figures in £'000's					
	<u>90/91 BUDGET*</u>		<u>90/91 COSTS</u>		<u>TOTAL</u>	<u>TOTAL</u>
	<u>CAP</u>	<u>REV</u>	<u>CAP</u>	<u>REV</u>	<u>BUDGET</u>	<u>COSTS</u>
Radyr Fish Pass	16	-	28.8	-	48	49.6
Llandaff Trap	80 **	-	0	-	80	0
Radio Listening St.	24	-	21.9	-	24	21.9
Acoustic Buoys	10	-	9.9	-	10	9.9
Fish Tags/Rewards	-	15.3	-	9.7		
Maint. / Repair	-	1.5	-	0		
Hire of Equipm't.	-	8.0	-	5.6		
Office facilities	-	9.0	-	9.0		
Office Equip./Stat.	-	5.7	-	7.3		
Transport	-	3.9	-	3.8		
Stocking Costs	-	13.5	-	13.5		
Tools / Gen.Equip.	-	3.3	-	4.3		
Salary - NRA Mgmt.	-	10.8	-	10.8		
Salary - Project team	-	27.5	-	30.7		
Totals	130	98.5	60.6	94.7	152	81.4
	228.5		155.3			

* All budgets at 1989/90 prices.

** Capital for Llandaff trap to be carried forward to 1991/92

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Table 1

The number and life stage of microtagged juvenile salmon
stocked into the River Taff since 1986

Year	Number	Life Stage	Source of Ova
1986	4700	2 year old smolts	Usk
1987	9300	2 year old smolts	Usk
1988	10000*	2 year old smolts	Usk
	2300	1 year old smolts	Usk
1989	10000*	2 year old smolts	Usk
1990	7200*	2 year old smolts	Usk
	3600	1 year old smolts	Taff

* Denotes adipose fin-clipped fish

TABLE 2

Catches by All Methods of Salmon and Sea Trout in the River Taff
(1983-1990) and the River Ely (1987-1990)

RIVER TAFF

YEAR	CATCH OF SALMON					CATCH OF SEA TROUT				
	ROD	ELECTROFISHING	TRAP	MORTALITIES	TOTAL	ROD	ELECTROFISHING	TRAP	MORTALITIES	TOTAL
1983	0	4	-	0	4					
1984	2	0	-	0	2					
1985	15	0	-	0	15					
1986	12	0	-	0	12					
1987	38(1)	20	-	0	58(1)	227	182	-	0	409
1988	114(45)	8(5)	-	2	124(50)	207	114	-	0	322
1989	4(3)	33(9)	-	0	37(12)	22	79	-	0	101
1990	72(23)*	100(41)*	25(9)	0	195(71)	85	22	62(5)	0	169

RIVER ELY

YEAR	CATCH OF SALMON					CATCH OF SEA TROUT				
	ROD	ELECTROFISHING	TRAP	MORTALITIES	TOTAL	ROD	ELECTROFISHING	TRAP	MORTALITIES	TOTAL
1987	0	-	-	0	0	0	-	-	0	0
1988	0	-	-	0	0	0	-	-	0	0
1989	0	9	-	4	13	0	15	-	8	23
1990	0	35(7)	-	16(1)	51(8)	0	56	-	17	73

Note Figures in parentheses are the numbers of microtagged fish

* indicates the recapture of one microtagged and floy-tagged salmon

Table 3 (1)

Details of Radyr Tran Operation and Catch
September 1990-January 1991

DATE	TRAP CONDITION	SALMON CATCH	LENGTH (cms)	NO. RADIO TAGGED	S.TROUT CATCH	LENGTH (cms)	NO. FLOY TAGGED
19/9/90	OPEN	0	----	----	0	----	----
20/9/90	OPEN	4	66,59,69 78	1	2	34,22,5	0
21/9/90	OPEN TRAP	0 CLOSED	----	----	1	61.5	1
			FROM	22/9/90	TO	8/10/90	
9/10/90	OPEN	0	----	----	1	48	1
10/10/90	OPEN	0	----	----	5	76,60,38	3
11/10/90	OPEN	0	----	----	4	36,5,53 58,62,50	3
12/10/90	OPEN	2	65,62	0	2	31 59,62	2
13/10/90	OPEN	2	65,21,5	1	2	62,65	2
14/10/90	OPEN	0	----	----	0	----	----
15/10/90	OPEN	2	65,65	0	3	70,67,37	2
16/10/90	OPEN	0	----	----	2	60,54	2
17/10/90	OPEN	2	73,67	1	1	37	0
18/10/90	OPEN	0	----	----	0	----	----
19/10/90	OPEN	0	----	----	0	----	----
20/10/90	OPEN	0	----	----	0	----	----
21/10/90	OPEN	0	----	----	0	----	----
22/10/90	OPEN	0	----	----	1	61	1
23/10/90	OPEN	0	----	----	0	----	----
24/10/90	OPEN	0	----	----	0	----	----
25/10/90	OPEN	0	----	----	2	32,28	0
26/10/90	OPEN	0	----	----	0	----	----
27/10/90	OPEN	0	----	----	0	----	----
28/10/90	OPEN	0	----	----	0	----	----
29/10/90	OPEN	0	----	----	4	70,59,28 33	2
30/10/90	OPEN	0	----	----	0	----	----
31/10/90	OPEN	0	----	----	1	27	0
1/11/90	OPEN	0	----	----	0	----	----

Table 3 (ii)

DATE	TRAP CONDITION	SALMON CATCH	LENGTH (cms)	NO. RADIO TAGGED	S.TROUT CATCH	LENGTH (cms)	NO. FLOY TAGGED
2/11/90	OPEN	0	----	----	3	60, 53, 60	3
3/11/90	OPEN	0	----	----	0	----	----
4/11/90	OPEN	0	----	----	0	----	----
5/11/90	OPEN	0	----	----	0	----	----
6/11/90	OPEN	0	----	----	0	----	----
7/11/90	OPEN	0	----	----	0	----	----
8/11/90	OPEN	0	----	----	0	----	----
9/11/90	OPEN	0	----	----	0	----	----
10/11/90	OPEN	0	----	----	0	----	----
11/11/90	OPEN	0	----	----	2	60, 35	1
12/11/90	OPEN	1	64	1	3	30, 73, 25	1
13/11/90	OPEN	1	70	0	6	36, 28, 61 69, 28, 38	2
14/11/90	OPEN	0	----	----	0	----	----
15/11/90	OPEN	0	----	----	1	32	0
16/11/90	OPEN	0	----	----	3	45, 60, 40	2
17/11/90	OPEN	1	65	0	0	----	----
18/11/90	OPEN	0	----	----	0	----	----
19/11/90	OPEN	0	----	----	3	35, 37, 35	0
20/11/90	OPEN	0	----	----	3	58, 69, 74	3
21/11/90	OPEN	0	----	----	0	----	----
22/11/90	OPEN	0	----	----	0	----	----
23/11/90	OPEN	0	----	----	1	54	1
24/11/90	OPEN	0	----	----	0	----	----
25/11/90	OPEN	0	----	----	0	----	----
26/11/90	OPEN	0	----	----	0	----	----
27/11/90	OPEN	5	73, 62, 62 69, 69	3	0	----	----
28/11/90	OPEN	1	59		1	57	1
29/11/90	OPEN	0	----	----	0	----	----
30/11/90	OPEN	0	----	----	0	----	----

Table 3 (iii)

DATE	TRAP CONDITION	SALMON CATCH	LENGTH (cms)	NO. RADIO TAGGED	S.TROUT CATCH	LENGTH (cms)	NO. FLOY TAGGED
1/12/90	OPEN	1	----	----	0	----	----
2/12/90	OPEN	1	55	0	0	----	----
3/12/90	OPEN	0	----	----	0	----	----
4/12/90	OPEN	1	66	0	0	----	----
5/12/90	OPEN	0	----	----	0	----	----
6/12/90	OPEN	0	----	----	0	----	----
7/12/90	OPEN	0	----	----	0	----	----
8/12/90	OPEN	0	----	----	0	----	----
9/12/90	OPEN	0	----	----	0	----	----
10/12/90	OPEN	0	----	----	0	----	----
11/12/90	OPEN	0	----	----	0	----	----
12/12/90	OPEN	2	76,66	2	1	59	1
13/12/90	OPEN	0	----	----	0	----	----
14/12/90	OPEN	0	----	----	0	----	----
15/12/90	OPEN	0	----	----	0	----	----
16/12/90	OPEN	0	----	----	0	----	----
17/12/90	OPEN	0	----	----	0	----	----
18/12/90	OPEN	0	----	----	0	----	----
19/12/90	OPEN	0	----	----	0	----	----
20/12/90	OPEN	0	----	----	0	----	----
21/12/90	OPEN	0	----	----	0	----	----
	TRAP	CLOSED	FROM	22/12/90	TO	2/1/91	
3/1/91	OPEN	0	----	----	0	----	----
4/1/91	OPEN	0	----	----	0	----	----
5/1/91	CLOSED	----	----	----	----	----	----
6/1/91	CLOSED	----	----	----	----	----	----
7/1/91	OPEN	0	----	----	0	----	----
8/1/91	OPEN	0	----	----	0	----	----
9/1/91	OPEN	0	----	----	0	----	----
10/1/91	OPEN	0	----	----	0	----	----

Table 3 (iv)

DATE	TRAP CONDITION	SALMON CATCH	LENGTH (cms)	NO. RADIO TAGGED	S.TROUT CATCH	LENGTH (cms)	NO. FLOY TAGGED
11/1/91	OPEN	0	----	----	0	----	----
12/1/91	CLOSED	----	----	----	----	----	----
13/1/91	CLOSED	----	----	----	----	----	----
14/1/91	OPEN	0	----	----	0	----	----
15/1/91	OPEN	0	----	----	0	----	----
16/1/91	OPEN	0	----	----	0	----	----
17/1/91	OPEN	0	----	----	1	28	0
18/1/91	OPEN	0	----	----	0	----	----
19/1/91	CLOSED	----	----	----	----	----	----
20/1/91	CLOSED	----	----	----	----	----	----
21/1/91	OPEN	0	----	----	0	----	----
22/1/91	OPEN	0	----	----	0	----	----
23/1/91	OPEN	0	----	----	0	----	----
24/1/91	OPEN	0	----	----	0	----	----
25/1/91	OPEN	0	----	----	0	----	----

Table 4

Rod Catch of Taff Salmon and Sea Trout. 1990

SALMON

WEIGHT	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NO DATE	TOTAL
No weight	0	0	0	0	0	0	0	0	0	0	0	0
0-8 LBS	0	0	0	0	1	3	16	5	9	30	0	64
8-14 LBS	0	0	0	0	1	0	2	1	1	2	0	7
14-22 LBS	0	0	0	0	0	0	0	0	0	1	0	1
22-28 LBS	0	0	0	0	0	0	0	0	0	0	0	0
28- LBS	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL WT.	0	0	0	0	14	15	91	35	48	187	0	390
AVE - WT.	0.0	0.0	0.0	0.0	6.7	4.8	5.0	5.8	4.8	5.6	0.0	5.4
TOT. EST WT.	0	0	0	0	14	15	91	35	48	187	0	390
TOTAL FISH	0	0	0	0	2	3	18	6	10	33	0	72

SEA TROUT

WEIGHT	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NO DATE	TOTAL
NO WEIGHT	0	0	0	0	0	0	0	0	0	1	0	1
0-1 LBS	0	0	0	0	1	0	0	0	1	12	0	14
1-4 LBS	0	0	1	4	1	1	5	7	7	31	0	57
4- LBS	0	0	0	0	0	1	0	1	2	9	0	13
TOTAL WT.	0	0	2	7	4	7	10	19	25	125	0	199
AVE - WT.	0.0	0.0	1.5	1.7	1.8	3.3	2.0	2.3	2.5	2.4	0.0	2.3
TOT. EST WT	0	0	2	7	4	7	10	19	25	128	0	202
TOTAL FISH	0	0	1	4	2	2	5	8	10	53	0	85

FISHING METHOD	FLY	SPN	BAIT	UNDEFINED	TOTAL
SALMON	6	60	1	5	72
SEA TROUT	12	68	2	3	85
TOTAL	18	120	3	8	157

Table 5

Fate of Salmon and Sea Trout Trapped and Electrofished
in the Rivers Taff and Ely. 1990

Capture Method	Total Catch	Fate of Fish			
		Radio-tagged Relocated	Trap Trial	Released into Taff	Cynrig Broodstock
SALMON					
Radyr Trap	25 (9)	7 (7)	2 (2)	16 (0)	0
Electrofishing - Taff	100 (41)	0	0	46 (16)	54 (25)
Electrofishing - Ely	35 (7)	0	0	22 (4)	13 (3)
TOTAL	160 (57)	7 (7)	2 (2)	84 (20)	67 (28)
SEA TROUT					
Radyr Trap	62 (5)	0	0	62 (5)	0
Electrofishing - Taff	22	0	0	22	0
Electrofishing - Ely	56	0	0	56	0
TOTAL	140 (5)	0	0	140 (5)	0

Note

Figures in parentheses are the number of microtagged fish

TABLE 6

The Origin of Microtagged Salmon Caught in the
Rivers Taff and Ely by Rod and Electrofishing, 1990

Tag Source	Capture Method		Total
	Angling	Electrofishing (Taff and Ely)	
Taff 1988	5	2	7
Taff 1989	3	17	20
OTHERS			
Rhymney	7	6	13
Usk	2	0 (1 from dead fish)	3
Ebbw	2	2	4
Tywi	1	0	1
Clipped fish with no microtag	0	3	3
TOTAL	20	31	51

TABLE 7

Details of Ascent and Descent of Radio-tagged Salmon, 1990ASCENT

FISH SEX	RELEASE	First Detection at A.L.S., Passage Time (P.T.) and Speed (P.S.)											
		SOPHIA			BLACKWEIR			BRITISH TELECOM			LLANDAFF		
		TIME	P.T.*	P.S.	TIME	P.T.	P.S.	TIME	P.T.	P.S.	TIME	P.T.	P.S.
1 M	17/10, 1300	25/10, 1850	197.8	33.4	12/11, 0835	398.3	3.0						
2 M	12/11, 1900	21/12, 2150	938.8	7.0	22/12, 0210	4.3	277.1						
3 M	27/11, 1515	28/11, 1650	25.6	258.0	21/12, 0830	543.7	2.2						
4 M	27/11, 2100	29/11, 1910	46.8	140.9	30/11, 2335	28.4	42.2	3/12, 1255	6.3	13.0	3/12, 1420	1.4	776.5
5 M	27/11, 2100	28/11, 2225	25.4	259.6	29/11, 0145	3.3	360.4						
6 F	12/12, 1730	21/12, 1310	211.7	31.2	21/12, 2350	10.7	112.5						
7 M	12/12, 2030	14/12, 0615	33.8	195.6	14/12, 0740	1.4	845.1						

NOTES:

P.T. = Passage time between stations in hours

P.S. = Passage speed in m/hour

* = Passage time of salmon ascending to Sophia is also their absence time from the river

Distance between stations:

Release point - Sophia = 6.6 km

Sophia - Blackweir = 1.2 km

Blackweir - B. Telecom = 0.8 km

B. Telecom - Llandaff = 1.1 km

Table 7 (cont.)

DESCENT

FISH SEX	RESIDENCE IN RIVER (DAYS)	Last Detection at A.L.S.											
		LLANDAFF			BRITISH TELECOM			BLACKWEIR			SOPHIA		
		TIME	P.T.*	P.S.	TIME	P.T.	P.S.	TIME	P.T.	P.S.	TIME	P.T.	P.S.
1 M	98							14/01, 0230			-		
2 M	22										12/01, 0410	180.0	6.7
3 M	17							13/01, 1650			14/01, 0750	15.0	80.0
4 M	26	25/12, 1115			25/12, 1120	0.1	13253.01	-			-		
5 M	27							16/12, 1310			25/12, 0000	202.8	5.9
6 F	15							-			5/01, 0415		
7 M	33							16/01, 1100			-		

NOTES:

P.T. = Passage time between stations in hours

P.S. = Passage speed in m/hour

* = Passage time of salmon ascending to Sophia is also their absence time from the river

Distance between stations:

Release point - Sophia = 6.6 km

Sophia - Blackweir = 1.2 km

Blackweir - B. Telecom = 0.8 km

B. Telecom - Llandaff = 1.1 km

TABLE 8

Summary of Freshwater Flow in the River Taff.
Gauged at Pontypridd 1990

MONTH	RIVER FLOW, CUMECs		
	MINIMUM	MEAN	MAXIMUM
January	16.2	55.5	133.7
February	24.5	70.3	331.6
March	7.8	13.7	35.3
April	4.9	6.6	8.9
May	3.6	4.6	13.4
June	3.2	6.9	18.3
July	4.1	8.1	25.8
August	3.5	4.9	19.6
September	3.0	4.7	24.6
October	5.8	16.6	59.4
November	8.3	17.8	41.5
December	6.4	23.3	114.9

10. LIST OF FIGURES

- | | |
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| Figure 1 | Location map |
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| Figure 7 | Movement of radio-tagged salmon in relation to freshwater flow |

Fig.1

Location Map

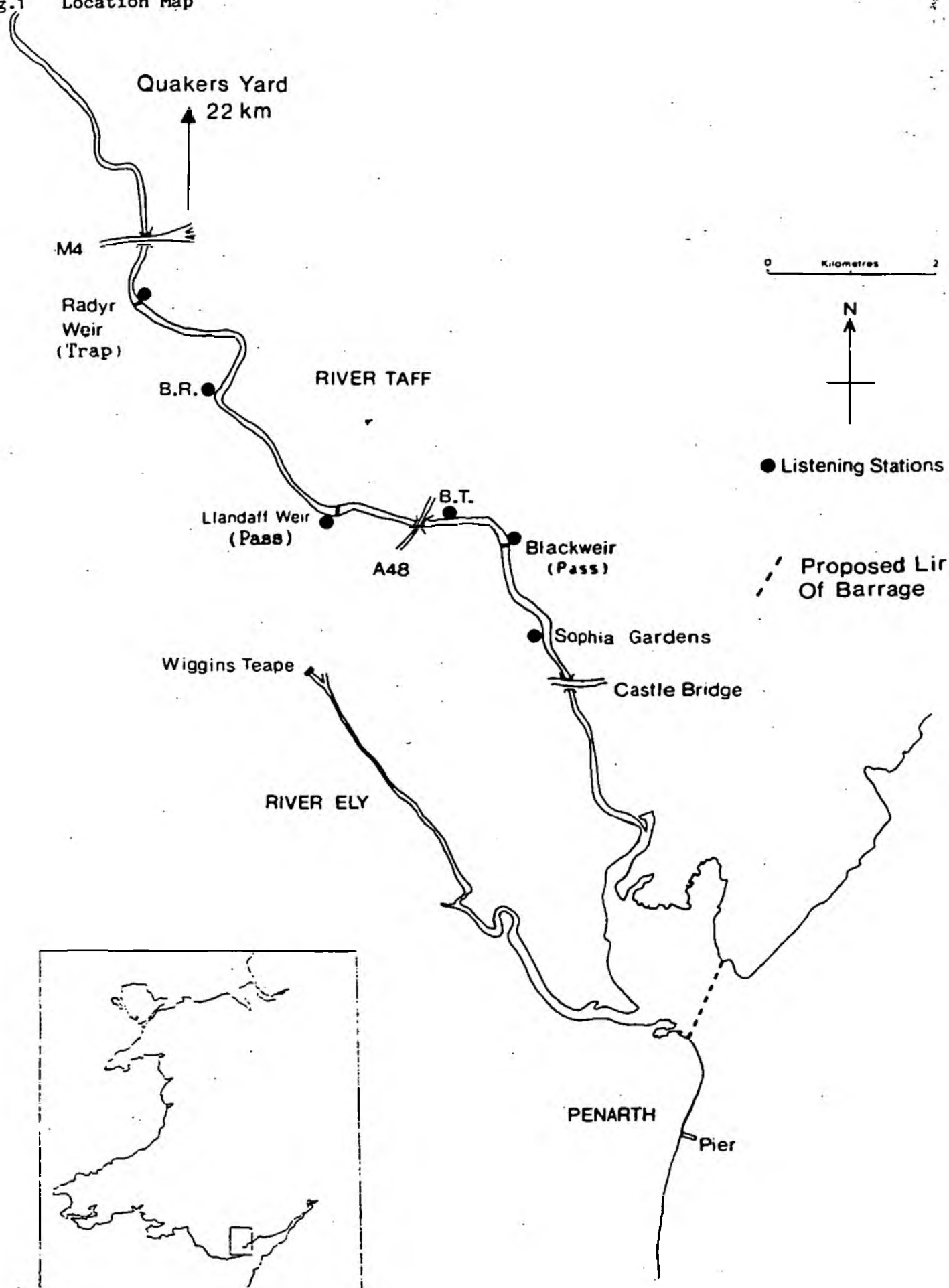


Fig. 2

Schematic Plan of Radyr Trap

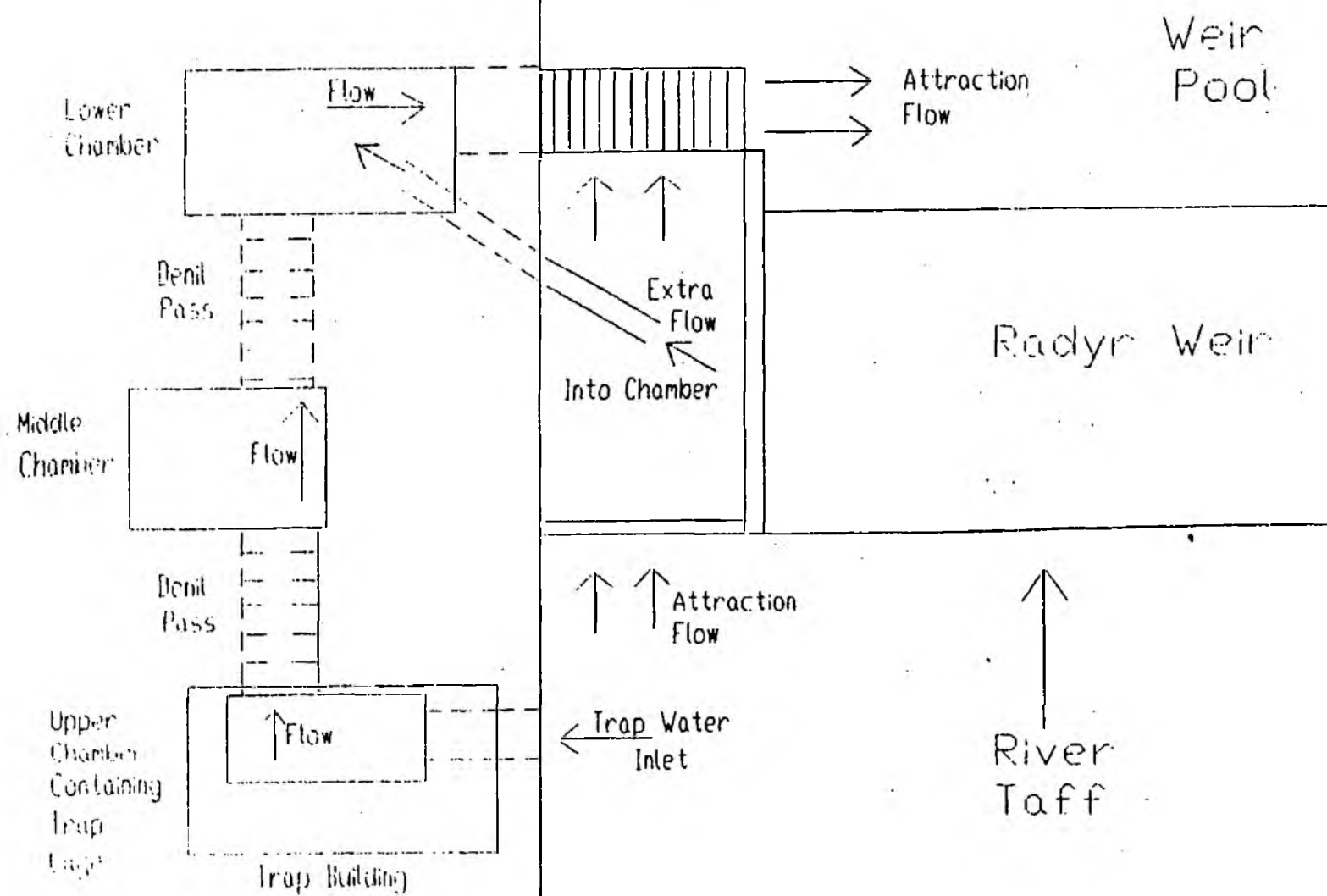


Fig. 3

Total daily catch of salmonids in relation to flow,
from 1st Feb. 1990 to 31st Jan. 1991.

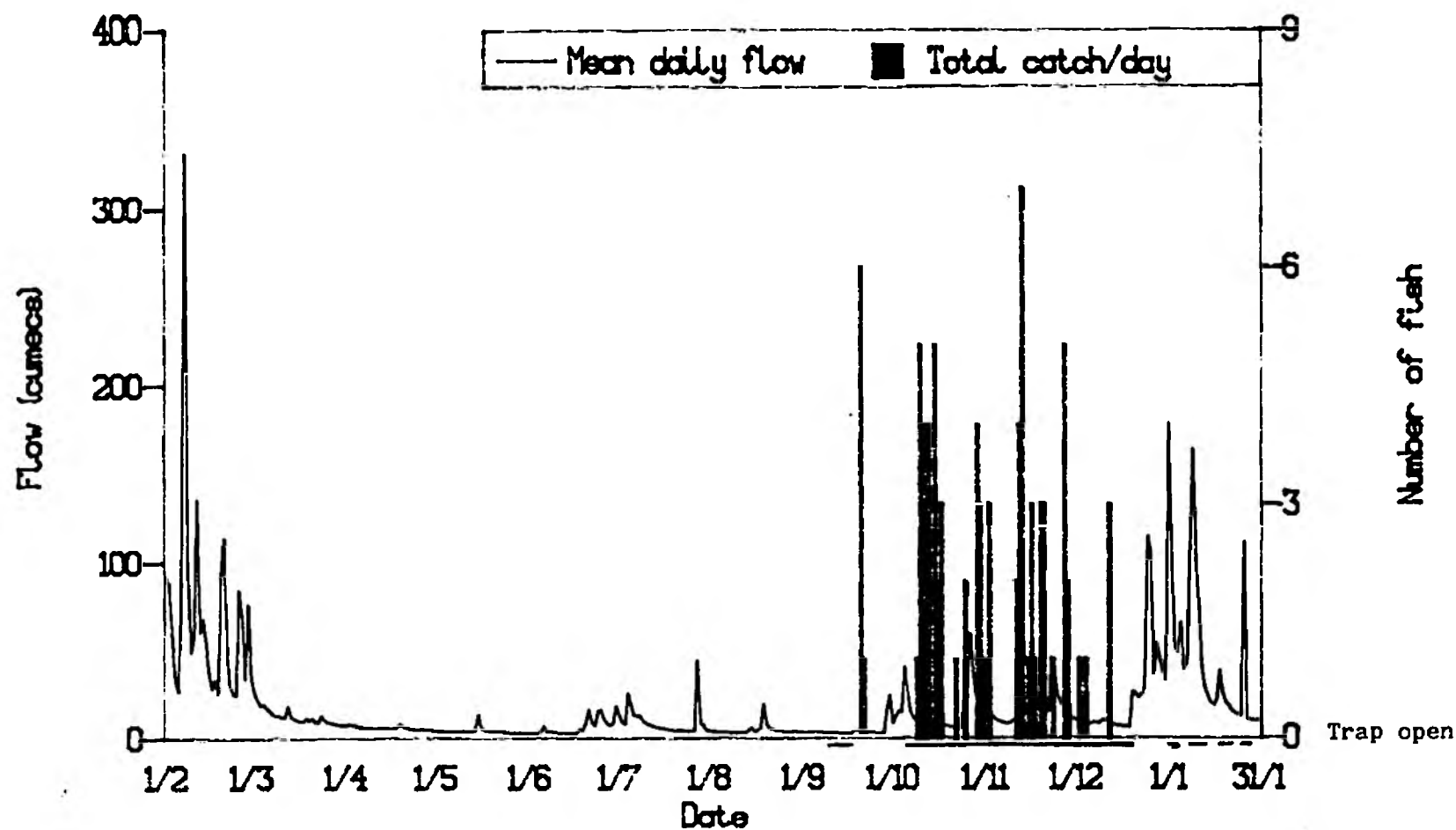


Fig. 4

Daily catch of salmon in relation to mean flow,
from 1st Feb. 1990 to 31st Jan 1991

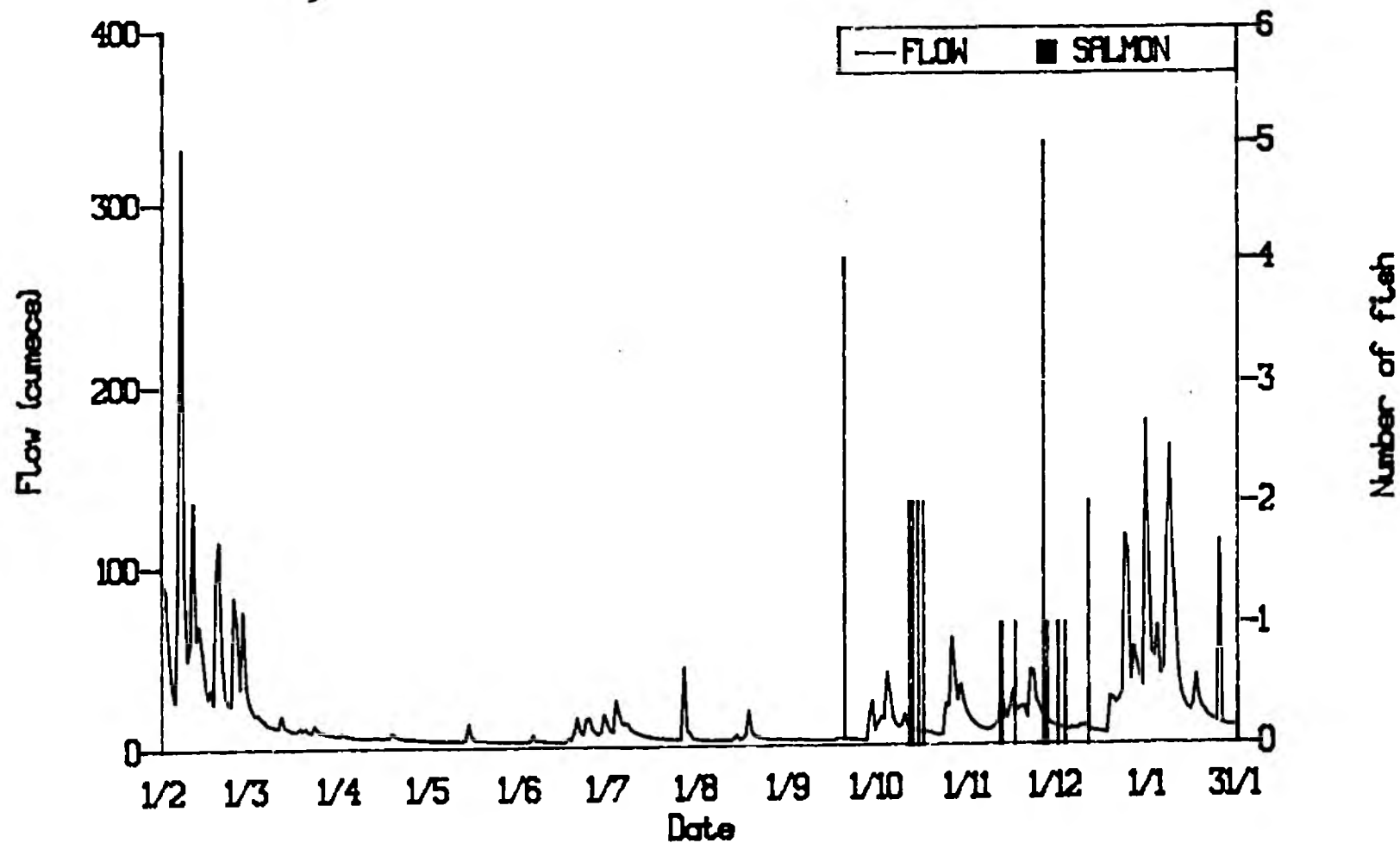


Fig. 5

Daily catch of sea trout in relation to mean flow,
from 1st Feb. 1990 to 31st Jan 1991

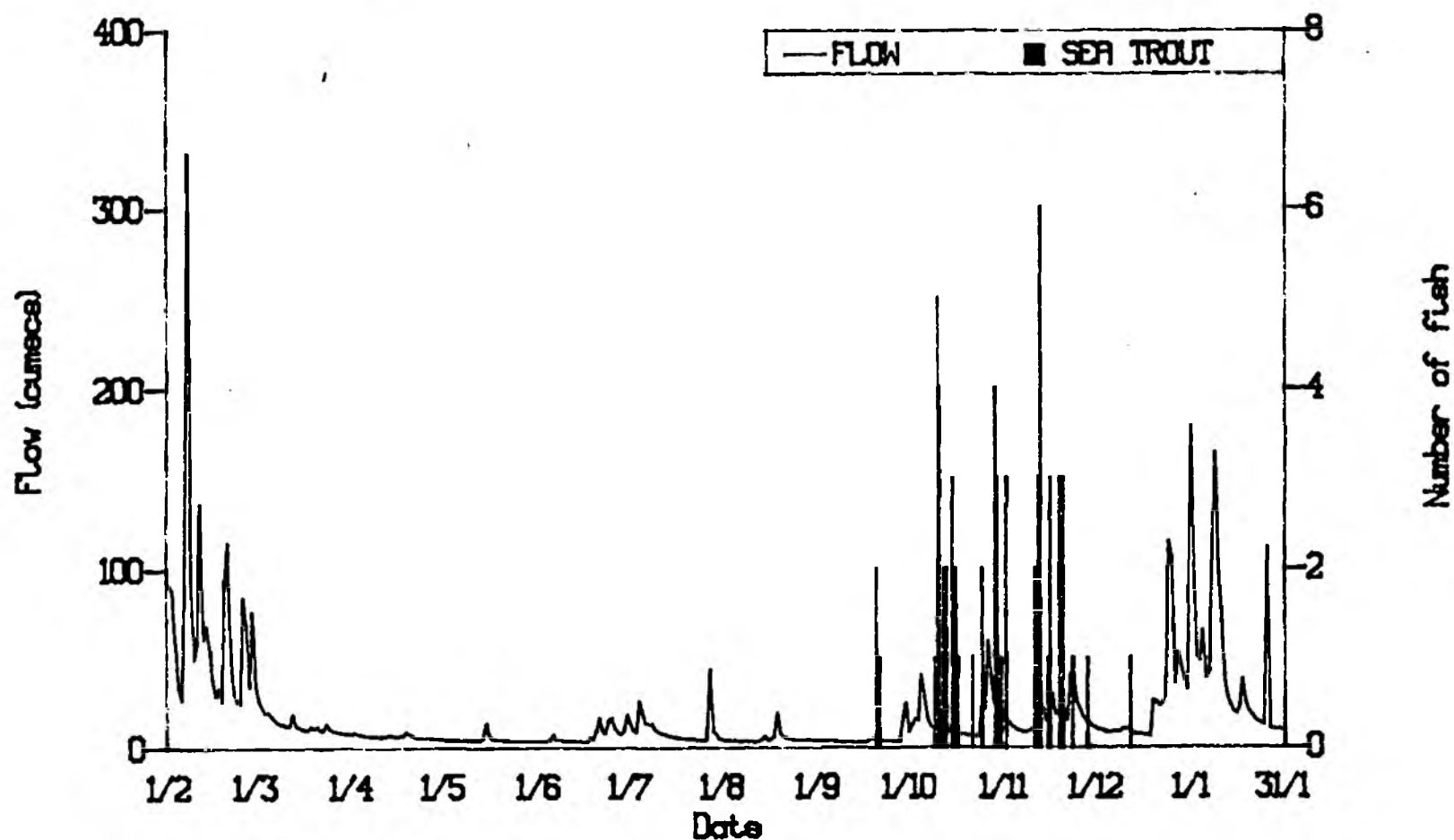


Fig. 6

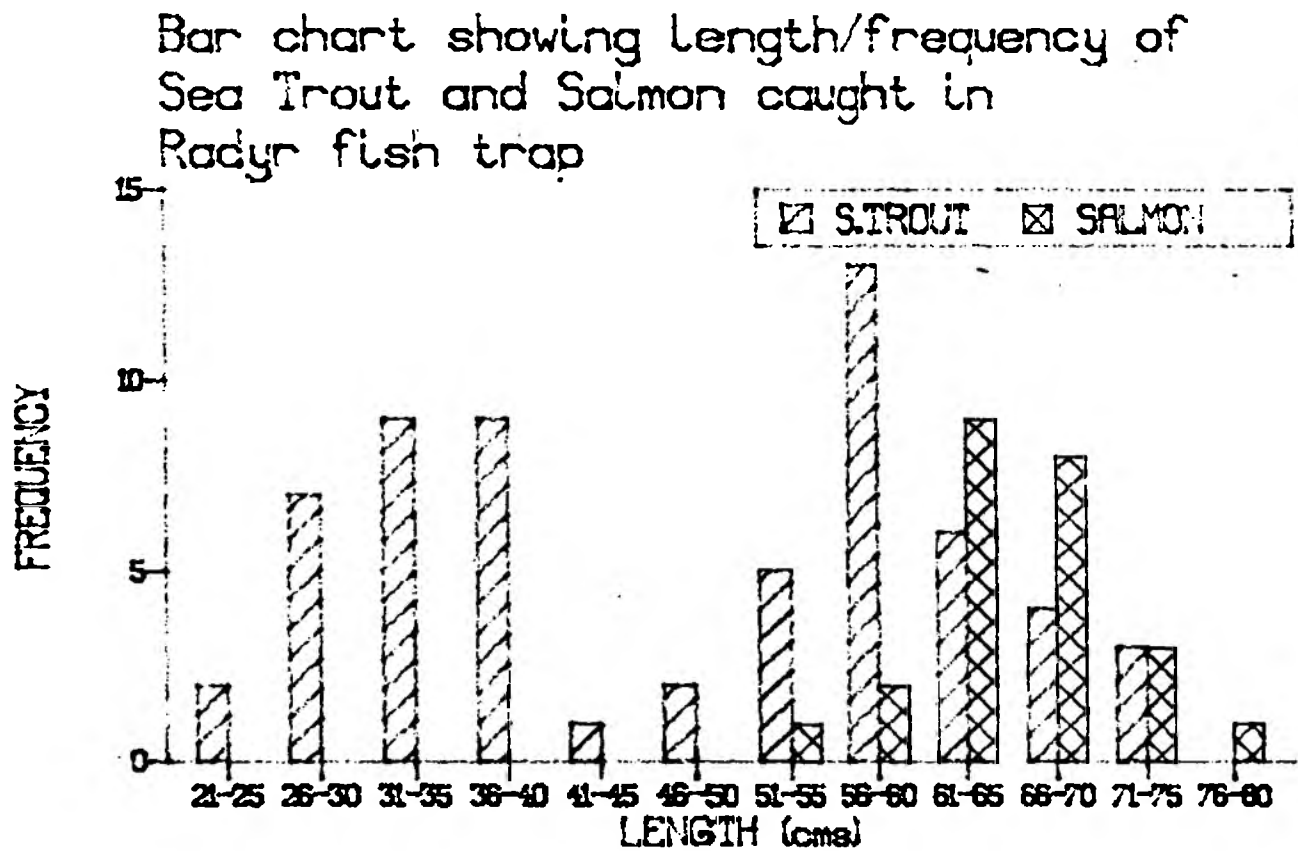
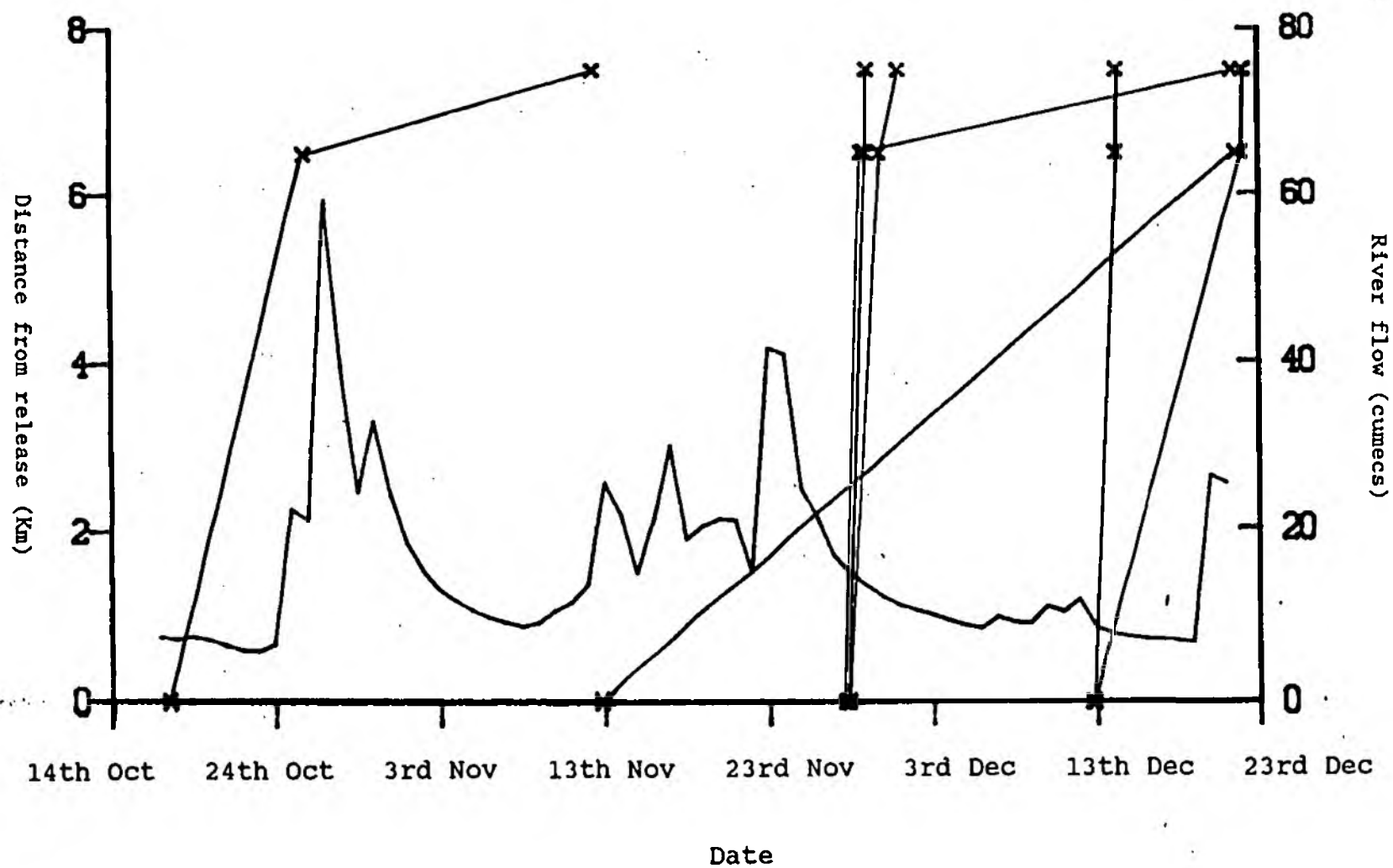


Figure 7. Movements of radio tagged salmon into freshwater in relation to river flow.



APPENDIX 1

Cardiff Bay Barrage - Assessment of the Impact
on Salmonid Fisheries of the River Taff

Document describing the salmonid monitoring programme proposed in accordance with section 23(2)(d) of the Cardiff Bay Barrage Bill 1988.

Cardiff Bay Barrage - Assessment of its impact on salmonid fisheries of the River Taff.

Summary.

1. The salmonid monitoring programme proposed by Welsh Water in accordance with section 23(2)(d) of the Cardiff Bay Barrage Bill 1988 is described.

2. The monitoring requirement is to assess the impact on the salmon and sea trout fishery of the river, in particular to examine:

(i) Migration into the river, time of entry and survival of adults.

(ii) Emigration and survival of smolts.

(iii) Emigration and survival of kelts.

(iv) The mechanism of any impact; this is an essential prerequisite to defining appropriate methods of alleviating or compensating for any damage.

3. A programme of investigation is presented, the main components of which are :

(i) Examination of the return rate of stocked salmon smolts and previously spawned adult sea trout by trapping of adults at Radyr weir in the lower Taff.

(ii) Comparison of these rates with a similar control experiment conducted on the Rhymney, which will be unaffected by impoundment.

(iii) Direct examination of migration patterns and success of fish entering and leaving the river, by tagging of adult spawners and kelts with radio/acoustic transmitters.

4. Assuming construction begins in 1992, investigations would comprise three years pre-construction study, to establish a baseline against which to assess changes, two years study during construction, and five years post-construction investigation.

5. For statistical reasons the present (three year) pre-construction timescale is already less than satisfactory, and a shorter pre-construction assessment period would not be acceptable to Welsh Water. Agreement on funding must be reached urgently to allow the programme to commence in the coming financial year.

6. The annual cost profile of the programme is shown below :

Year	Cost (£000)
89/90	340.5
90/91	179.0 *
91/92	104.0 *
92/93	104.0 *
93/94	104.0 *
94/95	104.0 *
95/96	104.0 *
96/97	104.0 *
97/98	88.0 *
98/99	88.0 *

* These costs will have to be adjusted to allow for inflation.

7. In addition to their statutory obligation, positive benefits to the promoters of implementing this programme are identified, including :

- (i) an improved basis for assessing low flow requirements for protection of migration, which could be very important in maximising the use of water when river flows are low,
- (ii) regular positive press coverage of stocking events,
- (iii) improved public perception of water quality in the Taff/Ely system as a whole.

Cardiff Bay Barrage - Assessment of its impact on the salmonid fisheries of the River Taff.

1. Introduction.

While Welsh Water recognise the efforts of the promoters to provide for the free migration of salmon and sea trout, there remains a strong possibility that the barrage scheme will adversely affect the number of these fish entering the Taff/Ely systems, and also the timing of fish runs. The potential for damage to the fishery is specifically recognised in the Cardiff Bay Barrage Bill. Section 23(2)(d) states :

"the undertakers shall pay to the Water Authority costs reasonably incurred by them in formulating..... and giving effect to a programme for monitoring the effect on fisheries of the construction and operation of the barrage....."

Section 40(17) also makes the undertakers liable for any mitigative action required to protect the fishery.

This paper describes the salmonid monitoring programme required by Welsh Water in accordance with section 23(2)(d) and the estimated cost to the promoters of implementing this programme.

2. Potential impacts

The barrage is a total exclusion barrage. The main passage routes for migratory salmonids are :

Upstream - Fish pass.

Downstream - High level sluices.

A variety of potential difficulties exist for migratory salmonids, some of which may be impossible to anticipate at the present time. Those considered most likely to occur are outlined below :

2.1 Problems facing upstream migrants

- (i) Fish have to locate the entrance to the pass, which is relatively small in comparison to the river mouth.
- (ii) There may be a sharp salinity and temperature gradient in the vicinity of the barrage wall where the entrance to the pass is located. This could deter fish from entering and ascending the pass.
- (iii) Other water quality factors ("taste") could be altered by the impoundment, resulting in poor homing or active deterrence of migrants.
- (iv) Passage through the impoundment could affect viability. Mortalities could occur at times of low freshwater flows if water quality declines. Low flow rates in the impoundment could impair migratory behaviour and successful passage.
- (v) Once through the impoundment, fish have to ascend Blackweir. This ascent may be difficult, particularly at times of lower flows. At the present time, fish temporarily obstructed by Blackweir (or other weirs) can fall back to sea if water quality/flow conditions are unsuitable for ascent. Following construction of the barrage fish numbers could build up in the impounded lagoon leading to increased exploitation and water quality related mortalities.

2.2 Problems facing downstream migrants

- (i) Downstream migrants may be delayed by the effect of the lagoon and deterred from passing over the sluices in low flows. This could result in increased mortality rates through effects

such as predation and water quality related mortality in the lagoon, and delay in their entry to the sea.

(ii) Physical damage may occur during exit.

(iii) Smolts and kelts may be osmotically stressed by the rapid transition from freshwater to saltwater at certain tidal states.

3. Proposed monitoring programme

3.1 Overall objective

To assess the impact of the barrage on the salmonid fisheries of the Taff and investigate the mechanism by which any impact is caused.

3.2 Approach

The monitoring programme is described in the following sections, each of which deals with different aspects of the monitoring. A specific objective, rationale and method is described for each programme element.

3.3 Assessment of impact on stocks

3.3.1 Objective

To detect any reduction in survival of salmon and sea trout caused directly or indirectly by the barrage.

3.3.2 Current monitoring of stocks

Existing monitoring of migratory salmonid stocks comprises:

- (i) declared catch returns from anglers,
- (ii) catches made by Welsh Water electrofishing operations.

While these provide minimum estimates of current runs, they are of limited value as a baseline against which the impact of the barrage can be measured, for two reasons.

(i) stocks in the river are expected to continue to expand rapidly due to improving water quality, stocking of juvenile fish, improved access of adults to spawning grounds, and the introduction of new byelaws reducing illegal fishing at sea.

(ii) catches represent an unknown and variable fraction of the runs of fish entering the river each year and are therefore a poor indicator of stocks.

More robust monitoring techniques, which are independent of the level of fish stocks, are therefore required. Such techniques, designed to meet specified objectives outlined are described in sections 3.3.3 , 3.3.4 and 3.4 below.

3.3.3 The return rate of tagged salmon smolts

3.3.3.1. Objective

To detect any reduction in the ability of smolts to migrate to sea from the Taff and subsequently return as adults.

3.3.3.2. Rationale

The rate of return of a known number of tagged smolts, as assessed by the capture of the returning adults in the lower reaches, will provide an estimate of juvenile to adult survival which is independent of stock size, provided that the proportion of returning adult fish caught remains relatively constant.

3.3.3.3. Method

- (i) Annually, 10,000 microtagged salmon smolts will be released into the Taff. Each stocking is expected to generate between 40 and 400 returning adults.
- (ii) Adapting and operating the fish pass at Radyr weir as a trap will provide a consistent method for assessing the number of tagged salmon returning as adults in each year. Monitoring of angler's catches below the trap for tagged fish would also be necessary, to account for year to year variation in angling success.
- (iii) An identical exercise, both stocking and trapping, is required on a control river, for two reasons.
 - (a) The mortality of smolts at sea is naturally variable. Consequently, to correctly identify with adequate precision any impact, or absence of impact, due to the barrage would require in excess of 5 years data pre-construction and a similar or greater period post-construction (Table 1). Given that construction is likely to commence in 1992, only three years pre-construction data would be available, assuming that monitoring commences immediately.

(b) The return rate of smolts is likely to increase about the time of construction due to the introduction of byelaws which will reduce illegal fishing for salmon at sea. In the absence of a control, it is therefore possible that a deleterious impact of the barrage on smolt survival would be masked.

(iv) The adjacent river Rhymney is considered most suitable as a control, although a trap would have to be constructed.

(v) Stocking of smolts and monitoring of returning adults should commence immediately and continue for at least five years after construction.

3.3.3.4 Extrapolation to sea trout

The urge to migrate to sea may not be as well developed in juvenile sea trout as in salmon. It is possible therefore that the impoundment may affect the two species differently. If it were feasible, the programme proposed for salmon would be repeated for sea trout. However, Welsh Water has neither the stock in hand, nor sufficient rearing capacity to commence such a programme before 1992, and suitable stock could not be obtained elsewhere. In the absence of a feasible option, the survival of salmon smolts will be assumed to be representative of sea trout smolts.

3.3.4 The return rate of previously spawned adults

3.3.4.1 Objective

To detect any reduction in the rate of return of previously spawned fish to the Taff.

3.3.4.2 Rationale

Sea trout frequently spawn several times. Previously spawned fish, by virtue of their large size and increased reproductive capacity are likely to be important to the maintenance of sea trout stocks. It is important therefore that the impact of the barrage on the return rate of previously spawned sea trout be assessed.

The rationale is similar to that for smolts except that adult sea trout will have to be captured for tagging rather than stocked.

3.3.4.3 Method

- (i) Adult sea trout would be trapped, then tagged and released, both in the Radyr trap when ascending to spawn, and in a downstream trap at Llandaff (see section 3.4), as kelts. Plastic Floy tags would be employed.
- (ii) On their subsequent return to freshwater, tagged sea trout would be monitored in the Radyr trap and anglers' catches.
- (iii) Again, the Rhymney, which has a sea trout population, would be used as a control.

(iv) The rate of return of previously spawned sea trout is generally high, in excess of 15%. Consequently, only a few hundred fish would have to be tagged on each river:

(v) The impact of the barrage on the return rate of salmon kelts is considered comparatively unimportant, since a relatively small proportion survive to spawn twice.

3.4 Migration Patterns

3.4.1 General Objectives

To quantify effect of the barrage on migration success and migration timing of both upstream and downstream adult migrants.

To identify, as far as possible :

(i) How the barrage might be operated to minimise any impact on migratory salmonid stocks while meeting other needs (e.g. water requirements for boat locking).

(ii) Whether the safeguards for fisheries, incorporated in the Bill (e.g. water quality criteria, the potential for 'flushing' smolts and kelts) are adequate.

3.4.2 Upstream migration

3.4.2.1 Objective

(i) To quantify effect of the barrage on migration success and migration timing of adult fish.

(ii) To identify how adult fish respond to the barrage, fish pass and bay under different conditions when migrating upstream.

3.4.2.2 Rationale

Equipment and techniques are now readily available for tagging adult fish with both radio and acoustic transmitters and monitoring their subsequent migration. Fish of known Taff origin (i.e. captured in traps in the river) will be fitted with transmitters, relocated to the sea and re-entry to the river monitored. Comparison of behaviour and re-entry success before, during and after construction will allow a direct assessment of the impact of the scheme on upstream migration, complementing the studies on the survival of smolts and kelts (sections 3.1.3 and 3.1.4).

3.4.2.3 Method

Assuming initial trials are successful, up to 100 adult fish per year will be trapped at Radyr, fitted with transmitters and relocated to sea. This will be undertaken for each of the three pre-construction years commencing summer 1989, throughout the construction period, and for the first three years of barrage operation. Where possible tagged fish, of known Taff origin, will be used, as they are more likely to try and re-enter the river.

It is recognised that the undertakers of the Bill will ensure that water quality in the lagoon, and flows through the bay, are monitored in accordance with Welsh Water requirements under other provisions of the act. This data will be examined in relation to migration of fish through both the

fish pass and impoundment. Both the flow and salinity in the fish pass will be varied and the passage of fish monitored using both radio tracking and the trap/fish counter on the barrage.

3.4.3 Downstream migration

3.4.3.1 Objectives

To identify whether:

(i) the barrage and bay delays the downstream migration of fish;

(ii) if delays occur, how the barrage might be operated to avoid them.

3.4.3.2 Rationale

The Bill allows for operation of the barrage to flush downstream migrants out of the bay but it is not clear either that this will be necessary, or that it will work.

The passage of downstream migrants through the lower river should therefore be monitored by radio-tracking. Although tags can be obtained which are suitable for adult kelts, tags suitable for smolts are not yet available. If tags were available, it would clearly be desirable to examine the passage of both kelts and smolts, but in the absence of suitable tags for small fish, tracking of downstream migrants will be confined to kelts.

3.4.3.3 Method

A trap to catch downstream migrants will be constructed at Llandaff weir. Each year, for the years described for upstream migrants (section 3.2.2), up to 40 kelts will be trapped, fitted with transmitters and released. Their migration as they exit the river will be monitored to identify effects.

4. Costs

The annual costs of implementing the programme are as follows :

<u>Year</u>	<u>Cost</u> (000)
89/90	340.5
*90/91	179.0
*91/92	104.0
*92/93	104.0
*93/94	104.0
*94/95	104.0
*95/96	104.0
*96/97	104.0
*97/98	88.0
*98/99	88.0
Total	1319.5

* These costs will have to be adjusted to allow for inflation.

Costs in the first two years include the capital costs associated with construction of traps and equipment.

5. Programme review/reporting

The programme provides for production of an annual interim progress report, available to both Welsh Water and the promoters. This report would be due on April 1st of each year. A final report would be due at the end of the programme.

Elements of this programme utilise methods and approaches which have limited technical precedent. While major research and development work is not involved, the right to delete or modify elements of the programme, is reserved. Such modifications would be undertaken following consultation with the promoters.

6. Benefit to promoters.

In addition to the statutory requirement to undertake the monitoring programme identified in the Bill, there are a number of potential advantages to the promoters in undertaking this programme. As examples, we cite the following :

(i) Salmon are seen by many of the public as a direct measure of the cleanliness and health of a river system. The protection and encouragement of a healthy salmon stock has obvious public relations importance in the context of the future perception of the impoundment by the public. An example of how this can be used to good effect to obtain regular, cheap national publicity, is provided by the Thames Water salmon rehabilitation project.

(ii) The incorporation of stocking into the monitoring programme would provide good positive news coverage on a regular basis.

(iii) Tracking of migratory fish past the barrage will provide a detailed understanding of migration patterns which could be very important in maximising the use of water when river flows are low.

TABLE 1

The average percentage change in the return rate of hatchery reared smolts which could be detected as statistically significant at the 5% level, given 3 or 5 years data pre-construction of the barrage (no control).

	<u>POST-CONSTRUCTION</u> (YEARS)	
	5	10
PRE-CONSTRUCTION		
3	65%	54%
5	56%	46%

Estimates are based on the variance reported for the return rates of S2 smolts, 1978-87, reported by the Salmon Research Trust, Ireland at Burrishoole.

TABLE 3

STAFF REQUIREMENTS FOR IMPLEMENTATION OF PROGRAMME

Task	Jan.	Feb.	Mar.	Apr.	May	June	Jul	Aug	Sep	Oct	Nov	Dec	# of Total
Operate Radyr upstream trap	1.0	1.0	1.0	2.0	4.0	4	4	4	4	4	4	2	22.44
Operate Rhymney upstream trap	1.0	1.0	1.0	1.0	3.0	3	3	3	3	3	3	1	16.67
Operate Llandaff downstream trap.	4.0	2.0	2.0	4.0	4.0	0	0	0	0	0	2	4	14.10
Additional fish capture operation for radio tracking.	0.0	0.0	0.0	0.0	0.0	4	4	4	4	0	0	0	10.26
Radio acoustic tracking	3.0	3.0	3.0	3.0	3.0	3	3	3	3	3	3	1	23.08
Administration + data collation and entry	1.0	1.0	1.0	1.0	1.0	1	1	1	1	1	1	1	7.69
Data validation and reporting	3.0	3.0	3.0	0.0	0.0	0	0	0	0	0	0	0	5.77
Total man days per week	13.0	11.0	11.0	11.0	15.0	15	15	15	15	11	13	11	100.00
Staffing level allowing for leave etc.	2.6	2.6	2.6	2.6	2.6	4	4	4	4	3	3	3	

From the above staffing requirement, it may be seen that an average of 13 working days are required in any one week, with actual values varying from 11 to 15, depending on season. Assuming one person provides 221 working days per year, this requires an average of just over three persons on a full time basis. Allowing that many tasks require a minimum of two persons for safety reasons, the profile in Table 3 is proposed, resulting in an average of 3.28 full time staff equivalents.

The successful operation of the project will require employment of scientifically trained staff, on a temporary contract basis, with one full time individual responsible for day to day supervision of the programme, in consultation with a Welsh Water manager. We recognise that this type of project will readily attract staff, reducing the need to offer high salaries. We have therefore calculated costs, based on what we consider to be the lowest grades appropriate to the tasks involved. One post has been assumed to be at Water Authority grade 4, to supervise the programme, the remainder being pro-rata at grade 1, the lowest in the industry. In addition 15% has been added for administrative on-costs, plus a further 20% to cover expenses, costs of appointment, overtime and anti-social hours payments.

This results in the following total annual staff cost:

1 x grade 4	£14,671 p.a. (inc. of all costs)
2.16 x grade 1	£17,750 p.a.
	<u>£32,421</u>

Appendix 2

**Cardiff Bay Barrage - Calculation of Mitigation Costs for
the Impact of the Cardiff Bay Barrage on Migratory Salmonids**

Document describing the basis for calculation of the mitigatory stocking of salmon smolts to compensate for any negative impact of the development.

CARDIFF BAY BARRAGE BILL

MEMORANDUM OF AGREEMENT

BETWEEN

THE SOUTH GLAMORGAN COUNTY COUNCIL

THE CARDIFF BAY DEVELOPMENT CORPORATION

THE NATIONAL RIVERS AUTHORITY

AND

DWR CYMRU CYFYNGEDIG

MEMORANDUM OF AGREEMENT made between the South Glamorgan County Council ("the Council") of the first part the Cardiff Bay Development Corporation ("the Corporation") of the second part the National Rivers Authority (Welsh Region) ("the Authority") of the third part and Dwr Cymru Cyfyngedig ("the Company") of the fourth part.

IT HAS BEEN AGREED between the Council, the Corporation, the Authority and the Company that, in consideration of these presents and the predecessor of the Authority and the Company (the Welsh Water Authority) refraining from opposition to the Cardiff Bay Barrage Bill ("the intended Act") in the House of Commons, the following provisions shall have effect between the parties:-

1. This Agreement shall be construed in accordance with the intended Act and -

"the Authority", "the Company", "the Corporation" and "the Council" includes any transferee of the relevant statutory functions of each such body;

"the conditions of licence" means the conditions specified in the provision of the intended Act of which the marginal note is "Barrage to be constructed under impounding licence";

"the protective provision" means the provision of the intended Act of which the marginal note is "For protection of the National Rivers Authority and Dwr Cymru Cyfyngedig";

and, for the purposes of this Agreement, an effect shall be taken to be significant within the reasonable balance of probabilities only when the probability of that effect resulting by chance is 40 per cent or less.

2. Whereas -

(a) by the conditions of licence and the protective provision the Council and the Corporation or either of them are required to pay costs (including a proper proportion of the overhead charges) reasonably incurred by the Authority -

(i) in formulating, in consultation with the Council and the Corporation or either of them, and in giving effect to, a programme

for monitoring the effect on fisheries of the construction and operation of the barrage;
and

(ii) in technical surveys (including routine water quality surveys) or modelling (including servicing and operating any model so provided) which are reasonably required by reason of the construction and operation of the barrage for the purpose of monitoring and recording the quality of the impounded water and related ecosystem upstream of the barrage;

- (b) by agreement between the Corporation and the Authority, the Authority commenced the fisheries monitoring programme on 1st January 1990;
- (c) in order to achieve a complete assessment of the impact on the fisheries of the construction of the barrage it would normally be necessary to monitor the present regime of the fisheries affected by such construction together with the regime of the fishery of a nearby river not so affected over a period of not less than three years before the closure or obstruction of the final 250 metres of 'free gap' in the barrage; and
- (d) such monitoring of an unaffected river being impracticable due to the expected programme for the construction of the barrage, it is not expected that such a programme of monitoring as can be

carried out could show that any reduction of up to 37 per cent in the return of smolts to the fisheries is attributable to the construction of the barrage within the reasonable balance of probabilities;

It is hereby agreed between the parties -

- (1) that the costs payable to the Authority as recited in paragraph (a) above include such costs reasonably incurred by them before the passing of the intended Act;
- (2) that, for the purpose of determining the impact on the fisheries of the construction of the barrage and the costs reasonably incurred by the Authority to protect the protected fishery against damage or to remedy any damage to that fishery, the construction of the barrage shall be taken to have caused a reduction in the return of smolts to the fisheries of at least 37 per cent unless at any time before those costs are incurred the Corporation can show that the average annual run, over a period of five years at any time after the impoundment, of migratory salmonids returning to the River Taff is at least 1000 salmon or salmon equivalents (taking 4 sea trout as equivalent to one salmon), not including any fish introduced to that river for the purpose of the fisheries monitoring programme;
- (3) that, for the purpose of determining the impact on

the fisheries of the construction of the barrage and the costs reasonably incurred by the Authority to protect the protected fishery against damage or to remedy any damage to that fishery, the construction of the barrage shall be taken to have caused a reduction in the return of smolts to the fisheries of more than 37 per cent if such a reduction is found to be significant within the reasonable balance of probabilities; and

- (4) for the purposes of determining costs incurred as mentioned in paragraphs (2) and (3) above during the period in which the monitoring programme is carried out, the total number of adult salmon and salmon equivalents caught at Račyr Weir or by anglers downstream of Račyr Weir shall be taken as the number of adult fish returns less the presumed reduction of 37 per cent as provided in paragraph (2) above or, as the case may be, less any reduction in excess of 37 per cent found as provided in paragraph (3) above.

3. It is further agreed between the parties as follows:-

- (1) All costs and expenses recoverable by the Authority from the Corporation and the County Council, or either of them, under the protective provision which are incurred by the Authority over any period longer than 6 months shall be repayable in 6 monthly instalments as so incurred, if so demanded

by an account rendered, and, if an account rendered in respect of any such costs and expenses is not paid within 56 days from the date on which it is rendered, the sum payable in respect of the account shall bear interest from the date on which it was rendered at the rate of 3 per cent above the base lending rate from time to time of the Royal Bank of Scotland.

- (2) All costs and expenses recoverable by the Company from the Corporation and the County Council, or either of them, under the protective provision shall be repayable as incurred, if so demanded by account rendered at monthly intervals, and, if an account rendered in respect of any such costs and expenses is not paid within 56 days from the date on which it is rendered, the sum payable in respect of the account shall bear interest from the date on which it was rendered at the rate of 3 per cent above the base lending rate from time to time of the Royal Bank of Scotland.

4. It is further agreed between the parties that unless the respective functions and responsibilities of the Council and the Corporation are defined in the intended Act -

- (a) the Corporation will be responsible for advising the Authority and the Company from time to time as often as may be necessary which of the Council and the Corporation is to be taken to be responsible in

the case of any provision of the Bill which refers to the Council and the Corporation or either of them as the undertakers;

(b) subject to any such advice the Authority and the Company or either of them will be entitled to treat with whichever of the Council and the Corporation holds itself out as the undertakers responsible in the case of any matters arising; and

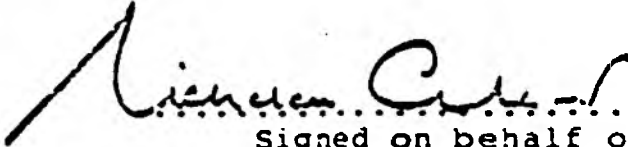
(c) if any communication from the Authority or the Company addressed to the Council or the Corporation, or any officer of the Council or the Corporation, on any matter should have been addressed to the other of them or to any officer of the other of them, it will be passed without delay to that other.


5. (1) In the event of any difference arising between the Council or the Corporation and the Authority under section 23(3)(d) or (e) or section 41(21) or (24) of the intended Act (as submitted for consideration in Committee in the House of Commons) or under clause 2 of this Agreement, the difference shall be referred to and settled by an arbitrator appointed by agreement between the parties or, in default of agreement, by an arbitrator appointed on the application of either party, after giving to the other not less than one week's notice in writing, by the President of the Institute of Fisheries Management.

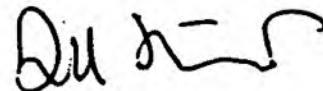
(2) Except as provided in paragraph (1) above, any

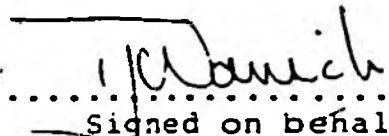
difference which may arise between the Council or the Corporation and the Authority or the Company under this Agreement shall be determined by arbitration in the manner provided by the intended Act.

DATED this 20th day of February, 1990.


Signed on behalf of
THE SOUTH GLAMORGAN COUNTY COUNCIL


.....
Signed on behalf of
THE CARDIFF BAY DEVELOPMENT CORPORATION


.....
Signed on behalf of
THE NATIONAL RIVERS AUTHORITY


.....
Signed on behalf of
DWR CYMRU CYFYNGEDIG

CARDIFF BAY BARRAGE BILL

MEMORANDUM OF AGREEMENT

BETWEEN

THE SOUTH GLAMORGAN COUNTY COUNCIL

THE CARDIFF BAY
DEVELOPMENT CORPORATION

THE NATIONAL RIVERS AUTHORITY

AND

DWR CYMRU CYFYNGEDIG