Series A (Freshwater) No. 34 1992

IRISH FISHERIES INVESTIGATIONS

M.F. O'Grady and J.J. King

Ecological changes over 30 years caused by drainage of a salmonid stream, the Bunree River

IRISH FISHERIES

INVESTIGATIONS

SERIES A (Freshwater) No. 34 (1992)

Roinn na Mara

(Department of the Marine)

Ecological changes over 30 years caused by drainage of a salmonid stream, the Bunree River

by

M.F. O'Grady and J.J. King

DUBLIN:
PUBLISHED BY THE STATIONERY OFFICE

TO BE PURCHASED THROUGH ANY BOOKSELLER, OR DIRECTLY FROM
THE GOVERNMENT PUBLICATIONS SALE OFFICE,
SUN ALLIANCE HOUSE, MOLESWORTH STREET, DUBLIN 2.

Price: £1.60

Ecological changes over 30 years caused by drainage of a salmonid stream, the Bunree River

by

M.F. O'GRADY and J.J. KING,
Central Fisheries Board,
Balnagowan, Mobhi Boreen, Glasnevin, Dublin 9, Ireland.

ABSTRACT

The general ecology of two sites in the Bunree River, Moy catchment are described for 1990 and compared with the observations of Toner, O'Riordan and Twomey, (1965) at the same sites 30 years ago when parts of this catchment were subjected to arterial drainage. Differences observed are discussed with particular reference to salmonid populations.

INTRODUCTION

Arterial drainage schemes on major Irish riverine catchments have been undertaken to provide flood relief, accelerate run-off and facilitate land reclamation. On the other hand, the channel alterations caused by drainage have a serious impact on the entire instream ecology, creating, at least in the short term, a shallow uniform canalised channel with an absence of instream and bank features. The ability of a channel to revert to something approaching its pre-drainage ecology and the time taken for this process depends on a variety of factors. Important among these are the channel gradient and the nature of the substrate and bank material in and upstream of the drained area. Pre- and post-drainage surveys of certain channel sections on Irish rivers indicate that post-drainage recovery can occur (Toner et al 1965, McCarthy 1977 and 1983, Kennedy 1980, O'Grady 1991).

The River Moy in Co. Mayo is one of Ireland's foremost salmon-producing catchments. As well as rod and line angling, the system supports a commercial draft net and a crib fishery in the town of Ballina (see Fig. 1). The Moy catchment drainage scheme (C.D.S.) was initiated in 1960 and included works on sections of its tributary, the Bunree River. This tributary discharges to the tidal reaches of the Moy and was thought to provide a significant portion (approximately 25%) of the spawning potential of the Moy catchment (Toner et al 1965). This channel was chosen for an ecological study of the impact of arterial drainage. One branch of the system was left undrained and a control site was chosen on it for comparison with a drained site on another branch. Both sites were examined pre- and post-drainage and the results reported (Toner et al, 1965).

In 1990, thirty years post-drainage, the Office of Public Works invited the Central Fisheries Board to re-survey the sites on the Bunree originally examined by Toner et al. Details of the site ecologies were compiled and are presented. These findings are compared with those of Toner et al (1965).

Study Sites

The Bunree catchment encompasses a series of small channels which rise in the Ox Mountains. These channels meet as they flow in a westerly direction before discharging to the Moy 1km. downstream of Ballina at Bunree (Fig. 1). The upper reaches of the catchment lie mainly on hard-rock strata of schist with some granite intrusions. However, the majority of the catchment is underlain by lower carboniferous limestone (Whittow 1975).

The different geological strata are reflected in the overlying soils. Low level blanket peat overlies the hard-rock strata in the upper reaches while the limestone is overlain by a complex soil association composed primarily of degraded grey-brown podzolics. The underlying drift material here is formed mainly from calcareous loam, material of Carboniferous limestone composition (Gardiner and Radford 1980). The coarse material in the drift consists of stones and boulders. The horizons of the grey-brown podzolic soil descend to a depth of approximately 1m.

The catchment has average rainfall of between 1,000 and 1,200 mm annually (Rohan 1986). The land use potential is limited and confined principally to grass growth and rearing of dry cattle, on the podzolic soil overlying the limestone.

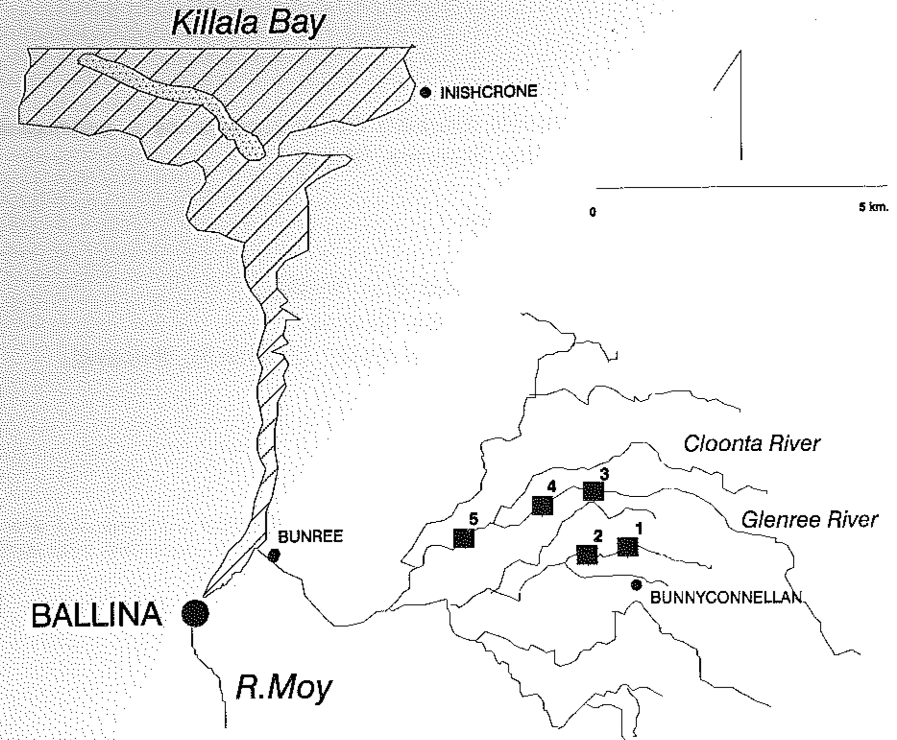

Figure 1. R. Bunree catchment showing location of sites 1–5 examined in 1990.

The Bunree River, pre-drainage, was a sinuous channel with a relatively broad base width. In low flow conditions the discharge was generally confined to a narrow portion of full channel base width. In many areas where a relatively level bed was present in cross-sectional area a braided channel existed in low flow conditions (J. Foley, pers comm). The physical changes brought about by drainage works are illustrated in Fig. 2 where typical drainage design for the Bunree is superimposed on the original cross section. The objectives of this scheme were two-fold; to confine summer flows to the new narrow channel base width and accelerate run-off in winter flood conditions. The end result in physical and hydraulic terms was to create a narrower, faster flowing, more abrasive channel. The natural sinuousity of the channel was not disturbed to any significant extent.

Five sites were electrofished in the middle reaches of the River Bunree in June 1990 (Fig. 1). Stations 1 and 4 in the 1990 series were the control and experimental sites respectively examined by Toner et al (1965) (E. Twomey, pers. comm). Sites 2, 3 and 5 were also examined in 1990 to confirm the representativeness of the control and experimental sites within their own sub-catchments.

The control at site 1 had a low unfenced bank on its left-hand side with no tree or bush cover. The right bank was higher with considerable bramble cover along with some young trees. This bramble cover trailed into the water providing cover for fish. The section fished had a good gradient. The channel consisted primarily of shallow glide areas with limited riffles at the head of the section. The substrate in the glide area was firm and consisted of fine gravel material with an absence of moss cover. The upper part of the section had a coarser substrate with large gravels and stones. The stones were heavily covered in moss.

Prior to drainage in 1960 the experimental area at site 4 had a relatively stable bed with some large moss-covered stones with some mud and gravels. The drainage operation removed all bank and instream cover, lowered the channel bed by a maximum of 1.25 m and created a channel of trapezoidal cross-section which, post-drainage, was circa 50% narrower (Plate 1) (Toner et al 1965). The drainage appears to have cut through the thin podzolic soil cover, exposing the underlying glacial drift material. In 1990 the channel banks were 1–1.5 m high. Both banks were fenced, a standard Board of Works procedure post-drainage, and both carried good tree and shrub cover in 1990. The left hand bank cover consisted mainly of low growing bushes of gorse and brambles. A variety of trees, including willow, silver birch, sycamore and ash grew to a maximum of 6.6 m on the right bank. This is in contrast to the pre-drainage situation when the site was unfenced and devoid of shrubbery (Plate 1). Instream hydraulic conditions were varied with an extensive glide area in the lower part of the section and a well developed riffle zone in its upper reaches. A sizeable pool area was formed at the right bank downstream of the riffles. The channel had a good gradient and was wider than the control site. Substrate in the glide area consisted of gravels and stones. The riffle area consisted of larger stones. Moss cover was widespread in the section, being most dense in the riffle area.

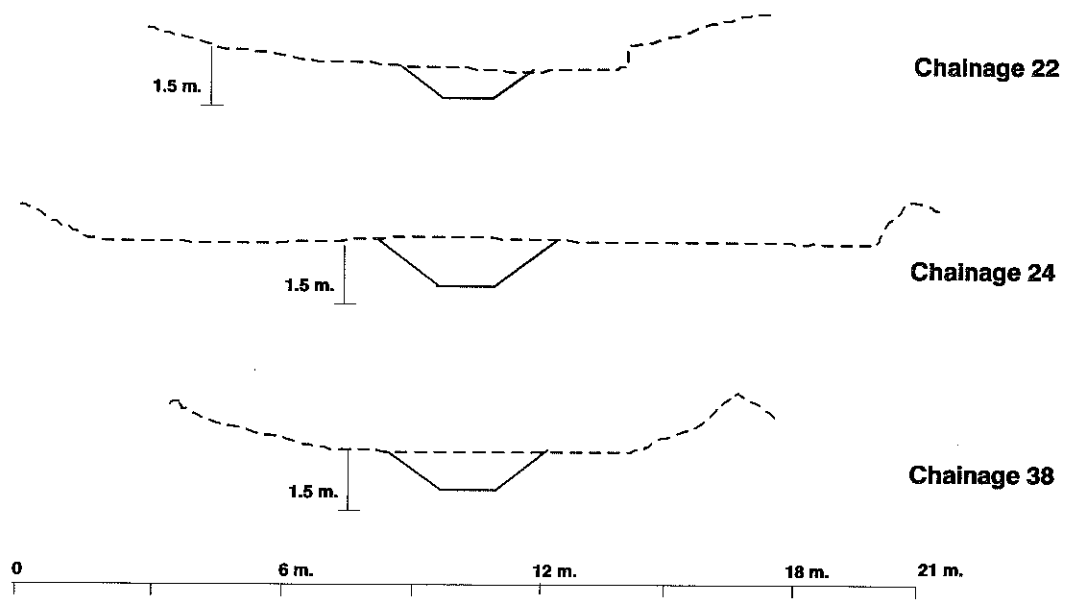

Figure 2. R. Bunree catchment: representative channel cross-sections pre-drainage (broken line) and post-drainage (solid line). Chainage is a 100 yard (91 m) length of channel. Cross-sections are from O.P.W. design for channel 1/5/6 containing sites 3–5.

Of the remaining three sections examined in 1990, site 2 was an undrained riffle-glide-pool area downstream of site 1, site 3 was a drained glide-pool area, similar to and upstream of the experimental area (site 4). Site 5 was a shallow drained riffle-glide area.

METHODS

Two sites, one drained and one undrained, were selected for detailed examination. These were the same sites as those examined previously by Toner et al (1965). The sites were visited twice during the study period, in mid June and early November 1990. On each occasion the fish stock was estimated by electro-fishing. Three additional sites were electrofished in June. Detailed collection of data relating to hydraulic regime and sampling of flora and invertebrates was carried out during the second visit. Water samples were collected at the two major sites in November for chemical analysis.

Readings of depth (D) and water velocity (at 0.6 D after Leopold, Wolman & Miller 1964) were taken along specific transects in each section using an OTT Z-200 flow meter and a graduated metal pole with foot plate to rest on the substrate. The readings were taken with the operator standing downstream of and to one side of the flow meter (after Modde and Platts 1990). The transects were spaced at 5 m intervals (Binns 1982). Within each of the two sections the area occupied by riffle, pool and glide was estimated.

A mapping of the macrophyte flora was not compiled due to the extensive but discontinuous moss cover (see Caffrey 1990). Moss material was collected for biomass determination in specific quadrats (0.125 m^2) within the riffle, pool and glide areas. Samples were air dried to constant weight. They were then weighed and results were expressed in terms of g/m^2 dry wt.

A Surber sampler (quadrat area 0.0625 m^2) was used to collect invertebrate material. Samples were taken in the riffle, glide and pool areas at each site and stored in alcohol for subsequent examination. A total of five samples were taken at each of two sites.

Fish stock estimates were carried out using the depletion method of Zippin (1958). In all cases, three fishings were carried out. Electrofishing equipment was used to collect the fish and each section was isolated during fishing using weighted stop-nets. All fish species encountered were taken for examination. All fish were counted and, in the case of salmon and trout, measured. Scales were taken from a representative range of salmon and trout for ageing. The fishing in June was carried out at five sites, including the two sites of Toner et al (1965), to give an indication of salmonid fry production in this catchment. The November fishing was confined to those sites examined previously by Toner et al (1965).

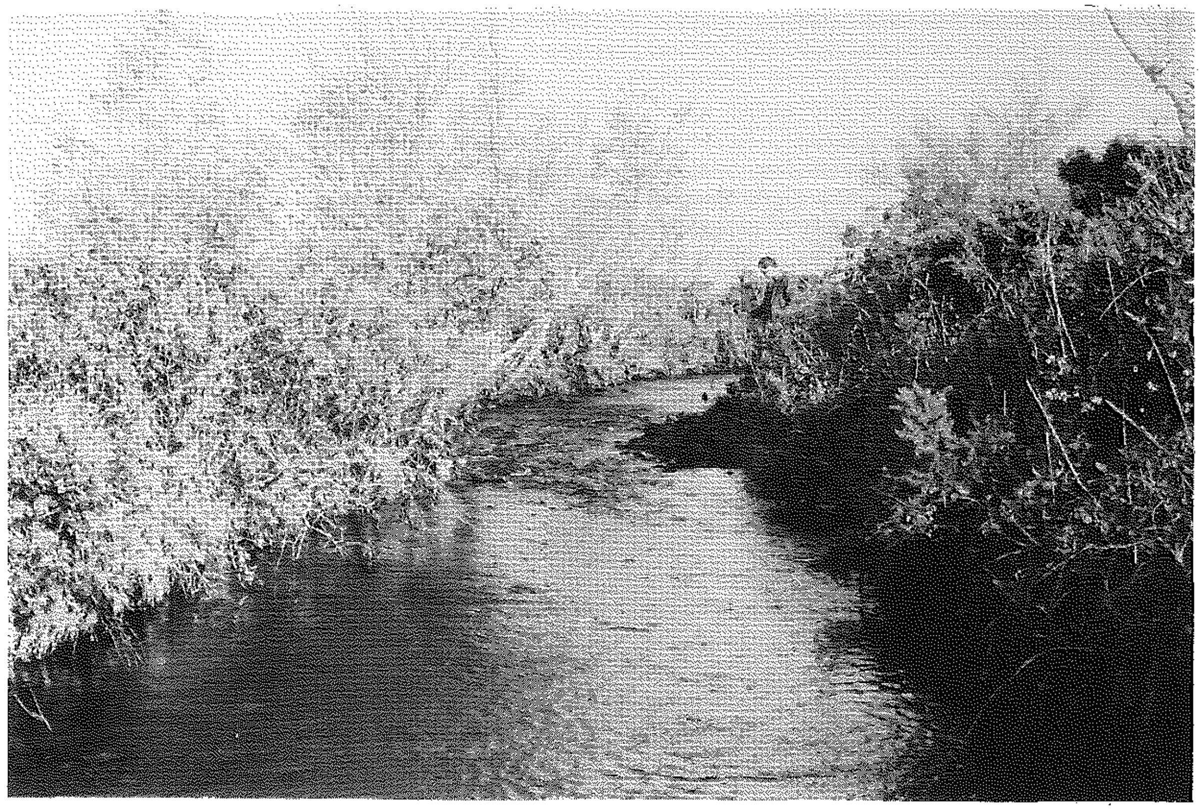

Plate 1. Section 4 on the Bunree River: during drainage works in March 1961 (upper, photo C. Moriarty) and in October 1990 (lower, photo M. O'Grady).

RESULTS

Water Chemistry

The data collected in November 1990 indicate that the waters in both channels have an alkaline pH and high values of conductivity, alkalinity and hardness. These reflect the influence of the underlying limestone strata. The pH and suspended solids data are similar to those of Toner et al (1965) collected prior to drainage.

Physical Measurements

The results of physical measurements are summarised in Table 1. The drained site had higher average values for width, depth and velocity than the undrained site (Fig. 3). Cross-sectional area and average velocity were calculated at each 5 m transect and from these an estimate of the average and range of volume discharge, at time of sampling, was calculated for each site. The results (Table 1) show a four fold difference in average discharge between the two sites.

The thalweg, a reflection of instream sinuousity, was measured as channel length along the line linking points of maximum depth in an up or downstream direction (see Binns 1982). Thalweg length was similar in the two stations. While the length of section may not have been sufficient to give an accurate indication of thalweg, the results do show that the drained channel did not undergo any longterm loss of thalweg due to the drainage process.

Despite higher values for channel dimensions, velocity and volume discharge, the drained channel gradient was only half that of the undrained site. In both cases gradient values were high, characterising both sites as erosive channels. Toner et al (1965) recorded large moss-covered stones and areas of mud and gravel prior to drainage. The O.P.W. channel cross-sections indicate that the drainage operation reduced channel width. This would have the effect of increasing velocity and scouring the channel. The wide shallow areas pre-drainage may be seen as a strategy on the channel's part to reduce the effects of the high gradient by creating meanders and wide shallow areas (Petts and Foster 1985). It is considered that the potential influence of the control site's higher gradient on the channel is offset by the high sill at the bridge immediately upstream which regulates the discharge downstream.

Flora

The aquatic moss *Rhincostegium riparoides* (Hedw.) C. Jens. was the dominant component of the flora at both sites in 1990. Biomass values (g/m^2 dry wt.) were notably higher at the drained than at the undrained site (Table 2). In the drained site, biomass values and degree of cover were greatest in the riffle area at the top of the section. This may be related to the large size of stone in the riffles, combined with a low depth regime and high velocities (Table 2). Poor cover was recorded in the pool area and biomass values here were the lowest in the drained section. Cover was far more localised in the undrained section. This may be due principally to the paucity of large stones suitable for colonisation by mosses (Caffrey 1990). The lower water velocities at the undrained site, as compared to the drained site, may also have had an adverse effect on moss colonisation (Table 2).

Apart from mosses, small clumps of *Mentha* and *Rorippa* were found instream locally in both sites close to the waters edge. A very similar floral regime was recorded in qualitative terms at these sites pre-drainage, the only difference being the presence of small clumps of *Potamogeton* sp. at the drained site (No. 4) prior to works (Toner et al 1965). The latter genus shows an ecological preference for silted muddy conditions (Caffrey 1990). Its absence in 1990 may be due to the more erosive nature of the channel since drainage.

Macro-invertebrates

Toner et al (1965) used a wooden quadrat of known size placed on the stream bed to collect quantitative faunal samples. In 1990 the authors used a similar technique (Surber sampler) for comparable purposes. We would stress that this type of sampling procedure is unlikely to produce a comprehensive species list for the habitats in question. However, this approach should illustrate relative changes in the dominant species present over the time period in question. Similar numbers of taxa were collected in individual samples at both the drained and undrained sites in 1990 (Table 3). Estimates of biomass and numbers of organisms/m^2 are also presented in Table 3.

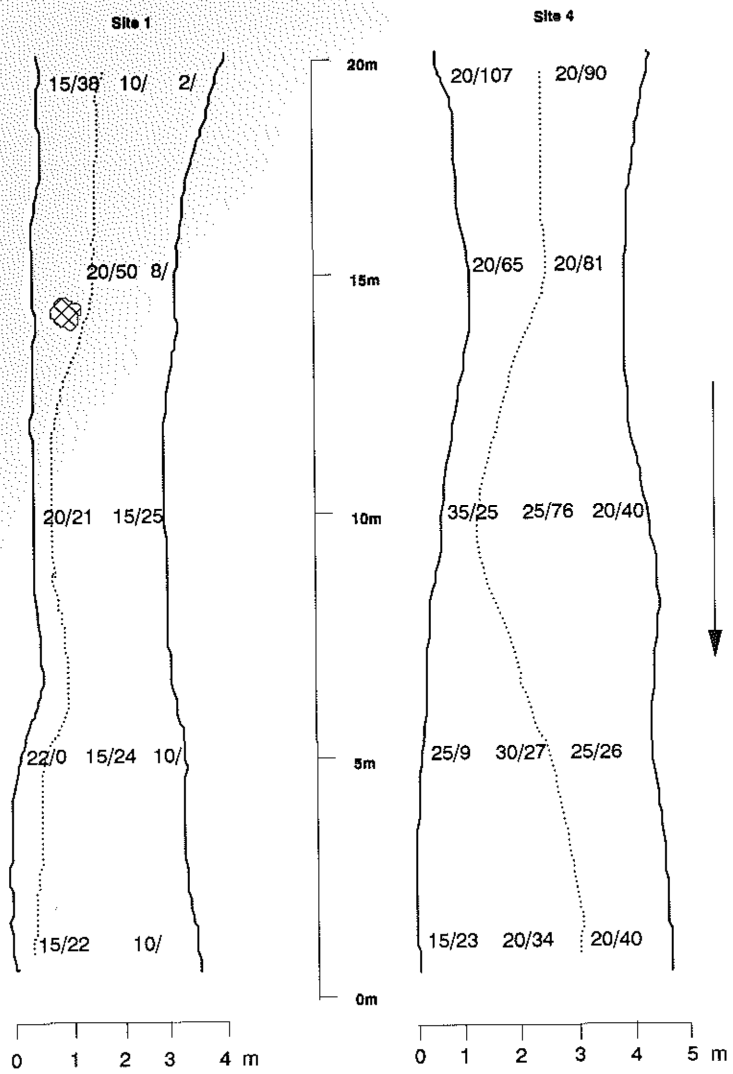

Figure 3. Depth (cm)/velocity (cm/sec) values at selected transects at Sites 1 and 4, R. Bunree November 1990. Dotted line denotes shape of thalweg, arrow indicates direction of flow ("x"/-indicates insufficient depth to operate flow meter).

The most significant differences evident between the drained and undrained sites in faunistic terms are in relation to Plecoptera and Oligochaeta. Four of the five plecopterans recorded were only noted in samples from the drained site. This may be due to the fact that there was a significantly greater number of large stones on the bed in the drained site. The oligochaetes recorded were all large (10–30 mm) lumbricids. When collecting the samples the authors noted that these appeared to be living exclusively in the moss colonies. The relative abundance of mosses in the drained area compared to the undrained site (Table 2) may account for their abundance in the former area and complete absence in the samples from the latter area.

Fish Stocks

(a) June 1990: Five sites were quantitatively fished. High total salmonid stock densities (> 1 fish/m^2) were recorded at all sites (Table 4). A notable feature of the results was the absence of salmon (fry and parr)

from sites 1 and 2 in the undrained channel. Toner et al (1965) recorded significant stocks of both trout and salmon in this channel at site 1. The complete absence of salmon here and further downstream at site 2 in 1990 cannot easily be explained. Local Fishery Board staff are unaware of any physical barriers which might now be preventing the entry of salmon to this tributary. The presence of significant juvenile trout stocks and a diverse macro-invertebrate fauna here in 1990 suggest that the absence of salmon is not due to any seasonal pollution problems.

All sites fished functioned as salmonid spawning and nursery areas with fry (0+) numbers being dominant. Where trout and salmon fry were present at the same site the salmon stock exceeded that of the trout by a factor varying from two to seven fold. Where trout only were present, the fry stock density estimates were lower than those recorded for the combined salmon and trout fry numbers at sites where both species were present (Table 4). The stock density values recorded for salmonids at all sites are excellent relative to other Irish catchments (Central Fisheries Board unpublished data).

(b) November 1990: Sites 1 (undrained) and 4 (drained), only, were quantitatively fished in low-water conditions in November. Salmon were again absent from site 1 which carried a relatively good brown trout stock (0.44/m^2). The trout stock was mainly composed of 0+ fish. Site 4 carried significantly larger salmonid stock (1.65/m^2), dominated by 0+ salmon with a smaller quantity of trout fry (Table 4).

(c) June vs. November 1990: A comparison of June and November results indicate a significant fall in trout fry numbers at site 1 over this period (Table 4). In contrast, no such decline was evident in either trout or salmon fry numbers at the drained site (No. 4). This difference may be due primarily to the fact that a greater water depth was maintained throughout the summer period at the drained site (No. 4) compared to the undrained location (No. 1) (Fig. 3). This would allow a greater percentage of the bed area at site 4 to be permanently occupied by small fish. The narrowing of the channel base width by drainage works is responsible for this phenomenon. In contrast, it is noteworthy that Toner et al (1965) recorded a significant reduction in salmonid stock density values over a summer period at both sites (1 and 4) prior to drainage works (Table 6).

There was a significant reduction in the older (1+ and 2+) trout numbers at both sites over this period. This may be due in part to the seaward migration of some individuals as the Bunree is a major sea-trout spawning and nursery area. A major decline in salmon parr (1+) numbers at site 4 over this period may also be in part a consequence of emigration. There is a significant autumnal migration of salmon smolts from the Moy system (M. Tolan, pers. comm).

Scales collected at the five sites in June 1990 were pooled for examination. The oldest trout present were in their third year i.e. 2+ fish. The oldest salmon present were in their second year i.e. 1+ fish. The length-at-age data are summarized in Table 5.

Toner et al (1965) measured salmonid stock densities at intervals prior to and following drainage works in November 1960 at sites 1 and 4 of the present study. A selection of their estimates and comparable data from 1990 are presented (Table 6). Comment on apparent change is limited because Toner et al (1965) only present total salmonid numbers recorded making no distinction between the relative strengths of the various age classes present or the balance of trout and salmon numbers. In addition no confidence intervals are presented for the 1960 to 1962 estimates. The data suggest a recovery in the stock density level of salmonids at the drained site by May 1962, 18 months after drainage. The June 1990 figures suggest continuation of this recovery. Available data for total salmonid numbers in the undrained site suggest a relatively stable situation although it must be stressed that the 1990 stock, unlike those of the 1960's, no longer contains a juvenile salmon component.

In addition to the salmonid stocks referred to above, eels were taken in small numbers at all five sites fished. Small numbers of sticklebacks were observed at both sites on the drained branch. The upper site here (site 3), a pool/glide area, also held a small number of minnow. Stocks of the non-salmonid fishes were not quantified.

Toner et al (1965) also noted the presence of sticklebacks and some eels at the drained site (No. 4) pre-works and observed that the former species disappeared up to 1962 after drainage works. The 1990 survey indicates that both species have re-established populations at this location.

DISCUSSION

The study of Toner et al (1965) at the drained site on the R. Bunree indicates clearly that the drainage works resulted in major temporary change in the ecology of the channel. It was initially clearly altered in physical and hydraulic terms and was, immediately post-works, relatively barren in floral, faunal and, to some extent, fish stock terms.

The review of the drained Bunree site in 1990 indicates that, since drainage, a complex and stable ecology suited to salmonids has evolved. While the rate of recovery cannot be plotted there are indications from the study by Toner et al (1965) that there had been a significant revovery in salmonid stocks only two years after works. The 1990 data clearly indicate that the channel now has a similar capacity to support juvenile salmonids as it did pre-drainage. The stock data compiled by the authors for two additional sites in the drained channel also confirm that the recovery evident in the Toner et al (1965) experimental section is not exceptional.

Pre-drainage, Toner et al (1965) described the Bunree as a "typical moorland river with alternating sharps and flats". Visual observation by the authors in 1990 confirm that the channel now conforms to that description — i.e. a riffle/glide/pool sequence in a meandering channel.

The recovery and current post-drainage state of the R. Bunree, in terms of salmonid productivity, is considered to have been facilitated by the relatively high channel gradient and erosion of glacial drift material from the new channel bed and banks. This drift material was exposed in the drainage operation. This sequence of recovery, and its rapidity, has been reported from other drained Irish river systems. The ecology of the R. Trimblestown, a tributary of the R. Boyne, has been documented both pre and post-drainage by McCarthy (1977, 1983). The study area of McCarthy has been the subject of recent investigation (O'Grady 1991) which indicated a general ecological recovery. Of importance in that recovery were the good channel gradient, well gravelled banks and development of a tree/shrub line, protected by fencing erected post drainage by the Office of Public Works. Research on the R. Camowen (Kennedy 1980) in Northern Ireland also showed a relatively rapid recovery of the channel's spawning potential after drainage. The upper reaches of the channel were not drained and downstream movement of gravel (from the undrained area) was identified as being a major factor in the recovery of the drained channel. Recovery of fry densities appeared to take place in a downstream sequence, following the progressive downstream consolidation of the substrate.

While the capacity of drained sections of the Bunree catchment to function as premier salmonid spawning and nursery zones has clearly been restored there is some evidence to suggest that, in a broader sense, the channel is significantly different. The narrowing of channel base width has created a number of changes. It is now a deeper, faster-flowing more erosive channel devoid of significant silt deposits. Toner et al (1965) make reference to channel bed areas pre-drainage being "covered with peat to a depth of three to four feet" and also mention that "dredging removed the peat tops and exposed the glaciated gravels. The authors did not observe significant siltation at any point in the drained Bunree channels in 1990.

Changes in nomenclature and differences in quadrat size and sampling method between the current study and that of Toner et al (1965) prevent direct comparision of the quantitative faunal data in both studies. The authors have attempted to compare the available data by calculating the ratio, between the drained Site 1 and undrained site 4, of the number of individual organisms (grouped under taxonomic headings) recorded at specific sampling dates (Table 7). This table includes ratio values from the Toner et al (1965) data base pre-drainage in 1960, immediately post-drainage in 1960 and in 1961, 1962 and 1990. The 1961 and 1962 data selected from Toner et al (1965) were most likely to be comparable to the November 1990 data. Results illustrate the dramatic instability in the faunal community, immediately after drainage, which persisted up to September 1962. By 1990 a more stable regime had obviously become established although differences with the pre-drainage situation are evident. Of particular note are the greater abundance of Plecoptera and Oligochaeta in the drainage site both before (1960) and since drainage (1990). The Trichoptera appear to have been adversely affected by the drainage process, a point noted by Toner et al (1965), and remained poorly represented at the drainage site up to two years after drainage. The 1990 survey indicates that the ecology of the drained site has now stabilised to a point where Trichoptera were as well represented both in numbers and species diversity, at the drained site as at the undrained site.

The differences observed in the salmonid fry carrying capacity of the drained and undrained sections, with the former supporting greater stocks over the summer period, is also likely to be a function of the physical changes caused by drainage. While the drained channel is now significantly narrower, loss of channel area in terms of fish carrying capacity appears to have been compensated for by the higher water levels in the narrower drained channel throughout the summer which ensure that most areas can support 0+ fish on a continuous basis. This phenomenon would be particularly advantageous in riffle and glide areas which, because of a relatively broad channel base, became braided channels in low flow regimes pre-drainage. In the author's experience braided zones cannot support significant 0+ salmonid numbers in low flow circumstances. Data available are inadequate to quantify the change, if any, in the overall production of salmonids in the drained catchment areas of the Bunree pre- and post-drainage. The fall in standing crop figures over a summer period at both sites as measured by Toner et al (1965) and by the authors at site 1 (undrained) in 1990 contrasts with the maintenance of higher stocks over the same period at the drained site in 1990. These results suggest that there may be no significant change in overall production of salmonids up to 2 years of age. It is possible that the capacity of the system to support larger adult trout (3+ and older) may have been reduced as a consequence of the reduced pool area post-drainage.

Fencing prevents bankside grazing by and channel access to cattle. This allows for the development of riparian vegetation which can stabilise channel banks and provide overhanging bankside cover for fish (Keller and Burnham 1982). Plate 1 indicates an absence of shrubbery on the banks at the drained site (No. 4) prior to works on the R. Bunree. The fencing of this channel post-drainage has been instrumental in allowing a tree line and shrubbery to become established post-drainage. This factor was identified as playing a role in the recovery of the Trimblestown River in the Boyne catchment (O'Grady 1991). A limited degree of bank cover, as presently exists at site 4, is widely recognised as being of major importance in enhancing the salmonid carrying capacity of streams.

ACKNOWLEDGEMENTS

The authors are most grateful to the Office of Public Works (Valuers Section) who funded this study. We would also like to thank John Howard, John Foley (since retired) and John Curtin of the Engineering Section, Office of Public Works for background information on the Moy drainage scheme. Special thanks are due to the Office of Public Works, Ballina Office, who measured the channel gradients at the behest of the authors. Miss Eileen Twomey, one of the co-authors of the 1965 Bunree study, kindly identified precise locations of the control and experimental sites and provided helpful advice on the manuscript.

We are most grateful to Dr. Declan Murray, Zoology Department, University College, Dublin and Dr. James O'Connor, Natural History Museum, who confirmed our macro-invertebrate faunal identifications. Thanks are due to Inspector Michael Tolan and his staff of the North Western Regional Fisheries Board who assisted with field operations. We wish to thank Dr. Patrick Fitzmaurice, Research Section, Central Fisheries Board for his constructive criticism of the text.

REFERENCES

Binns, N.A. (1982) *Habitat quality index procedures manual.* Wyoming Game and Fish Dept. 1982.

Caffrey, J. (1990) *The classification, ecology and dynamics of aquatic plant communities in some Irish rivers.* Ph.D. thesis, National University of Ireland. 254 pp.

Gardiner, M.J. and Radford, T. (1980) *Soil Associations of Ireland and their Land Use Potential.* An Foras Taluntais, Dublin 142 pp.

Keller, C.R. and Burnham, K.P. (1982) Riparian fencing, grazing and trout habitat preference on Summit Creek, Idaho. *N. Am. J. Fish. Mgmt.* (2): 53–59.

Kennedy, G. (1980) Drainage related changes in salmonid and invertebrate populations in the River Camowen. *Proceedings of the Institute of Fisheries Management Conference,* Magee University College, 63–68.

Leopold, L.B., Wolman, H.G. and Miller, G.P. (1964) *Fluvial processes in geomorphology.* Freeman & Co., San Francisco.

Modde, T. and Platts, B. (1990) Influence of operator position on the precision of measurements taken with hand-held velocity meters in rivers. *N. Am. J. Fish. Mgmt.* 10, 247–248.

McCarthy, D.T. (1977) The effects of drainage on the Trimblestown River 1. Benthic invertebrates and flora. *Ir. Fish. Invest.* A 16, 1–16.

McCarthy, D.T. (1983) The impact of arterial drainage on fish stocks in the Trimblestown River, in "Advances in Fish Biology in Ireland " ed. C. Moriarty. *Ir. Fish. Invest.* A, 23, 16–19.

O'Grady, M.F. (1990) Rehabilitation of the Boyne. *The Engineers Journal,* March, 1990, 22–24.

O'Grady, M.F. (1991) Ecological changes over 21 years caused by drainage of a salmonid stream, the Trimblestown. *Ir. Fish. Invest.* A 33.

Petts, G. and Foster, I. (1985) *Rivers and Landscape.* Edward Arnold, London. 274 pp.

Rohan, P.K. (1986) *The Climate of Ireland.* 2nd edition. The Stationery Office, Dublin 146 pp.

Toner, E.D., O'Riordan, A. and Twomey, E. (1965) The effects of arterial drainage works on the salmon stocks of a tributary of the Moy. *Ir. Fish. Invest.* A 1, 36–55.

Whittow, J.B. (1975) *Geology and Scenery in Ireland.* Penguin Books, England, 301 pp.

Zippin, C. (1958) The removal method of population estimation. *Journal of Wildlife Management.* 22(1) 82–90.

TABLE 1. R. Bunree: Physical measurements at the drained (Site 4) and undrained (Site 1) locations, November 1990

	Drained Site (Site 4)	**Undrained Site (Site 1)**
Surface area m^2	82	61.6
Length m	20	20
Thalweg m	21	20.2
Average width (inc. range) m	4.1 (3–4.8)	3.08 (2.5–3.5)
Average depth (inc. range) m	.227 (.15–.35)	.135 (.02–.22)
Average velocity (inc. range) m/sec	.49 $\pm$ .3 (.09–1.07)	.25 $\pm$ .15 (0–.5)
Average volume discharge (inc. range) m^3/sec	0.395 $\pm$ 0.24 (.191–.796)	0.079 $\pm$ .035 (.042–.133)
Channel gradient cm/100m	83	166

TABLE 2. R. Bunree: Moss biomass ranges (g/m^2 dry wt.) and hydraulic features from habitats within the drained (site 4) and undrained (site 1) sites, November, 1990. Numbers of samples in parentheses.

	Biomass range (g/m^2 dry wt.)		**Depth range (cm)**		**Velocity (cm/sec)**	
Habitat Type	**Drained**	**Undrained**	**Drained**	**Undrained**	**Drained**	**Undrained**
Riffle	419.2–518.4 (4)	37.2–119.2 (4)	20 (4)	2–20 (5)	65–107 (4)	38–50 (2)
Glide	224–287.2 (2)	0	15–30 (6)	10–22 (5)	9–40 (6)	0–24 (5)
Pool	33.6–108 (4)	0	35 (1)	—	25 (1)	—

TABLE 3. Number of invertebrates/quadrat (0.0625 m^2) at Site 4 (drained) and Site 1 (undrained), November, 1990. Five samples taken per site.

		Drained					Undrained				
Crustacea	*Gammarus duebeni*	8	8	11	31		12	4	17	14	21
Coleoptera	Helmidae (larvae)	81	109	196	568	180	450	229	183	83	305
	Helmidae (adults)	7	42	37	57	180	35		5	5	21
	Limnius volkmari			5	5			2	1	2	3
	Gyrinidae		1								
	Helodidae							1	4		
Ephemeroptera	*Baetis rhodani*	1	1		1					14	12
	Baetis sp.						20	8	15		
	Caenis rivulorum		3	3	2	4					
	Ecdyonurus sp.		1		1		1				2
Plecoptera	*Dinocras cephalotes*	3	4	8	3	1					
	Perla bipunctata	4									
	Protonemura myeri	3	10	5	1						
	Siphonoperla torrentium					2					
	Protonemura sp.							1	1		10
Trichoptera	*Hydropsyche pellucida*										2
	Hydropsyche siltalai	2	1	1	2	1			3		
	Rhyacophila dorsalis	2	1	1	3	1	5		2		2
	Odontocerum albicorne	7		8	10	2	4	4			4
	Glossosoma sp.				1						
	Agepetus sp.				1		2				
	Ecnomidae						3				
	Ecnomus tenellus		2								
	Polycentropus flavomaculatus						4	3			2
Diptera	*Dicranota* sp.				1		3	3	1		5
	Simulium (larvae)						6	5	5	2	4
	Simulium (pupae)							1	1	1	1
	Green chronomids						27	12	16	11	18
	Limnophora sp.										1
Arachnida	*Argyroneta aquatica*							1			
Mollusca	*Ancylastrum fluviatile*						1				
	Potamopyrgus jenkinsii						1				2
	Planorbis sp.						1				
Oligochaeta	Lumbricidae	5		5	3	1					
Hirudinea	*Piscicola geometra*						1				
	No. genera/sample	11	12	11	17	9	17	13	14	8	17
	No. organisms/m^2	2000	2928	4416	10960	5952	9184	4384	3840	2192	6768
	Biomass g/m^2	1.097	1.987	3.185	3.609	2.046	3.963	1.166	2.467	0.956	2.766

TABLE 4. Estimated salmonid stock density values (no. fish/m^2 ±95% confidence limits) at selected sites in the R. Bunree catchment in 1990 (for site locations see Figure 1).

	Undrained Channel			**Drained Channel**			
	Site 1 June	**Site 1 November**	**Site 2 June**	**Site 3 June**	**Site 4 June**	**Site 4 November**	**Site 5 June**
Brown Trout							
Fry	1.34±.14	0.42±.02	3.09±.18	0.30±.18	0.42±.22	0.35±.04	0.43±.19
Adult	0.16±.003	0.03±.001	0.33±.003	0.15±.02	0.30±.17	0.10±.01	0.03
Total	1.48±.11	0.44±.02	3.39±.16	0.43±.11	0.73±.29	0.45±.004	0.43±.13
Salmon							
Fry	0	0	0	0.74±.09	1.23±.43	1.23±.38	2.90±.64
Parr	0	0	0	0.22±.1	0.33±.07	0.09±.006	0.30±.02
Total	0	0	0	0.96±.12	1.52±.35	1.25±.28	2.99±.44
Total Salmonids	1.48±.11	0.44±.02	3.39±.16	1.39±.16	2.25±.45	1.65±.22	3.45±.47

TABLE 5: Length (cm) at age for brown trout and salmon in the R. Bunree catchment June, 1990

	Brown Trout		Salmon
	L1	L2	L1
Mean	7.5	13.3	6.3
Range	6–10	13–13.5	5–8
No.	21	3	11

TABLE 6. Salmonid stock density estimates (no./m^2) for sites 1 and 4 in the Bunree at intervals from 1960 to 1990. Data for 1960–1962 from Toner et al (1965).

	1 (Undrained Control)	**4 (Drained Nov. 1960)**
June 1960 (Pre-drainage)	1.0	1.3
September 1960 (Pre-drainage)	0.33	0.61
October 1961	0.64	0.475
May 1962	1.0	1.6
June 1990	1.48±0.11	2.25±0.45
November 1990	0.44±0.02	1.65±0.2

TABLE 7. Ratio of the number of individual organisms (grouped under appropriate taxonomic headings) between Site 4 (drained) and Site 1 (undrained) for specific dates (1960–62 data from Toner et al 1965).

	1960 September	**1960 November**	**1961 October**	**1962 September**	**1990 November**
Crustacea *(Gammarus)*	2 : 1	2 : 1	1 : 31	1 : 4	1 : 1
Plecoptera	—	3 : 1	—	—	4 : 1
Ephemeroptera	2 : 1	1 : 1	1 : 1	2 : 1	1 : 4
Trichoptera	1 : 2	1 : 11	1 : 12	1 : 13	1 : 1
Diptera (Nematocera)	3 : 1	1 : -	1 : 1	10 : 1	1 : 12
Coleoptera	3 : -	1 : 2	- : 20	1 : -	1 : 1
Mollusca	1 : 21	—	- : 19	—	- : 5
Oligochaeta	5 : 1	—	—	—	14 : -

IRISH FISHERIES INVESTIGATIONS SERIES A (Freshwater)

1. (1965) I. Review of the Irish Salmon Industry.
A. E. J. Went.
II. Salmon of the River Shannon (1957 to 1962).
Eileen Twomey.
III. The effects of Arterial Drainage works on the salmon stocks of a tributary of the River Moy.
E. D. Toner, Ann O'Riordan, Eileen Twomey.
IV. Recaptures of Irish tagged salmon off Greenland.
A. E. J. Went.

2. (1967) The movement of salmon *Salmo salar* through an estuary and a fish-pass.
P. A. Jackson and D. I. D. Howie.

3. (1968) "Specimen" brown trout and sea trout from Irish waters.
A. E. J. Went.

4. (1968) The early life of brown trout *Salmo trutta* L.
M. Kennedy and P. Fitzmaurice.

5. (1969) I. Irish Pike investigations. I. Spawning and early life history.
M. Kennedy.
II. Irish kelt tagging experiments 1961/62 to 1966/67.
A. E. J. Went.

6. (1971) I. The distribution of Irish char *Salvelinus alpinus*.
A. E. J. Went.
II. The crayfish *Astacus pallipes* of an Irish lake.
C. Moriarty.
III. Temperature and oxygen determinations in some Irish lakes.
Patrick Fitzmaurice.

7. (1971) Fluctuations in the characteristics in Irish salmon.
A. E. J. Went and Eileen Twomey.

8. (1972) Water quality investigations in the River Blackwater and River Martin, Co. Cork — 1966-1969.
P. F. Toner and Clodagh O'Connell.

9. (1972) The ecology of brown trout and salmon in River Ownenea, County Donegal.
D. T. McCarthy.

10. (1972) Studies of the eel *Anguilla anguilla* in Ireland. I. In the lakes of the Corrib System.
C. Moriarty.

11. (1973) Insect emergence data from four small lakes in the south and southwest of Ireland.
J. J. Bracken and D. A. Murray.

12. (1973) The age and growth of pike from four Irish trout rivers.
J. J. Bracken.

13. (1973) Studies of the eel *Anguilla anguilla* in Ireland.
2. In Lough Conn, Lough Gill and North Cavan Lakes.
C. Moriarty.

14. (1974) Studies of the eel *Anguilla anguilla* in Ireland. 3. In the Shannon catchment.
C. Moriarty.

15. (1975) Studies of the eel *Anguilla anguilla* in Ireland. 4. In the Munster Blackwater River.
C. Moriarty.

16. (1977) The effects of drainage on the Trimblestone River. I. Benthic invertebrates and flora.
D. T. McCarthy.

17. (1978) A comparative limnological study of two Irish lakes (Lough Sillan, Co. Cavan and Lough Dan, Co. Wicklow).
J. P. O'Connor and J. J. Bracken.

18. (1979) Sea trout from the tidal waters of the River Moy.
E. Fahy.

19. (1980) Sea trout from the Currane fishery in 1973 and 1974.
E. Fahy.

20. (1980) An investigation of the chemical and biological effects of pollution in the River Tolka.
M. A. O'Connor and J. J. Bracken.

21. (1981) A list of Rotatoria known to occur in Ireland with notes on their habitats and distribution.
J. P. K. Horkan.

22. (1981) Some direct gillnet selectivity tests for brown trout populations.
M. F. O'Grady.

23. (1984) Advances in fish biology in Ireland.
C. Moriarty (Ed.).

24. (1984) Observations on the Trichoptera of the Killarney lakes, Co. Kerry, Ireland.
J. P. O'Connor and E. J. Wise.

25. (1985) Feeding, growth and parasites of trout *Salmo trutta* L. from Mulroy Bay, an Irish sea lough.
E. Fahy.

26. (1985) Studies on the Minnow *Phoxinus phoxinus* (l.) from an upland Irish reservoir system.
H. A. Dauod, T. Bolger and J. J. Bracken.

27. (1985) Studies on the Three-Spined Stickleback *Gasterosteus aculeatus* L. from an upland Irish reservoir system.
H. A. Daoud, T. Bolger and J. J. Bracken.

28. (1986) Age growth and diet of the Brown trout *Salmo trutta* L. in the Roundwood Reservoir System.
H. A. Daoud, T. Bolger and J. J. Bracken.

29. (1987) The distribution of the crayfish *Austropotamobius pallipes* (Lereboullet) in Ireland.
J. Lucey and M. L. McGarrigle.

30. (1988) A Comparative Study of two tributaries of the River Dodder — Ireland. The Owendoher and the Dundrum Stream.
Mary Kelly-Quinn and J. J. Bracken.

31. (1988) The Currane, Co. Kerry Sea Trout Fishery 1980-1986.
Edward Fahy and Ruary Rudd.

32. (1989) An Analysis of the Gravels used by Spawning Salmonids in Ireland.
R. D. Fluskey.

33. (1991) Ecological changes over 21 years caused by drainage of a salmonid stream, the Trimblestone River.
M. F. O'Grady.

34. (1992) Ecological changes over 30 years caused by drainage of a salmonid stream, the Bunree River.
M. F. O'Grady and J. J. King.

Irish Fisheries Investigations Series B (Marine) deals with scientific research into marine fisheries.