A paper on the water-beetles of the Lake District, written a year ago, has been withheld until another season's collecting has been done. The collection made during the year has been submitted to Professor F. Balfour-Browne for identification.

TAXONOMIC AND FAUNISTIC WORK ON IMMATURE INSECTS. Hynes has been working on the stoneflies since November, 1938, and has already obtained results of considerable interest. Examination of the stomach contents of a number of nymphs has shown that in the group as a whole a wide variety of food is taken. Three genera are carnivorous, six are herbivorous and one regularly mixes both animal and vegetable food. Most genera are catholic in their tastes but *Taeniopteryx* appears to feed exclusively on algae and diatoms scraped from stones. Observations have also been made on the feeding habits of adults.

The nymphs of most species appear to occupy well-defined habitats and the most important factor in the ecology appears to be the rate of water movement and the nature of the bottom. In a succession of environments from small upland becks flowing over moss-covered rock, through larger stony streams, to rivers, there is a marked change in the generic composition of the stonefly fauna. This biological and ecological work cannot of course be completed until it is possible to identify each species in its nymphal stage, and with this end in view extensive breeding work has been undertaken.

Macan has continued to breed other groups of insects during the summer and some eighty dragonflies belonging to thirteen different species and over a hundred ephemerids belonging to eleven different species were reared successfully. The number of species of ephemerids bred out has thus been nearly doubled, and it is probable that not many still-water species remain to be found in the Lake District. As the still-water species are the least well-known it is hoped to continue the work on them in the coming year in some part of the country where species unknown in the Lake District may be taken.

THE GROWTH OF BROWN TROUT

by E. B. WORTHINGTON and G. H. SWYNNERTON.

The size attained by a fish is dependent on its rate of growth and its age. In trout the rate of growth is not constant throughout

life, and differs greatly according to the characteristics of the habitat. The extremes, as far as the British Isles are concerned, are represented on one hand by the southern chalk streams where three or four years' growth may produce fish of two or three pounds in weight, and on the other hand by some moórland streams and peaty lochs, where fish may reach an age of five or more years without exceeding a quarter pound in weight.

The association of the two types of growth with waters giving an alkaline or acid reaction (high and low pH respectively) has been suggested for many years, but the first person to produce scientific data on the subject was probably the late R. Southern, who showed that in Ireland brown trout waters fall into two categories, the first being lakes and rivers on limestone rocks in which trout grow rapidly, become sexually mature late, and live long, and the second being waters on granite, quartzite, sandstone and other non-limestone rocks in which the trout are small, become sexually mature early, and are short-lived. As types of the two kinds of water Southern studied the growth of trout in most detail from Lough Derg in the first category and Lough Atorick in the second. This conclusion, which has been confirmed by more recent work in Ireland by Miss W. Frost, appears to hold very well as far as that country is concerned, but many exceptions have come to notice, especially in Scotland, where, as F. T. K. Pentelow has recently pointed out, certain lochs in Caithness and Sutherland, on peat and non-calcareous rocks and therefore acid in reaction, contain trout of remarkably large size, up to three pounds and more.

Information on this subject is being collected steadily at Wray Castle, and, as explained on page 44 forms the first stage in a somewhat ambitious programme designed to elucidate the factors which control the size attained by trout in different waters and to work out methods of increasing that size. Rather fortunately the trout in each lake or tarn grow at a standard rate, and relatively few individuals depart far from the average. There may be exceptions in the case of large lake basins where part of the population is slow-growing in the early years because some of the young fish stay longer in the affluent streams than others, but we are concerned here only with broad comparisons, so this variable factor can be disregarded for the present. The principle of a standard growth rate for each body of water implies two

things : (1) that a growth curve based on the average of a fairly small sample of fish (say between 50 and 100) is accurate enough for comparative purposes, and (2) that the growth of the whole population in a given lake or tarn is being influenced by the same set of factors, whether they be the chemical contents of the water, the food supply, influence of predators, over- or under-population, or a combination of all these.

In discussing growth rates we cannot disregard the other factor influencing size, namely, the age attained, because it is a striking fact that, in so far as information is yet available, those waters which are notable for large fish have the advantage not only that their inhabitants grow quicker but also that they live longer. This may be in part a fallacy resulting from the fact that trout in waters favouring slow growth, though they may start fairly well, fall off rapidly in their growth rate, so that for several years at the end of their lives they may not register any appreciable growth on their scales. The fact is, however, that the age of fish from these waters, as determined by examination of their scales, is seldom more than five years, whereas in waters promoting fast growth, eight, nine, and ten year-olds are quite frequent.

The methods employed in this study are the usual ones of scale reading coupled with accurate measurements and weights of the fish. In some cases the fish were returned alive to the water after examination and in others samples have been killed for examination of food, genital organs, etc. The growth rates for six lakes and tarns differing markedly in general characteristics have been established by this means during the past year. The scales have all been read by Swynnerton, checked at intervals by Worthington and Allen, the work being done with an apparatus which incorporates a projecting microscope and measuring boards. The length of the fish at the end of each winter ring on each scale is ascertained by proportion, so that averages for the early years of growth are based on the whole sample of fish from each lake. This method is based on the assumption that the proportion of length of scale to length of body is constant throughout life. Small errors are probably involved, especially after individual fish have spawned and their scales have been subject to partial resorption (" erosion "), but in the present state of knowledge of trout scales no correction can be applied, and the errors are not considered to invalidate the broad comparisons between the growth rates from different localities, provided always that the sample of fish examined is larger than about 50.

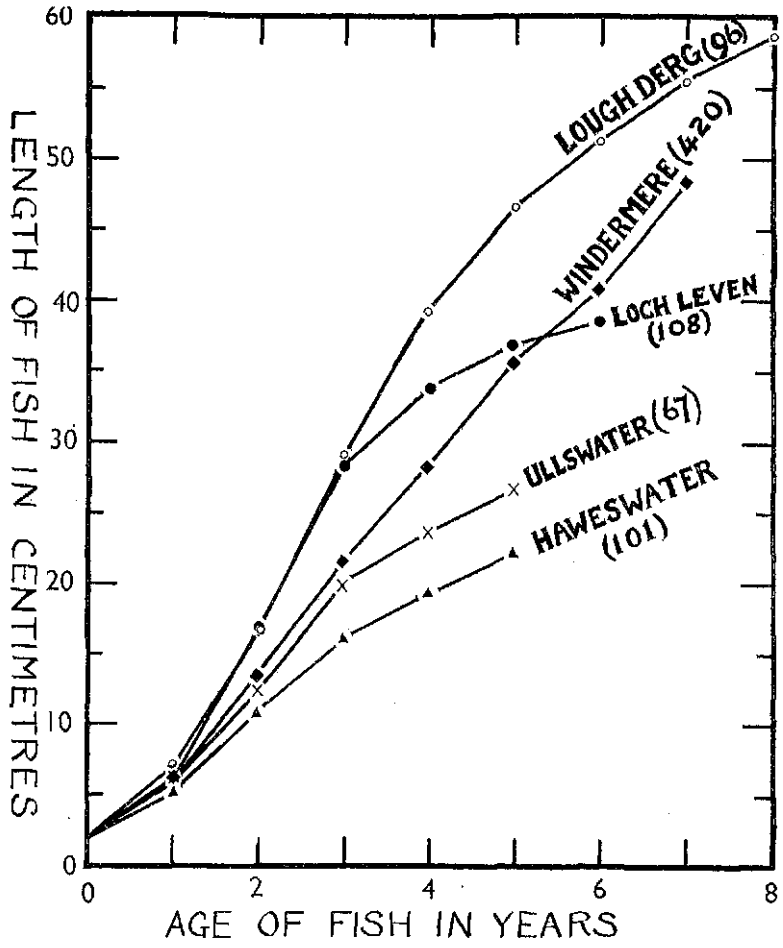

FIGURE 12. The average growth rate of brown trout in five lakes, as determined from their scales. The number of fish examined from each lake is indicated in brackets.

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The full results will be published in due course, but meanwhile the average growth rate of three waters, namely Loch Leven, Ullswater and Haweswater are shown graphically in figure 12, on which has been added the average growth rate for Windermere, from Allen's paper mentioned on page 37, and for Lough Derg, from Southern's results.

A proper discussion of these and similar results cannot be included in this article, but attention may be drawn to a few significant facts. Firstly, referring to Southern's distinction into alkaline and non-alkaline waters, the following table shows typical figures for pH and total hardness, expressed as $CaCO_3$, for the lakes considered here. It should be noted that total hardness is a better indication of degree of alkalinity than pH, especially in the soft unbuffered waters of the type found throughout the Lake District. Thus little significance can be attached to the fact that Haweswater and Ullswater have a higher pH than Windermere.

	L. Derg.	L. Atorick	Hawes-water	Ullswater	Winder-mere	L. Leven
pH ...	8.0–8.4	6.8	7.1	7.2	6.6–6.9	7.6–7.8
Total hardness ($CaCO_3$)	176	30	23	20	28	(57)*

*Carbonate hardness by titration.

From these figures it is obvious that all the waters of the Lake District fall quite definitely into the second category, but as shown by figure 12, the growth rates of their trout (Windermere, Ullswater and Haweswater) are by no means identical. The growth rate of trout in Lough Atorick is similar to that in Haweswater but is a little more rapid during the first two years and subsequently shows a more abrupt arrest. The conclusion therefore is that the relative alkalinity is not a sufficient explanation of the differences in growth rate found.

Another factor to which Southern attributes importance is the presence or absence of pike and other coarse fish. Lough Derg for example has many pike accompanying its fast-growing trout, while Lough Atorick has none. With this the results from the Lake District comply, Windermere having an abundant supply of pike and perch, Ullswater and Haweswater having no pike and but few other fish such as skelly (*Coregonus clupeoides*) and perch. In this connection Loch Leven is particularly instructive. The growth rate of its trout, which

in their first three years is almost identical with that of Lough Derg, falls off later, so that the fish have a remarkably standard size, averaging a little under a pound. In recent years pike have been practically exterminated from Loch Leven, but the history of the fishery shows that in past years there was a large number of pike sharing the lake with trout and perch; in 1903, when 1,400 pounds weight of pike were removed, only 2,000 trout were captured, compared with 58,000 in 1938, but their average weight was 1.38 pounds compared with 0.81 pounds in 1938.

Looked at from another point of view, it is a striking fact that the order of lakes according to the rate of growth of their trout is the same as the order of their classification according to the amount of change which has taken place in them since the Ice Age. Thus, of those included in figure 12, Haweswater has much less sediment and a much less advanced vegetation than Windermere, while Ullswater occupies an intermediate position. Loch Leven and Lough Derg are certainly at a still higher level of general production. A higher rate of production implies, of course, a larger food supply for fish and hence faster trout-growth, but it was pointed out many years ago by W. H. Pearsall that not only do the associations of plants change with the steady development of the freshwater environment, but those of fish do likewise, the change in the Lake District being from a fish association of trout, char and skelly to one of perch and pike. Thus, it appears that Windermere and probably also Lough Derg have already passed the optimum conditions for trout, because, although their trout grow large, they are unable to compete in numbers with coarse fish. Loch Leven would have done so likewise had not the fishery there been carefully managed by a ruthless war on pike to the point of their extermination, and considerable netting of perch.

In considering growth rates of fish, competition for food must be a factor of importance. It is significant, for example, that records from big trout fisheries such as those in Loch Leven and Blagdon show a striking inverse relation between number of fish captured and average size; usually in years when abnormally large catches have been recorded the average weight was relatively low, and *vice versa*. Although little is said about the food factor in this article, data on the food of trout and other fish are being accumulated, and results on that subject should be ready for publication before long.