

Best wishes,  
Pete C. Hunt,

## The effect of water level fluctuations on a littoral fauna

P. C. HUNT AND J. W. JONES

*Department of Zoology, University of Liverpool, Liverpool, England*

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The littoral fauna of Llyn Tegid, North Wales, in 1968/9 is compared with the results of similar faunal investigations made by Rothwell (née Dunn) in 1951/2 (Dunn, 1953) and Hynes in 1957 and 1959 (Hynes, 1961). The results show the long term effects upon the littoral fauna of the change in mean water level and the increased water level fluctuations produced for a time by the controlled outflow scheme, which came into operation in 1955. In 1961 Hynes recorded big reductions in numbers and variety of invertebrates living in the littoral zone. The reduced water level fluctuations in recent years has resulted in a re-establishment of some of the fauna.

### I. INTRODUCTION

The conversion of natural lakes into reservoirs for water supply and flood and drought control schemes results in changes in the level of the water. Changes in the mean level and increased fluctuations about the new mean, inevitably affect the littoral fauna. The effects are 2-fold. The fauna may be affected directly when organisms are left stranded by the receding flood water and the animals die of dessication. The ability of a species to follow changes in water level will determine its survival. Secondly, the change in mean level and increased fluctuations will not only alter the physical nature of the bottom, but result in loss of macrovegetation. Many species are deprived of a habitat and may be replaced either by new species or by increased numbers of existing species which are favoured by the new conditions. The changes that occur in the littoral zone will in turn affect the feeding and growth of fish.

Llyn Tegid is a mesotrophic lake lying in the hilly county of Merionethshire, North Wales, at an altitude of 164 m. Before 1955 the outlet from the lake was controlled by sluices constructed by Thomas Telford in the early years of the 19th century so that the water level fluctuated over a range of 2 m. A further control outflow scheme came into operation in 1955 which enabled the lake to be controlled over a range of 4.3 m (14 ft) by reducing the minimum lake level. This provided short term detention capacity to control floods in the river downstream and water for release into the river to maintain flow during periods when it would naturally fall below this flow. Llyn Tegid storage water was kept as low as possible in the winter for flood prevention and about  $\frac{1}{3}$  full in the summer, providing some water storage during the potential drought season. This was the reverse of the pre-1955 situation where winter rains kept the lake level up. The mean winter water level is 3 m lower than it was before the present scheme came into operation.

The littoral fauna of Llyn Tegid has been investigated twice previously. In 1951 and 1952, Dr D. R. Rothwell (née Dunn) made an extensive study of the fauna (Dunn, 1953, 1961) and in February of 1957 and 1959, Dr H. B. N. Hynes (1961) repeated the observations at some of Rothwell's shore stations. The present investigation was

Present address: Fisheries Research Division, Ministry of Agriculture & Fisheries,  
P.O. Ngapuna, Rotorua, NEW ZEALAND

intended to show the long term effects of the change in water level and the resulting increased water level fluctuations upon the littoral fauna of Llyn Tegid. Benthic fauna results are compared with those observed before and immediately after the barrage was installed in 1955.

Though water was theoretically not allowed to recede at a rate exceeding 15 cm a day, the lake level fluctuated widely and irregularly during the early years after the present barrage was constructed. Hynes (1961) showed that many species were lost as a result of the fluctuations and that new and dominant species had appeared. Hynes stated that a whole series of changes was started in the littoral zone when a lake becomes a reservoir and that many years would probably elapse before the position was again stabilized. Fluctuations were less violent in recent years primarily as a result of the construction of Llyn Celyn, an impounding reservoir on the Afon Tryweryn, 7 km north west of Bala. Water from Llyn Celyn effectively passes through Llyn Tegid before reaching the Afon Dyfrydwy (River Dee). Fluctuations in the years 1967 to 1969 were similar to those recorded before 1955 though the mean water level was approximately 2 m lower.

Hynes recorded a considerable alteration in the general appearance of the shores when the lake level was first dropped. The stony exposed shores remained so, but the lower parts were more silty than before the change. The sheltered shores gave way to gritty mud at 1 m below the previous mean water level, and then to soft and dangerous mud. The physical nature of the shoreline has changed little since Hynes made his observations, except that exposed shores are now more rocky. Mud has been removed by wave action. When the level of the lake is low all shores at 1 m depth are of soft mud. Rooted vegetation occurs to a depth of 3 m. The stony-silty exposed areas have little vegetation apart from algae and *Fontinalis* sp. *Littorella* sp. is dominant in the more sheltered shores. Macro-vegetation has increased considerably since Hynes made his observations.

## II. METHODS

Faunal sampling in the littoral zone of Llyn Tegid commenced in March 1968. Though not entirely satisfactory, a similar technique to that used by Rothwell and Hynes was adopted. A quantitative 'bin' sampler, similar in principle to that used by Berg (1938) was driven into the substratum and the contents removed with a hand net (F.B.A. type B, 20 meshes/in) into a large floating sieve (30 meshes/in). Double 'bin' samples were taken and combined. Large stones were washed and discarded. Any remaining mud was sieved from the sample and the resulting plant material, small stones and animals were transferred from the sieve to polythene bottles and taken to the laboratory. 3 min net sweeps were also taken at the same site, on each occasion, in addition to the 'bin' samples. The net samples were treated separately and have been used to adjust the results from 'bin' samples so that species occurring in small numbers in the fauna, and not taken in the drum, are included in the description. Two 'bin' samples and a 3 min net sweep were taken monthly at stations A, B, C, D, I and H shown in Fig. 1. A, B and D are sheltered shores whereas C, I and H are exposed shores.

All benthic fauna workers have criticized techniques used in sampling the littoral fauna. The distribution of fauna in the shallow areas of lakes is more uneven than in the profundal fauna. The littoral contains considerably more diverse environments and species in one area of a lake may be totally different from those in another area. Improvements upon existing littoral techniques consist entirely of increasing numbers of samples and sampling sites. The use of the 'bin' sampler provided results equally quantitative in comparison with the results of other workers, though very large numbers of samples would have been necessary to estimate the actual mean density of a species in any area of a reservoir, thus the density values given are approximate. The numbers of some species will be overestimated, others underestimated and it is possible that some species present in Llyn Tegid have not been recorded.

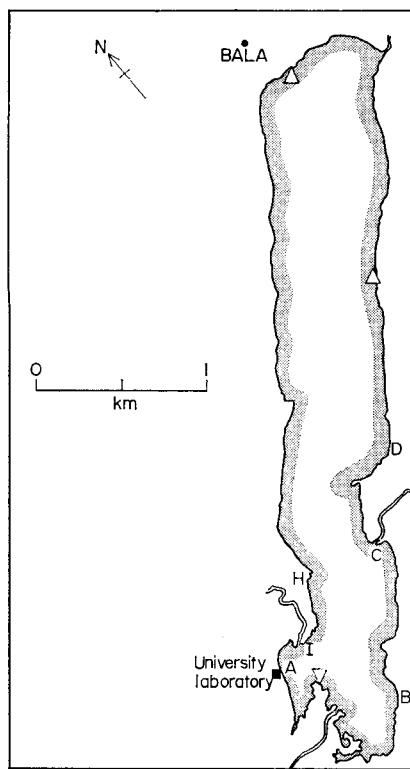


FIG. 1. Llyn Tegid sampling stations. A-I, Regular stations;  $\Delta$ , occasionally sampled.

### III. RESULTS

#### 1. WATER LEVEL FLUCTUATIONS

Records of daily water level fluctuations were supplied by the Dee and Clwyd River Authority. Apart from irregular rises in January and March 1968, the majority of the readings lay between 524 and 527 ft (159.7–160.6 m) above sea level. The winter water level was usually maintained at 524–525 ft (159.7–160.0 m) above sea level whereas the summer level (mid June to mid October) was maintained at between 526 and 527 ft (160.3–160.6 m) above sea level. The level remained above 527 ft (160.6 m) above sea level for only very short periods. Analysis of level fluctuations during the period 1955 to 1965 has shown wider, more irregular and rapid changes. In winter months, fluctuations throughout the maximum range of 522 to 536 ft (159.1 to 163.4 m) above sea level were common and long periods at 530 ft (161.5 m) were recorded. The water level was allowed to recede at 60–90 cm/day after heavy rains. This is greater than the theoretical maximum permitted.

#### 2. THE LITTORAL FAUNA

All animals were identified to species as far as possible. Table I shows the occurrence and distribution of all animals recorded in the littoral zone of Llyn Tegid. An assessment of the abundance of each animal in the profundal zone is also shown (Hunt, 1970).

#### IV. DISCUSSION

Considerable changes in the littoral fauna of Llyn Tegid have occurred during the last 20 years and these are summarized in Table II.

In 1957 Hynes found that the Porifera, Turbellaria, Naididae, *Eiseniella* sp., Hirudinea, Gastropoda, *Gammarus* sp., Hydracarina, Plecoptera, Ephemeroptera, some Corixidae and Trichoptera had almost completely disappeared from the littoral zone of Llyn Tegid as a result of its conversion to a reservoir. A reduction in the mean water level converted stony shorelines to muddy shores. Increased water level fluctuations stranded many species when the water level receded and destroyed much of the existing macrovegetation which was important as food, shelter and a place where many species deposited eggs. Mollusca, Coleoptera, Hemiptera, Odonata and Ephemeroptera suffered because they were dependent upon the existence of the macrovegetation in their environment. The losses of mobile forms such as *Gammarus* sp., Hydracarina, Coleoptera and Corixidae etc., resulted from the physical change in the littoral environment not the water level fluctuations. This loss was balanced by an enormous increase in the numbers of two worms, *Stylodrilus heringianus* and an unidentified Enchytraeid which inhabit the littoral muddy reaches. After a short period of regulation in Lake Kultsjon, Sweden, the absence of many insects, crustaceans and molluscs was reported by Grimås (1965a). Here also Oligochaeta became predominant and it was suggested by Grimås that it was a short term effect resulting from changes in the bottom deposits. Grimås (1961, 1962, 1964, 1965a, b, c) has also recorded similar changes in several impounded lakes in Norway and Sweden.

In 1959, Hynes showed that some Ephemeroptera, Trichoptera and Plecoptera were slowly returning to the environment since his survey in 1957. A single species, *Caenis moesta*, was completely re-established, but the Oligochaeta were more abundant. In Lake Ransaren, North Sweden, Nilsson (1964) found a sharp decrease in the abundance of bottom animals immediately after interference by man, followed by a reconstruction of the fauna. In all previous investigations on this topic, the changes induced by the impoundment of natural lakes has reduced the littoral fauna and in effect the availability and utilization of the fauna as fish food is also reduced. It is not surprising that Graham (1960) reported a poorer trout growth in 1959/60 compared with pre-impoundment (Ball & Jones, 1960). The earlier predominant food items, *Gammarus pulex* and Trichoptera were replaced in the diet by Oligochaeta and Chironomidae. 45% of the food utilized by the trout in the earlier survey had disappeared and consequently the growth rate was much reduced.

Usually littoral fauna reduction is followed by a period of stabilization in which new species are established or old species re-established to the new conditions and as stated by Hynes (1961) many years may elapse before stabilization is reached. The effects of a minor adjustment to the level of a lake may therefore influence the rate of growth of fish for many years.

The 1968/9 littoral fauna survey of Llyn Tegid has shown the long term effects of regulation upon what was previously a natural lake. The stabilization period was accelerated by a reduction of water level fluctuations which created similar fluctuations to those experienced by the animals before the impoundment scheme. The mean lake level was lower than in the previous period. Yet all the groups of animals recorded before the impoundment in 1955 were found in 1968/9 and most were fully re-established (Table II).

TABLE 1. Llyn Tegid littoral fauna

							6-40 m profundal zone								6-40 m profundal zone
Species	A	B	C	D	I	H		Species	A	B	C	D	I	H	
(a)															
<i>Polycelis nigra</i>		⊖	⊖	⊖	⊖			<i>Limnaea pereger</i>		⊖	⊖	⊖	⊖	⊖	I
<i>Helobdella stagnalis</i>	⊖	⊖	I	⊖	⊖	⊖	⊖	<i>Planorbis contortus</i>		I					
<i>Glossiphonia complanata</i>	⊖	⊖		⊖		I	⊖	<i>Pisidium</i> sp.	⊖	⊖	⊖	⊖		⊖	⊖
<i>Erpobdella octoculata</i>	⊖	⊖	⊖	⊖	I	⊖	⊖	<i>Gammarus pulex</i>		⊖	⊖	⊖	I	I	
Naididae		⊖	⊖	⊖				<i>Asellus meridianus</i>	⊖	⊖	⊖	⊖	I	⊖	⊖
<i>Pelosclex ferox</i>	⊖	⊖		⊖	I	I	⊖	<i>Megapus spinipes</i>	⊖	⊖	⊖	⊖	⊖	⊖	I
<i>Aulodrilus plurisetus</i>	⊖	I			⊖	⊖	⊖	<i>Libertia porosa</i>	⊖	⊖	⊖	⊖	⊖	⊖	
<i>Tubifex ignotus</i>	⊖	⊖					⊖	<i>Limnesia maculata</i>	⊖	⊖	I	⊖			⊖
<i>Euliyodrilus hammoniensis</i>		⊖		I				<i>Piona coccinea</i>	⊖	I	I	I			⊖
<i>Bothrioneurum vejvodskyanum</i>		⊖						<i>Midea orbiculata</i>	⊖						⊖
<i>Limnodrilus hoffmeisteri</i>	⊖	⊖			I	⊖	⊖	<i>Arrhenus</i> sp. ( <i>truncatellus</i> ?)	⊖						
Enchytraeidae	I	⊖	⊖	⊖	⊖	⊖		<i>Mideopsis orbicularis</i>	⊖						
<i>Lumbriculus variegatus</i>	⊖	⊖		⊖		⊖	⊖	<i>Wettina podagrica</i> (?)	I						
<i>Stylodrilus heringianus</i>	⊖	⊖	⊖	⊖	⊖	⊖	⊖	<i>Unionicola crassipes</i>			I		I		
<i>Epilodrilus lacustris</i>	⊖	⊖	⊖	⊖	⊖	⊖		<i>Nemoura avicularis</i>	I	⊖	⊖	⊖		I	
<i>Valvata piscinalis</i>	I			I			⊖	<i>Leuctra hippopus</i>		⊖	⊖	⊖		I	
<i>Valvata macrostoma</i>				I				<i>Diura bicaudata</i>				⊖			
<i>Ancylastrum fluviatile</i>		⊖	⊖	⊖		I		<i>Isoperla grammatica</i>				⊖			
<i>Limnaea glabra</i>			I		I			<i>Chloroperla torrentium</i>	I	I	⊖	⊖			
<i>Limnaea truncatula</i>	I	I	I	⊖				<i>Ephemera danica</i>	⊖	⊖	⊖	⊖	⊖	⊖	I
(b)															
<i>Caenis moesta</i>	⊖	⊖	⊖	⊖	⊖	⊖	I	<i>Limnephilus lunatus</i>	I		I	⊖			
<i>Ephemerella ignita</i>	⊖		⊖	I	I			<i>Limnephilus rhombicus</i>				⊖	⊖		
<i>Ecdyonurus venosus</i>			⊖	I	I			<i>Limnephilus</i> sp.				I	⊖		
<i>Leptophlebia marginata</i>		⊖	⊖	⊖	I	⊖		<i>Glyptotaelius pellucidus</i>				⊖			
<i>Siphonurus lacustris</i>				⊖				<i>Anabolia nervosa</i>	⊖	I					
<i>Baetis</i> sp.	⊖	⊖	⊖	I				<i>Potomophylax latipennis</i>	I	⊖	⊖	⊖	I		
<i>Sigara dorsalis</i>	⊖							<i>Halesus digitatus</i>				⊖	I		
<i>Sigara falleni</i>	⊖							<i>Athripsodes aterrimus</i>	⊖	⊖	⊖	⊖		⊖	I
<i>Micronecta poweri</i>	⊖	⊖	⊖	⊖	⊖	⊖		<i>Mystacides azurea</i>	⊖		I	I			
<i>Sialis lutaria</i>	⊖	⊖	⊖	I	⊖	⊖		<i>Mystacides nigra</i>						I	
<i>Rhyacophila dorsalis</i>				⊖				<i>Sericostoma personatum</i>		I	⊖	⊖			
<i>Agapetus fuscipes</i>				⊖	⊖	I		<i>Goera pilosa</i>			⊖				
<i>Agraylea multipunctata</i>				⊖				<i>Lepidostoma hirtum</i>	⊖	⊖		⊖			
<i>Oxythira</i> sp.	I							<i>Haliplus fluviatilis</i>	⊖	⊖	I	⊖			
<i>Philopotamus montanus</i>				I				<i>Graptodytes septentrionalis</i>	⊖		⊖	⊖	I	⊖	
<i>Plectrocnemia conspersa</i>		⊖		⊖		I		<i>Graptodytes pictus</i>			I				
<i>Polycentropus flavomaculatus</i>	I		⊖	I				<i>Hydroporus</i>			I				
<i>Cynurus trimaculatus</i>	⊖	⊖		I	⊖	⊖	⊖	<i>duodecempustulatus</i>							
<i>Tinodes waeneri</i>		⊖	I	⊖	I	⊖		<i>Hydroporus elegans</i>	⊖			I			
<i>Hydropsyche instabilis</i>		I	I					<i>Hydroporus marginatus</i>			I				
<i>Phryganea grandis</i>	I		I					<i>Platambus maculatus</i>	I						
(c)															
<i>Helophorus affinis</i>		I						<i>Dicrotendipes pulsus</i>	I			I	I	⊖	
<i>Hydraena rufipes</i>		I						<i>Pseudochironomus</i> sp.				I	I		
<i>Limnius tuberculatus</i>	I	⊖		⊖				<i>Polypedilum</i> sp.	⊖						I
<i>Tipula</i> sp.	⊖	⊖	⊖	⊖	⊖	⊖		<i>Chironomus 'thummi'</i>	⊖						⊖
<i>Dicranota</i> sp.		⊖	⊖	I	⊖										
<i>Tubifera</i> sp.	I														
Diptera larvae Indet.	⊖	⊖	⊖	I		I									
Ceratopogonidae	⊖	⊖	⊖	⊖	⊖	⊖	⊖								
Orthocladiinae	⊖	⊖		I	⊖	I	⊖								
<i>Procladius choreus</i>	⊖	⊖		I	I	I	⊖								
<i>Pentaneura 'monilis'?</i>	⊖						⊖								
<i>Procladius olivacea</i>	⊖	⊖		I	⊖	⊖	⊖								
<i>Tanytarsus</i> sp.	⊖	⊖			I	⊖	⊖								
<i>Stictochironomus pictulus</i>	⊖	⊖	I	⊖	⊖	⊖	⊖								
<i>Sergentia coracinus</i>		I					⊖								
<i>Microtendipes diffinis</i>		⊖	I	I		I	I								
<i>Cryptochironomus defectus</i>	⊖	⊖		⊖	I	⊖	⊖								⊖
<i>Glyptotendipes</i> sp.		⊖			I										
<i>Endochironomus</i> sp.		I					⊖								
<i>Polypedilum nubeculosum</i>					I		⊖								

⊖ = Rare, occasional or in small numbers  
⊖ = Regular, though not abundant  
⊖ = Abundant and regular  
I = Single recording

Number of months in twelve in which species occurred  
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The turbellarian, *Polycelis nigra*, was recorded at all stations when the water level was low. This species did not move up with rising water levels although the rapid change from a stony to muddy shoreline in the first years of increased fluctuations after impoundment probably resulted in its loss from sheltered shorelines. *Polycelis nigra* has possibly adapted itself to the new conditions and its abundance is now similar to that before impoundment.

The change in conditions on the shoreline has had a greater effect upon the Oligochaete fauna than on any other class of animals. Four littoral species were recorded by Rothwell in 1951/2. Two of these species, an Enchytraeidae, *Marionina glandulosa*, and a Lumbricidae, *Eiseniella tetraeda*, have disappeared. The third, a Naididae, *Stylaria lacustris*, is much reduced and the Lumbriculidae species, *Lumbriculus variegatus* has retained its position. The reduced species have been replaced by 10 further species, several of which occur in large numbers and have increased the Oligochaete representation in the fauna immensely. Six species of Tubificidae were identified and two of these, *Limnodrilus hoffmeisteri* and *Peloscolex ferox*, were recorded regularly from the sheltered shorelines. Rothwell showed that this family formed a negligible part of the littoral fauna although Hynes found their numbers to have increased in 1957 and 1959. There is little doubt that the increased numbers of Tubificidae is a result of the increased mud. An Enchytraeid, *Henlea* sp., and two further Lumbriculid species, *Stylodrilus heringianus* and *Epilodrilus lacustris* (after Cook, 1967) were recorded in large numbers. The Lumbriculidae now form greater than 70% of the Oligochaete fauna although the only species recorded by Rothwell in 1951/2, *Lumbriculus variegatus*, is now the least abundant species.

The two leeches, *Erpobdella octoculata* and *Glossiphonia complanata*, have reappeared after a complete loss in 1957 and 1959. *G. complanata* is not truly re-established although *E. octoculata* now has a similar distribution and abundance to that described by Rothwell. A third leech, *Helobdella stagnalis*, recorded occasionally on sheltered shores in 1951/2 was not recorded by Hynes, but this species was found in large numbers in 1968/9 whenever the water level was low. This characteristically shallow profundal species is now the second most abundant leech in the littoral zone and it has undoubtedly benefited from the changed conditions.

Of 9 Gastropoda recorded by Rothwell, only *Limnaea pereger* had reappeared in its original numbers after an almost total disappearance in 1957 and 1959. Although 8 species were recorded in the recent survey, only *L. pereger* and *Ancylastrum fluviatile* were regularly recorded. The Lamellibranchiate, *Pisidium lilljeborgii*, is another species which was drastically reduced in numbers after impoundment but which has recovered. The original loss of this species is surprising as *Pisidium* has been shown to move into newly flooded areas in Llyn Celyn where the water level fluctuated over 10 m (Hunt, 1970). The change from a rocky shoreline to mud in Llyn Tegid after 1955 does not explain this disappearance as large numbers inhabit the muddy profundal zone up to 40 m in depth. There is no doubt that the present population is numerically smaller and less continuous in distribution than that described by Rothwell, but much greater than found by Hynes.

The Crustaceans, *Gammarus pulex* and *Asellus meridianus*, are perhaps the most sensitive of invertebrates to increased water level fluctuations and their re-establishment is merely indicative of the decreased fluctuations in recent years. Both species were almost completely lost after increased regulation.

TABLE II. The occurrence and approximate abundance of the littoral fauna of Llyn Tegid

Species	1951-52			February 1957			February 1959			1968-69		
	E	S	No/m <sup>2</sup>	E	S	No/m <sup>2</sup>	E	S	No/m <sup>2</sup>	E	S	No/m <sup>2</sup>
<i>Euspongia lacustris</i>		+	varied									
<i>Polycelis nigra</i>	+	+		+			+		12	+	+	12-42
Naididae	+	+	6-260			18				+	+	6-120
<i>Pelosclex ferox</i>				+	+	36-132	+	+	6	0	+	6-30
<i>Aulodrilus pluriset</i>										+	+	6-12
<i>Tubifex ignotus</i>											0	
<i>Limnodrilus hoffmeisteri</i>										0	+	6-30
Enchytraeidae				+	+	112-516	+	+	6-12	+	+	18-150
<i>Lumbriculus variegatus</i>			150	+	+		+	+	150-342	+	+	60-300
<i>Stylodrilus heringianus</i>				+	+	36-258	+	+	1698	+	+	24-1000
<i>Epicidrilus lacustris</i>										+	+	1200
<i>Eiseniella tetraeda</i>	+	+	150									
<i>Erpobdella octoculata</i>	+	+	12-210				+			+	+	24-180
<i>Glossiphonia complanata</i>	+	+	18							0	0	6
<i>Helobdella stagnalis</i>	0						+		6	+	+	6-54
<i>Limnaea pereger</i>	+		10-20		+		+		6	+	+	6-300
<i>Physa fontinalis</i>		+	10-20								0	
<i>Planorbis contortus</i>		+	12								0	
<i>Ancylastrum fluviatile</i>	+	+	10-20				0			+		6-18
<i>Pisidium lilljeborgii</i>	+	+	170		+	6				+	+	6-288
<i>Gammarus pulex</i>	+	+	60-100							+	+	24-252
<i>Asellus meridianus</i>	+	+	100-700	0	+	6	+		12	+	+	48-228
<i>Lebertia porosa</i>	+	+	10							+	+	12-42
<i>Linesia maculata</i>		+	15								+	6-24
<i>Megapus spinipes</i>		+	10							+	+	12-486
<i>Diura bicaudata</i>	+									0		
<i>Nemoura avicularis</i>	+	+	12-24						0	+		6-24
<i>Leuctra hippopus</i>		0								+	+	12-96
<i>Leptophlebia marginata</i>	+	+	50-2250				0			+	+	18-162
<i>Caenis moesta</i>	+	+	35-800					+	1200	+	+	81-966

<i>Ephemerella danica</i>	+	+	12-20	+	+	+	72-992
<i>Baetis</i> sp.							6-12
<i>Sigara dorsalis</i>	+	+	10-30				6-36
<i>Sigara scotti</i>			10-30				
<i>Sigara falleni</i>							18-54
<i>Micronecta poweri</i>	+	+	common	+	common	+	common
<i>Sialis lutaria</i>	+	+	12		+		12-192
<i>Sericostoma personatum</i>	+	+	36-65				
<i>Agapetus fuscipes</i>	+	+	varied				
<i>Polycentropus flavomaculatus</i>	+	+	6				
<i>Cyrtus trimaculatus</i>						0	
<i>Tinodes waeneri</i>	+	+	250	+		+	6-48
<i>Mystacidides azurea</i>							30-126
<i>Mystacidides nigra</i>			12				6-24
<i>Anabolia nervosa</i>	+	+	30-250				
<i>Limnephilus</i> 3 spp.			44	+	6	0	6-12
<i>Halesus digitatus</i>			84-273				
<i>Potomophylax latipennis</i>	+	+	6-12	+	6	+	6-18
<i>Athripsodes aterrimus</i>							6-24
<i>Graptodytes</i> sp. (= <i>D. depressus</i> )	+	+		+		+	6
<i>Halipilus</i> sp.	+	+	12-30				6-30
<i>Limnius tuberculatus</i>	+	+	30-70				
<i>Tipula</i> sp.			6-80	+	60	18	
<i>Dicranota</i> sp.		0					18-42
<i>Ceratopogonidae</i>	+	+	50-200				6-42
<i>Orthocladinae</i>	+	+	50-200	+	18-30	12	108-362
<i>Prodiamesa olivacea</i>		+		+		6-30	28-84
<i>Tanypodinae</i>				+	6-42	6	12-30
<i>Dicortendipes</i> sp.	+		12-40	+	6	24	6-30
<i>Stictochironomus pictulus</i>	+	+	6-12			96	240-960
<i>Cryptochironomus defectus</i>	+	+	6-24	+		24-36	12-30
<i>Polypedilum</i> sp.				+		120	6-30
<i>Chironomus thummi</i>		+		+	48		6-30

E=Exposed shore; S=sheltered shore; +=regular occurrence; 0=Scarce; Where no density is given it was low.



In 1951/2 the Hydracarina formed only a small part of the littoral fauna. Three species were recorded regularly but in small numbers and 4 species were taken irregularly or singly. Hynes recorded no mites in 1957 or 1959. In this survey 9 species were found in shore samples and 3 were recorded regularly. The 3 principal species, *Libertia porosa*, *Limnesia maculata* and *Megapus spinipes* were the same as those recorded regularly by Rothwell in 1951/2 but were found in greater numbers than in the earlier survey.

The Plecoptera were important only in the vicinity of entering streams and were taken irregularly in small numbers at all other stations. Hynes did not record any nymphs in 1957 but recorded *Nemoura avicularis* as very scarce on exposed shores in 1959. After this initial disappearance, presumably resulting from the increased draw-down and level fluctuations, the Plecopterans have recovered and their abundance and distribution are now similar to that described in 1951/2.

Major qualitative and quantitative changes have occurred in the Ephemeropteran fauna since 1951/2. The 3 principal species recorded by Rothwell had disappeared in 1957 but by 1959 all had reappeared. The most abundant species before increased regulation, *Leptophlebia marginata*, remained scarce although in 1959 *Caenis moesta* had increased enormously in numbers. *Ephemera danica* densities in 1959 were similar to those recorded in 1951/2. This trend observed in 1959 has continued and both *Caenis moesta* and *Ephemera danica* are now abundant. A further species, *Baetis* sp., recorded irregularly and in small numbers by Rothwell has also benefited from the change in water levels and increased in numbers. *Leptophlebia marginata* has not recovered although numbers taken were greater than those recorded by Hynes.

The Hemipteran, *Micronecta poweri*, is the only species not affected by regulation changes and the abundance and distribution has remained unchanged in all 3 surveys. Hynes did not record any further species of Hemiptera in 1957 or 1959 but a sparse and discontinuous distribution of 3 species of *Sigara* in 1968/9 is similar to that described by Rothwell.

The muddy conditions in the littoral zone have clearly suited the Neuropteran, *Sialis lutaria*, which is now abundant at all stations, particularly during periods of low water levels. Rothwell recorded this species regularly in small numbers on both exposed and sheltered shores in 1951/2 but none were found by Hynes in 1957 although by 1959 some had returned to sheltered shores.

Rothwell recorded the larvae of 15 different species of Trichopterans in the littoral fauna in 1951/2, and of these 9 were recorded regularly and in large numbers. Hynes recorded only 1 species in 1957 and 2 species in 1959. Twenty-three species were recorded in 1968/9. Although nearly all species occur irregularly and in small numbers, caddis larvae are clearly re-established in the environment after an almost total obliteration after impoundment.

In 1951/2 Rothwell recorded 9 species of Coleoptera, of these the two most common ones were recorded by Hynes in 1959 though none had been caught by him in 1957. Ten species were found in 1968/9; none were taken regularly and only one of them was recorded by Rothwell.

There have been major changes in the Dipteran fauna. *Dicranota* sp. larvae have appeared in large numbers in recent years. Hynes did not record this species and Rothwell found single specimens on two occasions. *Tipula* sp. has reappeared and its distribution and abundance are now similar to that described by Rothwell. Similarly larvae of the Ceratopogonidae have now recovered and occur on all sheltered shores

in very large numbers. The Chironomidae formed a small part of the littoral fauna in 1951/2, when apart from the Orthocladiinae, few species were recorded. Despite a reduction in numbers of the Orthocladiinae, the Chironomidae are now abundant. This is mainly a result of an increased abundance of one species, but several species have increased in numbers. *Stictochironomus pictulus* was recorded irregularly at all stations in 1951/2; it is now the most abundant species in the littoral fauna of Llyn Tegid where it was recorded in very large numbers at all stations. There have been less pronounced increases in *Prodiamesa olivacea*, the 2 Tanypodinae, *Procladius choreus* and *Pentaneura monilis*, and 2 abundant profundal species, *Polypedilum* sp. and *Chironomus* 'thummi' gp. since 1951/2. An intermediate abundance for most species was described by Hynes in 1959.

The long term effects of the regulation have produced an enormous increase in the total numbers of animals in the littoral zone. Rothwell (1951/2) throughout one year recorded 1504–6488 animals/m<sup>2</sup>. In 1959 Hynes recorded a maximum of 3654 animals/m<sup>2</sup> in February. 2239–9224 animals/m<sup>2</sup> were recorded in 1968/9. This is a 42–49% increase on the number given by Rothwell in 1951/2, and is accounted for exclusively by Chironomidae and Oligochaeta. Grimås (1961, 1964), Cuerrier (1954), Rawson (1958), Miller & Paetz (1959) and Aass (1958) have also recorded that the proportion of Chironomidae in the fauna increases after longer periods of regulation. Hynes (1961) suggested that the Oligochaeta may become less common if the water level remains low for periods long enough for the silt to be removed by wave action. This is to be expected thus fewer Oligochaeta are now taken on exposed shores in the summer when the water level is high.

Gradual removal of silt by wave action and the re-establishment of macrovegetation will result in the littoral environment returning to its original physical status, provided water level fluctuations are not increased. The fauna is expected to adapt to these changes and revert eventually to its original composition. It may be years before the re-establishment is completed, but the trout should benefit from the already improved fauna.

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