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Guardians of the Water Environment

Diogelwyr Amgylchedd Dŵr

ENVIRONMENTAL IMPACT OF HYPOLIMNIAL RELEASES FROM LLYN BRIANNE

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EXECUTIVE SUMMARY

1. INTRODUCTION

Following a public enquiry in December 1966, the West Glamorgan Water (Llyn Brianne) Order of 1968 authorised the construction of Llyn Brianne reservoir in the R. Tywi upstream of Llandovery. Widespread public concern has subsequently been expressed regarding release into the river of water drawn from the hypolimnion of the reservoir. This concern is principally related to the effect of the reservoir on the thermal regime in the river.

This paper has the following objectives :

(i) To review existing evidence of ecological and fishery impact downstream of Llyn Brianne.
(ii) To assess the cause and extent of such impact.
(iii) To evaluate the requirement for installation of a multiple level release system.

2. CONCLUSIONS

(i) Important commercial and recreational fisheries are supported by the Tywi catchment, the rod catch of sea trout being the largest in Wales.

(ii) Examination of the literature available from studies of other river regulation schemes demonstrates that hypolimnial draw off regimes are ecologically detrimental.

(iii) Current good practice when designing major reservoir schemes in England and Wales is to include facilities for epilimnial or multiple level draw off.

(iv) Thermal stratification occurs in the reservoir during the summer, with colder water in the hypolimnial layer. In contrast, winter temperatures in the reservoir are higher than those in local rivers, because of the buffering capacity of the water body. As a direct result, the R. Tywi between Llyn Brianne and Llandovery is affected by :

(a) Reduction in mean summer temperatures by up to 8 degrees Celsius.
(b) Delays in the onset of temperature rise in spring.
(c) Increased temperatures during winter.

(v) The Llyn Brianne acid waters study has demonstrated that the upper Tywi catchment is seriously affected by acidification. Although detrimental effects of pH would be expected in the absence of the reservoir, use of hypolimnial water may, because of pH stratification, increase both the extent and severity of impact. These problems should, however, be resolved by liming of Llyn Brianne by the NRA later this year.

(vi) Hypolimnial draw off increases sedimentation downstream of the reservoir and results in elevated levels of manganese in the sediments.

(vii) Examination of the catchment has shown that invertebrate fauna are depleted for at least 11 km downstream of the reservoir.

(viii) Juvenile fish surveys have demonstrated a virtual absence of salmon, and reduced trout populations for up to 13 km downstream of the reservoir. Estimated annual cost of replacing this loss of production by restocking is £189,000 p.a. (1990 costs) or £2,752,000 over the next ten years, assuming constant 8% inflation.

(ix) Review of literature from studies of other impoundments predicts that temperature, sedimentation and acidification effects could each contribute to serious ecological and fishery damage, consistent with that described above.

(x) Sedimentation effects are likely to be important for up to 3 km, but are not likely to account for ecological paucity further downstream. While it is impossible to partition impact between temperature and pH, literature evidence suggests that both factors are independently capable of causing the observed environmental damage.

(xi) Installation of a multiple level draw off would ameliorate these problems, given that the acid water problem is being addressed by liming of Llyn Brianne in 1990.

3. RECOMMENDATIONS

(i) The NRA and it's predecessors have recognised the need for action to address public concern, and have previously co-funded detailed investigations with a view to establishing the cause, extent and solutions of the problem. These aspects are now clearly understood, and the NRA is already committed to liming of Llyn Brianne in the current financial year. This commitment should be given high priority.

(ii) Although it is recognised that the existing situation has effectively existed for 20 years, this is not a good reason for inaction. The NRA should therefore take all practicable measures to ensure the installation of a multiple level release at the earliest possible date.

(iii) In addition to the physical design of the draw off point, consultants / engineers contracted for design work should be asked to consider operational regimes. Consideration should be given to reduction of both temperature differentials and sediment deposition.

(iv) Further development of the Llyn Brianne scheme (eg HEP) should not be considered until these immediate problems have been resolved.

1. INTRODUCTION

Following a public enquiry, held in December 1966, the West Glamorgan Water (Llyn Brianne) Order of 1968 authorised the construction of L. Brianne river regulating reservoir in the headwaters of the R. Tywi, some 19 km north of Llandovery. This enquiry addressed a range of issues, including details of river regulation regimes, and the provision of mitigation for the loss of salmonid production from the area isolated by the construction of the reservoir (Howells and Jones, 1972). Although concern was expressed by anglers representatives at the enquiry, economics dictated a single, hypolimnial draw-off point (WNWDA,1976). No account of potential and / or observed impacts on the downstream watercourse was taken in either the Llyn Brianne Fisheries Protection Scheme (LBFPS), or in subsequent assessments of mitigation requirements (WWA, 1978; WWA, 1982).

Since the construction of the reservoir, considerable concern has been expressed by representatives of conservation bodies and angling associations, who state that invertebrate diversity and abundance has been reduced, and that the abundance of salmon (Salmo salar L.) in the Tywi has declined. In particular a widespread perception exists, referred to in both written and verbal correspondence, that the use of cold hypolimnial draw off water is damaging to the general ecology, fish stocks and fisheries of the Tywi downstream of the reservoir. Public concern in this respect has been further increased by the apparent failure of the LBFPS, even though this may be attributed to acidification of the headwaters (Edwards, Gee and Stoner, 1990). The strength of this concern has been recognised in the NRA corporate plan, which includes, as a key regional priority, a commitment to investigate 'the problem of cold discharges of compensation and regulation water into an important salmon fishery'.

This paper has the following specific objectives :

(i) To review existing evidence of ecological and fishery impact downstream of Llyn Brianne.

(ii) To assess the cause and extent of such impact.

(iii) To evaluate the requirement for installation of a multiple level release system.

2. BACKGROUND.

2.1 Catchment and fisheries

The R. Tywi (Fig 1.) rises at a height of 425m in an afforested and moorland area of Mid Wales. It is 111 km in total length and has a catchment area of 1335 km^2. The river supports a nationally important sea trout rod fishery, with an average declared Sea Trout (Salmo trutta L.) rod catch in excess of 6000 fish per annum since 1983, the largest in Wales. The declared annual salmon catch also averages more than 900 fish, and the river supports significant commercial fisheries, with 9 seine net crews licenced in the lower estuary, and 12 coracle nets licenced in the upper estuary.

2.2 Existing literature

A large body of evidence exists describing the effects of impoundments and river regulation, both in the UK and elsewhere (see for example reviews by Brooker, 1981 and Petts, 1984). In the United Kingdom, particular attention has been paid to thermal effects on the downstream river, resulting from hypolimnial draw-off (e.g. Lavis and Smith, 1972; Cowx et. al., 1987). Thermal effects have been shown by many authors to be associated with depleted invertebrate and fish populations (eg Crisp, 1977, 1984; Edwards, 1978; Lehmkuhl, 1972). More detailed discussion of these effects, and their applicability to the Tywi, is given in the appropriate section below.

2.3 Current practice

Although hypolimnial draw-offs were not uncommon in the period preceding the construction of Brianne, more recent schemes have recognised the clear evidence that hypolimnial releases are environmentally detrimental, and included multiple or epilimnial draw off facilities have been included (eg

Llys-y-Fran, Colliford, Roadford). When major schemes, such as Roadford, (R. Tamar system, Cornwall) have been examined at public enquiry in recent years, provision of multiple level draw has been identified in evidence as a requirement prior to scheme approval. If Llyn Brianne were now being promoted, a multiple level draw-off would therefore be included.

3. OBSERVED PHYSICAL AND CHEMICAL EFFECTS

Physical and chemical effects of storage within Llyn Brianne are present in both the reservoir and the river downstream. The most important of these are described below :

3.1 Reservoir waters.

Depth profile surveys have demonstrated the existence of temperature stratification, and a thermocline develops during the summer months, resulting in differences in temperature of up to 15°C between the top and bottom layers (WWA, 1988; fig. 2). In the deepest part of the reservoir, from where water is currently drawn for release, water temperatures remain below 8°C at all times. Despite the presence of a thermocline, the reservoir is well oxygenated throughout and there is very little variation in oxygen concentration with depth. However seasonal variations in pH, aluminium and calcium concentrations occur, and these do vary with depth. The lowest pH and highest aluminium and calcium levels occur in summer in the bottom layers (differences of up to 1 pH unit compared to surface waters, 0.2 mgl^{-1} and 0.5 mgl^{-1} respectively (WWA 1988)). Manganese concentrations increase with depth at all times of the year (difference up to 0.1 mgl^{-1} (WWA, 1988)) whereas dissolved iron concentrations show little discernible pattern.

3.2 Downstream impact.

The River Tywi downstream of Llyn Brianne is affected by the following :-

i) Thermal resetting (reduction in summer and increase in winter temperatures).

ii) The release of acidic water.

iii) The deposition of manganese rich sediments.

3.2.1 Thermal resetting.

In common with many upland impoundments (Crisp et al. 1987), Llyn Brianne has substantially altered the seasonal temperature regime of the downstream water course. The extent and magnitude of this efect varies in response to the relative discharges from the release valves, overflow weirs and local tributaries (WWA, 1987). In general the major impact on the Tywi can be summarised as:

(i) Lower summer temperatures (March to October).

(ii) Higher winter temperatures (November to February).

(iii) Lagging of spring warming.

As a result of the present hypolimnial draw-off, temperatures in the river below the reservoir are much lower than in tributaries feeding the reservoir, or in other comparable rivers such as the Doethie and the Cothi, during the summer months. (fig. 3). Increases in temperature during the spring and early summer are delayed downstream of Brianne, and maximum summer temperatures occur up to 2 months later than in comparable rivers. Mean summer temperatures are up to 8^{o}C lower than would be expected in the absence of the reservoir. Under normal summer conditions, reduced river temperatures extend as far as Llandovery, although extension much further downstream may occur during larger scale releases. A river management release in the summer of 1983 reduced river temperatures from 20^{o}C to 13^{o}C at Manorafon, 36km downstream of the reservoir (WWA, 1988).

In contrast to the summer period, in winter months, river temperatures are higher than in comparable rivers. As an example, the mean winter temperature of the River Tywi below Llyn Brianne in 1980/81 was 3^{o}C higher than the Tywi above Brianne (WWA, 1988).

3.2.2 Release of Acidic Water from Llyn Brianne

The presence and effects of acidification in the upper Tywi catchment have been well established and documented (WWA 1985 1986, Stoner and Gee 1985). The extent of downstream acidification depends on the rate of release from Llyn Brianne in relation to the natural tributary flows which will buffer and dilute the acidic water so reducing its effect. The Gwenffrwd, the Gwenlas and the Bran, which are major tributaries, ameliorate acidity by virtue of their higher hardness and pH. The Doethie, which joins the Tywi below Ystraddfin, exhibits quality similar to that of the main river and is also affected by acidification.

The use of poorer quality (lower pH) hypolimnial water, and releases of water from Llyn Brianne, for either abstraction or fisheries purposes, during periods of low base flows, may extend the effects of acidification. Monitoring of releases undertaken for fisheries purposes in 1985 showed a significant reduction in pH and increase in aluminium concentrations down to the confluence with the Bran.(figs 4,5).

3.2.3 Deposition of Manganese Rich Sediment

Iron, manganese and aluminium are all elevated in release waters. In the Tywi at Ystradffin, the mean dissolved iron and manganese concentrations were 0.16 mgl^{-1} and 0.275 mgl^{-1} respectively during 1985.
Sedimentation occurs downstream of reservoirs as a result of the settling of particles (viz planktonic debris) and, particularly from hypolimnetic release reservoirs, the deposition of iron and manganese rich materials. This process is enhanced by a stable flow regime arising from a constant reservoir release and results in the clogging of substrate interstices thereby reducing habitat heterogeneity (Ward 1976). Precipitates rich in manganese have been observed blanketing the bed of the Tywi below the reservoir, down to the confluence with the Doethie (3 km. WWA, 1986).

4. ECOLOGICAL IMPACT

4.1 Macrophytes

At present, rooted angiosperms are limited in their occurrence in the upper reaches of the River Tywi and probably reflect local areas of stable substratum. Aquatic bryophytes are more common but again development is restricted to areas of stable bedrock or boulders. Significant developments of algae can occur during periods of low stable flows.

The most important factors influencing macrophytes in the upper Tywi are flow and substratum stability. It is unlikely that changes in thermal regime resulting from a different draw off level will have a major effect on macrophytes downstream.

4.2 Invertebrates

4.2.1 Mechanisms of impact

The principal factors influencing the macroinvertebrate fauna of the River Tywi downstream of Llyn Brianne are changes in thermal regime, acidification, and sedimentation. These are discussed below :

(i) Thermal regimes

Changes in the temperature regime arising from hypolimnial release (see section 3.2.1) have a number of potential effects on the macroinvertebrate fauna. The egg stage of the life cycle is particularly sensitive to temperature changes. Some species have egg diapause stages (arrested development) which require extremes of temperature (viz. temperatures near freezing) before egg hatching can occur (Lehmkuhl, 1972). Successful egg development may be prevented as a result of elevated minimum temperatures in winter. Contrastingly, in species without such a diapause, unseasonally high river temperatures in winter may induce premature hatching and emergence at a time when ambient temperatures are unsuitable for the adult aerial stage.

The suppression of summer temperatures may slow down larval or nymphal development resulting in the non-completion of life histories and the failure of insect generations.

(ii) Acidification

The effects of stream acidification on macroinvertebrates have been widely described. A reduction in the species richness of acidified streams is observed, which may be related to direct physiological effects of hydrogen ions, aluminium toxicity or interaction through the food web. Some invertebrate taxa have been found to be particularly sensitive including mayflies and some caddis species, in contrast to stonefly nymphs which may be abundant in acidified streams (Sutcliffe and Carrick 1973).

(iii) Sedimentation

In the River Elan a reduction of species richness and the dominance of chironomids was linked with the sedimentation of iron and manganese rich materials (Scullion et al 1982). The level of manganese in the Tywi is considerably higher than in the Elan where the deposition of iron and manganese rich sediments was thought to be detrimental to the macroinvertebrate fauna.

4.2.2 Evidence for predicted effects

In a survey carried out in May 1985, the invertebrate fauna in the Tywi at site 1, closest to the reservoir (2 km downstream, Fig. 6) was found to be poor (12 taxa present) with an absence or poor representation of several invertebrate groups (e.g. mayflies, beetles and caddisflies, Table 1).

Downstream of this site, in a reach between 3.5 to 11.5 km downstream of the reservoir, the fauna improved with about 30 taxa present at each site. However, few species of mayfly, caddisfly and beetles were present and their abundance was low. A further improvement in the fauna occurred in a reach between 16.5 and 27.5 km downstream of the dam with an increase in the number of taxa present (average 42). Mayflies, caddisflies and beetles, absent in the upper reach, were abundant in this reach.

It is therefore clear that water from Llyn Brianne reservoir has a detrimental effect on the invertebrate fauna of the Tywi for at least 11.5 km downstream of the release point, and that this impact may extend further. However it is difficult to separately distinguish thermal, acidification and sedimentation effects.

Considering the uppermost section, there is clear visual evidence of sedimentation on the river bed as far downstream as the Doethie confluence (3 km downstream; WWA,1988) and it is likely that this is a significant factor, in addition to thermal effects and acidification, in causing a severe depletion of the invertebrate fauna in this reach of river.

Both thermal and acidification effects are likely to contribute to the depletion of the fauna in the 11.5 km reach downstream of the reservoir. The composition of the fauna in the affected reach exhibits some similarities with communities described as being 'Poor' and associated with low pH and hardness (average 5.8 and 8.5 mg/l Ca Co3 respectively; Ormerod, Wade and Gee, 1988). However the observed thermal impact described above is also sufficient to explain much of the depletion of the invertebrate fauna since one of the principal groups affected (viz Ephemeroptera) have been found to be vulnerable to temperature changes resulting from hypolimnion releases (Lehmkuhl 1972).

4.3. Fisheries

4.3.1. Mechanisms of impact.

(i) Thermal regimes

Thermal resetting may have a range of serious implications for the well being of the downstream salmonid populations. Those which are relevant to Llyn Brianne can be summarised as follows :

a) Effects on eggs and larvae of salmonids.

The development of salmonid eggs is temperature dependent between upper and lower threshold values and the incubation period tends to decrease with increasing temperature. The warmer winter temperature regime imposed by Llyn Brianne between November and February will therefore tend to shorten the incubation period in the affected part of the river. Using literature values for the relationship between temperature and egg development (Crisp, 1985) it can be estimated that at Ystradffin the incubation period for salmon and trout eggs will be reduced by about 15 days compared to the adjacent, unregulated R.Doethie (Table 2). Salmon swim up fry will not feed until the water temperature attains 6-7°C (Symons 1979), a temperature which is not reached in the upper Tywi until June (Fig.3). Consequently, using the 1985/6 temperature regime as an example, it can be predicted that there will be a lag of about 30 - 60 days between swim up and first feeding. It is probable that the fry would starve to death in this period.

b) Juvenile growth.

Elliot (1975) showed that trout growth was directly linked to temperature (betwen upper and lower thresholds) provided that food availablity was not limiting. The reduced duration and magnitude of summer warming should therefore affect the growth rate and hence smolt production from the affected area. Table 3 shows the predicted difference in growth rates between the upper Tywi at Ystradffin and the nearby unregulated Doethie, based upon Elliots models. It can be seen that a roughly 15% slower growth rate will occur at the latter site. These models are based upon fish fed at maximum rations and in reality the effects of low temperature in the Tywi may be exacerbated by low food availability (see section 4.2).

c) Smolt migration.

Solomon (1978) showed that on a Dorset chalkstream smolt emigration was triggered by a rise in water temperature to about 10-12° C. This is normally attained in April in the Doethie but will not be reached until late June in the upper Tywi at Ystradffin. Thus smolt migration could be delayed or inhibited, reducing migration success.

d) Adult migration and exploitation.

Since the construction of L.Brianne there have been many claims by fishermen that the cold water released to create artificial freshets leads to reduced catchability of salmon and sea trout.

(ii) Acidification.

Welsh Water (1986) reported that under some conditions the downstream limit of the lethal combination of low pH, low Calcium and high soluble aluminium would extend to Cilycwm bridge, some 13km below the reservoir. It is therefore not possible to distinguish the impact of acidification from that of thermal resetting at present as they effectively impact the same reach of river.

(iii) Sedimentation.

Deposits of fine sediment downstream of the reservoir could have two important effects on salmonid populations. The infiltration of fine sediment into the gravel substrate will reduce intra-gravel flows and hence the suitability for salmonid spawning. Secondly if as often the case the sediment contains high Manganese concentrations there is a potential physiological effect since high Manganese concentrations have been linked to skeletal deformities in trout (Reader 1986).

4.3.2 Evidence for the predicted effects.

(i) Juvenile surveys.

Two surveys have been carried out to assess the juvenile salmonid populations of the upper Tywi (Welsh Water 1986, 1987). The results are shown in Table 4. Salmon fry were absent in 1985 and 1986 at sites 1 and

2 (and 3 in 1985) whilst density was reduced at site 4 when compared to other sites on the main river (6,7 and 9) and the Tywi catchment in general. Population levels had recovered significantly by site 6 some 13 km below the reservoir and this point, which is coincidental with the lower limit of the acidified reach, may be taken as the downstream limit of the impact on juvenile salmon. Juvenile trout populations showed similar, variations to salmon, although the impact was less pronounced. Reduced densities were observed at all main river sites. Welsh Water (1986) reviewed redd counting data on the Tywi and looked for evidence of a contraction in spawning range in the preceding 15 years. Only at sites 1 and 2, in the affected area of the upper Tywi, were salmon fry not captured from historically recorded spawning gravels.

(ii) Egg development.

Welsh Water (1986) showed that salmon egg development was faster in the Upper Tywi at Ystradffin compared to the adjacent R. Doethie which is unregulated. After 81 days 100% of surviving ova had hatched in the Tywi compared with only 77% on the Doethie.

(iii) Juvenile growth.

During surveys insufficient juvenile salmon and trout were caught from the impacted area to allow validation of the predictive models. It is probable that this is a result of the greater impact of other aspects of thermal resetting and possibly acidification.

5. BENEFITS OF A MULTI-LEVEL DRAW-OFF.

5.1. Physical

A multi-level draw-off would allow the discharge from the reservoir of warmer epilimnetic water in summer months, thus producing a more natural temperature regime for the Upper Tywi. Some damping of diurnal variations and other episodic changes in temperature of the river will still occur due to the large mass of water within the reservoir. However the most drastic seasonal effects, such as the delay in maximum summer temperatures and the depression of mean summer temperature should be eliminated. The discharge of water from the surface layers is unlikely to completely rectify the increased winter temperatures which are observed downstream of the dam, because the body of water is mixed at this time of year and the average temperature does not fall below about $5^{o}C$.

There would also be limited improvement in downstream acidification as the result of using a high level draw-off. However the problem of acidification is to be further addressed by a programme of limestone dosing of the reservoir which is expected to resolve the problem.

The use of a high level draw-off, in conjunction with restrictions on the timing of the use of scour valves, should minimise the deposition of fine, manganese rich sediments in the upper river. Scouring operations could be carried out during winter spates when the reservoir is over-topping and there is a large volume of water passing down the Llyn Brianne spillway.

5.2. Ecological/Fishery

Significant ecological and fishery benefit would be expected to accrue as a result of the above physical improvements. Although elevation of winter temperatures also occurs downstream of reservoirs with epilimnial releases, and there may still be effects on egg diapause and insect emergence, investigations of other regulated catchments have established that hypolimnial release has a more substantial and extensive detrimental effect on the macroinvertebrate fauna. For example, downstream of the deep release Clywedog Dam, species richness and biomass are about half that at a similar location in the River Vyrnwy, which receives an intermediate release from L. Vyrnwy (Petts 1984). Similarly Armitage (1977) found that marked changes in the benthos of the River Tees persisted for only about 500m downstream of Cow Green Reservoir (mixed release), whereas Ward (1974,1976) found that the hypolimnetic release from Cheesman Dam (Colorado, USA) affected the invertebrates of the South Plate River for about 32 km downstream.

In view of the strong evidence for the reduction in fisheries status of the Tywi below Llyn Brianne, WWA (1987) calculated the cost of replacing this lost production by stocking with hatchery reared juvenile salmon and sea trout, which represents the only viable option. The annual cost worked out at about £150,000 for both species together. Whilst the initial calculation was somewhat simplistic and made a number of assumptions, no better data has yet been collected. It is therefore proposed that this calculation, increased in line with inflation at 8%, is adopted as standard. In this case the cost of mitigation would rise to £189,000 p.a. (1990) or £2,752,000 over the next decade (assuming constant inflation at 8%). The fishery improvements would therefore represent the equivalent of a £2 million stocking programme over 10 years, and benefits would continue to accrue in perpituity. These improvements would be seen in up to 20km of main river. Action of this type would have a high public profile, and would both improve public perception of the NRA and raise general public awareness of the organisation.

6. SUMMARY AND CONCLUSIONS

(i) Important commercial and recreational fisheries are supported by the Tywi catchment, the rod catch of sea trout being the largest in Wales.

(ii) Examination of the literature available from studies of other river regulation schemes results in the conclusion that hypolimnial draw off regimes are ecologically detrimental.

(iii) Current good practice when promoting major reservoir schemes in England and Wales is to include facilities for epilimnial or multiple level draw off.

(iv) Thermal stratification occurs in the reservoir during the summer, with colder water in the hypolimnial layer. In contrast, winter temperatures in the reservoir are higher than those in local rivers, because of the buffering capacity of the water body. As a direct result, the R. Tywi between Llyn Brianne and Llandovery is affected by :

(a) Reduction in mean summer temperatures by up to 8 degrees Celsius.
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7. RECOMMENDATIONS

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(iv) Further development of the Llyn Brianne scheme (eg HEP) should not be considered until these immediate problems have been resolved.

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TABLE 1

INVERTEBRATE DISTRIBUTION DOWNSTREAM OF LLYN BRIANNE RESERVOIR

Site No	1	2	3	4	5	8	10
TAXA GROUP*							
Tricladida	5	72	1	5	13	109	1
Ephemeroptera	0	5	6	2	10	450	547
Plecoptera	9	587	120	178	386	549	151
Coleoptera	0	20	1	10	9	60	18
Trichoptera	3	33	8	15	14	69	85
Chironomidae	10	44	15	25	32	177	67
Simuliidae	0	28	4	3	7	55	14
TOTAL NO.OF TAXA	12	31	26	30	30	50	48

* Number per 3 min. kick sample

TABLE 2

PREDICTED EFFECT ON HATCH AND TIME FROM HATCH TO FIRST FEEDING (TAKEN AS AVERAGE DAILY TEMPERATURE = 5°C)

	Salmon		Trout	
	Hatch time (days)	Days to 1st feeding (5°C)	Hatch time (days)	Days to 1st feeding (5°C)
Doethie 1984/85	114	1	123	0
Ystradffin 1984/85	96	39	107	28
Doethie 1985/86	102	0	112	0
Ystradffin 1985/86	88	57	101	44

TABLE 3

PREDICTED GROWTH OF A 10 GRAM TROUT FROM JULY 1ST TO THE END OF JUNE IN THE FOLLOWING YEAR. ON MAXIMUM RATIONS

	Final Weight		
	Doethie	Ystradffin	% reduction at Ystradffin
1984/85	48.0	41.9	12.7
1985/86	50.3	42.1	16.3

TABLE 4

SALMON AND TROUT DENSITIES IN 1985 AND 1986 SURVEYS. (NOS $100M^{-2}$)

SALMON

Site Code	Age 0+		>0+	
	1985	1986	1985	1986
1	0.0	0.0	0.0	0.0
2	0.0	0.0	0.9	1.0
3	0.0	Not sampled	0.0	Not sampled
4	2.6	0.8	0.7	2.0
6	Not sampled	16.0	Not sampled	12.0
7	Not sampled	6.0	Not sampled	9.0
9	Not sampled	35.0	Not sampled	4.0

TROUT

Site Code	Age 0+		>0+	
	1985	1986	1985	1986
1	2.9	0.2	2.0	5.0
2	10.7	5.0	5.6	3.0
3	7.1	Not sampled	1.6	Not sampled
4	9.0	8.0	1.7	1.0
6	Not sampled	10.0	Not sampled	5.0
7	Not sampled	7.0	Not sampled	3.0
9	Not sampled	6.0	Not sampled	0.6

Fig 1 **TYWI CATCHMENT SHOWING LOCATION OF LLYN BRIANNE RESERVOIR**

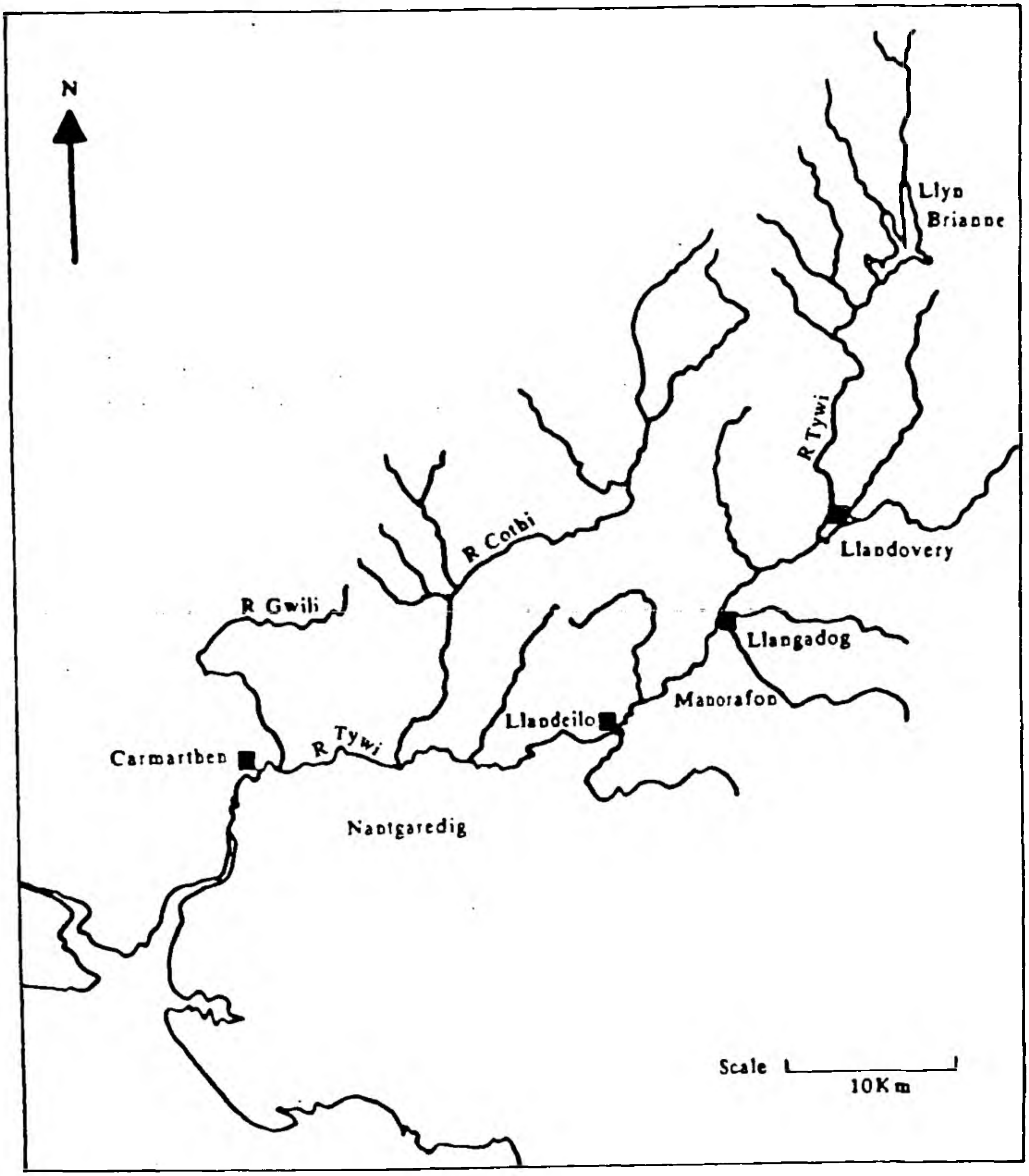
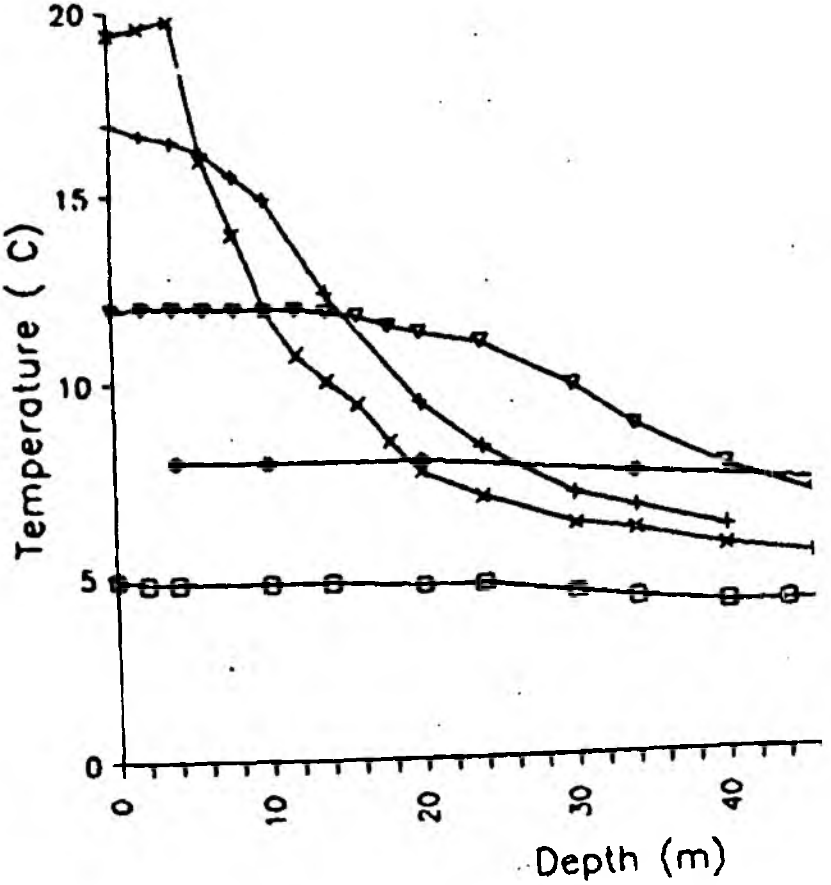


FIG. 2 LLYN BRIANNE DEPTH PROFILES



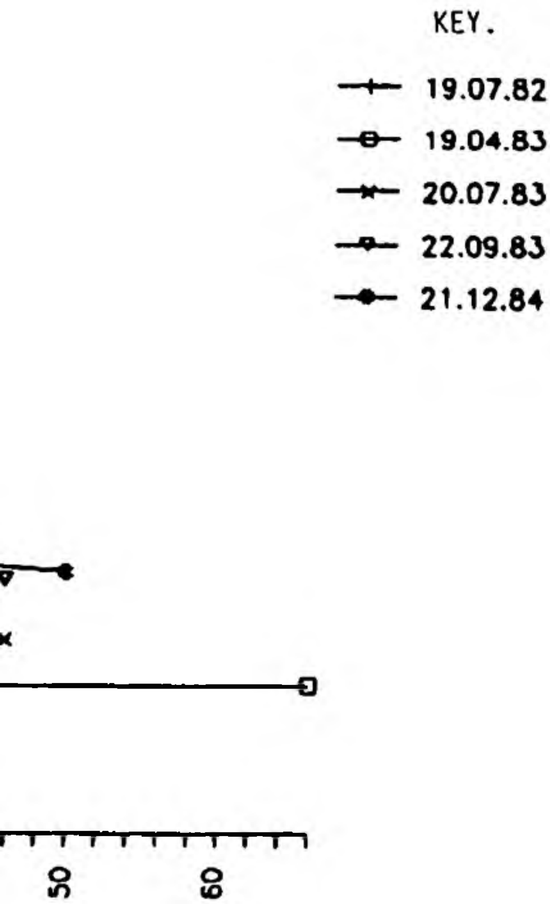
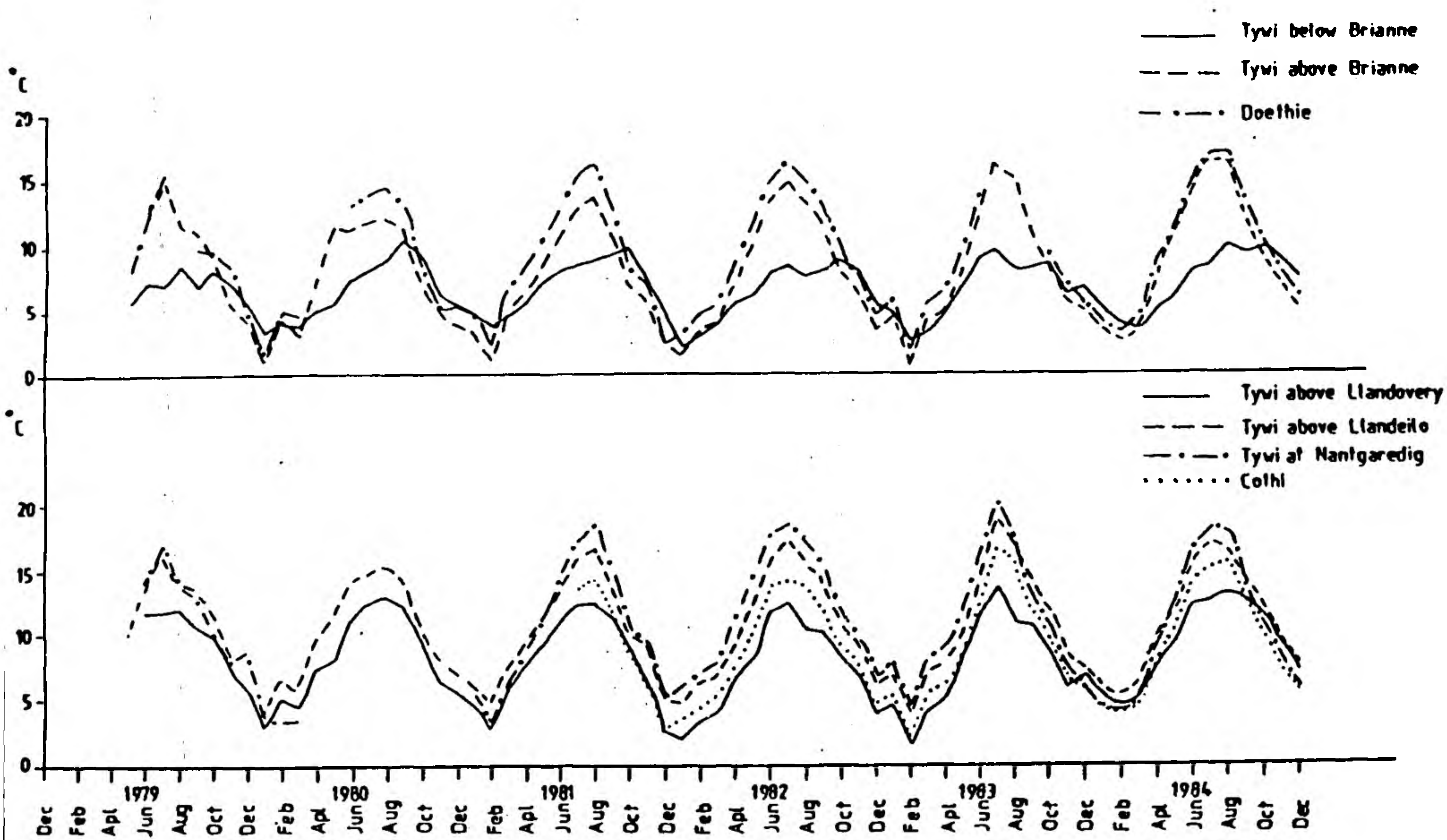

KEY.
19.07.82
19.04.83
20.07.83
22.09.83
21.12.84
50
60

Fig.3 MEAN WATER TEMPERATURES IN THE TYWI CATCHMENT.



[illegible] Brianne [illegible]

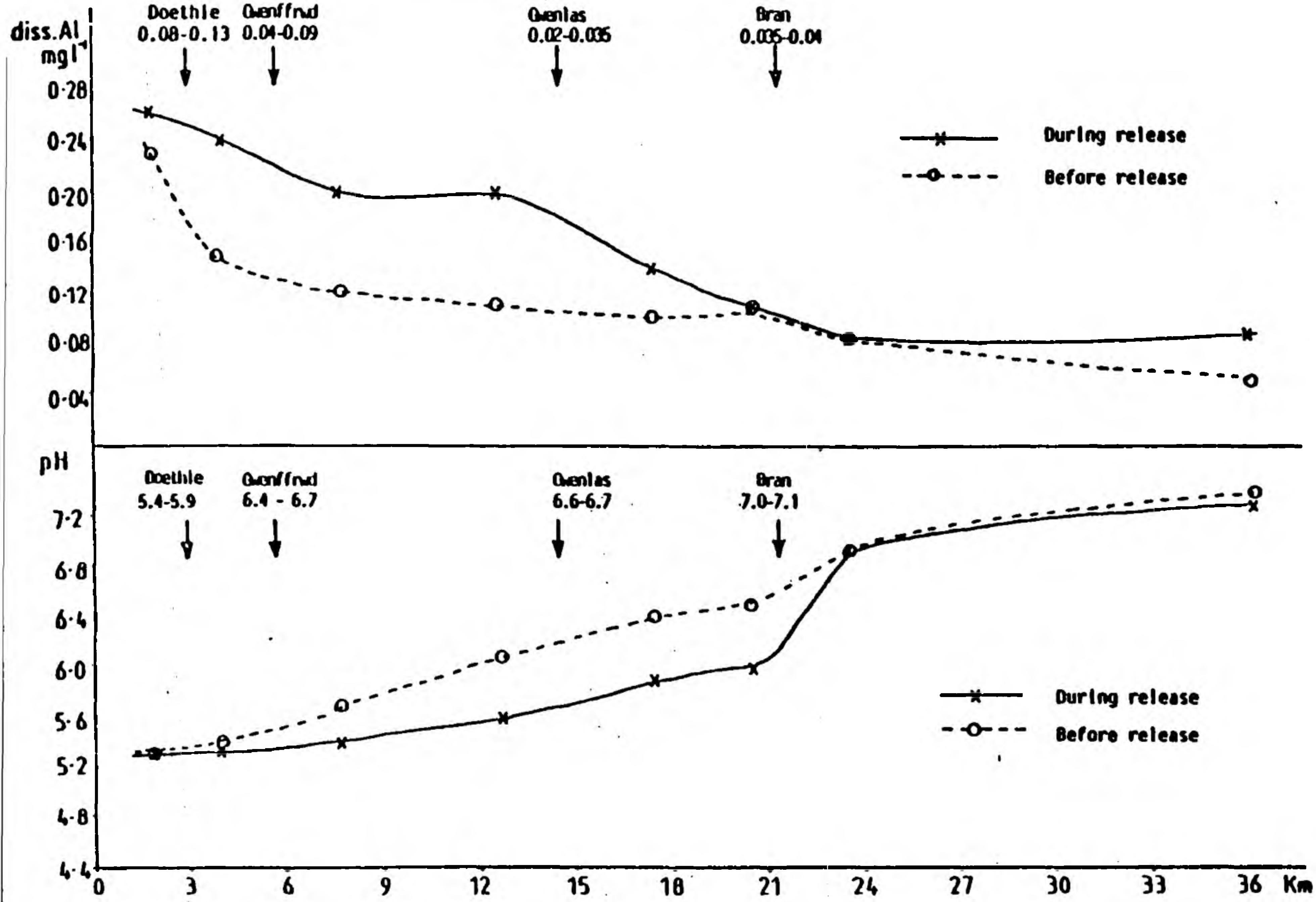

diss.Al
mg l⁻¹
Doethie
0.08-0.13
Gwenffrwd
0.04-0.09
Gwenlas
0.02-0.036
Bran
0.035-0.04
0·28
0·24
0·20
0·16
0·12
0·08
0·04
During release
Before release
pH
Doethie
5.4-5.9
Gwenffrwd
6.4 - 6.7
Gwenlas
6.6-6.7
Bran
7.0-7.1
7·2
6·8
6·4
6·0
5·6
5·2
4·8
4·4
During release
Before release
0
3
6
9
12
15
18
21
24
27
30
33
36
Km

Fig. 5 RELEASE 2 - JUNE 1985

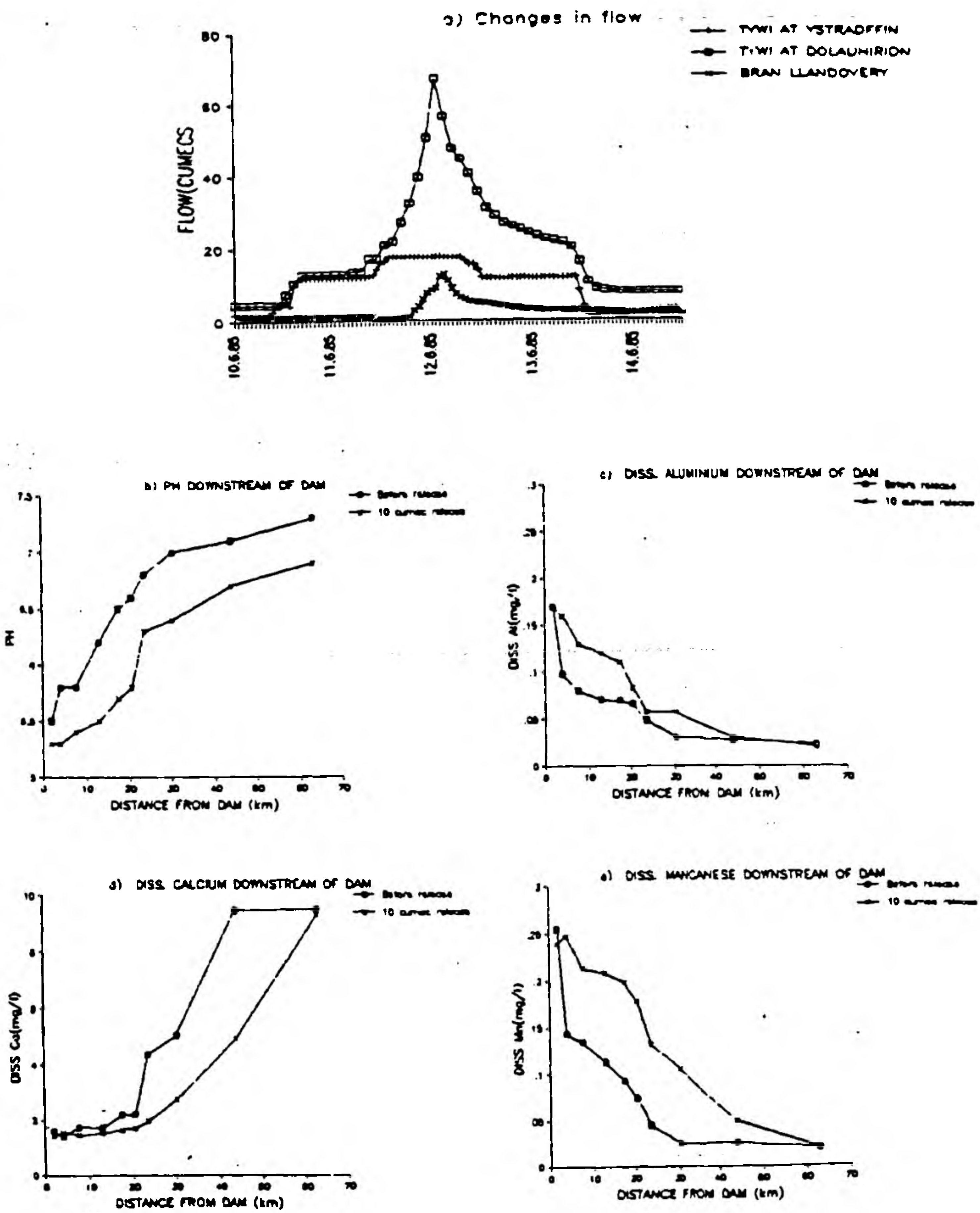


Fig.6. FISHERIES (F) AND BIOLOGICAL (B) SAMPLING SITES ON THE RIVER TYWI DOWNSTREAM OF LLYN BRIANNE RESERVOIR