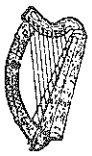

IRISH FISHERIES INVESTIGATIONS

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AN ROINN IASCAIGH
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DUBLIN:
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TO BE PURCHASED FROM THE
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DUBLIN.

Price: 75p.

IRISH FISHERIES INVESTIGATIONS

SERIES A
(FRESHWATER)

No. 17

(1978)

J. P. O'CONNOR AND J. J. BRACKEN

A COMPARATIVE LIMNOLOGICAL STUDY OF TWO IRISH LAKES (LOUGH SILLAN, CO. CAVAN AND LOUGH DAN, CO. WICKLOW).

A Comparative Limnological Study of Two Irish Lakes (Lough Sillan, Co. Cavan and Lough Dan, Co. Wicklow)

by

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Received 14th March, 1977.

Abstract

A comparative study of Lough Sillan (Co. Cavan) and Lough Dan (Co. Wicklow) revealed that these two Irish lakes differ markedly in their physico-chemical and faunal characteristics. The possible causes of these observed dissimilarities are reviewed and discussed. Lough Sillan may be classified as moderately eutrophic while Lough Dan is both humic and oligotrophic.

Introduction

Base-line studies of Irish lakes have been initiated in recent years (Partridge and Foy, 1972; Flanagan and Toner, 1975; O'Connor and Norton, 1977) but with the exception of the Killarney Valley Survey (in preparation), no comprehensive lacustrine studies have been carried out. In the past, particular physico-chemical or faunal aspects have been directly or indirectly examined (e.g. Johnson and Halbert, 1902; Southern, 1909, 1936; King and Halbert, 1910; Stelfox, 1911; Stephens 1920; Southern and Gardiner, 1926, 1932; Praeger 1929; Halbert, 1935, 1944; Reid, 1939; Seymour, 1939; Balfour-Browne, 1940, 1950, 1958; Went, 1945; Webb, 1947; MacNeill, 1949; Grainger, 1952, 1957; Macan and Lund, 1954; Gorham, 1957; Charlesworth, 1963; Kennedy, 1964; Kennedy and Fitzmaurice, 1968, 1971, 1974; Fitzmaurice, 1971; Moriarty, 1963, 1971, 1972, 1973; O'Riordan, 1971; Murray, 1972; Bracken and Murray, 1973; McCarthy, 1975) but little attention has been paid to their interrelationships in any one system.

The present study consists of a detailed comparison of Lough Sillan (Co. Cavan) with Lough Dan (Co. Wicklow) using certain selected physico-chemical and biological parameters. It is hoped that the presented data will provide valuable base-line information on two lakes of contrasting trophic status and thus stimulate further research. The present paper complements the Killarney Valley Survey in the south-west as it reports on lakes in two other areas.

Field-work was mainly completed between December 1970 and January 1972, but additional faunal samples were taken in 1973 and 1974. An effluent entering L. Sillan was also critically examined as a potential pollution hazard.

Topography and geology

Lough Sillan (H 7007) is situated amid drumlin countryside beside the town of Shercock, Co. Cavan, and is glacial in origin. It is 3.2 × 0.8 km in extent and approximately 15 m deep. The lake is part of the River Annalee system and has several small tributary streams (Fig. 1). In the district, the baserock is Ordovician covered by acid brown earths, peaty and normal gleys.

Lough Dan (O 1503) lies in a glacial valley in the Wicklow Hills, the nearest village being Roundwood, Co. Wicklow. The lake, 2.5 × 0.5 km, is smaller in area than L. Sillan but has a greater maximum depth (40m). Except at the southern end, L. Dan is surrounded by hilly country. Two rivers enter the lake, the Cloghoge in the north-east and the Inchavore in the north-west. The Annamoe or Avonmore River drains it in the south (Fig. 1). The surrounding geological strata are Ordovician in the east, west and south with granite in the north. Acid brown earths, brown and peaty podzolics, climatic peat and lithosols characterise the associated soils. Both the inflowing rivers drain extensive areas of granite and peat-bog.

The shore-lines of the lakes are irregular and littoral habitats diverse, ranging from rocky shore to reed-bed. In the two areas, the differential effects of the surrounding hills acting as wind-breaks often produce these contrasting conditions on the same shore-line.

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However, the biotopes in L. Sillan are more varied, particularly in their vegetation and substrate characteristics. As most of this lake is accessible, one physico-chemical and six faunal sampling stations were selected (Fig. 1). The faunal stations are described (Table 1). It was difficult to sample L. Dan satisfactorily because of the inaccessibility of long stretches of shore-line, the general narrowness of the littoral zone and the surrounding hill formations which acted as a wind tunnel. Nevertheless, one physico-chemical and three faunal sampling stations were established (Fig. 1, Table 1).

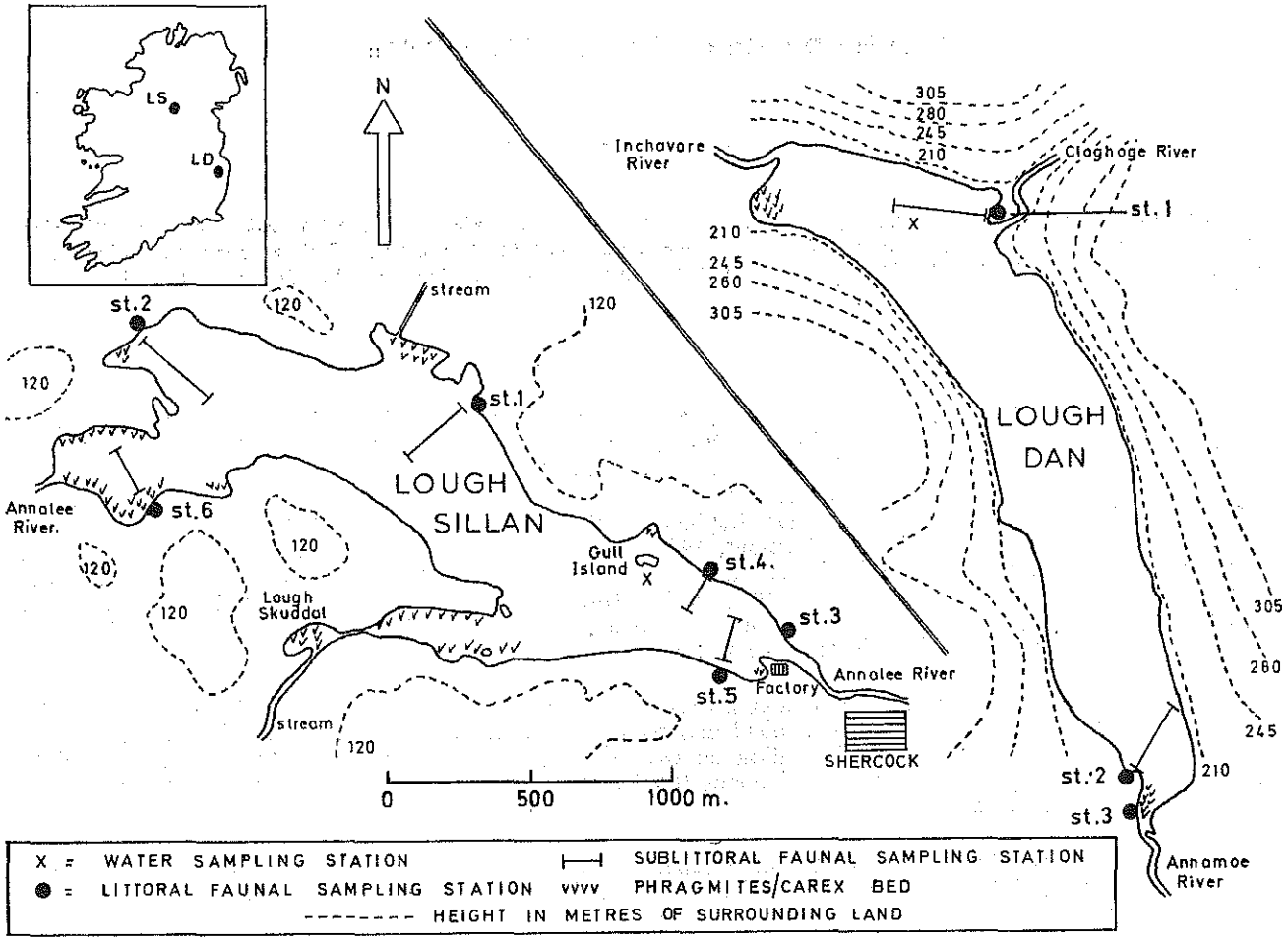

Figure 1. The two lakes and their surroundings.

Materials and methods

A total of thirteen physico-chemical parameters were examined once a month. A brief summary of the methodology is given (Table 2). In the two lakes, water samples were collected in a Ruttner bottle at the surface and at four metres depth. These were stored according to established procedures (Mackereth, 1963) and subsequently used for chemical analyses.

In L. Sillan, extra samples were taken at two-metre intervals between the surface and bottom, and at the point of discharge of the factory effluent. These were employed in the determination of ionic variation and effluent composition. In addition to the physico-chemical tests mentioned above, ammonia concentrations were measured in November and December 1971.

Many techniques have been described for sampling littoral fauna (e.g. Moon, 1935; Berg, 1938; Macan and Maudsley, 1968, 1969; Macan, 1974) but because of the extremely variable nature of the substrata in the different habitats, no completely satisfactory quantitative and comparative method has yet been devised. In the present investigation, an attempt was made to discover the groups or species present and to indicate their relevant importance. Temporal and logistic difficulties did not permit an intensive statistical sampling programme and the results should only be considered as comparative. Undoubtedly, certain active forms such as corixids escaped from the main sampler and some species had a clumped or non-random distribution.

Between November 1970 and December 1971, monthly littoral samples were taken using a square frame (1/16 sq. m). A second frame was attached at right angles and carried a net (12 meshes per cm). In use the frame was pressed against the substratum and the enclosed animals and detritus scooped into the net. Qualitative sampling was carried out with a standard F.B.A. net (12 meshes per cm). In 1973 and 1974, collections were made on a strict time basis at certain selected stations using a standard F.B.A. net and rake. Sublittoral and profundal regions were sampled with a Petersen grab.

Results

Physico-chemical

The physico-chemical data demonstrated that the lakes stood in marked contrast. The pH, alkalinity, total hardness, calcium, nitrite, nitrate and phosphate levels in L. Sillan were comparatively high while low humic content was indicated by the pH and colour. L. Dan, by contrast, had concentrations of the former substances which were markedly lower with higher humic content (Table 3).

From July 1970 to December 1971, the effluent from a chicken processing factory on L. Sillan was analysed. Samples were taken at the point of entry. Nitrite (0.005-0.64 p.p.m.), nitrate (0.10-1.20 p.p.m.) and phosphate (0.005-0.192 p.p.m.) often exceeded the normal concentrations recorded for the lake (Table 3). In addition, the December readings for ammonia were higher than the levels obtained for the lake water (0.8 versus 0.04/0.07 p.p.m.). These results indicate that the effluent was contributing nutrients to the lake and may have been an important factor in the change in water quality noted by Flanagan and Toner (1975). However, treated sewage from Shercock also enters the lake via an underwater pipe. It and other point sources were not monitored.

In August 1971, sampling in L. Sillan showed that the phosphate concentration at the bottom was three times that of the surface (0.036 p.p.m. $P\text{-}PO_4^{\equiv}$ at 10 metres versus 0.012 p.p.m. at surface). This difference may be attributed to a release of phosphates from the bottom sediments suggesting anaerobic conditions (Mortimer, 1941-1942). Striking seasonal variations were obtained for this nutrient in the two water bodies (Fig. 2).

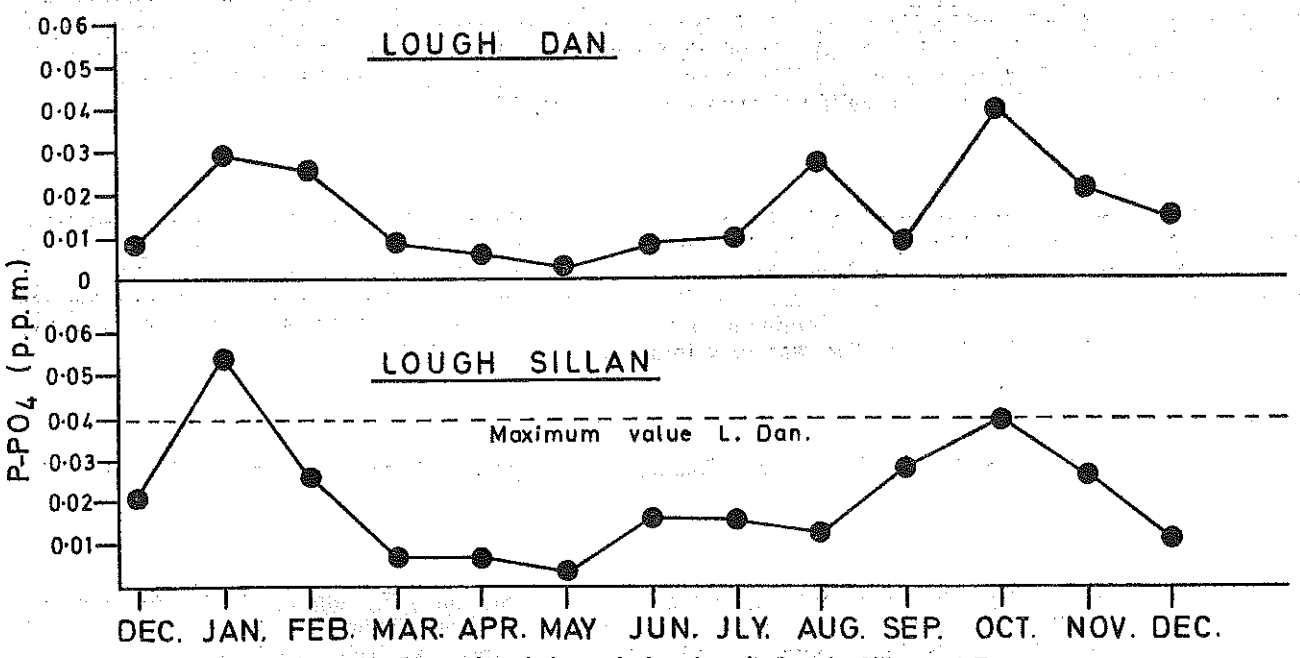

Figure 2. Seasonal variations of phosphate in Loughs Sillan and Dan.

Littoral fauna

The littoral fauna of L. Sillan was richer both in the diversity of groups and in the number of species present. A distinct difference was observed between the faunas of the two lakes. While triclads, isopods, amphipods and molluscs were abundant in L. Sillan, they were scarce or absent from L. Dan. With the exception of oligochaetes, insects predominated in the latter (Table 4).

A total of 123 and 78 littoral species were recorded, respectively, from L. Sillan and L. Dan, with 51 species common to both.

The more important and interesting results are now reviewed. A comprehensive faunal list is presented in the Appendix.

Tricladida:

This group was abundant in L. Sillan and four species were represented. Only a single specimen (*Polycelis nigra* (Müller)) was recorded in L. Dan.

Oligochaeta:

These animals were important in both lakes. O'Grady *et al.* (in prep.) compare the oligochaete faunas of this survey with those of other Irish lakes.

Hirudinea:

Helobdella stagnalis (L.) and *Erpobdella octoculata* (L.) occurred in both waters. A further three species were obtained in L. Sillan.

Isopoda/Amphipoda:

Asellus aquaticus (L.) and *Gammarus duebeni* Lilljeborg were confined to L. Sillan where they were ubiquitous (Table 5).

Plecoptera:

Stoneflies were scarce with a restricted distribution in L. Sillan. *Chloroperla torrentium* (Pictet) was only found at Stations 1 and 3 while *Nemoura avicularis* Morton was only taken in qualitative collections at Station 3. The Plecoptera was the sole insect order in which the number of species recorded (6) was greater in L. Dan. However, the *Protonemura meyeri* (Pictet) nymphs at Station 1 may have drifted from the Cloghoge since this animal normally inhabits swiftly flowing water (Hynes, 1967).

Ephemeroptera:

In all, eight species were captured in L. Sillan compared with three in L. Dan. In the first-named lake, *Baëtis rhodani* (Pictet) probably originated in the Annalee as it is a lotic form (Kimmins, 1972). Other species had a limited expression. *Ephemera danica* Müller, *Heptagenia fuscogrisea* (Retzius) and *Leptophlebia vespertina* (L.) were rarely taken, while *H. sulphurea* (Müller) was mainly restricted to Station 1. *Caenis horaria* (L.) and *C. moesta Bengtsson* were the dominant mayflies. The former also inhabited L. Dan where a few individuals were obtained. *L. vespertina* was very important in L. Dan (Table 5).

Odonata:

The nymphs of *Coenagrion puella* (L.) and *Enallagma cyathigerum* (Charpentier) were collected in the two lakes.

Hemiptera:

A total of six corixid species were captured in the reedbed at Station 6 (L. Sillan). *Callicorixa praeusta* (Fieber) and *Sigara distincta* (Fieber) were dominant while *Corixa dentipes* (Thomson), *C. punctata* (Illinger) *S. falleni* (Fieber) and *S. dorsalis* (Leach) were present in smaller numbers. Analysis of 206 specimens collected in Autumn 1973 revealed the following proportions:—*S. distincta*, 98 : *C. praeusta*, 89 : *S. falleni*, 10 : *C. dentipes*, 5 : *C. punctata*, 4. *Micronecta poweri* Douglas and Scott was restricted to the exposed Stations 1, 4 and 5. In L. Dan, *S. dorsalis* and *S. venusta* (Douglas and Scott) were plentiful in the reedbed (Station 3) while *M. poweri* occurred on the exposed shores.

Megaloptera:

High numbers of the alderfly *Sialis lutaria* (L.) were present at Station 6 (L. Sillan).

Trichoptera:

Caddis flies were plentiful in L. Sillan and L. Dan. In all 38 species were noted in the former lake, dominant species being *Polycentropus flavomaculatus* (Pictet), *Tinodes waeneri* (L.), *Limnephilus lunatus* Curtis, *L. vittatus* (Fabricius), *Anabolia nervosa* (Curtis), *Goera pilosa* (Fabricius), *Lepidostoma hirtum* (Fabricius) and *Sericostoma personatum* (Spence). Interesting and rare species included *Agrypnia pagetana* Curtis, *Limnephilus nigriceps* (Zetterstedt) and *Molanna palpata* McLachlan.

A total of 33 species were identified from larval, pupal and imaginal material taken in L. Dan. The more important Trichoptera were *P. flavomaculatus, T. waeneri* and *L. hirtum*. *Rhyacophila dorsalis* (Curtis) recorded at Station 1 may have entered the lake from the Cloghoge River. *Hydroptila* and *Oxyethira* spp. were common in L. Dan and one of the species, *H. cornuta* Mosely, is new to Ireland. These animals were almost absent from L. Sillan. The normally lotic *Plectrocnemia conspersa* (Curtis) inhabited both exposed and sheltered habitats in L. Dan (Appendix A).

Coleoptera:

This order was represented by eight and six species in L. Sillan and L. Dan respectively. *Oulimnius tuberculatus* (Müller) was the most widespread beetle and was found at most stations (Table 5). While elminthid larvae were frequent in the two lakes, haliplid larvae were mainly confined to L. Sillan. These insects were particularly abundant on the very exposed shore-line at Station 1 (Table 5).

Diptera:

Chironomid results related only to genus or "type" and are of limited value. The identified taxa are listed (Appendix A). Other Diptera included the families Ceratopogonidae (*Bezzia* spp.) and Tipulidae (*Tipula* spp.) in both waters.

Hydracarina:

Twelve species were taken in L. Sillan and seven in L. Dan. Numbers collected were never high. Only *Limnesia maculata* (Müller) and *Piona variabilis* (Koch) were recorded in both the survey areas.

Gastropoda:

Thirteen species were identified in L. Sillan and the more important ones are listed (Table 5). By contrast, only three specimens were found in L. Dan. On separate occasions, one individual each of *Lymnaea peregra* (Müller) and *Planorbis carinatus* Müller were obtained in the frame samples. Another gastropod (also *P. carinatus*) was taken qualitatively. The presence of this animal is very unusual and the possibility of accidental introduction cannot be totally discounted.

Lamellibranchia:

While *Pisidium* spp. were well represented in L. Sillan, they were scarce in L. Dan (Table 5).

The faunal results demonstrate the influence of exposure on littoral communities. In L. Sillan, *C. torrentium* and *H. sulphurea* were practically confined to the most exposed sampling site (Station 1). Other characteristic inhabitants were *T. waeneri* and haliplid larvae. The more sheltered conditions of Station 5 favoured *Polycelis nigra/tenuis, Caenis* spp., *A. nervosa, L. vittatus, Potamopyrgus jenkinsi* (Smith) and *Planorbis leucostoma* Millet. The relatively calm environment of Station 6 was suitable for *Cloëon dipterum* (L.), corixids and *S. lutaria*.

In L. Dan, *T. waeneri*, elminthid larvae and *O. tuberculatus* were most abundant at the exposed Station 1. *N. avicularis* and Chironomidae spp. abounded at Station 2 which was less disturbed by wave action. *L. vespertina* and corixids preferred the reedbed (Station 3).

Sublittoral and profundal fauna

As Welch (1952) considers the sublittoral zone to commence at the lakeward limit of rooted vegetation, faunal samples were taken at depths greater than two-three metres in both lakes. An examination of these

collections revealed a sublittoral fauna which was distinct from that of the littoral region. A decrease in diversity was also noted. Oligochaetes and chironomids predominated in the two waters. In addition, bivalves were important in L. Sillan (Table 6).

The fauna was rich and varied in L. Sillan. Important taxa included Tubificidae spp., *Procladius/Psilotanypus* sp., *Chironomus* spp. (*bathophilus* and *plumosus* types), *Pseudochironomus* sp. and *Pisidium* spp. Sublittoral numbers were low in L. Dan but *Lumbriculus variegatus* (Müller), *Stylodrilus heringianus* Claparède and *Stictochironomus* sp. present in this lake were not found in the comparable zone in L. Sillan.

Because of the shallowness of L. Sillan, a comparison of profundal faunas is not possible but qualitative sampling showed that oligochaetes and chironomids were present in L. Dan.

Discussion

Physico-chemical and biological interactions can explain many of the observed faunal differences between the two lakes. The paucity of flatworms, leeches and molluscs in L. Dan, for example, may be largely attributed to the low calcium concentrations coupled with the humic environment (Boycott, 1936; Mann, 1955; Reynoldson, 1958a, b; Tucker, 1958; Reynoldson and Davies, 1970a, b).

Related factors, including food availability, the presence or absence of predators and competitors also affect other groups or species. Plecopteran and ephemeropteran eggs and nymphs are vulnerable to predation by carnivores, omnivores and even herbivores (Macan, 1965, 1970; Macan and Maudsley, 1968, 1969). Presumably because many of these predators (e.g. triclads, *Asellus, Gammarus* and molluscs) are either absent or scarce in L. Dan, several species of stonefly have successfully colonised it. Despite these favourable circumstances, however, *Leptophlebia vespertina* was the only mayfly which was common and abundant in the lake. Other species apparently failed to exploit it because of the humic conditions, an environment which suits *L. vespertina* (Harris, 1956). By contrast, in L. Sillan the ephemeropteran fauna was comparatively rich and varied. The more diverse range of habitat and diet available there probably compensates for the greater number of potential predators.

Differences in the species composition of many groups must be due to their mode of colonisation. The distribution of water mites for instance is largely dependent on their method of dispersal (Macan, 1974). A similar argument applies to the leech *Theromyzon tessulatum* (Müller) (McCarthy, 1975). Likewise the distribution of the Coleoptera is probably the result of sporadic migration and the accidental discovery of new localities.

Several caddisfly species appear to be absent from L. Dan because they are still extending their ranges and have not yet reached that particular area (O'Connor, 1975). Although the British distribution of *Asellus* has aroused considerable discussion (e.g. Moon, 1957a, b, 1968; Reynoldson, 1961; Williams, 1962; Reynoldson and Young, 1966), it is most likely that it too has not yet reached the lake. Since *Asellus* is an important "food refuge" for *Dendrocoelum lacteum* (Müller) (Reynoldson, 1967), its absence probably accounts for that of the latter. While Sutcliffe (1967) suggests that *Gammarus duebeni* is unable to colonise the Wicklow area encompassing L. Dan owing to the low sodium content, the physico-chemical and other factors already outlined may have an important role in excluding it.

Undoubtedly many faunal differences together with many similarities may be related to habitat diversity. Several species were observed to have marginal and localised existences based on specialised environmental requirements or the exploitation of definite niches. Particular examples are *Chloroperla torrentium, Sialis lutaria* and *Agraylea multipunctata* Curtis. The first and last-named species maintained small populations on the very exposed shore-line in L. Sillan while *S. lutaria* was plentiful in the reed-beds. Although both lakes have many common biotopes, L. Sillan has the greater variety and this is reflected in the species list.

When the faunas of other lakes are compared with those of L. Sillan and L. Dan (e.g. Berg, 1938; Macan and Lund, 1954; Berg and Petersen, 1956; Dunn, 1961; Macan and Maudsley, 1968, 1969; Macan, 1970; Partridge and Foy, 1972; O'Connor and Norton, 1977, in prep.; Killarney Valley Survey, in prep.), some notable differences become evident. After the deletion of the non-Irish taxa, several lentic species remain which were not collected during the present study. These include *Bdellocephala punctata* (Pallas), *Asellus meridianus* Racovitza, *Capnia bifrons* (Newman), *Diura bicaudata* (L.), *Leuctra fusca* (L.), *Centroptilum luteolum* (Müller), *Ecdyonurus dispar* (Curtis), *Ephemerella ignita* (Poda), *Heptagenia lateralis* (Curtis), *Sigara fallenoidea* (Hungerford), *Agapetus fuscipes* Curtis, *Metalype fragilis* (Pictet) and *Tinodes maculicornis* (Pictet). All these animals have been taken in at least one Irish lake (King and Halbert, 1910; Macan and Lund, 1954; Harris, 1956; Partridge and Foy, 1972; McCarthy, 1973; O'Connor and Norton, 1977, in prep.; Killarney Valley Survey, in prep.).

Macan and Lund (*op. cit.*) suggest that *E. dispar* and *H. sulphurea* might be vicariants. They mention

that this may also apply to *H. lateralis* and *H. sulphurea* but Partridge and Foy (1972) have since found both species to be present in considerable numbers in Lough Feeagh, Co. Mayo. Another three species, *S. fallenoidea, M. fragilis* and *T. maculicornis,* appear to be confined to waters of a high calcium content (O'Connor, unpublished data). However, the non-occurrence of the other listed species is very difficult to explain because of our inadequate knowledge regarding their ecological requirements and distribution in this country. These data will be a necessary requisite, therefore, if benthic invertebrates are to be used in the compilation of indices of either pollution or eutrophication.

Some dissimilarities with British lakes are of note. In L. Sillan *Gammarus duebeni* appears to occupy the niche of *G. pulex* (L.), an animal which has now been introduced into Ireland (Gledhill *et al.*, 1976). *Heptagenia fuscogrisea,* although fairly common in stony limestone lakes here, is very rare in Britain (Harris, 1956; Shires and Wallace, 1973). *Sigara distincta* appears to be common more often in this country than elsewhere (Macan, pers. comm.) and the abundance of *S. venusta* in L. Dan seems unusual (Macan, 1955). *Oulimnius tuberculatus* was often plentiful in both water-bodies but it is considered to be uncommon on stony lake shores (Holland, 1972). Four of the recorded species of mollusc (i.e. *Bithynia tentaculata* (L.), *Lymnaea stagnalis* (L.), *Myxas glutinosa* (Müller) and *Planorbis carinatus* are normally hard water species (Macan, 1969).

Macan (1974), summarising research carried out on European lakes, suggests that insects are more abundant than non-insects in unproductive waters while the reverse holds true in more productive ones. The present study supports that assertion.

In conclusion, from the compiled data L. Sillan may be classified as a moderately eutrophic lake while L. Dan is both humic and oligotrophic.

Acknowledgements

The authors are indebted to Professor C. F. Humphries for reading and criticising this manuscript; Mr. M. J. D. Brendall, Professor J. Conroy, Drs. E. G. Easton, J. P. Harding, P. Hiley, C. R. Kennedy, T. T. Macan, D. A. Murray, I. D. Wallace and E. J. Wise for identifying or confirming the identifications of certain difficult species; Mr. M. G. Doyle for plant determinations; Mr. and Mrs. P. McDaniel, Mrs. I. McCullagh, Mr. and Mrs. P. McEntee for their invaluable assistance; Mr. M. Foster for his help with field work and the preparation of diagrams; Drs. T. T. Macan and P. Toner for their advice and our colleagues for their encouragement. J. P. O'Connor was supported by a Fisheries Science Studentship from the Department of Agriculture and Fisheries, Dublin.

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Table 1. Characterisation of the littoral faunal sampling stations.

Station	Exposure	Substratum	Vegetation
Lough Sillan 1	Exposed	Boulders, rocks, gravel and stones.	*Juncus acutiflorus* Hoffm; *Littorella* sp. and *Epilobium* spp.
2	Exposed	Shore-line strewn with large boulders and rocks. Small stones and gravel are present between the boulders and rocks.	*J. acutiflorus* and *Littorella* sp.
3, 4	Exposed	Stones, gravel and mud. When the lake was visited in 1975, it was noted that Station 4 was greatly modified and disturbed by dredging. This had taken place after faunal sampling was completed.	*Eleocharis palustris* Roem and Schult, *J. acutiflorus, Elodea* sp., *Potamogeton* sp. *Hydrocotyle* sp. and *Phragmites* sp. were only found at Station 3.
5	Exposed	Stones and gravel.	*E. palustris, Littorella* spp., *Potamogeton* sp., *J. acutiflorus.*
6	Sheltered	A few scattered rocks and stones present. Decaying organic material plentiful and mainly composed of *Phragmites* sp.	Faunal samples taken at and in a bed of *Phragmites* sp. isolated from the shore-line by a narrow stretch of water containing *E. palustris, Equisetum fluviatile* L. and *J. acutiflorus.*
Lough Dan 1	Exposed	Gravel and sand. A few scattered rocks and stones.	*J. acutiflorus*
2	Exposed	Gravel and sand with scattered boulders, rocks and stones. Decaying leaves of *Quercus* and *Salix* sp. overlie much of the inorganic material.	*J. acutiflorus*
3	Sheltered	Gravel and sand. A few rocks and stones present. Decaying organic material composed of *Carex vesicaria* L., *Quercus* sp. and *Salix* sp. abundant.	Faunal samples taken in bed of *C. vesicaria. J. acutiflorus* present near the shore-line's edge.

Table 2. Summary of physico-chemical methodology.

Physico-chemical test	Method	Results expressed as:
Depth	Ferrograph echosounder	Metres
Transparency	Secchi disc of 25 cms diameter	Metres
Temperature	E.I.L. Oxygen/Temperature meter, model 15A	°C
Oxygen concentration	ditto	% saturation
Hydrogen ion concentration	Radiometer pH meter	pH units
Water colour	Nessleriser	Hazen units
Bicarbonate alkalinity	Mackereth (1963)	MEQ HCO_3/L
Total water hardness	E.D.T.A. method	ppm $CaCO_3$
Calcium hardness	E.D.T.A. method	ppm $CaCO_3$
Other hardness	Total-calcium hardness	ppm $CaCO_3$
Calcium	Mackereth (1963)	ppm Ca^{++}
Ammonia	Nessler	ppm
Nitrite	Griess-Llosvay	ppm $N\text{-}NO_2^-$
Nitrate	Mackereth (1963)	ppm $N\text{-}NO_3^-$
Phosphate	Mackereth (1963)	ppm $P\text{-}PO_4^{\equiv}$

Table 3. Summary of physico-chemical results for L. Sillan and L. Dan.

Test	L. Sillan			L. Dan			Depth
	MAX.	MIN.	MEAN	MAX.	MIN.	MEAN	
Transparency	1.8	0.9	1.5	1.8	1.4	1.6	
Temperature	19.0	4.75	10.75	19.0	4.6	10.1	Surface
	18.5	4.6	10.5	19.0	4.6	10.0	4 m
Oxygen saturation	110	88	97.6	120	83	91.4	Surface
	108	76	97.2	110	83	91.4	4 m
pH	8.22	7.20	7.75	5.84	5.20	5.48	Surface
	8.21	7.20	7.66	5.80	5.30	5.51	4 m
Colour	20.0	15.0	20.0	70.0	40.0	65.0	Surface
	20.0	20.0	20.0	70.0	40.0	65.0	4 m
Alkalinity	0.75	0.59	0.651	0.085	0.03	0.040	Surface
	0.705	0.525	0.622	0.075	0.02	0.038	4 m
Total hardness	53.0	44.0	48.1	16.0	6.0	10.1	Surface
	53.0	42.0	47.0	15.0	6.0	9.8	4 m
Calcium hardness	38.0	31.0	34.2	8.0	4.0	5.1	Surface
	37.0	30.0	34.00	8.0	4.0	5.2	4 m
Other hardness	16.0	11.0	13.9	8.0	2.0	4.6	Surface
	17.0	9.0	13.1	7.0	2.0	4.6	4 m
Calcium	9.0	3.0	6.0	2.6	1.2	1.9	Surface
	7.8	3.6	6.0	2.6	1.2	1.8	4 m
Nitrite	0.004	<0.001	0.001	0.002	<0.001	0.002	Surface
	0.004	<0.001	0.001	0.002	<0.001	0.003	4 m
Nitrate	0.30	0.10	0.165	0.20	0.05	0.10	Surface
	0.30	0.10	0.15	0.10	0.05	0.10	4 m
Phosphate	0.053	0.003	0.020	0.039	0.003	0.016	Surface
	0.0415	0.005	0.020	0.0285	0.005	0.014	4 m

Table 4. A list of the more important groups collected in L. Sillan and L. Dan.

	Sillan (*frame*)						Sillan (*fixed time*)			Dan (*frame*)			Dan (*fixed time*)		
	1	2	3	4	5	6	*1*	*5*	*6*	1	2	3*	*1*	*2*	*3*
"Non-insects"															
Amphipoda:	3,970	2,183	2,867	773	379	935	*646*	*607*	*713*	—	—	—	—	—	—
Isopoda:	465	1,232	284	735	611	949	*470*	*72*	*471*	—	—	—	—	—	—
Tricladida:	195	189	219	152	396	39	*10*	*54*	*3*	—	—	—	—	—	—
Gastropoda:	19	107	229	74	1,639	100	*1*	*33*	*19*	—	1	1	—	—	—
Bivalvia:	15	2	33	143	153	70	—	*8*	*61*	—	—	—	—	*1*	—
Hirudinea:	6	12	13	35	6	15	—	*1*	*23*	25	33	37	*4*	*6*	*50*
Oligochaeta:	243	98	318	416	352	280	*9*	*48*	*61*	543	482	185	*463*	*352*	*110*
"Insects"															
Chironomidae:	793	667	463	1,058	436	412	*231*	*95*	*248*	196	569	158	*342*	*279*	*199*
Trichoptera:	361	167	279	181	264	59	*105*	*178*	*63*	1,315	124	110	*578*	*284*	*165*
Coleoptera:	429	35	67	32	53	5	*17*	*4*	*2*	328	89	24	*87*	*196*	*27*
Ephemeroptera:	82	5	83	139	323	2	*111*	*7*	*1*	103	208	472	*167*	*781*	*2,246*
Acarina:	34	10	22	41	61	1	—	—	—	9	1	4	—	*1*	*8*
Other Diptera:	6	2	26	17	16	1	—	—	—	42	5	4	*6*	*16*	—
Corixidae:	—	—	—	2	—	8	—	—	*148*	—	—	47	—	—	*163*
Plecoptera:	36	—	1	—	—	—	*8*	—	—	159	142	27	*19*	*104*	*105*

*This station was inaccessible January 1971. For comparative purposes, the totals for February 1971 have been doubled.

Note: For clarity, *Sialis lutaria* (L.) has been omitted from the table. This insect was only collected at Station 6 (L Sillan). Frame: Aggregate of twelve monthly samples taken with a frame (1/16 sq. m), January-December 1971. Total numbers given for this period. Fixed time: Aggregate of two five-minute rake and net samples, taken separately in August 1973 and March 1974 Total numbers given. The stations are arranged in decreasing order of exposure, starting with Station 1.

Table 5. Relative numbers of the more important taxa collected by frame.

	L. Sillan						L. Dan		
Faunal Taxa	1	2	3	4	5	6	1	2	3
Gammarus duebeni (Amphipoda)	3,970	2,183	2,867	773	379	935	—	—	—
Haliplidae spp. larvae (Coleopt.)	334	7	8	1	4	1	+	—	—
Microtendipes sp. (Chironomid.)	637	396	315	569	310	181	31	101	53
Polycentropus flavomaculatus (Trichopt.)	119	97	74	41	10	14	90	7	1
Lepidostoma hirtum (Trichopt.)	43	12	2	4	6	—	37	30	3
Heptagenia sulphurea (Ephemeropt.)	39	—	—	3	—	—	—	—	—
Asellus aquaticus (Isopoda)	465	1,232	284	735	611	949	—	—	—
Planorbis carinatus (Mollusca)	1	89	3	—	6	75	—	—	1
Lymnaea peregra (Mollusca)	1	3	41	1	4	5	—	1	—
Glyptotendipes sp. (Chironomid.)	42	29	68	240	58	81	8	2	18
Potamopyrgus jenkinsi (Mollusca)	6	1	166	59	1,538	11	—	—	—
Polycelis nigra/tenuis grp. (Triclad.)	178	179	197	120	380	37	+	—	—
Caenis horaria (Ephemeropt.)	7	2	15	41	155	—	1	2	—
C. moesta (Ephemeropt.)	23	2	43	83	154	1	—	—	—
Pisidium spp. (Mollusca)	15	2	33	143	152	70	+	+	+
Anabolia nervosa (Trichopt.)	11	13	43	25	107	13	—	+	4
Limnephilus vittatus (Trichopt.)	25	18	40	20	91	8	—	—	—
Planorbis leucostoma (Mollusca)	—	—	1	1	53	5	—	—	—
Sialis lutaria (Megalopt.)	—	—	—	—	—	73	—	—	—
Tinodes waeneri (Trichopt.)	104	9	7	35	4	—	1,105	19	1
Elminthidae spp. larvae (Coleopt.)	48	16	25	15	25	—	211	49	11
Chloroperla torrentium (Plecopt.)	36	—	1	—	—	—	100	57	11
Oulimnius tuberculatus (Coleopt.)	35	3	28	4	14	—	100	21	2
Amphinemura sulcicollis (Plecopt.)	—	—	—	—	—	—	25	21	1
Nemoura avicularis (Plecopt.)	—	—	+	—	—	—	6	62	15
Helobdella stagnalis (Hirudinea)	1	9	3	23	+	9	5	28	21
Leptophlebia vespertina (Ephemeropt.)	4	—	24	1	8	1	102	206	472

Note: The presented totals represent an aggregate of twelve monthly samples (January-December 1971). Station 3 (L. Dan) was inaccessible January 1971. For comparative purposes, the totals for February 1971 have been doubled. + indicates that specimens were taken in qualitative collections. The stations are arranged in decreasing order of exposure, starting with Station 1.

Table 6. Sublittoral fauna of Loughs Sillan and Dan.

	L. Sillan	L. Dan
Peloscolex ferox (Oligochaeta)	27	15
Tubificidae spp. (Oligochaeta)	268	15
Lumbriculus variegatus (Oligochaeta)	—	30
Stylodrilus heringianus (Oligochaeta)	—	15
Procladius/Psilotanypus sp. (Chironomid.)	47	9
Psectrotanypus sp. (Chironomid.)	1	—
Chironomus sp. *bathophilus* type (Chironomid.)	162	12
Chironomus sp. *plumosus* type (Chironomid.)	32	—
Cryptochironomus sp. (Chironomid.)	8	3
Glyptotendipes sp. (Chironomid.)	5	6
Limnochironomus sp. (Chironomid.)	2	—
Pseudochironomus sp. (Chironomid.)	26	3
Polypedilum sp. (Chironomid.)	5	—
Stictochironomus sp. (Chironomid.)	—	6
Microspectra sp. (Chironomid.)	2	—
Chaoborus sp. (Culicid.)	8	3
Acarinid nymphs (Hydrac.)	3	—
Pisidium spp. (Bival.)	35	—
Sphaerium corneum (Bival.)	9	—
Total number of grabs	35	15

For comparative purposes, totals represent approximate density per square metre and littoral migrants (*sensu* Humphries, 1936) have been omitted.

Appendix

Faunal list

S = L. Sillan; D = L. Dan; 1, 2, 3, etc. = littoral sampling stations; sl = sublittoral region; p = profoundal region; A = Only adults of these Trichoptera definitely identified.

Platyhelminthes—Tricladida

Dendrocoelum lacteum (Müller) : S 1, 2, 3, 4, 5, 6.

Dugesia polychroa (Schmidt) : S 1, 2, 3, 4, 5.

Polycelis nigra (Müller) : S 1, 2, 3, 4, 5, 6; D 1.

P. tenuis Ijima : S 1, 2, 3, 4, 5, 6.

Annelida—Oligochaeta

Aulodrilus pluriseta (Piguet) : S 1, 2, 3, 4, 5, 6; D 2, 3, p.

Eiseniella tetraedra (Savigny) : S 1, 2, 3, 4, 5.

Enchytraeidae spp. : S 1, 2, 3, 4, 5, 6, sl; D 1, 2, 3, sl.

Limnodrilus claparedeianus Ratzel : S 4.

L. hoffmeisteri Claparède : S 2, 3, 4, sl; D 2.

L. udekemianus Claparède : S 4.

Lumbriculus variegatus (Müller) : S 1, 2, 3, 4, 5, 6; D 1, 2, 3, sl.

Nais communis Piguet : S 4.

N. simplex Piguet : S 4.

Peloscolex ferox (Eisen) : S 1, 2, 3, 4, 5, 6, sl; D 1, 2, 3, sl.

Potamothrix hammoniensis (Michaelsen) : S 4.

Rhyacodrilus coccineus (Vejdovsky) : S 4, D 2.

Stylaria lacustris (L.) : S 4, 5; D 2.

Stylodrilus heringianus Claparède : S 1, 2, 3, 4, 5, 6; D 1, 2, 3, sl.

Tubifex ignotus (Stolc) : S 1, 2, 3, 4, 5, 6; D 1, 2, 3.

Tubificidae spp. : S 1, 2, 3, 4, 5, 6, sl; D 1, 2, 3, sl, p.

Annelida—Hirudinea

Erpobdella octoculata (L.) : S 1, 2, 3, 4, 6, sl; D 1, 2, 3, sl.

Glossiphonia complanata (L.) : S 3, 4, 5.

Haemopis sanguisuga (L.) : S 1, 2, 3, 4, 5.

Helobdella stagnalis (L.) : S 1, 2, 3, 4, 5, 6, sl; D 1, 2, 3, sl.

Theromyzon tessulatum (Müller) : S 6.

Arthropoda

Crustacea—Isopoda

Asellus aquaticus (L.) : S 1, 2, 3, 4, 5, 6, sl.

Crustacea—Amphipoda

Gammarus duebeni Lilljeborg : S 1, 2, 3, 4, 5, 6, sl.

Insecta—Plecoptera

Amphinemura sulcicollis (Stephens) : D 1, 2, 3.

Chloroperla torrentium (Pictet) : S 1, 3; D 1, 2, 3.

Isoperla grammatica (Poda) : D 1, 2.

Nemoura avicularis Morton : S 3; D 1, 2, 3.

N. cinerea (Retzius) : D 2.

Protonemura meyeri (Pictet) : D 1.

Insecta—Ephemeroptera

Baëtis rhodani (Pictet) : S 4.

Caenis horaria (L.) : S 1, 2, 3, 4, 5, sl; D 1, 2.

C. moesta Bengtsson : S 1, 2, 3, 4, 5, 6.

Cloëon dipterum (L.) : S 6.

Ephemera danica Müller : S 1, 3, 4, 5.

Heptagenia fuscogrisea (Retzius) : S 1, 2, 3, 4, 5.

H. sulphurea (Müller) : S 1, 4.

Leptophlebia vespertina (L.) : S 1, 3, 4, 5, 6; D 1, 2, 3.

Siphlonurus lacustris Eaton : D 3.

Insecta—Odonata

Coenagrion puella (L.) : S 3, 6; D 3.

Enallagma cyathigerum (Charpentier) : S 6; D 3.

Insecta—Hemiptera

Callicorixa praeusta (Fieber) : S 6.

Corixa dentipes (Thomson) : S 6.

C. punctata (Illinger) : S 6.

Gerris lacustris (L.) : S 6; D 3.

Hydrometra stagnorum (L.) : S 4, 6; D 2.

Micronecta poweri (Douglas and Scott) : S 1, 4, 5,; D 1, 2.

Nepa cinerea L. : S 1.

Notonecta glauca L. : S 6; D 3.

Sigara distincta (Fieber) : S 6.

S. dorsalis (Leach) : S 6; D 3.

S. falleni (Fieber) : S 6.

S. venusta (Douglas and Scott) : D 3.

Velia saulii Tamanini : D 1.

Insecta—Megaloptera

Sialis lutaria (L.) : S 6.

Insecta—Trichoptera

Agraylea multipunctata Curtis : S 1; D 2.
Agrypnia pagetana Curtis : S 4, 6.
Anabolia nervosa (Curtis) : S 1, 2, 3, 4, 5, 6; D 2, 3.
Athripsodes aterrimus (Stephens) : D-A.
A. cinereus (Curtis) : S-A; D-A.
A. dissimilis (Stephens) : S-A.
A. fulvus (Rambur) : S-A; D-A.
A. senilis (Burmeister) : S-A.
Athripsodes spp. : S 1, 2, 3, 5; D 1, 2, 3.
Chaetopteryx villosa (Fabricius) : D-A.
Cyrnus flavidus McLachlan : S 2, 3, 5, 6, sl.
C. trimaculatus (Curtis) : S 2, 6; D 3.
Ecnomus tenellus (Rambur) : S 3, 4.
Glyphotaelius pellucidus (Retzius) : S-A.
Goera pilosa (Fabricius) : S 1, 2, 3, 4, 5, sl.
Grammotaulius atomarius (Fabricius) : S-A.
Halesus radiatus (Curtis) : S-A; D-A.
Halesus sp. : S 1, 2, 3, 4, 5, 6; D 1, 2, 3.
Holocentropus picicornis (Stephens) : S 3, 4, 6; D 3.
Hydroptila cornuta Mosely : D-A.
H. tineoides Dalman : S-A; D-A.
Hydroptila spp. : S 4; D 1, 2, 3.
Lepidostoma hirtum (Fabricius) : S 1, 2, 3, 4, 5; D 1, 2, 3,.
Leptoceridae sp. : S sl.
Limnephilus auricula Curtis : D-A.
L. centralis Curtis : D-A.
L. flavicornis (Fabricius) : S-A.
L. lunatus Curtis : S 1, 2, 3, 4, 5, 6; D 3.
L. luridus Curtis : D-A.
L. marmoratus Curtis : S-A; D-A.
L. nigriceps (Zetterstedt) : S-A.
L. sparsus Curtis : D-A.
L. vittatus (Fabricius) : S 1, 2, 3, 4, 5, 6; D-A.
Limnephilus spp. *flavicornis* grp : S 1, 2, 3, 4, 5, 6; D 1, 2, 3.
Limnephilus sp. *nigriceps* grp : S 6.
Limnephilidae sp. : S sl.
Molanna palpata McLachlan : S 1, 3, 4.
Mystacides azurea (L.) : S 1, 3, 6; D 3.
M. longicornis (L.) : S 6; D-A.
Oecetis lacustris (Pictet) : S-A; D-A.
O. ochracea (Curtis) : S-A.
Oecetis spp. : S 3, 5, 6, sl; D 1.

Oxyethira flavicornis (Pictet) : S-A; D-A.
Oxyethira spp. : D 1, 2, 3.
Phryganea grandis L. : S 6.
P. obsoleta McLachlan : S-A.
P. striata L. : S 6.
P. varia Fabricius : S 3, 4, 6; D 2, 3.
Plectrocnemia conspersa (Curtis) : D 2, 3.
Polycentropus flavomaculatus (Pictet) : S 1, 2, 3, 4, 5, 6, sl; D 1, 2, 3, sl.
P. irroratus (Curtis) : S 3; D-A.
P. kingi McLachlan : D-A.
Potamophylax cingulatus (Stephens) : D-A.
P. latipennis (Curtis) : S-A; D-A.
Potamophylax sp. : S 4, 5; D 1, 2.
Rhyacophila dorsalis (Curtis) : D 1.
Sericostoma personatum (Spence) : S 1, 2, 3, 4, 5; D 1, 2.
Tinodes waeneri (L.) : S 1, 2, 3, 4, 5; D 1, 2, 3, sl.
Triaenodes bicolor (Curtis) : S-A.

Insecta—Coleoptera
Agabus bipustulatus L. : S 6.
Deronectes 12-pustulatus Olivier : S 1, 2, 3, 4, 5; D 2, 3.
Dytiscidae spp. : S 2; D 3.
Elminthidae spp. : S 1, 2, 3, 4, 5; D 1, 2, 3.
Gyrinus distinctus Aube : D 2.
G. marinus Gyllenhal : S 3, 5, 6.
G. natator L. : S 5; D 3.
Gyrinidae spp. : S 1, 2, 4, 6; D 2, 3.
Haliplus confinis Stephens : S 1, 2, 3, 4, 5, 6.
Haliplidae spp. : S 1, 2, 3, 4, 5, 6, sl; D 1.
Hydroporus sp. : S 4; D 1, 3.
Limnius volckmari (Panzer) : D 2, 3.
Limnius spp. : S 1, 2, 4, 5, 6; D 1, 2, sl.
Orectochilus villosus Müller : S 4.
Oreodytes borealis Gyllenhal : D 1, 2.
Oulimnius tuberculatus (Müller) : S 1, 2, 3, 4, 5; D 1, 2, 3, sl.
Rhantus exsoletus Forster : S 6.

Insecta—Diptera
Ablasbesmyia sp. : S 1, 3, 5, 6; D 1, 2, 3, p.
Atanytarsus sp. : S 3.
Bezzia spp. : S 1, 2, 3, 4, 5, 6; D 1, 2, 3.
Brilla sp. : S 3; D 1, 2, 3, sl.

Chaoborus sp. : S sl; D sl.
Chironomus sp. *bathophilus* type : S 1, 2, 3, 4, 5, 6, sl; D 3, sl.
Chironomus sp. *plumosus* type : S 2, 4, 5, 6.
Cricotopus sp. : S 3; D 1, 2.
Cryptochironomus sp. : S 2, 3, 4, 5, sl; D 1, 2, 3, sl, p.
Dicranota sp. : D 1.
Dicrotendipes sp. : S 2, 4, 5.
Endochironomus sp. : S 1, 2, 3, 4, 5, 6, sl.
Glyptotendipes sp. : S 1, 2, 3, 4, 5, 6, sl; D 1, 2, 3, sl.
Microspectra sp. : S sl.
Microtendipes sp. : S 1, 2, 3, 4, 5, 6, sl; D 1, 2, 3.
Paratanytarsus sp. : S sl.
Polypedilium sp. : S 1, 2, 3, 4, 5, sl.
Procladius/Psilotanypus sp. : S 1, 3, 4, 5, 6, sl; D 1, 2, 3, sl, p.
Psectrocladius sp. : S 5, 6.
Psectrotanypus sp. : S sl.
Pseudochironomus prasinatus (Staeger) : S 4.
Stictochironomus sp. : S 1, 3, 4, 5, 6, sl; D 1, 2, 3, p.
Synorthocladius semivirens (Kieffer) : S 1.
Tanytarsus sp. : S 3, sl; D 2.
Tipula spp. : S 3, 5; D 1, 2, 3.

Arachnida—Acarina
Arrenurus leuckarti Piersig : D 1, 3.
Eylais extendens (Müller) : S 5.
Hygrobates fluviatilis (Strom) : S 1, 2, 3, 4, 5.
H. longipalpis (Hermann) : S 3, 4, 5.
Lebertia curvipalpis Halbert : S 1, 2, 3, 4, 5, 6.
L. porosa Thor : S 1, 3, 4, 5.
Lebertia sp. : S 2, 4, 5.
Limnesia maculata (Müller) : S 1, 2, 3, 4, 5, 6; D 1, 2, 3.
L. undulata (Müller) : S 3, 4, 5.
Limnesia sp. : S 2, 4, 5.
Limnochares aquatica (L.) : D 3.
Mideopsis orbicularis (Müller) : S 4.
Neumania callosa (Koenike) : D Plankton.
Piona coccinea (Koch) : S 4.
P. disparilis (Koenike) : D 2, 3.
P. longipalpis (Krendowsky) : D 2.
P. neumani (Koenike) : S 3, 4.
P. variabilis (Koch) : S 2, 4, 5; D 1, 3.
Piona sp. : S 4.

Thyas rivalis Koenike : D 1.
Unionicola crassipes (Müller) : S 1, 4.

Mollusca—Gastropoda
Ancylus fluviatilis Müller : S 1, 2, 3, 4, 5.
Bithynia tentaculata (L.) : S 1, 2,
Lymnaea peregra (Müller) : S 1, 2, 3, 4, 5, 6; D 2.
L. stagnalis (L.) : S 6.
Myxas glutinosa (Müller) : S 3, 4, 5.
Physa fontinalis (L.) : S 3, 4, 5.
Planorbis albus Müller : S 1, 2, 3, 4, 5, 6.
P. carinatus Müller : S 1, 2, 3, 4, 5, 6; D 3.
P. laevis Alder : S 2, 6.
P. leucostoma Millet : S 3, 4, 5, 6.
P. planorbis (L.) : S 2, 5.
Potamopyrgus jenkinsi (Smith) : S 1, 2, 3, 4, 5, 6.
Valvata piscinalis (Müller) : S 1.

Mollusca—Lamellibranchiata
Pisidium spp. : S 1, 2, 3, 4, 5, 6, sl; D 1, 2, 3.
Sphaerium corneum L. : S 5.

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(8969)126203. 750. 12-79. F.P.—G3.