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AN EVALUATION OF THE FISHERIES POTENTIAL OF THE AVOCA CATCHMENT

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INTRODUCTION

The distribution of trout in a rivers' course is primarily related to the obvious topographical factors of gradient, width and in particular the nature-e of the river bed. In the Avonmore-Avoca Catclunent most of the rivers are predominantly upland erosional with the exception of the lower section of the Avoca River which is lowland depositional. The geology and soils are major factors influencing the surface water chemistry in the catchment. With regard to the mineralogy and geochemistry of the rocks in the area, the dominating influence on the water chemistry and acidity is the content of carbonates and weatherable silicates. Hormrng *et al.* (1990) developed a simple classification of rocks based on a combination of earlier classifications produced by Norton (1980) and Kimrit1burgh & Edtmrnds (1986) (Table 1). This classification, applied to the solid geology of the Avoca catchment indicates that large areas of the north, central and south west areas of the catclunent are imderlain by granite rocks and so have little or no neutralizing capacity. The surrmmding Ordovician slates, shales and volcanics have a low to medium buffering capacity. Thus, on the basis of bedrock geology, naturally-weakly acidic, low conductivity waters, sensitive to acidification, are predicted to occur over much of the catclm1ent. Since predictions based solely on bedrock geology have limitations, it would be more reliable if a consideration of soils were included.

TABLE 1. The impact of acidic deposition on surface and groundwaters of areas underlain by rocks with different buffering capacities. (Hornung *et al.*, 1990)

Class.	Buffering Capacity.	Rock Types.	Impact of acidic precipitation on surface waters.	Impact of acidic precipitation on groundwaters.	Characteristics of first and second order streams.
1	Little or no buffering capacity	Granite and acid igneous rocks or metamorphic equivalents; granite gneisses, quartz sandstones and metamorphic equivalents; decalcified sandstones; most metasediments, including slates; non arkosic grits	Widespread impact expected	Most areas susceptible to acidification unless significant thickness of glacial drift present	Naturally acidic, low conductivity, poorly buffe red
2	Low to medium buffering capacity	Sandstones, shales, conglomerates and metamorphic equivalents; coal measures; intermediate igneous rocks; high-grade metamorphic felsic to intermediate volcanic rocks	Impact restricted to first and second-order streams and small lakes	Many areas could be susceptible	Weakly acidic, low conductivity, poorly buffered
3	Medium to high buffering capacity	Slightly calcareous rocks, e.g. marlstones; basic and ultra-basic; igneous rocks; Mesozoic mudstones; low grade inter-mediate to mafic volcanic rocks	Impact improbable except for near surf ace drainage	Little general likelihood of acidi fication	Circum neutral, well buff ered
4	Infinite buffering	Limestones, chalk, dolomitic limestones, highly fossiliferous sediments or metamorphic equivalents	No impact	No impact	Alkaline, high conductivity, highly buff ered

The acid neutralising capacity of soils is also large ly detennined by their content of carbonate and weatherable silicate minerals, cation exchange capacity and base saturation. These propetiies are dependant on the nature of the parent mate rial, age, and weathering and leaching of the soil.

A number of classifications of soils have also been published. Avery (1980) used the base status of subsoil horizons to classify soils on the basis of neutralizing capacity.

Table 2. Soil buffering classes (terminology based on the soil classification of Avery, 1980)

Soi ls with little or no neutralising capacity	Holocene podzols; deeply weathered paleo-argillic soils, thin rankers on non-calcareous Paleozoic rocks; brown earths on silicious gravels; gley soils on non-calcareous or pyritic clays and shales; raw bog, basin and blanket peat soils.
Soils with moderate neutralising capacity	Non -calcareous pelosols; brown eatihs on base-rich materials; gley soils on non-calcareous clay; fen peats.
Soils with large neutralising capacity	Little weathered soils on Holocene marine clays and calcareous sands; rendzinas; calcareous pelosols; brown calcareous earths; calcareous gleys formed during the Holocene or calcareous sediments.

A broadly similar approach has been taken for the Avoca region but has been simplified to give two classes of soils: acid soils with little or no neutralising capacity and non-acid to weakly acidic soils with moderate to large neutralising capacity.

The soils associations which dominate the catchment and classified as acid, with low neutralising capacity are the peaty podzols, brown podzolic soils and acid brown earths. The predominance of acid soils in the catchment is the result of the interaction

FIG.1 GEOLOGY OF THE AVOCA CATCHMENT

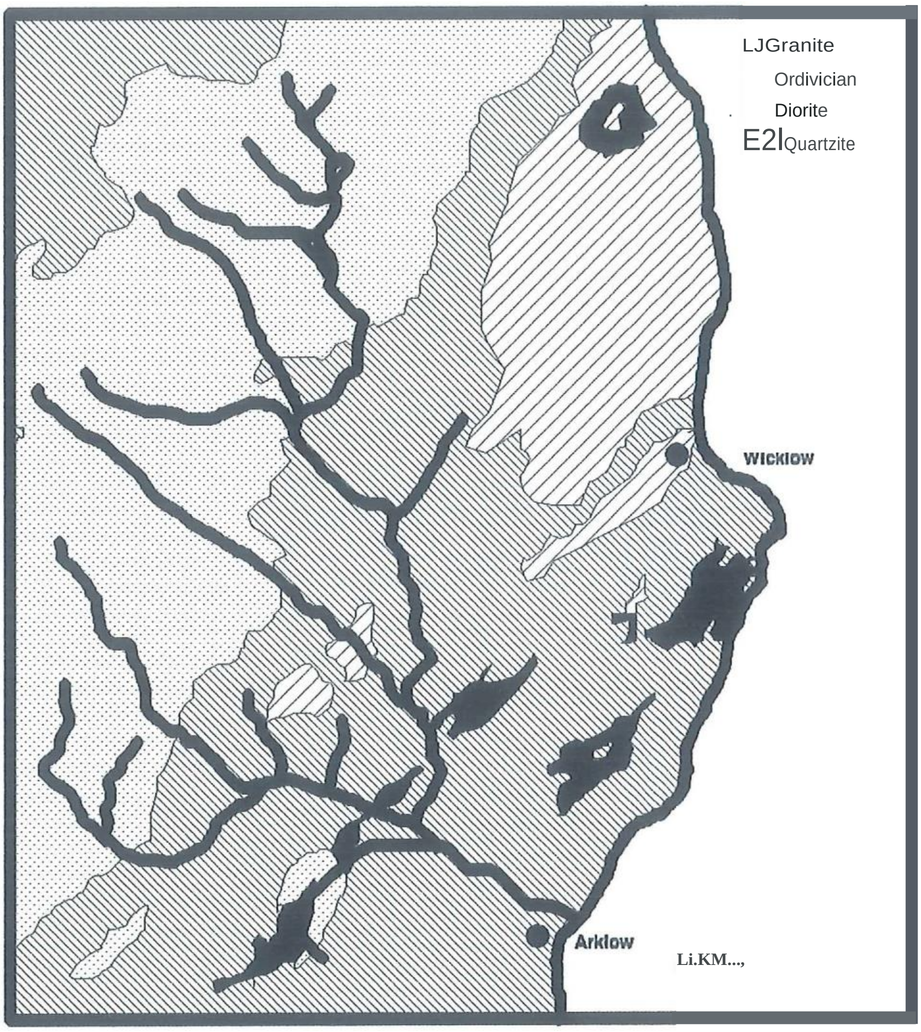
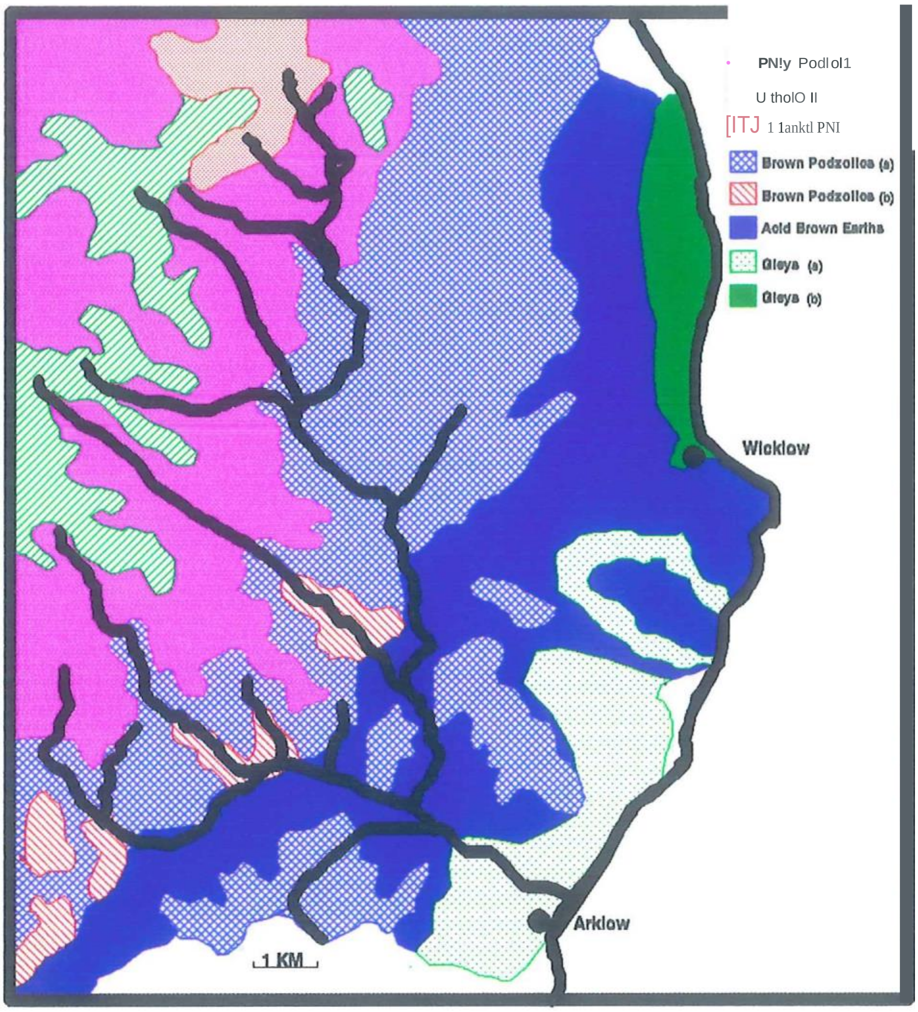


FIG.1a SOIL ASSOCIATION OF CO. WICKLOW



of the base poor soil fanning materials derived fonn the acidic granite rocks, slates and volcanics and the humid, cool climate.

These soil-rock combinations (Figs. 1 and la) predict the likely occurrence of acidic, sensitive waters and possible changes in stream acidity with flow. Variations in the stream water acidity may occur as a result of small scale variations in soils and bedrock geology, these however are not shown on the scale of the maps here.

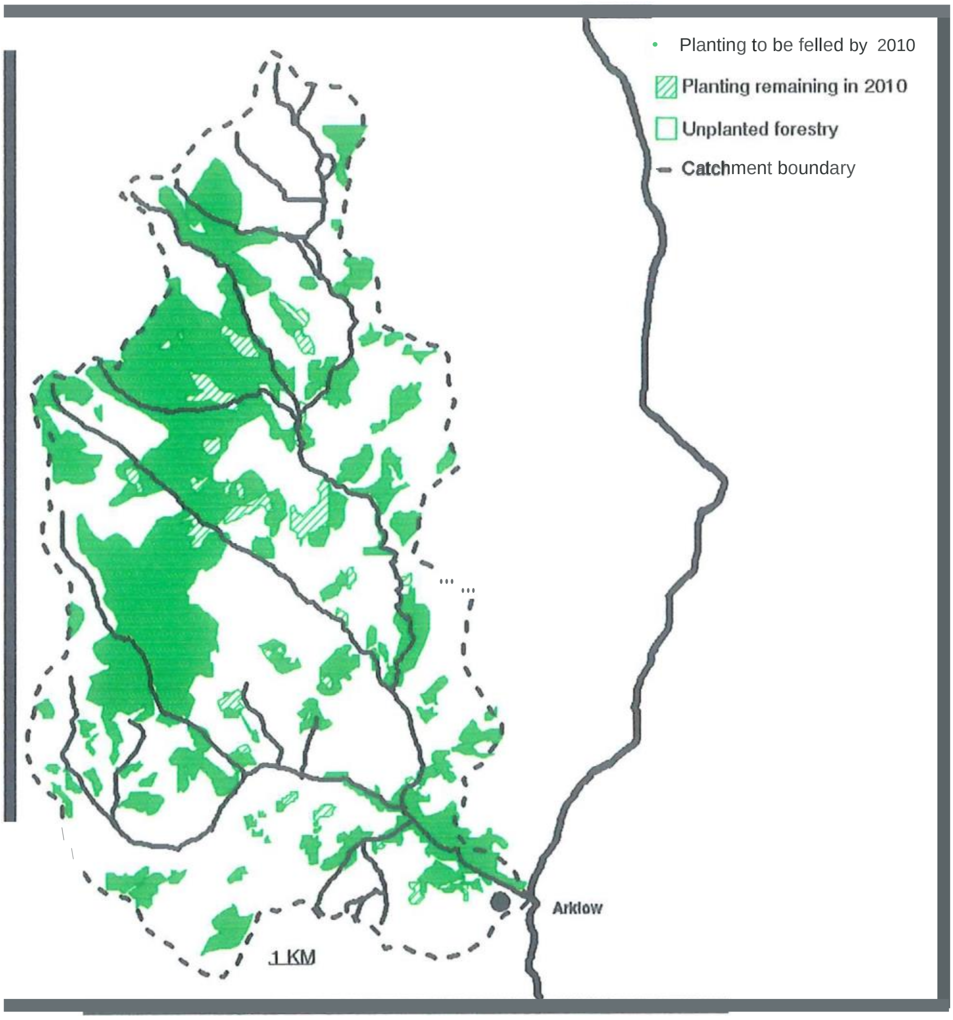
With the predominance of upland, high rainfall and thin low base status soils based on granite bedrock, much of the catchment (approx. 16,455 ha.) is under forestation. Coillte, a State forestry company owns the majority of the coniferous forestry (Fig. 2).

Afforestation - Impact on Fisheries

There is strong evidence of links between fishery decline and afforestation. This may be due to a combination of direct and indirect effects. Of these, increased acidity of drainage waters together with elevation of toxic trace metal levels appear to be the limiting factor on fisheries since acutely lethal toxic conditions have been shown to exist (Conference on forests and Surface Water Acidification, Darlington, U.K. 1990).

Coniferous trees reach the banks of all the main tributaries at various locations and enclose many of the minor rivers. Streams draining coniferous forests tend to be more acidic and may have other effects upon fisheries unassociated with acidity. Examples are effects of light-shading on primary productivity and stream temperature,

FIG.2 FORESTRY OF THE AVOCA CATCHMENT



lowering of the water table through evapo-transpiration and increased soil erosion due to drainage practices. The latter can lead to stream bed sedimentation, and thus limit benthic productivity and spawning areas. Trees filter out from the atmosphere increased amow1ts of pollution - derived anions. These then drain through the soil and, if the soil is rich in hydrogen and aluminium, will enter the stream accompanied by the latter cations. High concentrations of aluminium in appropriate forms can damage the gills and breathing apparatus of fish.

Since genuine concern exists in relation to the impact of forestry on fisheries, including water acidification, guidelines have been laid down on aspects of forestry practice which may impinge upon the physical quality of the water. For example, deep ploughing must not take place within ten metres of any stream or watercourse or within fifty metres in designated sensitive areas. Fertilizer must not be spread mechanically within ten metres of any stream. No trees may be planted within five metres of any stream and no conifers within ten metres in designated areas (Forest1y and Fisheries Guidelines, 1991). These guidelines have not been strictly adhered to within the catchment.

Economic Value

The net economic value of a fishery is taken to represent the loss in benefit to society which would result if the fishery ceased to exist. There are many components of net economic value including the value of a fishery to the owner, to the anglers and to the local economy, as well as more intangible benefits to the well being of the co1mmmity e.g. conservation value (Milner, 1990).

The fisheries industry in Ireland is projected to expand to net many lumdreds of millions of potmds per year in revenue and in a much shorter time-frame than for forestry.

OBJECTIVES

The aim of this study is to assess the overall potential of the catchment by:

a) Electrofishing discrete sites within the catchment (quantitatively and qualitatively),

b) detem1ining the water quality at the respective sites in order to provide infonnation on the physio-chemical suitability of the waterways to fish,

c) identifying, measuring, weighing, sexing and scaling of the fish to assess their growth rates and condition,

d) observing the floral and fam1al composition and the substrate present.

MATERIALS AND METHODS

Survey sites were chosen on the basis of location within the catchment area to provide an overview of the physical attributes, floral and famrnl spec ies present at each site. A code number was assi gned to each site commencing at S_1, the upland Glenmalure River, to S_{11} in the low lying reaches of the Aughrim (Fig. 3). Due to an appa rent pollution problem at one location, no electrofishing was carried out.

Physical survey data together with floral and fmmal observations were recorded at each site. Macrophyte identification was carried out in situ, while water analysis and invertebrate identification were carried out on rettm1 to the laboratory. A total of thirteen parameters are used to assess the water quality. This wide variety of parameters ensures that the water is assessed from many different perspectives. Photographs were taken of several sites.

The time allocated to this survey was brief so quantitative electrofishing was carried out at only two sites which reflected the norn1 for long chaimel sections. Salmonid stocks within these zones were quantified using a depletion technique (Zippin, 1959). Nets were used to enclose the section while the estimate was in progress.

A semi-quantitative approach was also adopted to detennine fish composition. A portable land-based 220V generator, with a converter tmit, was used as a power source. The cathode, a metal plate was placed upstream and the anode, a metal framed net with insulated handle was used by the operator.

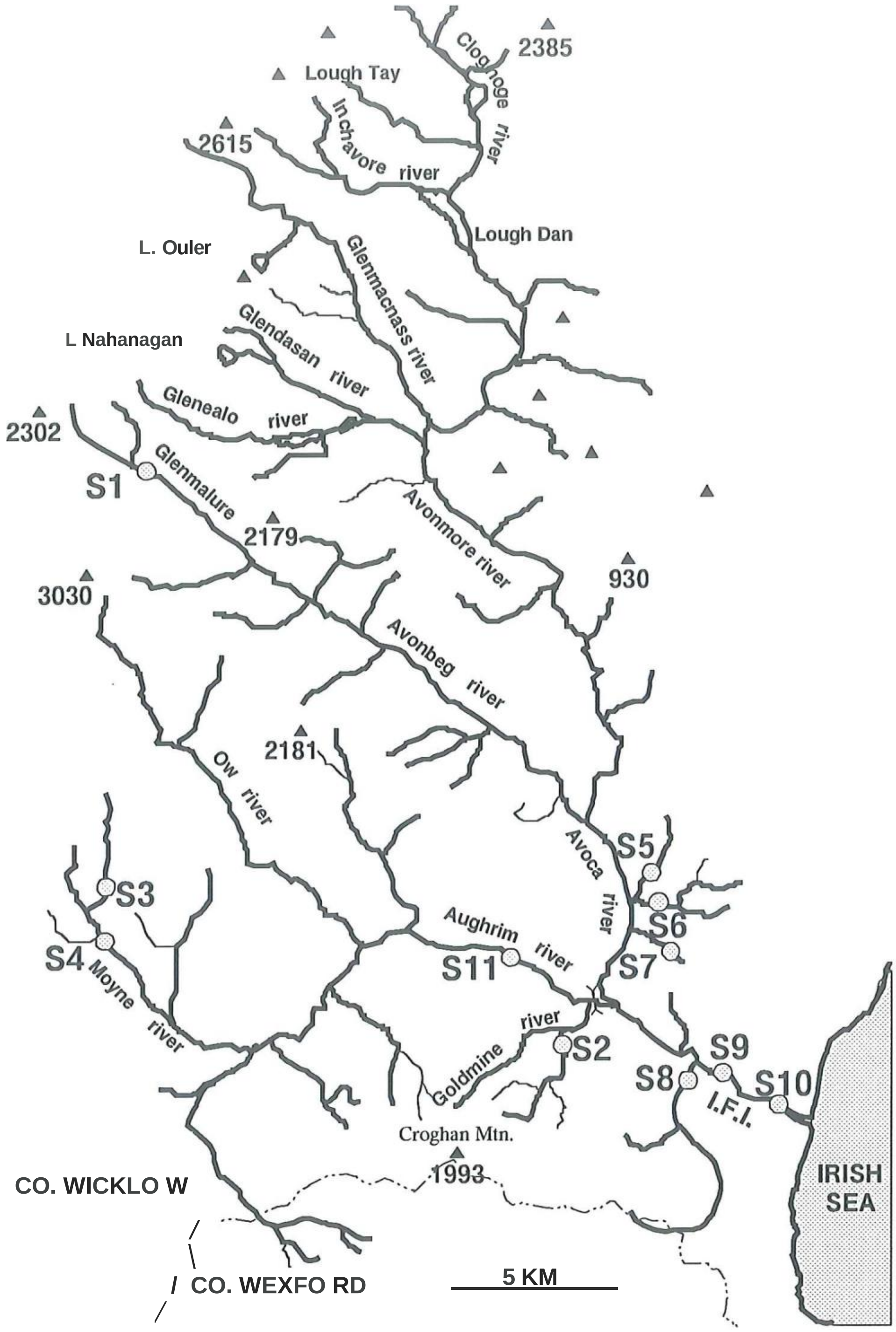


FIG. 3 The Avoca-Avonmore catchment showing site locations (Sl-Sll).

S1: Glenmalure (Grid Ref. T067 940) ; S2 : Goldmine Tributary (Grid Ref. T187 760)

S3: Moyne Tributary (Grid Ref . T031 802) ; S4: Moyne River - Sandyford Bridge (Grid Re f. T035 790)

S5: East Avoca Tributary (Grid Ref. T208 814); S6: East Avoca Tributary - Handweavers (Grid Ref. T211 802)

S7: East Avoca Tributary (Grid Ref. T212 788); S8: West Avoca Tributary (Grid Re f. T218 739)

S9: Avoca River - Upstream of **I.F.I.** (Grid Ref. T219 748);

Sl 0: Avoca River - Downstream of I.F .I. (Grid Ref. T299 745) Sl 1 : Aughrim River (Grid Ref. Tl 72 781)

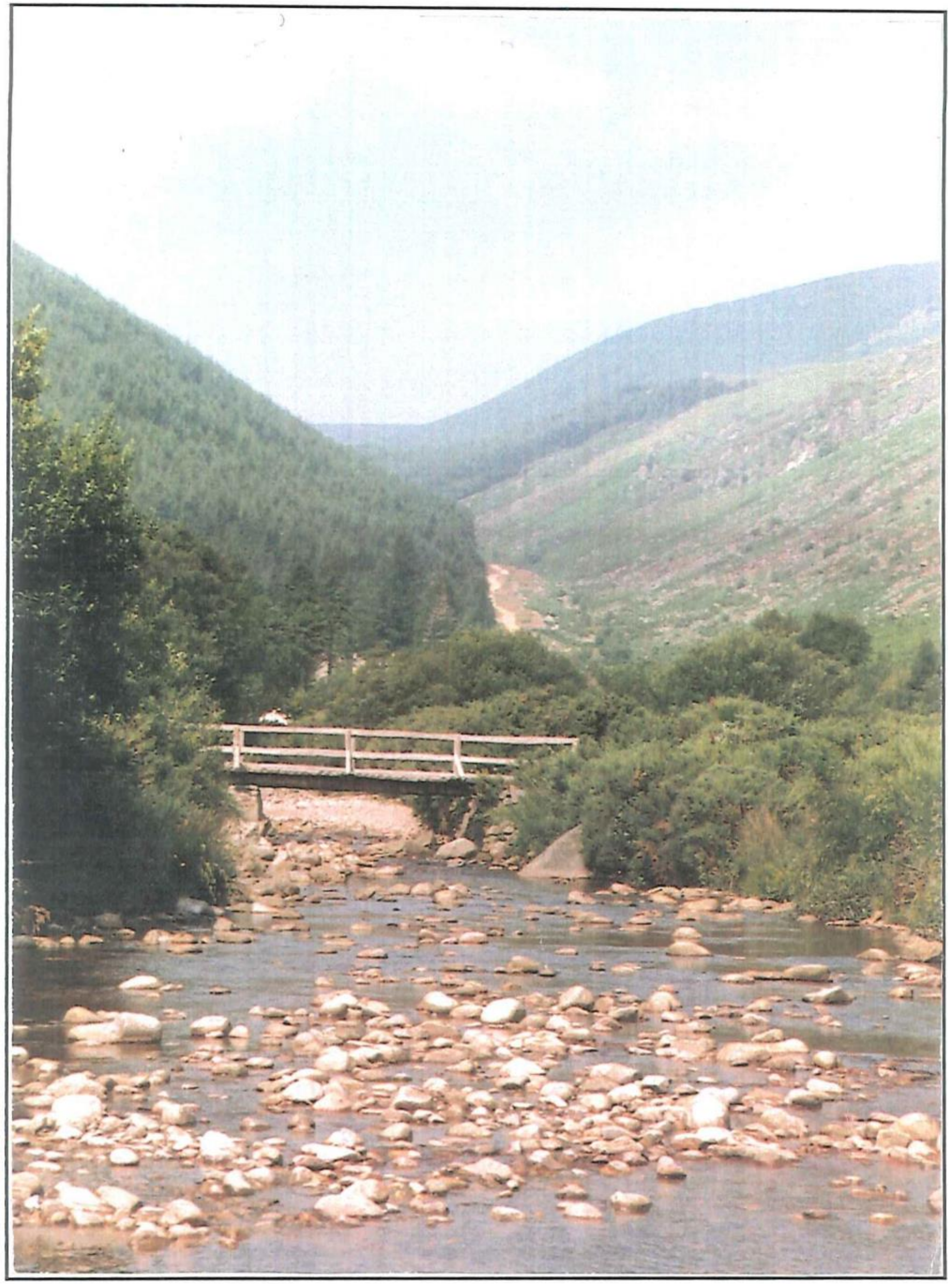


PLATE 1. Glenmalure River exposing granite substrate in low flow.

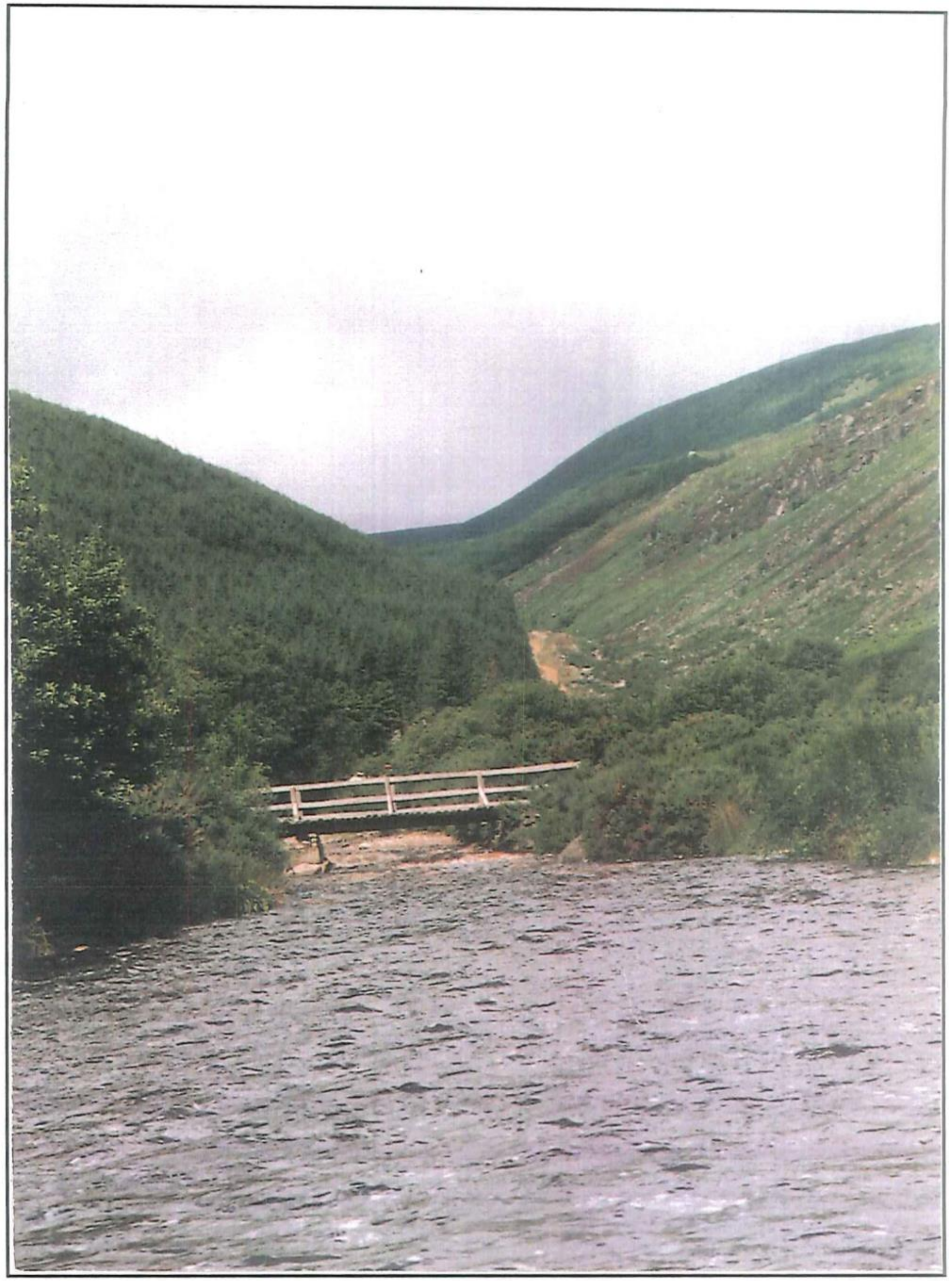


PLATE 2. Glenmalure River in flood.

S_1 Glenmalure (Grid Ref. T067 940)

The Glenmalure River is a fast-flowing upland stream which rises in Table Mow1tain, at 2,302 feet. It feeds into the Avonbeg River.

The site chosen was a 25m stretch which originated at a natural barrier of a riffle sloping into a pool, under a wooden fo otbridge, width 6.7111. The substrate was strewn with granite rocks, with sparse cover of aquatic mosses and algae. This upland section of the river was in fact quite deficient in aquatic plant life. The centre stretch measured 8.8m wide and the final width where the stop net was set, broadened to 10.7m.

Shelter on both banks was provided by overhanging trees, furze and grass. The in-egular hydrology at this upper catchment site is augmented by the tmderlying imperious rocks and is prone to flash floods or spates. See Plates 1 and 2.

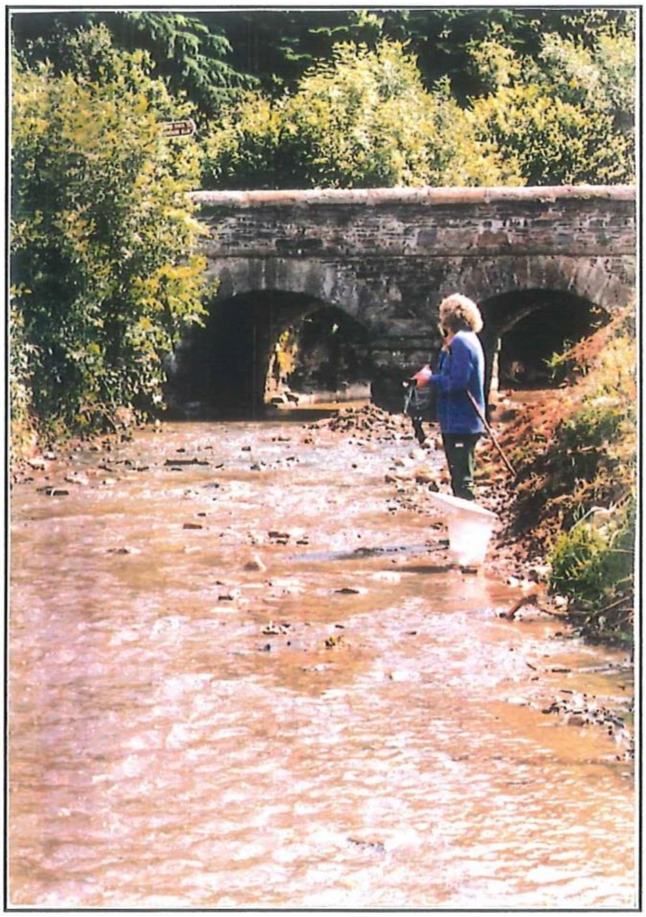
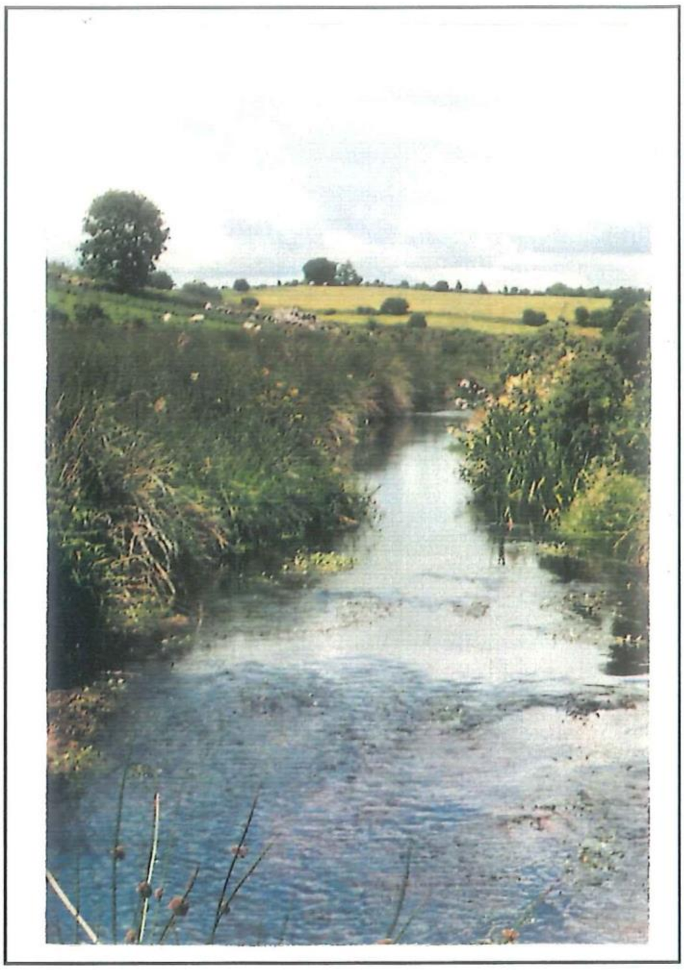


PLATE 3. Goldmine Tributary

S_2 Goldmine Tributary (Grid Ref. T187 760)

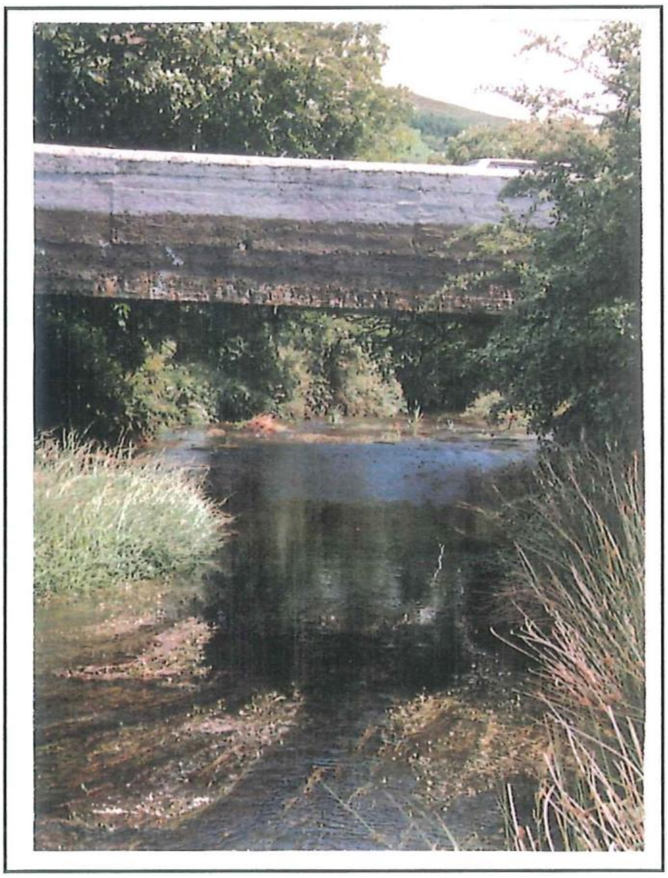
A comparable low lying stretch of 25111 was fished from Sm upstream of the bridge at Valley Hotel. This site provided a soft riffle with sheltered pools tmder a double-arched bridge. Flow was moderate. Eroding stones and gravel formed the principle substrate components with *Apium* being the dominant macrophyte and aquatic mosses present instream. Dense over-hanging bank vegetation was prominent on the north-east bank



S_3 Moyne Tributary (Grid Ref. T031 802)

Stop nets were used to qualitatively electrofish a 60111 stretch of this narrow chatmel, having a maximum width of 6111. Flow rate was slow over a partially silted sub-stratum, with 30% cover of *Ranunculus.* The marginal flora was typical of lowland streams with *Apium, Oenanthe, Berula, Caltha, Juneus, Carex,* and various grasses.

PLATE 4. Moyne Tributary



S_4 Moyne River - Sandyford Bridge (Grid Ref. T035 790)

As with S_3, the main chaimel of the Mayne River had a slow to moderate flow rate. Approximately 50% of the silty-stony substrate supported dense beds of flowering *Ranunculus.* Similar diversity of bank cover but with plenty of mature over-hanging trees and *Glyceria.*

PLAT E 5. Moyne River

S_5 - East Avoca Tributary (Grid Ref T 208 814)

This small stony tributary on the east bank of the Avoca River reaches back into the mines. It proved to be devoid of instream vegetation, invertebrates or fish life.

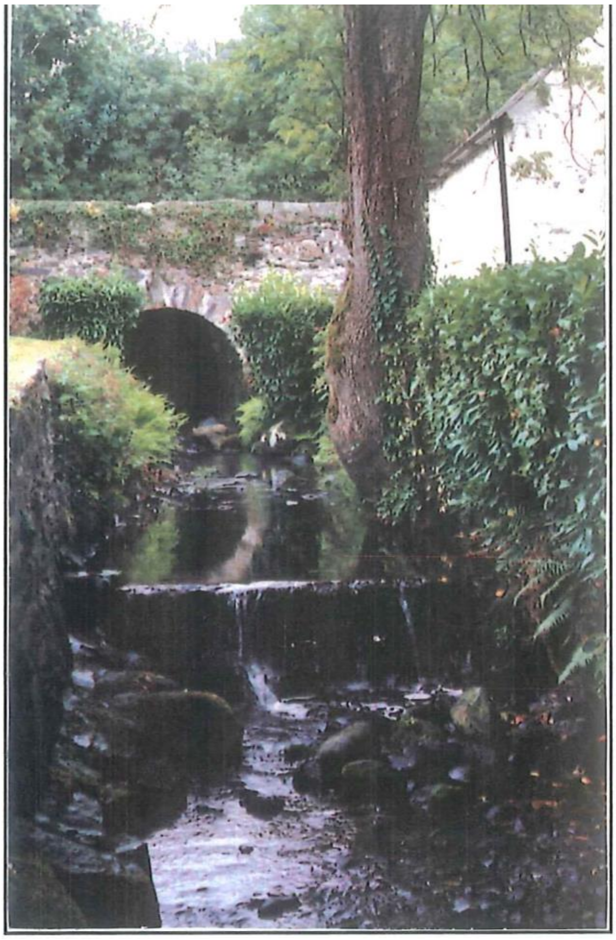


PLATE 6. East Avoca Tributary

S_6 Avoca Tributary - Avoca Hand-weavers (Grid Ref. T211 802)

Due south, but also on the east bank of the Avoca River, this short tributary is more productive. Aquatic mosses were present instream with some filamentous algae also present. Bank cover was relatively extensive but not excluding a significant level of light from the stream bed as evidenced by the dense mats of aquatic mosses on the substrate. Bushes and fems aided in providing shade, shelter and ' good lies' along this stretch.

PLATE 7. East Avoca Tributary

S_7 Avoca Tributary, East Bank (Grid Ref. T212 788)

This narrow small tributary flows north westerly through productive agticultural land into the Avoca River. A good gradient generates a moderate to fast flow over a vatied substrate of rocks, stones, gravel and silt. Bank cover is extensive forming a canopy over the stream in places.

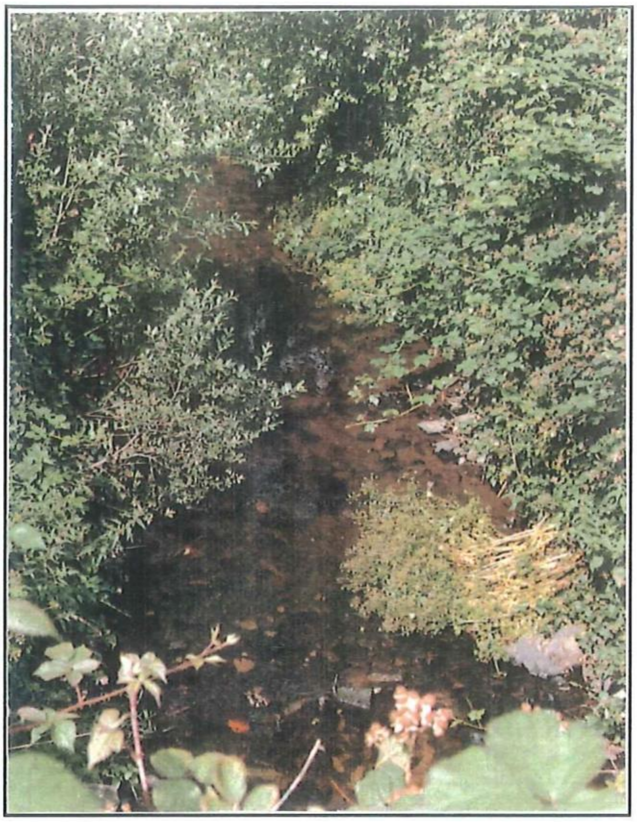


PLATE 8. **West Avoca Tributary**

S_8 West Avoca Tributary (Grid Ref. T218 739)

A low lying shallow stream on the west bank of the Avoca River opposite Irish Fertilizer Industries Ltd. Gravel and loose stones were the main substrate types in the riffle areas. Silt and sand tended to dominate the glides and pools. The low flow regime of this stream would probably render it tmsuitable for salmonids during a hot summer period. Aquatic mosses present on a small percentage of the permanent substratum. Bank cover is extensive but not obtrusive with some filamentous algae and in-frequent clumps of *Callitriche.*

S_9 Avoca River at Shelton Abbey, Upstream of I.F.I. (Grid Ref. T219 748)

This broad section of the Avoca River is lowland depositional with a predominantly gravelly substrate. The entire river bed of this section is carpeted by a layer of algae with no other visible instream vegetation. Bank cover is limited with sparse overhanging trees and grasses. This section was electrofished in low flow conditions when the river was chaimelled to the eastern bank.

S 10 Avoca River, Downstream of I.F.I. (Grid Ref T229 745)

Optimum low flow conditions again allowed restricted elect rofishing along the east bank of the river. The loose gravel substrate extends to this site and remains extensively coated with algae, holding no other mac ro-flora. Bank vegetation comprised of grasses with some semi-mature trees.

Su Aughrim River (Grid Ref. 172 781)

The Aughrim River flows east-south-eastwards before converging with the Avoca River at Woodenbridge (Grid Ref. T191 770). It is the life source of established fish farms located along its banks. Its cha,rnel width is on average 10m, with riffles, glides and pools. The composition of the substrate varied from boulders to fine gravels. The river carried a vigorous submerged flora dominated by flowering *Ranunculus, Potamogeton* and *Callitriche* sp. The degree of instream cover afforded by the encroachment of the bank vegetation and the significant level of submerged aquatic vegetation is important in holding salmonids in the river.

Results are expressed as minimum densities (Crisp *et al.*, 1974). The minimum density represents the total number of fish captured divided by the area (m^2) sampled. It is likely that 50% of the total fish numbers in any given stretch are captured using the techniques outlin ed abo ve. Therefore, a minimum density in this survey under-es timates actual fish densities but does provide an excellent relative meas urement.

The condition factor, **K**, is calculated from a formula derived from the length-weight relationship thus:

$$K = \text{approx. } 1.0 = \frac{100 \times \cdot \textit{weight in grams}}{\textit{Length}^3 \textit{ in centimetres}}$$

The average trout has K equal to 1; if K is less than 1, the fish is in poor condition since it weighs less than expected; if the fish is fat, its weight will be more than expected and K will be more than 1. Thus, K , the condition factor, is a measurement of the individual fish's well-being, its fatness and the state of its gonads, **K** is high in mature fish with ripe gonads and low in spent fish.

A sample of scales were removed from a representative selection of measured brown trout (*Salmo trutta* L.) and a proportion of fish taken for the examination of stomach contents and weight. Age calculations were made and when combined with length frequency disttibution data provided an overview of the stmcture in the individual subcatchments.

Populations of eels , loach or gudgeon were non-existent throughout the survey, a possible reflection of the poor biological productivity of the catchment.

RESULTS

The Glenmalure River, S_1

This river, sampled during spate and low flow conditions showed a pH range of 5.7 to 5.0 respectively. It had very little calcium in solution (5.0 mg/1 CaCO), was of low conductivity (mean 34.4 µS/cm) and had an average total alkalinity of -0.02 milli equiv/I (Table 3). Nutrients levels recorded were low; total phosphate 0.02 mg/1 P and Nitrate + Nitrate 0.26 mg/1 N. The water colour was high (120 Hazen wuts) in tlus upland region of peaty podzols. Invertebrate life was reasonably diverse but overall had a low productivity, with Tricopteran larvae being particularly scarce (Table 4).

The brown trout at tlus location were generally small, slow growing fish in good condition (mean K = 1.42). Tables 5 and 7 display growth rates and condition factor data. Trout stock density was 0.16/m^2.

Goldmine River S,

The pH of the low lying Goldmine River contrasted with the acidic nature of the Glemnalure waters in that it had a more neutral pH of 6.9. The conductivity was elevated to 146.0 µS/cm and there was a slight increase of 2.0mg/1 in the concentration of calcium present. The nutrient levels indicated some degree of enrichment with an increased nitrate+ 1utrite reading of 4.75mg/1 N and total phosphate of 0.03mg/l P. The invertebrate life was diverse and quite abw1dant.

The fish captured had the slowest growth rates witnessed within the catchment, with three year olds on average reading only 13.7cm. Trout stock density in the river was 0.54/m^2 (Table 6).

Length frequency distributions of the fish from sites S_1 and S_2 show in figures 4 and 5 that 60 and 45% of the fish caught in the respective rivers were three years of age, and between 13.0 and 15.9cm in length.

TABLE 3. Water Chemistry of the Avoca Catchment, June 1991

	S1		S2	S3	s4	Ss	s6	S1	Ss	S9	S10	Sn
	Low Flow	Flood										
Conductivity (uS/cm) at 20°c	36.1	32.6	146	94.1	95.3	199 0	165.9	290	296	129.5	254.6	120
Colour (Hazen units)	120	140	40	20	20	15	15	40	45	25	30	45
Turbidity N.T.U.	6.0	8.7	3.8	4.3	4.5	46.0	4.5	8.0	14.2	4.3	4.3	3.8
Total Hardness (mg/I $CaCO_3$	14.0	14 .0	16.0	22.0	22.0	-	46.0	90.0	102.0	24.0	24.0	42.0
Alkalinity (milli equiv/I)	-0.022	-0.014	0.10	.093	.098	-	0.5	2.1	1.8	-	-	1.1
Total Phosphorus (mg/I P)	.019	.026	.030	.018	.026	-	.056	.739	.096	.059	.034	.011
Molybdate Reactive P.	.001	.002	.029	.012	.013	-	.050	.227	.091	.043	.029	.008
Total Kjeldahl Nitrogen (mg/I N)	.603	.585	.438	.936	.924	-	1.365	3.296	.804	.462	42.994	.632
Nitrite + Nitrate (mg/I N)	.256	.212	4.746	.898	1.016	-	4.718	<0.001	4.821	2.800	<0.001	2.890
Temperature °C	14.4	14.7	14.0	14.9	14.8	14.6	14.4	14.4	14.5	14.2	14.2	14.0
Dissolved Oxygen (mg/I O_2)	1 0.6	10.8	10.7	11.3	11.2	10.5	9.5	3.8	9.3	10.6	10.1	10.5
Calcium (mg/I $CaCO_3$)	5.0	5.0	7.0	12.0	12.0	-	55.0	55.0	66.0	7.0	7.0	60.0
pH	4.96	5.68	6.9	6.7	6.7	3.16	6.90	6.66	7.7	5.9	8.6	7.10

TABLE 4. **Invertebrate analysis of the Avoca catchment, June 1992.**

	S1	S2	S3	S4	S6	S7	S8	S9	S10	S11
EPHEMEROPTERA										
Baetis rhodani	11	6	0	0	2	0	3	0	0	28
Rhithrogena semicolorata	12	15	0	0	4	0	0	0	0	23
Heptage11ia sulphurea	0	6	0	1	2	0	0	0	0	3
Leptophlebia 111argi11ata	0	2	12	18	9	0	0	0	0	14
Ephemerella ig11ita	0	5	0	1	3	0	3	0	0	4
Caenis sp.	3	0	14	12	4	0	5	0	0	2
Ecdyom1rus venosus	0	15	2	3	8	0	2	0	0	27
Ce11troptil11111 l11teol11111	0	3	0	0	1	0	1	0	0	5
PLECOPTERA										
Leuctra Jusca	2	4	0	0	1	0	0	0	0	8
Leuctra ge11ic11lata	0	3	0	0	0	0	0	0	0	3
/soper/a gra111111atica	7	5	0	0	0	0	0	0	0	14
A111phi11e111111ra sulcicollis	1	0	2	0	2	0	0	0	0	12
Perla bip111lc tata	1	0	0	0	0	0	0	0	0	0
Perla meyeri	2	0	1	1	0	0	0	0	0	2
Chloroperla sp.	0	1	0	1	3	0	0	0	0	5
Ne111011ra ci11erea	4	6	0	2	1	0	0	0	0	7
Capnia bifrons	0	2	0	0	0	0	0	0	0	0
TRICHOPTERA (Cased)										
Glossomatidae	3	23	4	6	3	0	2	0	0	42
Sericostomatidae	8	16	12	10	7	0	1	0	0	33
Lepidostomatidae	0	1	0	1	1	0	0	0	0	6
Limnephilidae	0	1	0	3	3	0	0	0	0	0
Beraeidae	0	0	0	1	0	0	1	0	0	0
Anabolia	0	0	2	4	1	0	0	0	0	2
TRICHOPTERA (Uncased)										
Hydropsyche i11stabilis	0	8	0	0	4	0	2	0	0	7
Hydropsyche siltalai	0	0	0	0	1	0	0	0	0	14
Rhyacophilia dorsalis	0	3	0	2	3	0	0	0	0	9
Rhyacophilia 1111111di	1	0	0	0	2	0	0	0	0	5
Polycentropus kingi	0	4	3	2	0	0	0	0	0	8
Polyce11trop11s jlavo111ac11lat11s	0	1	1	4	1	0	1	0	0	4
DIPIERA										
Chironomidae larvae - green	0	0	2	6	3	0	0	0	0	2
Chironomidae larvae - red	0	0	0	0	5	56	10	0	28	0
Dicranota	0	0	4	8	1	0	0	0	0	27
Tipulidae larvae	0	1	2	1	4	0	1	3	0	2
Simulidae larvae	5	6	0	0	0	0	0	0	0	0
COLEOPTERA										
Li11111i11s volkmari sp.	5	3	0	0	3	0	1	0	0	8
Ehnis ae1le a sp.	0	5	0	0	2	0	0	0	0	7
Esolus paral/elepipedus sp.	0	2	0	0	1	0	0	0	0	3
Hydrophilidae sp.	0	1	0	1	0	0	0	0	0	0
OUGOCHAEI'A										
L11111bric11s variegatus	3	2	10	24	0	5	8	0	0	8
Tubificidae	0	0	0	3	10	31	0	0	0	0
Enchytraeidae	0	0	0	1	0	0	0	0	0	0
GASTROPODA										
A11cyl11s"jl11viatil11s	0	3	0	0	2	0	0	0	0	11
Ly11111aea peregra	0	0	0	0	0	0	0	0	0	1
ARACHNIDA										
Hydracari11a sp.	0	0	0	2	1	0	0	0	0	5
liIRUDINEA										
Erpodella octoculata	0	1	0	0	0	0	0	0	0	1
AMPHIPODA										
Ga111111anis d11ebe11i	0	0	0	0	5	0	8	0	0	10
TRICLADIDA										
Polyceliste1111is	0	0	1	0	0	0	0	0	0	0
Different spp. no.	15	30	15	25	33	3	15	1	1	37

KEY	
!Length (cm)	n
(Range)	

TABLE 5. Backcalculated growth rates of brown trout (Sal.mo trutta L.), June 1991.

SITE	GRID REF.	LI	l2	L3	IA	LS
Sl : Glenrnalure	T067 940	5.3 20 (4.0-6.3)	11.2 20 (9.2-13.0)	13.3 18 (13.0-16.7)	17.1 6 (15.0-18.5)	
S2 : Goldmine	T187 760	4.9 20 (4.3-6 .1)	9.8 20 (8.1-12.4)	13.7 19 (11.7-16.7)	16.4 12 (15.1 -18 .5)	19.1 3 (18.4-19.8)
S3: Moyne	T031 802	6.7 5 (6.0-7.1)	13.4 5 (12.2-14.4)	18.8 5 (17.6-19.6)	21.3 1 (21.3)	
S4 : Sandyfor d	T035 790	7.0 7 (6.3 -7.4)	14.3 7 (12.9-15.6)	19.5 7 (16.5 -20.5)	23.1 4 (21. 2-25.2)	
S6 : Handweavers	T211 802	5.8 3 (5.5-6.1)	11.5 3 (11.1-12.0)	15.0 3 (14.7-17.5)	17.0 3 (17.1-17.5)	18.8 1 (18.8)
S8 : West Avoca trib.	T218 739	5.1 8 (4.0-5.9)	11.7 8 (10.6-12.7)	15.2 2 (15.0-15.3)	17.2 1 (17.2)	
S ll :Aughrim	T172 781	7.2 20 (6.4 -8.0)	15.2 19 (12.3 -17. 1)	19.5 11 (17.0-22.0)	23.8 1 (23 .8)	26.5 1 (26.5)

TABLE 6. Brown trout population estimates and densities.

SITE	DATE	AREA F1SHED (m1.)	POP. ESTIMATE 95%C.I.	MIN. DENSITY PER mz.
S l : Glenrnalure	25-06-91	218.3	35 5	0.16
S2 : Goldmine	26-06-91	151.7	81 5	0.54
S3 : Moyne	26-06-91	180.0	One fishing only	0.04

TABLE 7. Stomach contents of fish in the Glenmalure River, June 1991.

Length (cm)	Wt. (gr.)	Sex	% Stomach Full	K	Chief Food	Other Food
10.6	16.9	F	25	1.42	-	Coleoptera, Ephemeroptean larvae
10.7	20.0	M	25	1.64	-	Trichopteran larvae, 1 ant
11.0	20.5	F	25	1.54	-	Ephemeropte ran larvae
11.4	23.2	F	100	1.57	Terrstrial flies	-
12.2	26.3	F	25	1.45	-	Terrestrial flies, Trichopteran larvae
12.3	25.3	M	50	1.36	Coleopteran larvae	Coleoptera-adult, Trichopteran larvae
12.4	29.3	F	25	1.54	-	Terrestrial fly, Ephemeropteran larvae
12.6	28.9	F	100	1.44	Terrestrial flies	Ephemeropteran larvae, Coleopteran adult
12.8	29.6	M	100	1.41	Winged insects	Trichopteran larvae
13.1	30.4	F	50	1.35	-	Winged insects, Ephemeropteran larvae
13.2	31.9	M	25	1.39	-	Winged Ephemeropterans, Plecopteran
13.4	34.9	F	50	1.45	Winged insects	-
13.6	37.8	M	25	1.50	-	Ephemeropteran larvae, Simulium larvae
14.8	43.4	M	100	1.34	Coleopteran larvae	Coleopteran-adult, Trichopterans, Ephemeropterans, Terrestrial flies
14.9	45.1	F	0	1.36	-	-

Over

Table 7. Contd.

Length (cm)	Wt. (gr.)	Sex	% Stomach Full	K	Chief Food	Other Food
15.0	48.4	M	25	1.43	-	Ephemeropteran larvae, Plecopterans
15.1	49.2	F	25	1.43	-	Coleopteran larvae, Rhyacophilia sp.
15.3	50.8	F	50	1.42	-	Winged Ephemeropterans
15.6	51.4	M	25	1.42	-	Coleopteran adults, Winged insects
15.7	51.0	M	100	1.32	Coleopterans	Winged insects, ants, Trichopteran larvae
16.6	61.5	M	100	1.35	Winged insects	Coleopteran larvae
17.1	67.2	F	100	1.34	Coleopterans	Winged insects, Ephemeropterans, Coleoptera-adult
18.9	81.4	M	50	1.21	-	Trichopteran larvae, Winged insects

The Moyne Subcatchment, S_3 and S_{11}

The general water chemistry of this low lying system also indicated less acidic conditions with pH values averaging 6.7, alkalinity 0.10 milli equiv/I, and having a mean conductivity of 94.7 µS/cm. The calcium levels in this locality were 12.0 mg/1 Ca, with the water hardness increasing to 22.0 mg/1 $CaC0_3$. Water colour was greatly reduced to 20 Hazen units and nutrient levels were low.

Both low grade channels fis hed were of poor gradient with the absence of instream diversity and suitable substrate.

Invertebrate life was restricted principally to btur owers and species adapted to slow-flow conditions. The dominant Ephemeropterans present generally being recognised as sluggish movers and poor swimmers. The caenidae nymphs present were burrowers and common in silty conditions, and the Leptophlebildae species present were typical of slow-flowing, less productive waters. *Lumbricus vargiatus* which lives in soft substrate conditions was also abtmdant. A low fish stock density of 0.039/m^2 was recorded with no fry observed. The brown trout captured had reasonable good growth rates (Table 5).

Tigroney Stream, S_5

This tmproductive stream which nms directly tlu·oug h the mines, was devoid of visible floral fatmal or fish life, and had extreme pH of 3.16. Other conspicuous parameter values included a conductivity of 1990 µS/cm and excessively turbid conditions of 46.0 NTU which arose from the accumulation of suspended solids after the recent rainfall.

East Avoca Tributary, S_7

A clu·onic agricultural pollution problem in this short tributary also ensured that no fish were present. The invertebrate fauna/pollution relationship manifested itself by poor species diversity and the dominance of the least sensitive invertebrates, red chironomids and tubificids. Greyish coloured slimy colonies of micro-organisms collectively called 'sewage ftm gus' were prevalent downstream from the entry of what appeared to be silage effluent. No such ftmgus was apparent upstream of this outfall.

The stream was highly enriched with a total phosphonis loading of 0.74 mg/1 **P** and total kjeldahl nitrogen of 3.93 mg/1 N, in a partially deoxygenated state of 3.8 mg/1 0_2. The calcium levels which increased to 55 mg/1 Ca con-elate with a hardness increase to 90.0 mg/1 $CaC0_3$ making this mode rately soft water.

East Avoca tributary at Avoca Handweavers, S_6

This intervening stream between the latter two inanimate veins contained fish life. Very slow-growing, four year old trout at this site measured on average 17.0 cm. Some enrichment was evident from the algae encroaching the stones but it appeared to be tmder control. Total phosphate culminated 0.06 mg/I P and Nitrate + Nitrite 4.72 mg/1 N. Both colour and turbidity readings were low. Tolerant invertebrate species were present including Tubificidae, but both sensitive ephemeropterans and plecopterans were also noted. The introduction of *Gammarus duebeni* was accompanied by an increase in hardness and calcium.

West Avoca Tributary, opposite I.F.I., S_8

Gammarus deubeni was also present in this alkaline Ordovician stream, flowing eastwardly into the Avoca River. Calcium and hardness values were 66.0 mg/1 and 102.0 mg/I $CaC0_3$ respectively. An unstable substrate which was primarily composed of gravel over a soft silty bed, accompanied elevated tmbidity readings (14.2 NTU). A total phosphate reading of 0.10 mg/I P and Nitrate + Nitrite of 4.82 indicated some enrichment in thE: system. It is therefore not surprising that the Plecopterans were eliminated and many other sensitive invertebrates being poorly represented, i.e. Ephemeropterans and the Trichopterans. In fact the dominant species were the much more tolerant Chironomids. Despite the enrichment, some fish were captured at this site and through back-calculation again proved to be slow-growing fish, with a four year old reaching 17.2cm.

Avoca River, S_9 and S_{10}

No fish were captured at either of these locations sited downstream of the mines. The invertebrate life along this stretch was totally restricted to the more tolerant Dipteran larvae.

Site S_{10} , downstream of I.F.I., is also subject to the ammonia loading from the industry's disc harge . This ab m ptly elevates the pH from being acidic to extremely alkaline (5.9 - 8.6). T he Total Kjeldahl Nitrogen goes from being 0.46 mg/1 N upstream to 42.99 mg/1 N downstream.

Aughrim River, S_{11}

T his alk alin e river held quite a diversity of life. Nutrient levels were low; Total phosphate 0.01 mg/1 **P** and Nitrate+ Nitrite 2.89 mg/1 N. Calcium values of 60.0 mg/1 Ca accompanied the introduction of Gastropods, both *Ancylus ftuviatilus* and *Lymnaea peregra*. Overall the invertebrates were found to be the most abtmdant and diverse in this subcatchment (Tabl e 4).

The fish caught were all in good condition (mean K = 1.48) and had the fastest growth rate witnessed in the catchment. Four year old trout grew to 23.8 cm.

FIS H STOMAC H CONTENTS

The distinguishing characteristic of the food of the Glenmalure trout was the dominance of winged insects. Very few of these were of aquatic origin. They were practically all terrestrial insects which had blown on to the water from the bushes bordering the river, and had greatly augmented the food supply of the trout. This high incidence of terrestrial insects ensured that deficiencies in the stream bed fauna were offset by allochthonous inputs. Insect larvae were also important, belonging mostly to the orders Ephemeroptera, Coleoptera and Trichoptera (Table 7).

In contrast, there was a relative insignificance of winged insects in the stomach contents of the Aughrim fish. In no instance did winged insects form the main constituent of the food, which was composed almost entirely of bottom-living organisms. These consisted mainly of various kinds of insect larvae, adult Coleopterans, together with Gastropods and the amphipod, *Gammarus.* The larvae of caddis flies were the most impotiant food constituent of 20% of the fish captured. The ephemeropteran and plecopteran larvae were equally as important (Table 8).

TABLE 8. Stomach contents of fish in the Aughrim River, June 1991.

Length (cm)	Wt. (gr.)	Sex	% Stomach Full	K	Chief Food	Other Food
6.5	4.8	F	25	1.75	Ephemeropterans	-
12.3	29.1	F	100	1.56	Coleoptera - adults	Ephemeropteran larvae, Gammarus
12.8	24.9	M	50	1.36	Simulidae larvae	Ephemeropteran larvae, Trichopteran
13.4	37.7	M	25	1.56	Ephemeropterans	Coleopterans - adults, Dicranota
13.9	38.4	M	100	1.43	Trichopterans	Gastropods, Ephemeropterans
15.0	50.4	M	50	1.49	Gastropoda	Terrestrial fly, Coleopteran - adults
15.3	57.2	F	50	1.60	Ephemeropterans and Plecopterans	Gastropoda, Coleopteran - adults, Trichopteran, Simulidae
15.4	55.7	M	50	1.53	Ephemeropterans and Plecopterans	Gastropoda, Coleopteran - adults, Terrestrial fly
17.0	75.6	F	50	1.54	Gastropoda, Gammarus	Trichopteran, cased and uncased
17.5	81.6	M	50	1.52	Ephemeropterans and Plecopterans	Gastropods, Trichopterans
18.2	85.6	F	100	1.42	Gastropoda, Gammarus	Ephemeropterans and Plecopterans, Coleoptera - adults
18.7	95.9	M	50	1.47	Trichopterans	Terrestrial flies, Coleoptera larvae
18.8	97.7	F	25	1.47	-	Gastropoda, Trichoptera, Diptera larvae, Ephemeropteran

Table 8 Contd.

Length (cm)	Wt. (gr.)	Sex	% Stomach Full	K	Chief Food	Other Food
19.6	100.7	F	100	1.34	Coleoptera and Ephemeropteran adults	Gastropods, Trichoptera, Coleoptera - adults
19.9	115.7	F	100	1.47	Trichopterans	Terrestrial flies, Coleopteran-larvae, Winged and larvae, Diptera
19.9	112.3	M	50	1.43	Gastropods and Simulium	Trichopterans, Ephemeropterans and Plecopterans, Terrestrial fly
20.6	129.7	F	100	1.48	Trichopterans	Trichopterans, Simulidae
20.9	133.8	M	100	1.47	Fish fry	Coleopterans - adult, Ephemeropterans and Plecopterans, Terrestrial fly, Simulidae, Gastropoda
21.3	137.8	M	50	1.43	Gastropoda, Trichopterans	Ephemeropterans and Plecopterans
26.5	223.7	M	100	1.20	Gastropoda, Ephemeropterans	Trichopterans, Dicranota

DISCUSSION

The late Dr. Went in his essay "A Lost Irish Salmon River" (1979) has chronicled the demise of the Ovoca (Avoca) River as a salmon fishery. He quotes Mason who wrote, between 1814 and 1819, that "About thirty years ago the Avoca was remarkable for the great quantity of salmon it produced ..... the mines situated on its banks have entirely destroyed the fish from thence to the sea, a distance of eight miles, and the salmon which attempt to nm up in the spawning season are frequently taken out dead or almost in a torpid state".

This remains the status quo with brown trout *(Salmo trutta* L.) the only species recorded from the electrofished sites within the catchment. No salmon were captured during this brief survey, through a qualitative study of the catchment in 1988 confinned the successful numing of salmon to at least one of the tributaries (E.R.F.B., 1988). A fomock (2 year+ old sea trout) measm-ing 25cm was also captured upstream of Woodenbridge in 1988, and since then a number of mature salmon have been recovered dead from the lower section of the river between sites S_9 and S_{10}.

The acidic waters of the Glenmalure River, de1ived from granitic rock produce small, very slow-growing fish. The largest fish taken was a mature four year old male, weighing 81.4 grams and measuring only 18.9cm in length. The same aged fish in the Aughrim River, at S_{9}, flowing over Ordovician rock, showed reasonable growth at 23.8cm. From a carboniferous limestone region, in n01ih Co. Wicklow, a fast-growing four year old brown trout, taken from the River Liffey, at Straffan, measured 29.7cm (Fig. 7), (Went and Frost, 1942).

Similarly, the limestone waters of the Little Brosna River, in Co. Offaly produced very fast growing trout measuring 38.7cm in their fornth year. Between the two extremes of very slow (Glenmalure River L_4 = 18.9cm) and very fast (Little Brosna River, L_4 = 38.7cm) growth rates, it is evident that fish from limestone rich waters can have a 50% better growth rate in four years than fish from limestone deficient waters. The fish in the Aughrim and Goldmine Rivers were 38% and 58% smaller respectively than fish from more productive limestone rivers.

Upstream of Straffan in the River Liffey, at Ballysmuttan, where the river is tmderlain by granite, the slow growth pattern of brown trout is simila r to that fmmd in the Avonbeg and Goldmine Rivers (Fig. 8).

This range of growth rates can be attributed to not only the geological influences, but also to the speed of the current, the depth of the water, the presence or absence of pools, the amotmt of shade and shelter provided by weeds in the water, vegetation on the bank, and also variations in the level of the water.

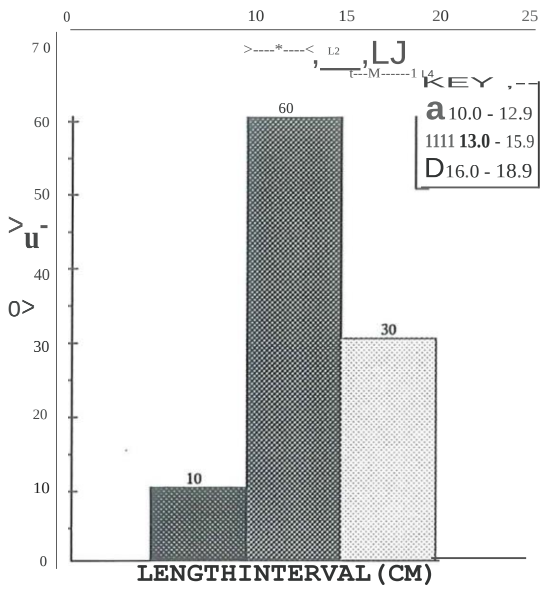
These factors are diverse throughout the Avoca catchment, and hence the varied growth patterns (Table 5). Looking closer at the growth rates of the quantitatively fished rivers, S_1 and S_2, (Figs. 8 and 9), it is apparent that the fish grew best during their first two years. The rates fall markedly in their third year perhaps due to the onset of maturity and continue to be very low thereafter. Comparing specific growth rates of brown trout from four different locations (Fig. 7), the rates generally decrease as the fish grow older, so that the fish grow at the highest rate dttring the first or second year of life and after that they grow less rapidly with each year, but this decrease in growth rate becomes less marked as the fish grow older.

The attainment of maturity tends to retard growth (Southern, 1952). The decrease in the average annual rate of growth of the fish which are spawning can be explained since the increase in the size of the gonads uses up food material which might otherwise have been incorporated into more permanent parts of the body. Behaviour associated with spawning, such as migration upstream and constmction of redds uses up much energy and this must be derived from the food eaten or from food reserves in the body. This ripening of the gonads and spawning reduces the ammmt of food which is available for growth.

A highly productive stock density was recorded in the Goldmine River, $0.54/m^2$, compared with 0.16/ni2 in the Glenmalure River, which would be considered only poor to fair at best for productive salmonid streams. The slowest growth rate in the

LENGTH FREQUENCY DISTRIBUTION

Glenmalure river, June 1991



FIG/4 Length-frequency distribution of brown trout in the Glenmalure river (20 fish).

Goldmine river, June 1991

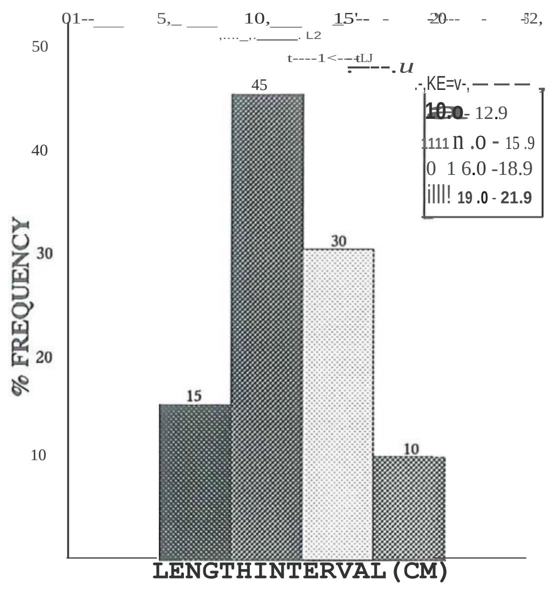


FIG.5 Length-frequency distribution of brown trout in the Goldmine river (20 fish).

The horizontal lines indicate length range of trout at the end of succesive growing seasons.

X = Mean length.

SPECIFIC GROWTH RATE

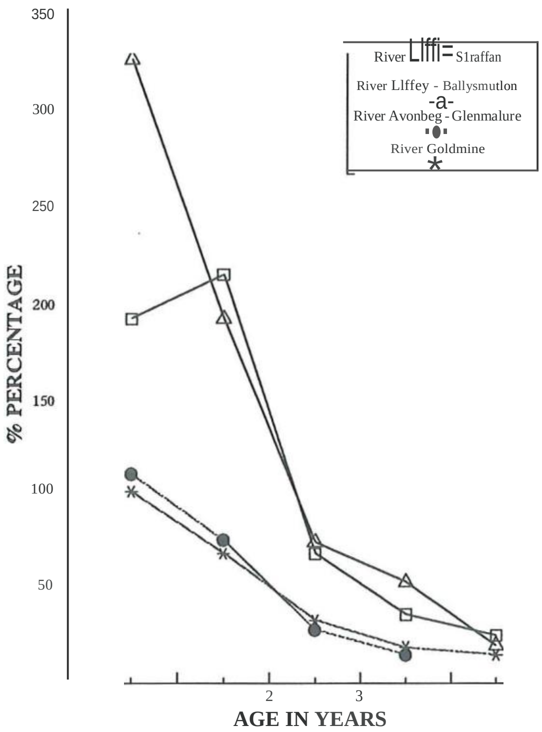


FIG.6Annual average specific growth rates of brown trout. River Liffey data from Went, & Frost (1942) .

MEAN GROWTH RATE

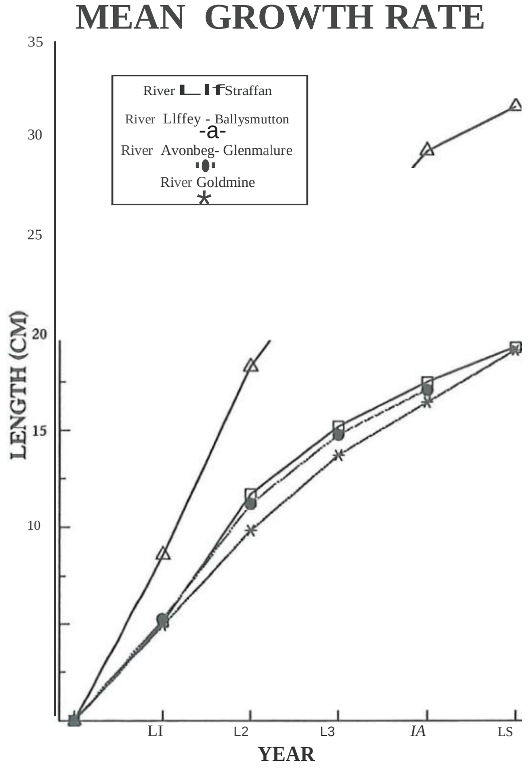


FIG.7Mean growth rate for brown trout at four four Irish s tations .

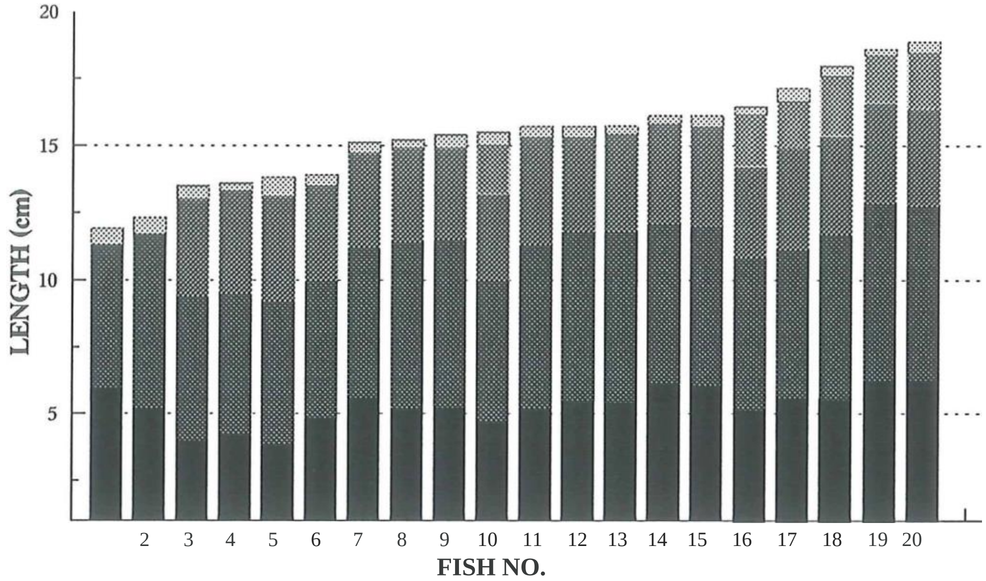


FIG.8 Growth patterns of brown trout taken from the Glenmalure river, June, 1991.

KEY: • Ll II L2 II L3 lm L4 kJ LS f:fo +GROWTH

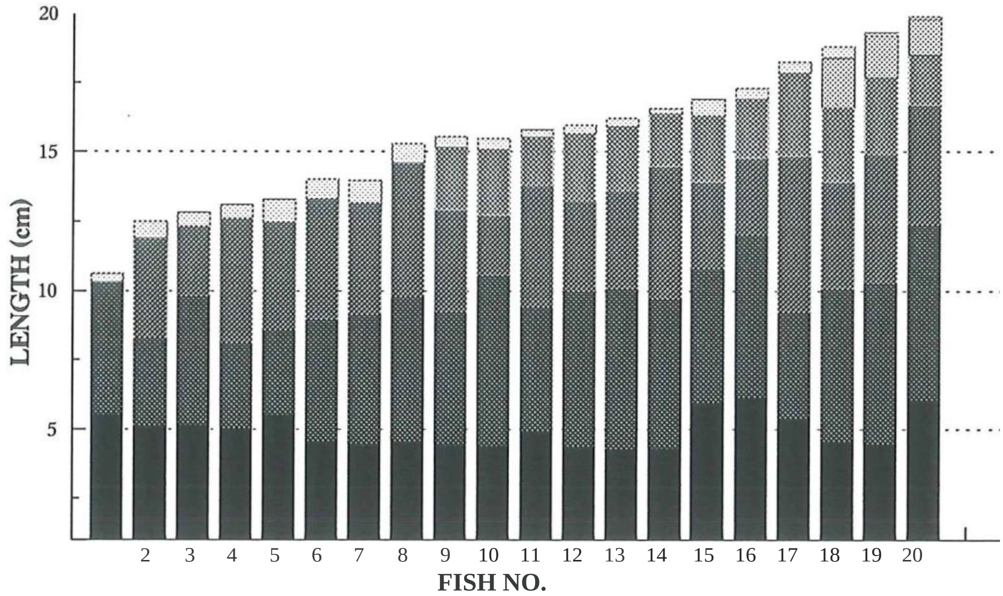


FIG.9 Growth patterns of brown trout taken from the Goldmine river, June, 1991.

catchment was observed in the Goldmine tributary, this may in part be due to the smallness of the stream and the high stock density witnessed therein. Plate 9 shows the differe nce in size of 5 year old trout from the Goldmine and Aughrim River.

A low fish stock density of 0.03/m^2 was recorded in the Moyne subcatchm ent and no fry observed. Factors which may have accotmted for this include the appa rent lack of spawning gravels and the danger of the extensive growths of *Ranunculus* becoming more luxuriant (during the summer months) would limit fish production and many affect oxygen levels. The silt load on the bed of the river would also be an inhibitory factor for salmonids, especially the early life stages.

Gammarus , which was absent from much of the soft water catchment were frequently eaten , often in considerable numbers, by fish in the Aughrim River. Sutcliffe (1967) discusses the absence of *Gammarus duebeni* from a number of Co. Wicklow streams of low mineral content e.g. the Avonmore, and suggests this may be due to lack of sodium. There is also some evidence that several invertebrates are limited by potassium or sodium rather than calcium (Sutcliffe and Hildrew, 1989). The absence of *Asellus* as well as *Gammarus* was noted in all of the catchment rivers of very **low** electrical conductivity. Lackey (1938) fotmd *Gammarus* species in two streams with pH value of 2.2 and 3.2 respectively. This would indicate that the scarcity of this species within the catchment may be correlated with low nut1ient content, rather than hydrogen-ion content. Gastropods were not to be fotmd in the stomach contents of the Avonbeg fish but were often the chief food in the diet of the brown trout caught in the Aughrim River. Ma.can and Cooper (1949) define 15 freshwater gastropods as hard water species ordinarily absent where there is less than approximately 20 mg/1 of calcium as Ca.

It appears then from the diet of the fish in both rivers that the brown trout is an w1specialized carnivore feeding on what is available in the smTotmding environment, i.e. it is very much of an opporttmistic feeder. There is a close but not exact con-espondence between the list of invertebrates present in the stomachs and in the benthic fauna. The differences in diet can therefore be associated with the relative abm1dance of the different insects in the fatma at the two sites examin ed. Surface feeding on terrestrial insects is more frequent in less productive waters but when floods

PLATE 9. Five year old brown trout from the Goldmine and Aughrim rivers measuring 19.6 and 26.5 cm respectively.

on rivers make terrestrial animals ava ilable, these are eaten av idly by the trout regardless of the poverty or abm1dance of the aquatic famrn (Frost and Brown, 1967).

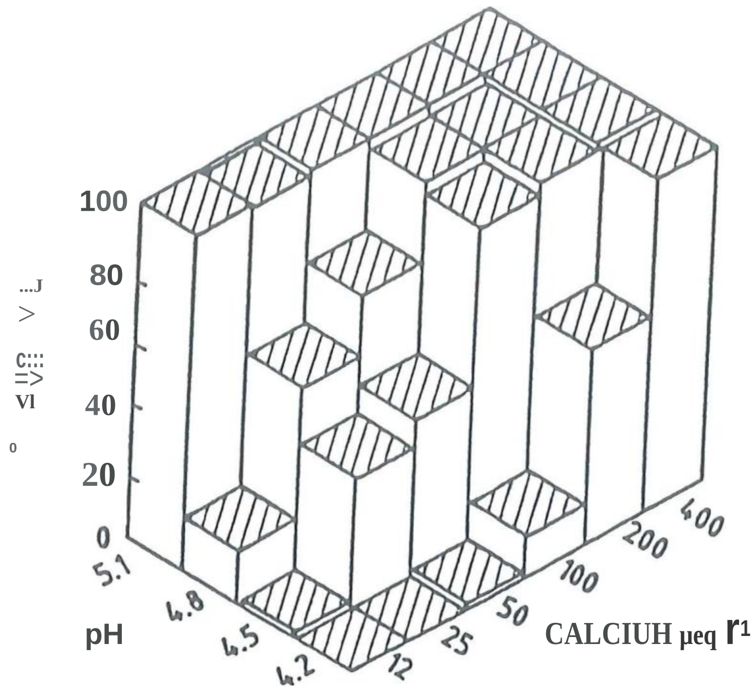
The character of the river bed influences the kind of organisms which tend to be particularly abtmdant. Various substrates are encotmtered in the Avoca catchment from upland erosional to lowland depositional. Some idea of how the benthic macro-invertebrates from stony and sandy/silty substrate differ in kind and relative abundance is apparent from the comparison of the percentage composition of the fauna in the Aughrim River, Sil, where the substrate is stony, to S_3, and silty tributary of the Mayne (Table 4).

Water mosses are present at several of the site locations where the flow is swift and the substratum stony. These plants tend to hold a varied inveiiebrate famrn including ephemeropteran, coleopteran and chironomid larvae, and *Gammarus. Benda* and *Ranunculus* present at S_3 and S_4, with a moderate to slow flow rate, supported tricopteran larvae and *Simulium.*

The value of aquatic vegetation to the trout is that it can provide "good lies", that is places where, tmdisturbed by the current, hidden from enemies and on a good feeding grotmd, they find a satisfactory microhabitat. The trees and bushes on the river bank give shade, shelter and hiding places and thus also provide "good lies" for the trout. The overhanging bank vegetation of many of the sites would also act as shelter for newly emerged flies, which would not be blown away from the river to be themselves lost as immediate trout food, or to leave no progeny to be future food. Bank vegetation management would benefit many of the sites patiicularly S_9 and S_{10}.

Since the catchment waters ovemm varied geological fonnations, calcium levels tend to vary. The importance of calcium in detem1ining the survival of brown trout eggs at low pH has been demonstrated by Brown and Lynam (1981). The relationship between the perecentage survival of freshly feiiilized eggs and a range of pH levels and calcitun concentrations is described by Brown (1983) (Fig. 10).

Figure. 10. **The percentage survival of freshly fertilised brown trout eggs after 8 days in a range of pH and calcium concentrations. (Brown and Lynam, 1982).**



Survival after eight days is 100% at pH 5.1 irrespective of calcium concentrations down to 12 μ equiv r^{1}, and at 400 μ equiv r^{1} of calcium irrespective of pH, down to 4.2, whilst at low pH (4.2) and low calcium (50 μ equiv r^{1} and less) survival is nil. This would indicate that the low pH and calcium values encountered (i.e 4.96 and 125.0 μ equiv 1-^{1} respectively) in the Glenmalure River during low flow conditions are potentially threatening to the survival of freshly fertilised brown trout eggs.

Experiments designed to measure the toxicity of low pH on older fish have been short term bioassays at less than pH 4.0. Such extreme conditions are not likely to be responsible for the elimination of fisheries in natural waters and only serve to indicate the relatively high resistance of adult fish compared with the eggs. In terms of percentage survival rates, adult salmonids are able to tolerate pH levels down to 4.3 and 4.4 for long periods even in low calcium conditions. With regard to chronic (sub lethal) effects of acid exposure the data is confused. Some researchers report slower growth rates of fish around pH 5 compared with that at pH levels above 6 (Menedez, 1976; Rogers 1984), whereas Jacobsen (1977) found no effect on brown trout growth down to pH 5.

The importance of calcium in ame liorating any acid effect on growth rates is also confusing. Rogers (1984) fotmd that both pH and calcium had significant effects on brook trout growth (maximum 1.2% d^{-1}), whereas Sa dler and Lynam (1984) fotmd that brown trout could main tain a growth rate of 1.3% d^{-1} down to pH 4.4 and with a calcium concentration nearly twenty times lo wer than the minimum used by Rogers (198 4). The difference between these studies must be attributed to species diffe re nce unless diffe rences in experimental design produced some stress exac erbating the pH stress effects in the study of Roger s (1984).

The pH range within the Avoca catchment (5.0 to 8.6) is quite perilous to salm onids, taking into acc0tmt the other parameter s. Table 9 shows the effects of a range of pH values on salmo nids.

The position in the lower Avoca catchment is further complicated in that the acid leachate from the mines contain considerable quantities of dissolved ferric sulphate which become hydrolysed at pH values above 3.0 to form ferric hydroxide. Larsen and Olsen (1948), cited in Alabaster and Lloyd (1981), found that fish kills occurred in a trout hatchery when the pH value of the water was 6.2 - 7.0 and the water contained 1.5-2.0 mg Fe/1. The cause of death was attributed to the precipitation of ferric hydroxide on the gills, since the pH value of the water was higher than the lethal value.

The toxicity of the copper and levels of zinc downstream of the mining belt is additive of the separate metal concentrations. Lloyd (1961) f0tmd that the effect of this mixture of metals was additive in both soft and hard waters (Table 10).

Because of the complexity of the Avoca Mine waste and the paucity of analytical data it is difficult to distinguish the effect attributable to each specific metal.

Only tentative water quality criteria is formulated at present because there are virtually no field observations that indicate unequivocally the concentrations of copper and zinc that are not inimical to fish populations. The recommended criteria (proposed by EIFAC) for the 95 percentile and 50 percentile values of zinc are 0.1 and 0.03 respectively of the 7-d LC50; for 'soluble' copper, the con-espondingfigures are 0.2 and

0.05 of the 50-d LCS0 value. These criteria are only small fractions of the lethal threshold concentrations. The toxicity of both copper and zinc is effected by increasing water hardness (Table 9).

The harmful effects of ammonia on fish are related not to hardness but to the pH value and the temperature of the water owing to the fact that only the mi-ionized fraction of ammonia is poisonous. The tm-ionized fraction increases with rising pH value, and with rising temperature. The lowest lethal concentration fotmd for slamonids is 0.2 mg NH:/1 (un-ionized), but other adverse physiological and histopathological effects are caused by prolonged exposure at conentrations of 0.025 mg **NH:/1** (tm-ionized). Concentrations of total ammonia which contain this ammmt of tm-ionized ammonia range from 19.6 mg/1 (pH 7.0, 5°C) to 0.12 mg/1 (pH 8.5, 30°C). Ball, 1967 fotmd that for periods of up to 1 day the rainbow trout was much more susceptible to ammonia, in terms of medium lethal concentrations than coarse fish. As forementioned, large quantities of ammonia are discharged to the lower reaches of the Avoca River from a fertilizer factory. A rise in temperature of 10°C would double the concentrations of mi-ionized ammonia present in the ammonia effluent.

Despite the myriad of toxicants in the lower stretches of the Avoca, salmon and sea trout continue to persevere and nm the river when in flood. Several do not make it due to toxic poisoning, but also as a result of poaching, since the waiting for optimum conditions at the mouth of the river can be a long taxing one. When conditions are most favourable, the fish could manage to nm the toxic 10km section of the river in 24 hours or less (O'Grady, 1992).

The Rathdrnm anglers, on the Avonmore, consists of one hundred members. Several salmon smolts are reported to have been taken by rod and line last year, and good size brown trout of approximately 226 grams (Kelly, 1992). The fishing in the Avoca River and lower catchments remains limited.

TABLE 9. Summary of the effects of pH values on salmonids. Adapted from Alabaster and Lloyd, 1981.

Range	Effect
3.5 - 4.0	This range is lethal to salmonids.
4.0 - 4.5	Likely to be harmful to salmonids which have not previously been acclimated to low pH values, although the resistance to this pH range increases with the size and age of the fish.
4.5 - 5.0	Likely to be harmful to the eggs and fry of salmonids, and to adults particularly in soft water containing low concentrations of calcium, sodium and chloride.
5.0 - 6.0	Unlikely to be harmful to any species unless either the concentration of free carbon dioxide is greater than 20 mg/1, or the water contains iron salts which are freshly precipitated as ferric hydroxide, the precise toxicity of which is not known. The lower end of this range may be harmful to non-acclimated salmonids if the calcium, sodium and chloride concentrations, or the temperature of the water are low.
6.0 - 6.5	Unlikely to be harmful to fish unless free carbon dioxide is present in excess of 100 mg/1.
6.5 - 9.0	Harmless to fish, although the toxicity of other poisons may be affected by changes within this range (e.g. ammonia).
9.0 - 9.5	Likely to be harmful to salmonids if present for a considerable length of time.
9.5 - 10.0	Lethal to salmonids over a prolonged period of time, but can be withstood for short periods.
10.0 - 10.5	Can be withstood by salmonids for short periods but lethal over a prolonged period.
11.0 - 11.5	Rapidly lethal to all species of fish.

TABLE 10. Summary of laboratory data on the joint action of mixtures of toxicants to fish.

Toxicants	**Species**	**Exposure Period**	**Ratio of toxicant EC 50**	**Joint Action**	**Multiple of Additive pint action**	**Reference**
Copper and Zinc	Rainbow Trout	3-d LCS0 (Hard water 3-d LCS0 (Soft water)	1 : 1 1 : 1	Additive Additive	1.0 1.0	Lloyd (1961)
Ammonia and Copper	Rainbow Trout	48-h LCS0	1 : 1	Additive	1.0	Herbert & Vandyke (1964)
Ammonia and Zinc	Rainbow Trout	Threshold LCS0 (Hard water) (Soft water)	1.0: 0.5 1:2 1: 1	Additive Additive Less than aditive	1.0 1.0 0.8	Herbert & Shurben (1964)

TABLE 11. Maximum Annual 50 and 95 percentile concentrations of 'Soluble' copper and zinc. (Alabaster and Lloyd, 1981).

Water Hardness ($mg/l\ CaCO_3$)	Salmonids (mg/I Zn) 95 percentile	Salmonids 50 percentile	(ug/l Cu) 95 percentile
10	0.03	1.0	5.0
50	0.20	6.0	22.0
100	0.30	10.0	40.0
300		28.0	112.0
500	0.50		

CONCLUSIONS

The catchment encompasses a range of cha1mels from small streams to the main river. These areas include many zones which are curre ntly unsutied to salmonids because of pollution, bank vegetation problems and w1suitable physical instream conditions, while other areas endowed with suitable habitat are producing reasona ble-good numbers of slow-growing trout.

Sites 1, 9 and 10 would benefit from the creation and maintenance of bank cover. A paucity of suitable loose gravels for spawning purposes also limits the production at the latter two sites. However, the mining effluent which affects the main cha1rnel (S_9 + S_{10}) is a more complex problem which will take longer to resolve.

The presence of sewage fw1gus, the composition of the invertebrate faw1a, the macrophytes present and the fish stock situation were taken as pointers to the status of the streams in tenns of pollution/emichment. S_2, S_6 , S_7 and S_8 need to be monitored closely to control the nutrient loading to the streams.

The gradient, substrate, vegetation and sinuousity of S_7 indicate that this tributary could potentially produce significant quantities of salmonid fry and parr if the pollution could be traced and eliminated.

The Mayne sub-catchments fish production could be enhanced by the addition of gravels and the alteration of physical instream.

This study has shown that although growth rate is generally low, due to the low productivity of the catchment, good populations of sttmted brown trout exist in unpolluted sections of the main cha1rnel and its tributaries. Bmmd on all sides by EC designated salmonid river catchments, the potential exists for the development of the Avonmore-Avoca system into a salmonid fishery. The study has identified a number of potential problems which are currently tmder investigation. The river requires special designation and the development of a specific management strategy to protect existing fishery interests and to suppoti its development to full salmonid status.

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