IRISH FISHERIES INVESTIGATIONS

SERIES A (Freshwater)

No. 20 (1980)

An Roinn Iascaigh agus Foraoiseachta
(Department of Fisheries and Forestry)

DUBLIN:
PUBLISHED BY THE STATIONERY OFFICE

TO BE PURCHASED FROM THE
GOVERNMENT PUBLICATIONS SALE OFFICE, G.P.O. ARCADE,
DUBLIN.

Price: 60p.

IRISH FISHERIES INVESTIGATIONS

SERIES A

(FRESHWATER)

No. 20

(1980)

M. A. O'CONNOR AND J. J. BRACKEN

AN INVESTIGATION OF THE CHEMICAL AND BIOLOGICAL EFFECTS OF POLLUTION IN THE RIVER TOLKA.

An investigation of the chemical and biological effects of pollution in the River Tolka

by

M. A. O'CONNOR

and

J. J. BRACKEN

Zoology Department, University College, Dublin.

ABSTRACT

Physico-chemical and biological sampling show that the River Tolka is affected by organic pollution over most of its length. Domestic sewage is the major contaminant. A distinct zonation of the river is noted as certain polluted areas are succeeded by downstream recovery zones. Many of the effluents and tributaries are investigated. Oxygen depletion and excessive ammonia concentrations are the factors most likely to have caused the observed faunal changes.

INTRODUCTION

Three rivers, the Liffey, Dodder and Tolka, drain much of Dublin City and its hinterland. Flanagan and Toner (1972) demonstrated that the River Tolka was the most seriously affected by pollution. Flanagan (1974) later confirmed these findings. Both investigations were carried out as part of the National Survey of Irish Rivers and provide base-line data for the River Tolka prior to 1974.

The River Tolka was renowned as a 'good spring river' until the early sixties. Flowing over Carboniferous Limestone strata, the river water is relatively hard and provides excellent growth potential for fish and macroinvertebrates. In 1967, however, a major trout (*Salmo trutta* L.) kill took place; repeated restocking and the occasional release of experimental fish above Abbotstown did not restore a permanent stock, a factor attributed to successive deoxygenation problems, particularly in summer.

The present survey, which took place between October 1974 and May 1975, attempts to expand existing knowledge of this system. A detailed faunal investigation was carried out in conjunction with a physico-chemical programme in which the major pollution sources were located and their effects monitored.

STUDY AREA

The River Tolka is 30 km long, lies below 103 m O.D. and has a catchment area of 146 km^2 (Figure 1). Width, depth and flow measurements are shown (Table 1). The river runs on Carboniferous Limestone; Upper, Middle and Lower Limestones all being represented. The Limestones are accompanied by glacial drifts of various forms. Ten stations were chosen for detailed study. These were locations sampled by Flanagan and Toner (1972). Subsidiary measurements were made on some of the effluents and tributaries (Table 1).

Macrophytic vegetation was absent from Station 9 to the estuarine portion of the system. In this stretch glass, metal, sewage solids and anaerobic sludge were evident in the substratum. Elsewhere *Rorippa nasturtium aquaticum* L. was widespread while *Fontinalis antipyretica* Hedw. and *Ranunculus fluitans* Lan. were locally abundant. Other macrophytes identified from the system included *Apium nodiflorum* (L.), *Iris pseudacorus* L., *Juncus inflexus* L., *Lythrum salicaria* L., *Potamogeton crispus* L. and *Ranunculus trichophyllus* Chaix.

MATERIALS AND METHODS

The detailed study involved the analysis of water and fixed-area faunal samples from twelve stations. The subsidiary study included effluent and tributary characterisation, together with various qualitative faunal investigations.

Monthly water samples were collected from October 1974 to May 1975 inclusive at the stations chosen for detailed study. Conventional methods for routine analysis were employed (Tables 2, 3). Total and faecal coliform testing was carried out by Membrane Filtration techniques. Quantitative faunal sampling was confined to riffle areas, which comprised at least 90% of the stream bed at each sampling location. It has been demonstrated that the riffle is the most suitable habitat for lotic pollution and faunal diversity studies (Ulfstrand, 1967; Edington, 1968; Chandler, 1970). A total of four samples was taken at each station since, in the habitat studied, this number is reported to give 95% species diversity levels (Zagil, 1972). Two collections were made, the first in October 1974 and the second in March 1975. The four replicates at each station were taken on a transect of the river. The method employed was similar to that of Langford (1965) and involves the collection of animals from a 25 × 50 cm area of river bed using a rectangular frame net, 100 meshes per cm², placed on the stream bed downstream of the designated area. Qualitative collections were taken with dredge and F.B.A. net and were supplemented by imaginal collections. Standard preservation and identification procedures were then carried out.

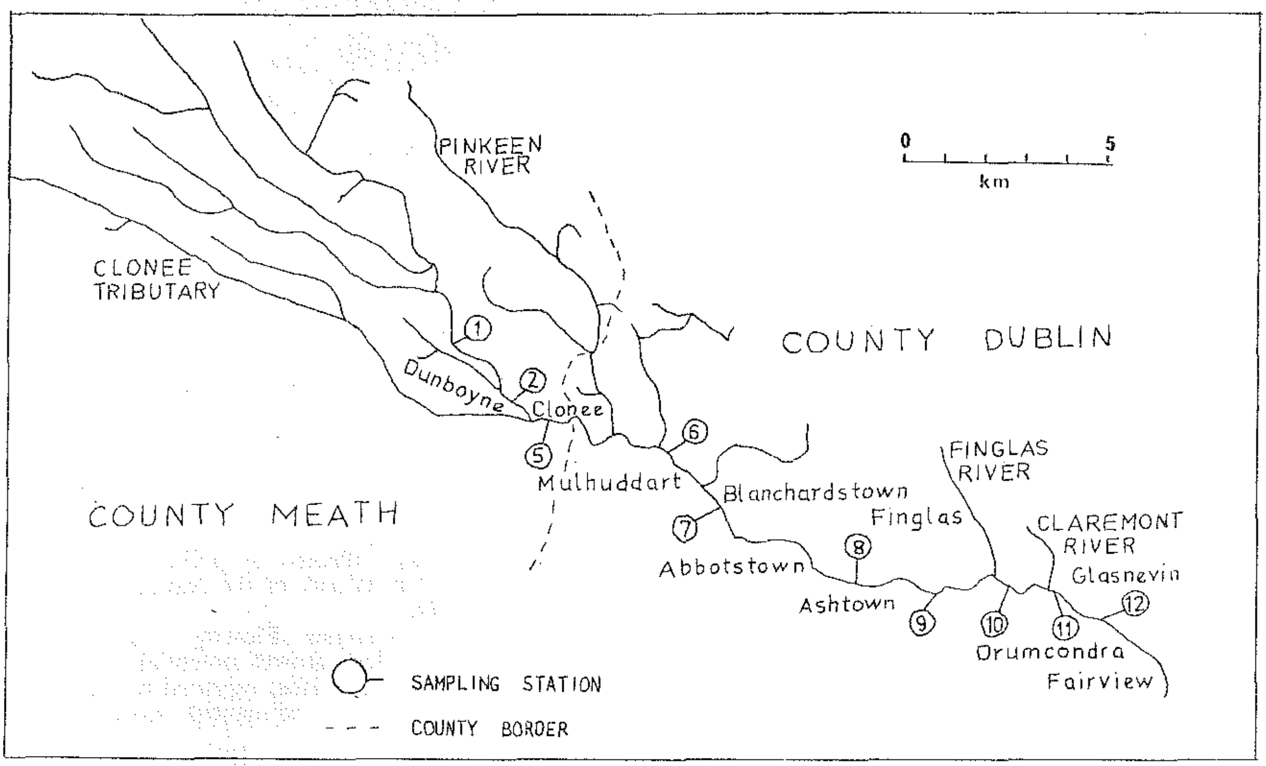

Figure 1. River Tolka: detailed sampling survey.

RESULTS

PHYSICO-CHEMICAL RESULTS (TABLES 2 AND 3)

High pH and conductivity reveal that the river is naturally eutrophic. Nutrient levels increased at Station 5 with a recovery zone extending from here to Station 9. More severe nutrient pollution was recorded at Stations 10 and 11 with partial recovery at Station 12.

Throughout the year the river water was almost colourless, the mean pH at least 7.9 at all stations while mean conductivity was 570 μScm^{-1}. High total and calcium hardness indicate that the river is rich in dissolved ionic substances. The above values are consistent with catchment geology and indicate an alkaline system with good buffering capacity.

High suspended solid values occurred in winter and may be attributed to run-off or erosion at high flow. Levels declined in later months. Chloride concentrations, which varied from 14-38 $mg.1^{-1}$, conform to those of other rich rivers (Hawkes, 1974) (Table 3). Neither the Tolka, its tributaries nor the major effluent sources show evidence of heavy metal contamination. Observed values may be considered insignificant at all locations.

Dissolved oxygen was satisfactory throughout the winter months when water temperatures were low and flow rate was high. In May 1975 warmer conditions were accompanied by serious oxygen depletion. Fry (1957) states that oxygen levels below 7 $mg.1^{-1}$ cause stress to Salmonidae. Such levels were found in May at all stations except Stations 1 and 2. Summer deoxygenation has been indicated as a feature of the Tolka (Flanagan, 1974). The severe deoxygenation recorded by Flanagan was not noted during this survey though mean Biochemical Oxygen Demand at Stations 7, 10, 11 and 12 is unsatisfactory while the maximum demand recorded from Stations 2, 7, 10 and 12 exceeds 10 $mg.1^{-1}$.

Ammonia concentrations are high throughout the River Tolka but especially at Stations 5, 6, 10, 11 and 12. At 10°C the threshold of toxicity to fish (0.025 $mg.1^{-1}$ unionised ammonia) is reached at approximately 0.8 $mg.1^{-1}$ total ammonia at the pH of the River Tolka. Values in excess of this were recorded at six of the ten stations.

Mean nitrite levels rise with increase in ammonia but drop off more slowly indicating that considerable nitrification is in progress in the recovery zones between Stations 7 and 9 and again at Station 12 (Figure 2). Nitrate concentrations are generally low but are highest at Stations 5, 6, 8, 10 and 11. Mean phosphate values at all stations exceed 0.05 $mg.1^{-1}$ $PO_4\equiv$—P, which is the recommended maximum limit (Institute for Industrial Research and Standards, 1970). Agricultural wastes may contribute to the relatively high concentrations at Stations 1 and 2. Mean phosphate increases at Station 5 and this trend continues until Station 8 despite the fact that during the period of study no major effluent entered the system between Stations 5 and 8. This may be explained by the fact that polyphosphates, which are not measured by the molybdenum method, break down gradually in river waters (Soltero, 1969) to give orthophosphates. A recovery zone commences at Station 8 but at Station 10 levels again rise to over four times the acceptable limit.

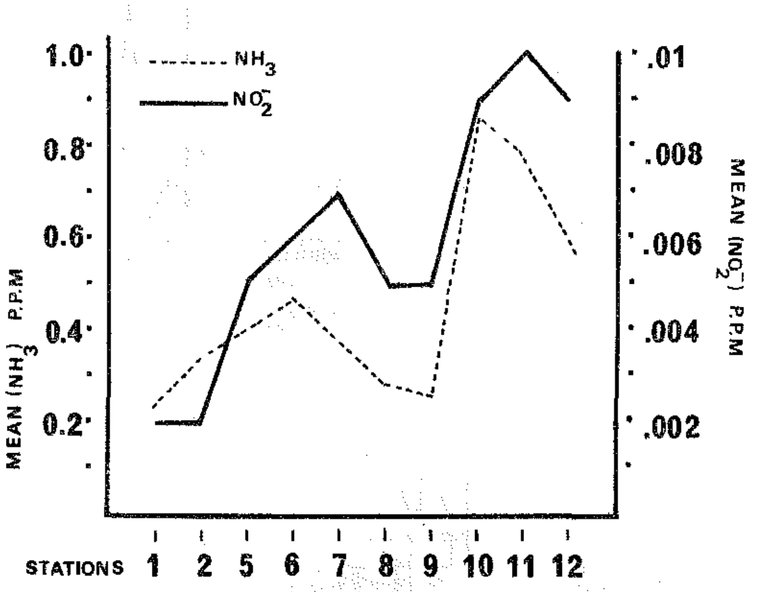

Figure 2. A comparison of ammonia and nitrate levels.

The subsidiary study included analysis of water samples from effluents and tributaries (Table 4). A twenty-four hour investigation was undertaken at Station 11 on 26/27th December 1974. During this period dissolved oxygen ranged from 8.4 to 10.6 $mg.1^{-1}$, ammonia from 0.52 to 17.6 $mg.1^{-1}$, nitrite from 0.010 to 0.032 $mg.1^{-1}$ NO_2^-—N and phosphate from 0.078 to 0.183 $mg.1^{-1}$ $PO_4\equiv$—P. These ranges are not included in Table 2.

BIOLOGICAL

Coliform Testing

Where the ratio of total coliforms to faecal coliforms approaches unity mammalian waste matter is indicated as the major, if not the only source of coliform bacteria. If this ratio departs greatly from unity the major contamination may be from another source, such as decaying vegetation. Alternatively, differential die-off rates may operate due to conditions in the receiving water.

The absence of faecal coliforms from drinking water and the presence of less than 200 per 100 ml in the recreational water is to be recommended, with certain exceptions (World Health Organisation, 1970). In untreated water the maximum allowable value should be 2,000 per 100 ml (Federal Water Pollution Control Administration, 1968). It is possible that even these stringent standards are not satisfactory.

In the Tolka high faecal coliform counts are recorded for those locations where chemical pollution is most severe. This fact further implicates sewage waste as an important contaminant of the system. At Stations 5, 8, 9, 10, 11 and 12 the mean faecal coliform value exceeds 2,000 per 100 ml, while at Stations 5, 10, 11 and 12 the mean is considerably greater (Table 5, a, b). Recovery zones, similar to those for chemical pollutants, are seen from Stations 6 and 7 and again at Station 12. Coliform organisms at Stations 1 and 2 can be attributed, as in the case of phosphate levels, to agricultural activity.

Macroinvertebrate Studies

The percentage expression of the dominant groups at each station is shown for both autumn and spring collections (Figures 3, 4 and Tables 6, 7). Faunal composition is closely related to changes in water quality. There are again three major zones seen in the river. At Stations 1 and 2 the faunal communities are typical of relatively clean water. At Station 5 there is partial or total loss of sensitive species. Recovery begins at Station 6 and progresses to Station 9. At Station 10, where pollution is very severe, only insensitive species are common. Finally, at Station 12, a slight reduction in pollutants is indicated by an increase in molluscan density.

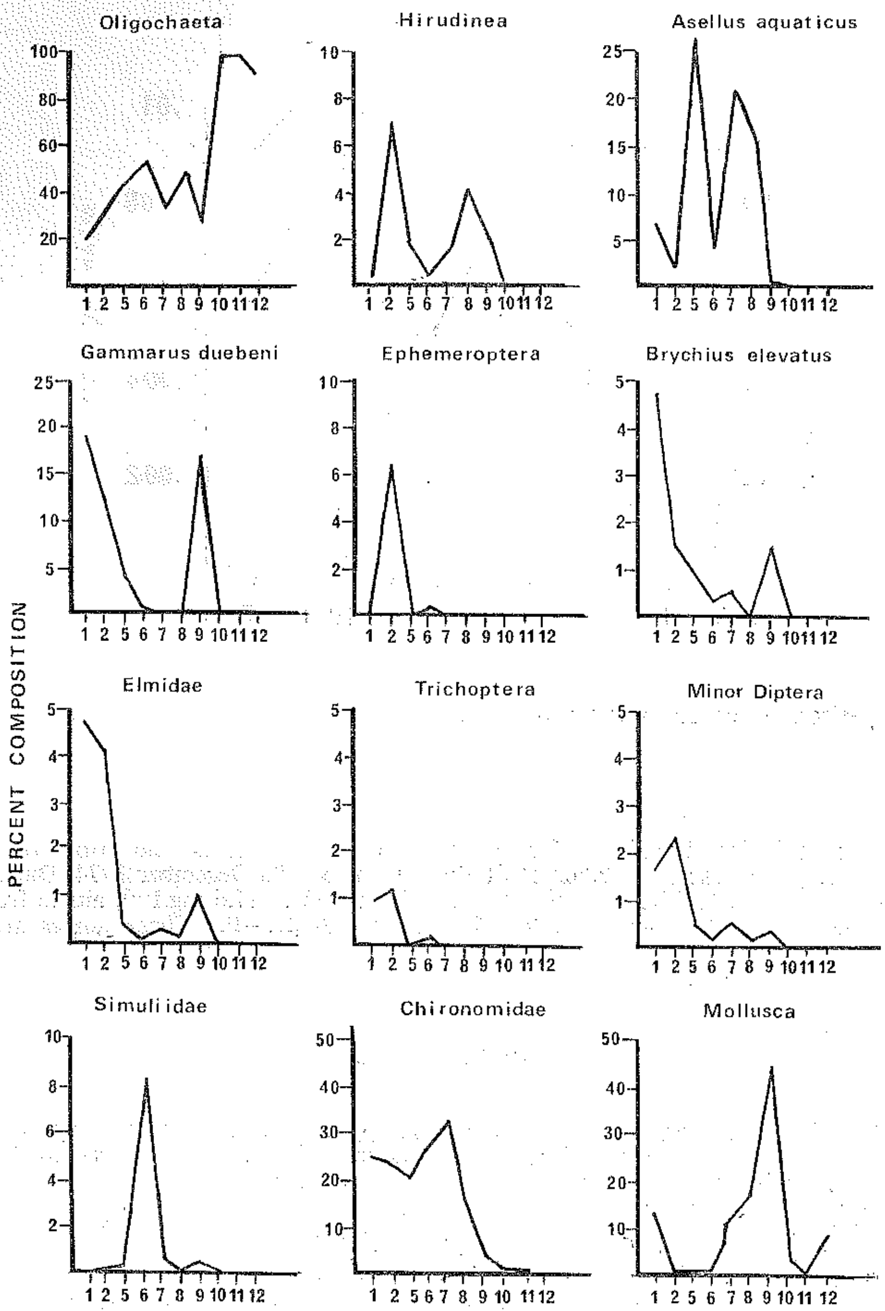

Figure 3. Variation in faunal composition: October. Station numbers on horizontal axes.

The Oligochaeta are the only group whose population densities vary directly with pollution levels. *Tubifex tubifex* Müll. and *Limnodrilus hoffmeisteri* Clap. are the dominant oligochaetes at all stations. They are the only representatives of the Tubificidae at and below Station 10. Both of these species are tolerant of organic pollution (Brinkhurst, 1965; Aston, 1973). While they may be dominant in clean eutrophic conditions they are accompanied in such situations by a large variety of species (Brinkhurst, 1966). In the River Tolka five species are found at Station 1, below this the sequential elimination of species follows the pattern described by Aston (1973).

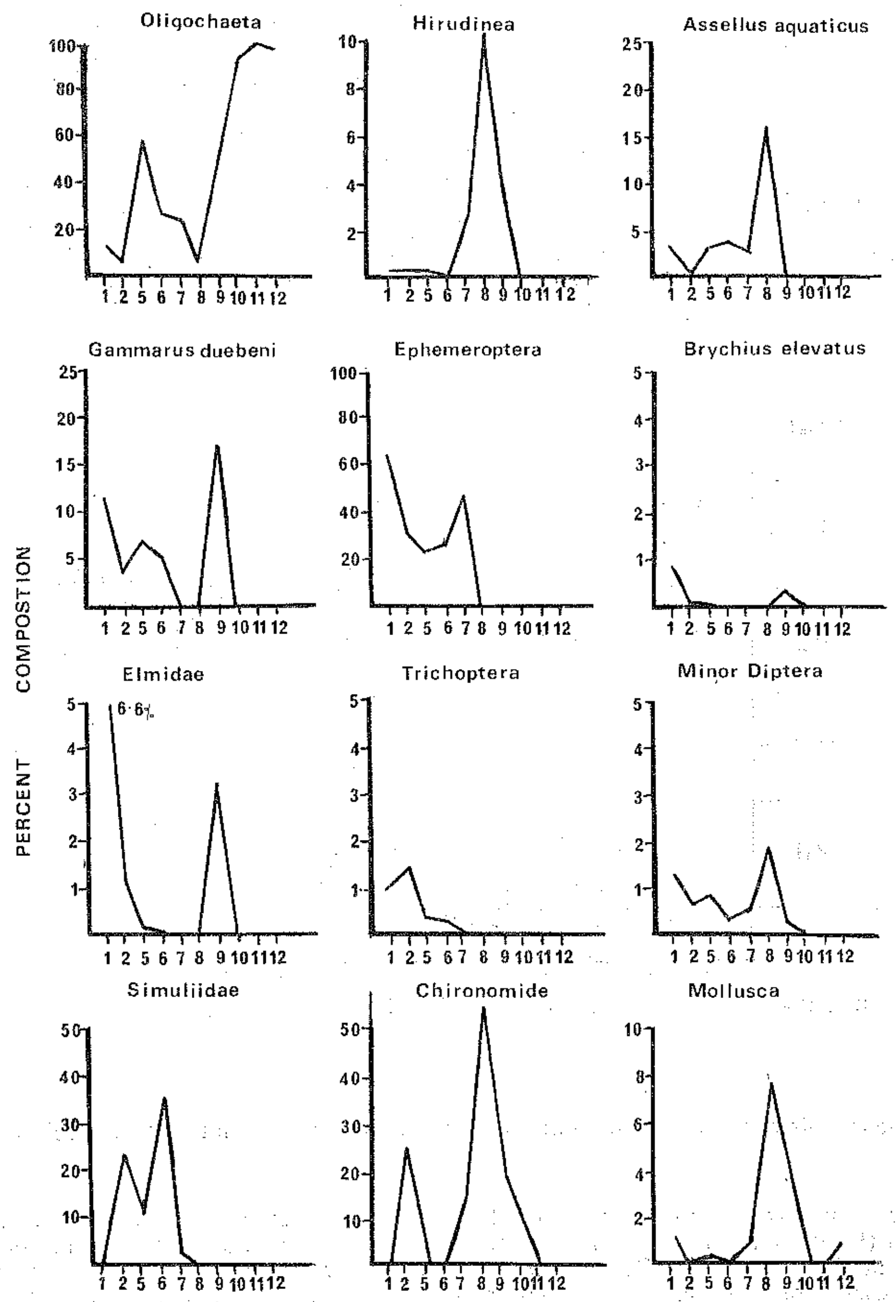

Figure 4. Variation in faunal composition: March. Station numbers on horizontal axes.

Pollution-sensitive species show an inverse association with pollutant levels. *Gammarus duebeni* (Lillj.) is virtually absent from Stations 6 to 8 and is re-established at Station 9. Although the percentage composition of *G. duebeni* is lower at Station 5 than at Stations 1 and 2 the appreciable numbers recorded here are ascribed to drift, a feature of the species (Elliott and Minshall, 1968; Elliott, 1971). The Trichoptera are poorly represented below Station 6 where only free-living forms occur. Species recorded by King and Halbert (1910) from the vicinity of Station 11 can no longer be found in the system. Both *Brychius* (Haliplidae) and the Elmidae are very sensitive, their distribution is restricted below Station 2, and closely resembles that of *G. duebeni.*

Certain species are favoured by mildly or even moderately polluted conditions but cannot establish themselves in areas subject to severe pollution. Such species in the River Tolka reach maximum expression in the recovery zone between Stations 6 and 9. There is first a *Simulium* peak at Station 6. The *Simulium ornatum* complex is the dominant form. This *Simulium* peak is followed in sequence by the reappearance and maximum expression of other groups as they overcome the reduced pollution or enrichment. Station 7 shows maximum numbers of the Chironomidae in October and of *Baëtis rhodani* in spring. The spring chironomid maximum is at Station 8 while the Mollusca are at their most diverse and abundant at this station.

Changes in percentage composition of the various sub-families of the Chironomidae are shown (Figure 5). The Orthocladiinae, which require well-oxygenated water, are dominant from head-waters to Station 10, and are replaced downstream by genera of the Chironomini which are tolerant of oxygen depleted substrata (Brundin, 1958; Hynes, 1960; Thienemann, 1974). *Baëtis rhodani* is one of the most tolerant of the Ephemeroptera; it is the dominant member of the family in the River Tolka where it is abundant from source to Station 7 and is found in small numbers as far downstream as Station 10. Both *Physa fontinalis* (L.) and *Lymnaea peregra* Mull. are found in large numbers at Station 12 while none of the twelve other Molluscan species recorded from the river are found below Station 10.

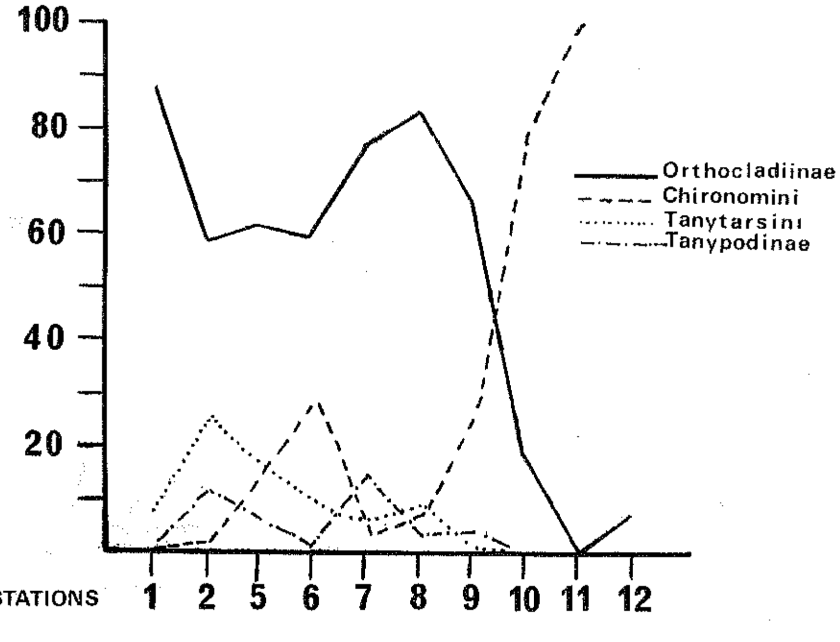

Figure 5. Frequency distribution of sub-families as percentage of total numbers of Chironomidae.

Similar patterns are seen for most forms in both October and March. The October increase in the tolerant *Asellus aquaticus* (L.) at Stations 5 and 7 is not noted in March. Conditions prior to the present survey may have favoured it at these locations. The richness of even the upper reaches of the River Tolka may be gauged by the presence of 480 asellids per square metre in the riffles at Station 1, a habitat only colonised by this species in eutrophic or polluted waters (Hynes, 1960; Maitland, 1966). Only small numbers are recorded below Station 9 where conditions may have been too severe for this species.

A total of 114 taxa were recorded during the present study, 92 at specific level (Appendix A).

Fish

Fish were qualitatively sampled using electrical fishing gear. *Salmo trutta* was observed only at Stations 1 and 6 while *Phoxinus phoxinus* (L.), *Anguilla anguilla* (L.), *Gasterosteus aculeatus* L. and *Pungitius pungitius* L. were abundant from Stations 1 to 9. Fish were not recorded below Station 10.

DISCUSSION

Little overall change in the water quality of the River Tolka is apparent in the period 1971 to 1975. The faunal and chemical results of the present study demonstrate that organic matter is the chief and perhaps the only important pollutant of the system. Heavy metal contamination was absent while the Oligochaeta and Mollusca, traditionally considered sensitive to metallic pollution (Jones, 1940), are common at all stations.

The major source of organic pollution becomes obvious when faecal coliform results are examined. For many years *Escherischia coli,* tested for specifically by the faecal coliform test, was considered as a relatively harmless or even a non-pathogenic organism (Hynes, 1960). Recent evidence suggests that transferable antibody resistance is spreading dramatically in coliform populations (Grabow, Prozesky and Smith, 1974). These R+ factors allow *Escherischia coli* to assume the role of a true pathogen (Hawkes, 1974). They can, in addition, be transferred to accompanying organisms in sewage waste, such as *Salmonella.* A real or at least a potential health hazard therefore exists at Station 12, where a mean concentration of over 10,000 faecal coliforms per 100 ml was measured and where children are known to drink the river water.

Of the parameters investigated dissolved oxygen and ammonia are the factors most likely to affect the fauna of the River Tolka. Present winter water quality should, however, be sufficient to support trout stocks though the conditions are not ideal. Summer deoxygenation would appear to form the major barrier to salmonid recolonisation over much of the river. At present sticklebacks occupy the niche normally held in Irish rivers by *Salmo trutta.* The normally cryptic sticklebacks hunt openly in mid-stream in a trout-like manner.

The River Tolka flows through Dublin City for the last 6 km of its course and the area between Blanchardstown and Finglas is currently undergoing intensive housing development. At present there are two public parks (near Stations 11 and 12) on the river banks, with a third (below Station 9) presently under construction. The amenity value of the river must be obvious. These new estates, the effluent from which pollutes the Tolka, house thousands of people who could benefit from the fishing and recreational potential generated if the river were properly treated. However, over the last twenty years water quality in the Tolka has been allowed to deteriorate as a result of the addition of urban and agricultural waste.

ACKNOWLEDGEMENTS

The authors would like to express their gratitude to Professor C. F. Humphries who read and criticised the manuscript, to Dr. P. E. O'Connor, Civil Engineering Dept., U.C.D., and Mr. P. Carney, B.Sc., who provided facilities for, and assistance with bacteriological work, and to Dr. C. Murphy, State Laboratory, for help with heavy metal analysis. Grateful thanks are also due to Professor J. C. Conroy, Dr. D. J. Douglas, Mr. G. Doyle, Dr. M. P. Kerney, Dr. J. P. O'Connor and Dr. E. J. Wise for their helpful advice and confirmation of identifications. Finally, we are indebted to Mr. M. Foster, Senior Technician, Zoology Department, for his help with the text figures and his assistance in the field.

REFERENCES

American Public Health Association, American Water Works Association and the Water Pollution Control Federation, 1955. *Standard Methods for the Examination of Water and Wastewater.* American Public Health Association, New York.

Aston, R. J., 1973. Tubificids and water quality : a review. *Environ. Pollut.* 5, 1-10.

Brinkhurst, R. O., 1965. Observations on the recovery of a British river from gross organic pollution. *Hydrobiol.* 25, 9-51.

Brinkhurst, R. O., 1966. The Tubificidae (Oligochaeta, Annelida) of polluted waters. *Verh. Int. Ver. Limnol.* 16, 854-859.

Brundin, L., 1958. The bottom faunistical lake type system and its application to the southern hemisphere. Moreover a theory of glacial erosion as a factor of productivity in lakes and oceans. *Verh. Int. Ver. Limnol.* 13, 288-297.

Chandler, J. R., 1970. A biological approach to water quality management. *J. Wat. Pollut. Control,* 415-422.

Edington, J. M., 1968. Habitat preferences in net-spinning caddis larvae with special reference to the influence of water velocity. *J. Anim. Ecol.* 37, 675-692.

Elliott, J. M., 1971. The distances travelled by drifting invertebrates in a Lake District Stream. *Oecologia* 6, 350-359.

Elliott, J. M. and Minshall, G. W., 1968. The invertebrate drift in the River Duddon, English Lake District. *Oikos* 19, 39-52.

Federal Water Pollution Control Administration, 1968. *Water Quality Criteria.* Report of the Nat. Tech. Advis. Comm. to the Sec. of the Inter., Washington.

Flanagan, P. J., 1974. *The National Survey of Irish Rivers. A Second Report on Water Quality.* An Foras Forbartha; Water Resources Division.

Flanagan, P. J. and Toner, P. F., 1972. *The National Survey of Irish Rivers. A Report on Water Quality.* An Foras Forbartha; Water Resources Division.

Fry, F. E. J., 1957. The aquatic respiration of fish. In *The Physiology of Fishes, Volume I—Metabolism* ed. by Margaret E. Brown. Academic Press, New York.

Grabow, W. O. K., Prozesky, O. W. and Smith, L. S., 1974. Drug resistant coliforms call for a review of water quality standards. *Wat. Res.* 8, 1-9.

Hawkes, H. A., 1974. Water quality; biological considerations. *Chemy. Ind.* No. 24, 990-1000.

Hynes, H. B. N., 1960. *The Biology of Polluted Waters.* Liverpool University Press.

Institute for Industrial Research and Standards, 1970. *Recommendations for the Disposal of Industrial Effluent Waters.* S.R. 5.

Jones, J. R. E., 1940. The fauna of the River Melindwr, a lead polluted tributary of the River Rheidol in North Cardiganshire, Wales. *J. Anim. Ecol.* 9, 188-201.

King, J. J. F. X. and Halbert, J. N., 1910. A list of the Neuroptera of Ireland. *Proc. R. Irish Acad.* 28, (Sect. B) 29-112.

Klein, L., 1957. *River Pollution. Vol. I. Chemical Analysis.* Butterworths, London.

Langford, T. E., 1965. Mayflies (Ephemeroptera) in Lincolnshire. *Ent. Mon. Mag.* 101, 189-191.

Maitland, P. S., 1966. *Studies on Loch Lomond. Vol. 2. The Fauna of the River Endrick.* Blackie and Son. Ltd., Glasgow.

Soltero, R. A., 1969. Chemical and physical findings from pollution studies on the East Gallatin River and its tributaries. *Wat. Res.* 3, 687-706.

Thienemann, A., 1974. *Die Binnengewässer. Band XX. Chironomus. Leben, Verbreitung und wirtschaftliche Bedeutung der Chironomiden.* E. Schweizerbart'sche Verlagsbuchhandlung, Stuttgart.

Ulfstrand, S., 1967. Microdistribution of benthic species (Ephemeroptera, Plecoptera, Trichoptera, Diptera; Simuliidae) in Lapland streams. *Oikos* 18, 293-310.

Vogel, A. I., 1968. *A Textbook of Quantitative Inorganic Analyses, Including Elementary Instrumental Analysis.* 3rd Ed. Longman, London.

World Health Organisation, 1970. *European Standards for Drinking Water,* 2nd Ed., Geneva.

Zagil, J. E., 1972. *Water Pollution : Disposal and Reuse.* Vols. 1 and 2. Dekker. New York.

Table 1. Description of sampling stations.

Station No. (Flanagan and Toner, 1972)	Location	National Grid Reference	*Width m	*Depth cm	*Flow $m.sec^{-1}$	Substratum
DETAILED SURVEY						
1	Bridge just north Dunboyne	0 017 429	5	20	0.8	Pebbles and large stones
2	Bridge just u/s Dunboyne tributary	0 027 416	7.5	10	0.6	As Station 1
5	Clonee Bridge	0 035 411	6.3	22	0.4	As Station 1
6	Mulhuddart Bridge	0 067 403	5	32	0.5	Stones and gravel
7	Bridge u/s Blanchardstown	0 078 390	5.5	25	0.9	Small stones
8	Bridge Abbotstown Gate	0 109 376	13	15	0.8	Boulders with rock fragments
9	Cardiffs Bridge	0 123 377	7.5	38	0.3	Stones and gravel
10	Finglas Bridge	0 141 375	8	15	0.75	Large stones in anaerobic ooze
11	Below Bridge at Botanic Gardens	0 152 372	16	35	0.3	Large stones overlying gravel
12	Drumcondra Bridge	0 162 367	17	15	0.4	As Station 11
SUBSIDIARY SURVEY						
3	5 km u/s Dunboyne (on trib.) = a	N 981 443				Muddy
4	At Dunboyne (on trib.) = b	0 011 417				Muddy
	Pipe at Dunboyne = c	0 011 417				
	Pipe just above Cardiffs Bridge = d	0 023 377				
	Pipe draining dump = e	0 127 376				
	Stream draining dump = f	0 129 375				Stony
	Finglas River just above Finglas Bridge = g	0 140 376				As Station 10
	Pipe just above Finglas Bridge = h	0 140 375				
	Pipe in Finglas Bridge support = i	0 141 375				
	River below pipe i = j	0 141 375				As Station 10
	Burst pipe at Finglas Bridge = k	0 141 375				
	Pipe below sewage station at Station 10 = l	0 142 375				
	Claremont River = m	0 153 373				
13	Annesley Bridge = n	0 174 358				

* measurements made under low flow conditions.

Table 2. Detailed study results (1): mean and range obtained from monthly samples for each station.

Station			1	2	5	6	7	8	9	10	11	12
PARAMETER	Dissolved oxygen ($mg.l^{-1}$)	Mean	10.4	10.9	10.4	10.1	9.6	10.4	9.7	9.7	9.1	9.8
METHOD	Winkler	Range	9.3—11.4	8.3—13.7	5.5—11.1	5.3—14.3	4.7—11.5	5.3—12.9	5.1—12.1	3.8—11.7	4.2—11.6	5.1—11.8
PARAMETER	Dissolved oxygen (% saturation)	Mean	91	95	93	89	82	91	84	84	79	85
METHOD	————	Range	78—108	67—144	58—143	55—133	48—102	58—120	55—110	39—109	44—93	55—113
PARAMETER	B.O.D. ($mg.l^{-1}$)	Mean	2.7	4.2	2.0	2.3	9.6	2.9	2.6	6.8	5.2	6.3
METHOD	A.P.H.A. Standard Methods (1955)	Range	0.4—6.3	0.4—15.6	0.4—6.1	0.6—4.2	4.7—11.5	1.2—5.3	1.0—4.4	2.6—17.7	2.8—8.0	0.7—11.6
PARAMETER	Ammonia ($mg.l^{-1}$ NH_3)	Mean	0.23	0.35	0.40	0.47	0.37	0.29	0.26	0.86	0.77	0.58
METHOD	Nessler	Range	0.04—0.56	0.02—0.54	0.08—0.88	0.12—0.88	0.24—0.64	0.06—0.48	0.06—0.80	0.20—1.90	0.24—2.24	0.16—1.30
PARAMETER	Nitrite ($mg.l^{-1}$ $N—NO_2^-$)	Mean	0.002	0.002	0.005	0.006	0.007	0.005	0.005	0.009	0.010	0.009
METHOD	Greiss-Ilosvay	Range	0.001—0.004	0.001—0.004	0.002—0.010	0.002—0.012	0.002—0.012	0.004—0.008	0.004—0.006	0.004—0.012	0.006—0.016	0.002—0.016
PARAMETER	Nitrate ($mg.l^{-1}$ $N—NO_3^-$)	Mean	0.10	0.27	0.59	0.60	0.54	0.73	0.54	0.69	0.68	0.56
METHOD	Brucine-sulphanilic acid	Range	<0.02—0.16	0.09—0.34	0.05—3.00	0.20—1.20	0.09—2.90	0.18—3.20	0.08—2.90	0.16—3.40	0.09—3.40	0.06—2.90
PARAMETER	Phosphate ($mg.l^{-1}$ $P—PO_4\equiv$)	Mean	0.060	0.061	0.131	0.164	0.166	0.123	0.120	0.181	0.174	0.160
METHOD	Molybdenum-blue	Range	0.028—0.097	0.028—0.080	0.048—0.192	0.100—0.299	0.093—0.214	0.060—0.165	0.060—0.155	0.150—0.225	0.105—0.385	0.120—0.210

Table 3. Detailed study results (2): mean and range obtained from monthly samples.

Parameter	Method	Mean	Range
Colour (Hazen units)	Comparator	9	5—20
pH	Radiometer pH meter 29	8.1	7.6—8.4
Conductivity (μScm^{-1})	Environmental multiprobe E1	570	—
Total hardness ($mg.l^{-1}$ $CaCO_3$)	E.D.T.A. titration	123	74—254
Calcium hardness ($mg.l^{-1}$ $CaCO_3$)	E.D.T.A. titration	77	18—142
Manganese ($mg.l^{-1}$)	Atomic Absorption	0.055	0.010—0.085
Iron ($mg.l^{-1}$)	Atomic Absorption	0.024	0.003—0.110
Copper ($mg.l^{-1}$)	Atomic Absorption	0.008	0.002—0.020
Zinc ($mg.l^{-1}$)	Atomic Absorption	all	<0.1
Lead ($mg.l^{-1}$)	Atomic Absorption	all	<0.1
Cadmium ($mg.l^{-1}$)	Anodic Stripping Voltammetry	0.0003	<0.0001—0.0008
Chloride ($mg.l^{-1}$ Cl^-)	Mohr titration (Vogel, 1968)	27	14—38
Suspended solids ($mg.l^{-1}$)	Gravity filtration through GF/B paper	20	4—153

Table 4. Bacteriological and chemical results of subsidiary study. Units as for Main Study.

Location			Probable nature of pollution
(a) Station 3	Total coliforms	650-5450/100 ml	Contamination by sewage effluent
	Faecal coliforms	200-2500/100 ml	
	D.O.	60-94%	
	B.O.D.	0.7-9.2 $mg.l^{-1}$	
	Ammonia	0.20-0.72 $mg.l^{-1}$	
	Nitrite	0.002-0.006 $mg.l^{-1}$	
	Nitrate	0.08-2.60 $mg.l^{-1}$	
	Phosphate	0.055-0.263 $mg.l^{-1}$	
(b) Station 4	Total coliforms	2,800-10,900/100 ml	As for Station 3
	Faecal coliforms	900-7,000/100 ml	
	D.O.	45-93%	
	B.O.D.	1.0-14.4 $mg.l^{-1}$	
	Ammonia	0.40-1.60 $mg.l^{-1}$	
	Nitrite	0.002-0.012 $mg.l^{-1}$	
	Nitrate	0.03-2.90 $mg.l^{-1}$	
	Phosphate	0.046-0.280 $mg.l^{-1}$	

Table 4 (continued).

Location			Probable nature of pollution
(c) Pipe at Station 4	Total coliforms	10,200/100 ml	A mixture of sewage and surface water. Installed in March 1975.
	Faecal coliforms	8,800/100 ml	
	D.O.	87%	
	B.O.D.	25.2 $mg.l^{-1}$	
	Ammonia	0.28-1.60 $mg.l^{-1}$	
	Nitrite	0.002-0.008 $mg.l^{-1}$	
	Nitrate	0.09-1.70 $mg.l^{-1}$	
	Phosphate	0.280-0.952 $mg.l^{-1}$	
(d) Pipe below Station 9	Total coliforms	570 x 10^3-1,600 x 10^3/100 ml	Large amounts of raw sewage. This pipe burst in February, 1975 killing the grass over which it flowed.
	Faecal coliforms	230 x 10^3-940 x 10^3/100 ml	
	D.O.	84%	
	B.O.D.	22.8 $mg.l^{-1}$	
	Ammonia	1.70-17.92 $mg.l^{-1}$	
	Nitrite	0.008-0.064 $mg.l^{-1}$	
	Nitrate	0.05-5.6 $mg.l^{-1}$	
	Phosphate	0.310-1.080 $mg.l^{-1}$	
(e) Pipe running off dump d.s. Station 9	Ammonia	5.20 $mg.l^{-1}$	Drainage from dump.
	Nitrite	0.001 $mg.l^{-1}$	
	Phosphate	0.055 $mg.l^{-1}$	
(f) Stream from dump	Ammonia	0.16 $mg.l^{-1}$	Drainage from dump. Macrobenthic fauna was absent from the stream, toxic influence of some kind therefore suspected.
	Nitrite	0.006 $mg.l^{-1}$	
	Phosphate	0.072 $mg.l^{-1}$	
(g) Finglas River	B.O.D.	22 $mg.l^{-1}$	Heavy pollution by sewage effluent. The large volume of poor quality water from this river is thought to be a large factor in the deterioration of quality at Stations 10, 11 and 12.
	Ammonia	2.16 $mg.l^{-1}$	
	Nitrite	0.024 $mg.l^{-1}$	
	Nitrate	0.39 $mg.l^{-1}$	
	Phosphate	0.125 $mg.l^{-1}$	
(h) Pipe below golf course	Ammonia	0.06 $mg.l^{-1}$	Surface water.
	Nitrite	0.024 $mg.l^{-1}$	
	Phosphate	0.075 $mg.l^{-1}$	
(i) Pipe in bridge support, Station 10	Ammonia	11.84 $mg.l^{-1}$	Raw sewage. The volume of effluent carried by this pipe is small.
	Nitrite	0.008 $mg.l^{-1}$	
	Phosphate	1.370 $mg.l^{-1}$	

Table 4 (continued).

Location			Probable nature of pollution
(j) River below effluent i	Ammonia	1.28 $mg.l^{-1}$	Sewage effluent contamination from pipe i.
	Nitrite	0.012 $mg.l^{-1}$	
	Nitrate	5.5 $mg.l^{-1}$	
	Phosphate	0.512 $mg.l^{-1}$	
(k) Burst pipe at Station 10	Ammonia	0.52 $mg.l^{-1}$	Surface water. Pipe discharged for 1 week only.
	Nitrite	0.016 $mg.l^{-1}$	
	Nitrate	0.20 $mg.l^{-1}$	
	Phosphate	0.110 $mg.l^{-1}$	
(l) Pipe below sewage station, Station 10	Total coliforms	290,000/100 ml	Raw sewage. This pipe ceased to discharge at the end of January 1975.
	Faecal coliforms	60,000/100 ml	
	Ammonia	0.72 $mg.l^{-1}$	
	Nitrite	0.010 $mg.l^{-1}$	
	Nitrate	0.29 $mg.l^{-1}$	
	Phosphate	0.128 $mg.l^{-1}$	
(m) Claremont River	Total coliforms	65,900/100 ml	Various, including oil, sewage and surface water. Odour nuisance and foaming recorded on occasion.
	Faecal coliforms	10,700/100 ml	
	D.O.	112%	
	B.O.D.	20 $mg.l^{-1}$	
	Ammonia	0.24-1.72 $mg.l^{-1}$	
	Nitrite	0.008-0.024 $mg.l^{-1}$	
	Nitrate	0.25-4.7 $mg.l^{-1}$	
	Phosphate	0.100-0.484 $mg.l^{-1}$	
(n) Station 13	Total coliforms	13,100-51,000/100 ml	Dilute organic matter. Slight estuarine influence at high tide.
	Faecal coliforms	3,225-20,500/100 ml	
	D.O.	76-107%	
	B.O.D.	5.8-12.3 $mg.l^{-1}$	
	Ammonia	0.20-0.72 $mg.l^{-1}$	
	Nitrite	0.006-0.010 $mg.l^{-1}$	
	Nitrate	0.20-0.33 $mg.l^{-1}$	
	Phosphate	0.120-0.360 $mg.l^{-1}$	
	Chloride	37-90 $mg.l^{-1}$ at low tide	

Table 5A. Total coliform results (No/100 ml).

Stations	1	2	5	6	7	8	9	10	11	12
MAX.	3,400	2,100	24,750	19,800	7,000	14,100	15,300	91,000	163,500	64,500
MIN	450	200	3,600	400	1,500	3,750	400	10,500	19,150	9,000
MEAN	1,537	1,225	11,858	7,633	4,342	7,800	7,950	52,800	73,708	45,740

Table 5B. Faecal coliform results (No/100 ml).

Stations	1	2	5	6	7	8	9	10	11	12
MAX.	1,300	850	21,950	4,200	2,500	8,700	10,100	46,600	185,000	32,100
MIN.	200	0	400	300	200	1,800	200	2,500	2,000	1,000
MEAN	633	450	8,658	1,717	1,208	3,600	2,767	20,458	57,775	10,520

Table 6. Distribution of the invertebrate fauna.
The locations where species or other taxa were taken in the detailed programme are indicated.
X indicates species or groups taken in qualitative collections only.

Major Group		Genus/species	Locations
Phylum	Platyhelminthes		
Class	Turbellaria		
Order	Tricladida		
Family	Planariidae		
		Planaria torva (O.F. Müll.)	St 2, 8
		Polycelis sp. (*nigra/tenuis* grp.)	St 2
		Dugesia polychroa (Schmidt)	St 8, 9
Family	Dendrocoelidae		
		Dendrocoelum lacteum (Müll.)	St 2, 8
Phylum	Aschelminthes		
Class	Nematoda		
		spp. indet	St 1, 2, 5, 6, 7, 8, 10
Phylum	Annelida		
Order	Oligochaeta		
Family	Naididae		
		Nais communis Pig.	St 1

Table 6 (continued).

Major Group		Genus/species	Locations
Family	Tubificidae	*Tubifex tubifex* Müll.	All stations
		Limnodrilus hoffmeisteri Clap.	All stations
		Potamothrix hammoniensis (Mich.)	St 1, 6
		Rhyacodrilus coccineus (Vej.)	St 1
Family	Enchytraeidae	spp. indet	All stations
Family	Lumbricidae	*Eiseniella tetraedra* Sav.	St 1, 2, 6, 8, 9, 10, 11
Order	Hirudinea		
Suborder	Rhynchobdellae		
Family	Piscicolidae	*Piscicola geometra* (L.)	St 1, 2, 8, 9
Family	Glossiphoniidae		
		Theromyzon tessulatum (O.F. Müll.)	X, between Sts 7 and 8
		Glossiphonia complanata (L.)	St 1, 2, 5, 6, 8, 9
		Helobdella stagnalis (L.)	St 1, 2, 5, 6, 7, 8, 9
Suborder	Pharyngobdellidae		
Family	Erpobdellidae	*Erpobdella octoculata* (L.)	St 2 5, 6, 7, 8, 9, 10, 12
Phylum	Arthropoda		
Class	Crustacea		
Order	Isopoda		
Family	Asellidae	*Asellus aquaticus* (L.)	St 1, 2, 5, 6, 7, 8, 9, 10
Order	Amphipoda		
Family	Gammaridae	*Gammarus duebeni* (Lillj.)	St 1, 2, 5, 6, 8, 9
Class	Insecta		
Order	Plecoptera		
Family	Taeniopterygidae	*Brachyptera risi* Mort.	St 1
Family	Nemouridae	*Nemoura cinerea Retz.*	X, above St 5
Family	Capniidae	*Capnia bifrons* Newm.	St 2, 5, 6
Order	Ephemeroptera		
Family	Baëtidae	*Baëtis rhodani* (Pict.)	St 1, 2, 5, 6, 7, 9, 10
Family	Ecdyonouridae	sp. indet	St 1
Family	Ephemerellidae	*Ephemerella ignita* (Poda)	St 1, 2, 5, 6
		Ephemerella notata Etn.	St 2
Family	Caenidae	*Caenis moësta* Bgtss.	St 1, 2, 5
Order	Hemiptera		
Family	Veliidae	*Velia caprai* Tamn.	X, St 1, 2, 3
Family	Corixidae	*Sigara distincta* (Fieb.)	X, Pool St 6
		Sigara dorsalis (Leach)	X, St 1, 2, 4, 6, 9
		Sigara concinna (Fieb.)	X, Pool St 6

Table 6 (continued).

Major Group		Genus/species	Locations
Order	Trichoptera		
Family	Rhyacophilidae		
		Rhyacophila dorsalis (Curt.)	St 2, 5
		Agapetus fuscipes Curt.	St 1
Family	Polycentropodidae		
		Plectrocnemia conspersa (Curt.)	X, St 1, above St 5
		Polycentropus flavomaculatus (Pict.)	X, St 5
		Cyrnus trimaculatus (Curt.)	St 2
Family	Psychomyiidae		
		Tinodes waeneri L.	X, St 8
Family	Hydropsychidae		
		Hydropsyche pellucidula Curt.	St 1, 2, 6
		Hydropsyche siltalai Döhler	St 2, 5
		Diplectrona felix McLach.	St 1
Family	Hydroptilidae		
		Allotrichia pallicornis (Etn.)	X, above St 8
Family	Limnephilidae		
		Limnephilus marmoratus Curt.	St 1, 2
		Limnephilus lunatus Curt.	St 1, 2, 5, 6
		Glyphotaelius pellucidus (Retz.)	X, St 3
		Anabolia nervosa (Curt.)	X, St 1
		Halesus radiatus/digitatus grp.	St 1, 2, 5, 6
		Stenophylax sequax (McLach.)	X, St 6
Family	Leptoceridae		
		Athripsodes sp. indet	X, St 6
Family	Sericostomatidae		
		Sericostoma personatum (Spence)	St 2
Order	Coleoptera		
Suborder	Adephaga		
Family	Gyrinidae		
		Gyrinus natator L.	X, St 3
Suborder	Hydraephaga		
Family	Haliplidae		
		Brychius elevatus Panz.	St 1, 2, 5, 6, 7, 8, 9, 11
		Haliplus confinis Steph.	X, below St 9
		Haliplus fulvus Fabr.	X, St 2
Family	Dytiscidae		
		Deronectes depressus Fabr.	X, below St 9
		Hydroporus tessellatus Drap.	X, St 3
		Hydaticus seminiger Deg.	X, below St 6
Suborder	Palpicornia		
Family	Elmidae		
		Elmis aenea P. Müll.	St 1, 2, 5, 6, 7, 8, 9
		Limnius volckmari Panz.	X, St 1
		Oulimnius tuberculatus P. Müll.	St 1, 2, 5, 8
Order	Neuroptera		
Family	Sialidae		
		Sialis lutaria (L.)	St 2

Table 6 (continued).

Major Group		Genus/species	Locations
Order	Diptera		
Family	Tipulidae	*Tipula* sp. indet	St 1, 2, 5, 9
Family	Limoniidae		
		Pedicia rivosa (L.)	St 1, 2, 6
		Dicranota sp.	St 1, 2, 5, 6
Family	Simuliidae	*Simulium brevicaule* (Dorier et Grenier)	St 6
		Simulium (Wilhelmia) equinum L.	St 5, 7
		Simulium ornatum complex	St 1, 2, 5, 6, 7, 8
		Simulium ornatum Meig.	X
Family	Chironomidae	Imagines = [I], Larvae = [L]	
Subfamily	Tanypodinae	(only larvae taken)	
		genus *Ablabesmyia*	St 5
		genus *Macropelopia*	St 5
		genus *Procladius*	St 2, 7
		genus *Psectrotanypus*	St 1, 2
		genus *Pentaneurini*	St 2, 5, 6, 7, 8, 9
Subfamily	Prodiamesinae	*Prodiamesa olivacea* Meig. [L+I]	St 1, 2, 6, 8, 9, 10
Subfamily	Orthocladiinae		
		Brillia modesta (Meig.) [L]	St 6, 9
		Cricotopus (Isocladius) sylvestris (Fabr.) [I]	X St 9
		Cricotopus tibialis (Meig.) [I]	X St 9
		Cricotopus (Isocladius) tricintus (Meig.) [I]	X, St 9
		genus *Cricotopus* type A [L]	St 7, 8, 12
		genus *Eukiefferiella* [L]	St 5, 9
		Orthocladius oblidens (Walker) [I]	X, St 9
		Orthocladius rubicundus (Meig.) [I]	X St 9
		Parametriocnemus stylatus (Kieff.) [I]	X, St 9
		genus *Rheorthocladius* [L]	St 1, 2, 5, 6, 7, 8, 9, 10
Subfamily	Chironominae		
Tribe	Chironomini	*Chironomus* spp. [I]	X
		Chironomus (anthracinus grp) [L]	St 2, 5, 6, 8, 9, 10, 11, 12
		genus *Dicrotendipes* [L]	St 1, 2, 5, 7, 10, 11, 12
		genus *Microtendipes* [L]	X, St 1
		genus *Paratendipes* [L]	X, St 6
		Paratendipes albimanus (Meig.) [I]	X, St 6
Tribe	Tanytarsini	genus *Micropsectra* [L]	St 1, 2
		genus *Paratanytarsus* [L]	St 6
		Tanytarsus sp. [L]	St 1, 2, 5, 6, 7, 8, 9
Family	Empididae	*Hilara maura* Fabr.	X, above St 8
Family	Ceratopogonidae	*Bezzia* spp. indet	St 1, 2, 5, 6, 7, 8, 9

Table 6 (continued).

Major Group		Genus/species	Locations
Subphylum	Chelicerata		
Class	Arachnida		
Order	Acarina		
Superfamily	Lebertioidea		
Family	Lebertiidae		
		Lebertia crassipalpis Halb.	St 2
		Lebertia porosa (Thor.)	St 2
Family	Hygrobatidae		
		Hygrobates fluviatilis (Strom)	St 2
		Hygrobates longipalpis (Herm.)	St 2
Phylum	Mollusca		
Class	Gastropoda		
Order	Prosobranchia		
Family	Valvatidae		
		Valvata cristata Müll.	St 8
		Valvata piscinalis (Müll.)	St 1, 2, 5, 7, 8
Family	Hydrobiidae		
		Potamopyrgus jenkinsi (Smith)	St 7, 8, 9
Family	Bithyniidae		
		Bithynia tentaculata (L.)	St 8, 9
Family	Physidae		
		Physa fontinalis (L.)	St 2, 8, 9, 10, 12
Family	Lymnaeidae		
		Lymnaea peregra (Müll.)	St 1, 2, 7, 8, 9, 10, 11, 12
		Lymnaea stagnalis (L.)	St 1, 2, 9
Family	Planorbidae		
		Planorbis carinatus Müll.	St 1, 8
		Planorbis contortus (L.)	X, above St 5
Family	Ancylidae		
		Ancylastrum fluviatile (Müll.)	St 8, 9
Family	Acroloxidae		
		Acroloxus lacustris (L.)	X, St 1, above St 8
Class	Lamellibranchiata		
Order	Eulamellibranchiata		
Family	Sphaeriidae		
		Sphaerium corneum (L.)	St 1, 2, 6, 8, 9
Family	Pisididae		
		Pisidium nitidum Jen.	St 1, 2, 5, 6, 7, 8, 9
		Pisidium subtruncatum Malm	St 1, 2, 5, 6, 7, 8, 9

Table 7. Data from quantitative samples.

Station	1	2	5	6	7	8	9	10	11	12
mean no. of animals/2,500 cm^2	781	659	1,132	746	188*	516	566	771	1,467	3,181
mean no. of taxa per sample (2,500 cm^2)	31	30	23	19	17*	21	20	7	5	7
mean no. of individuals per species = mean no. of animals per 2,500 cm^2 ÷ mean no. of taxa recorded	25	22	49	39	11*	25	28	110	293	454

* Low numbers per unit area at Station 7 are attributed to river bed disturbance during road construction prior to the present survey.

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 the River Owenea, 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 Trimblestown 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.

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

(9209)132263. 650. 8-81. F.P.—G3.