

SURVEY OF SCOTTISH LAKES.<sup>1</sup>

THE three papers mentioned below complete the account of the survey of the lochs which lie within the drainage basin of the Tay, and show that the excellent work carried on by Sir John Murray and the late Mr. F. P. Pullar is being continued in a manner worthy of the importance of the subject. It may be recalled that part i. of these publications appeared in the *Geographical Journal* for April, 1900, and dealt with the lochs of the Trossachs and Callander district; part ii. appeared in the *Journal* for March, 1901, and dealt with the remaining lochs of the Forth basin; part iii., No. 1, appeared in the same *Journal*, and dealt with Lochs Ericht and Garry in the basin of the Tay. Part i. was noticed in these columns on May 17, 1900 (see NATURE, vol. lxi. pp. 65-67).

In the introductory remarks to the first paper under notice, reference is made to the attempt to induce the Government to undertake a bathymetrical survey of the principal Scottish lakes; to the commencement of such a survey by Sir John Murray and the late Mr. F. P. Pullar, which was brought to a standstill by the sad death of Mr. Fred. Pullar; to the desire of his father, Mr. Laurence Pullar, to continue and complete the work in which his late son took such an active part; to the resolutions passed by the councils of the Royal Societies of London and Edinburgh, and by the British Association, affirming the importance and scientific value of the contemplated survey; to the interest taken in the work by the directors of the Ordnance Survey and Geological Survey, the hydrographer of the Admiralty, and the controller of H.M. Stationery Office; to the steps taken to carry out the work under the direct supervision of Sir John Murray and the staff appointed to assist him; and to the progress made up to the time of publication.

The drainage basin of the River Tay is the largest in Scotland, covering an area exceeding 2500 square miles, and it includes several large fresh-water lochs as well as many small ones, nearly all of which have now been sounded by Sir John Murray and his colleagues. The relative positions of the lochs will be seen at a glance in the index map shown in Fig. 1. In the first paper now under notice, thirteen of the lochs are dealt with, the most important being Lochs Rannoch and Earn; in the second paper fourteen lochs are dealt with, including Lochs Tay and Tummel; and in the third paper thirty-one of the smaller lochs are discussed, making a total of fifty-eight lochs fully described and elaborately mapped. Adding Lochs Ericht and Garry, previously published, the total is increased to sixty, so that only a few little lochs within the Tay basin remain unsurveyed. These sixty lochs cover an area of about forty square miles, and they drain an area twenty times greater—an area of more than eight hundred square miles. The number of soundings necessary to indicate with sufficient accuracy the relief of the bottom varies greatly, according to the dimensions, depth, and form of the basin, but usually a relatively much larger number of soundings is taken in a small loch than in a large one. Nearly seven thousand soundings were recorded in these sixty Tay lochs, or an average of 114 per loch, or 172 per square mile of water-surface. In the thirty-one little lochs included in the third paper the average number of soundings per square mile of surface is 383, while in the largest loch (Loch Tay) the average is only 91.

The sixty lochs lie at elevations varying between 140 and 2575 feet above the sea; the last mentioned, the only one above the 2000 feet level, being the little Loch nan Eun at the head of Glen Taitneach, a tributary of the well-known Glenshee, and the highest loch visited by the Lake Survey. Of the four largest lochs, Loch Ericht is the highest, 1153 feet above sea-level, then Loch Rannoch, 668 feet, then Loch Tay, 349 feet, and Loch Earn, 317 feet.

In this short notice it is impossible to refer to all the lochs dealt with, and therefore attention will be directed only to the larger and more interesting lochs. In order to show

their relative dimensions and depths, the principal Tay lochs are arranged in the following tables according to (1) superficial area, (2) length, (3) volume of water, (4) maximum depth, and (5) mean depth, the particulars being given in round numbers:—

(1) Superficial Area.

Square miles		Square mile	
Loch Tay ... ..	10½	Loch Tummel ... ..	I
„ Rannoch ... ..	7½	„ Bà ... ..	I
„ Ericht ... ..	7¼	„ of Lintrathen ... ..	½
„ Earn ... ..	4	„ Garry ... ..	½
„ Laidon ... ..	2	„ Freuchie ... ..	½

(2) Length.

Miles		Miles	
Loch Tay ... ..	14½	Loch Lintrathen ... ..	1½
„ Ericht ... ..	14½	„ Iubhair ... ..	1½
„ Rannoch ... ..	9¾	„ Loch ... ..	1½
„ Earn ... ..	6½	„ of the Lowes ... ..	1½
„ Laidon ... ..	5½	„ Turret ... ..	I
„ Tummel ... ..	2¾	„ Benachally ... ..	I
„ Garry ... ..	2½	„ of Forfar ... ..	I
„ Bà ... ..	2¼	„ Daimh ... ..	I
„ Lyon ... ..	1¾	„ Con ... ..	I
„ Freuchie ... ..	1¾		

(3) Volume of Water.

Millions of cubic feet		Millions of cubic feet	
Loch Tay ... ..	56,550	Loch Drumellie ... ..	222
„ Ericht ... ..	38,027	„ Bà ... ..	206
„ Rannoch ... ..	34,387	„ Lowes ... ..	194
„ Earn ... ..	14,421	„ Daimh ... ..	190
„ Laidon ... ..	1,762	„ Benachally ... ..	178
„ Tummel ... ..	1,317	„ Clunie ... ..	170
„ Garry ... ..	846	„ Iubhair ... ..	147
„ Lyon ... ..	461	„ Ordie ... ..	133
„ Lintrathen ... ..	405	„ Kennard ... ..	108
„ Freuchie ... ..	347	„ Derculich ... ..	108
„ Turret ... ..	228	„ Loch ... ..	103

(4) Maximum Depth.

Feet		Feet	
Loch Ericht ... ..	512	Loch Kennard ... ..	72
„ Tay ... ..	508	„ Lintrathen ... ..	70
„ Rannoch ... ..	440	„ Derculich ... ..	70
„ Earn ... ..	287	„ Ordie ... ..	69
„ Laidon ... ..	128	„ Clunie ... ..	69
„ Tummel ... ..	128	„ Iubhair ... ..	65
„ Garry ... ..	113	„ Benachally ... ..	64
„ Lyon ... ..	100	„ Freuchie ... ..	62
„ Daimh ... ..	95	„ Drumellie ... ..	58
„ Loch ... ..	81	„ Skiach ... ..	55
„ Turret ... ..	79	„ Lowes ... ..	53
„ Fender ... ..	78	„ nan Eun ... ..	50

(5) Mean Depth.

Feet		Feet	
Loch Tay ... ..	199	Loch Clunie ... ..	29
„ Ericht ... ..	189	„ Drumellie ... ..	29
„ Rannoch ... ..	167	„ Ordie ... ..	26
„ Earn ... ..	138	„ Benachally ... ..	25
„ Garry ... ..	50	„ Iubhair ... ..	25
„ Tummel ... ..	48	„ Derculich ... ..	25
„ Lyon ... ..	45	„ Lintrathen ... ..	23
„ Daimh ... ..	39	„ Freuchie ... ..	23
„ Laidon ... ..	35	„ Fingask ... ..	23
„ Turret ... ..	32	„ Giorra ... ..	22
„ Fender ... ..	32	„ nan Eun ... ..	22
„ Kennard ... ..	32	„ Lowes ... ..	20
„ Loch ... ..	29		

The general conformation of the principal lochs may now be indicated briefly; for further details the reader is referred to the papers cited.

Loch Tay is slightly sinuous in outline and comparatively simple in conformation. A depth of 100 feet is met with about a quarter of a mile from the upper (south-western) end, and about one-third of a mile from the lower end. The basin exceeding 200 feet in depth is eleven miles in length,

<sup>1</sup> Bathymetrical Survey of the Freshwater Lochs of Scotland. Under the direction of Sir John Murray, K.C.B., F.R.S., D.Sc., and Laurence Pullar, F.R.S.E. Part iii. Nos. 2-6, *Geographical Journal*, vol. xxii., pp. 237-269, with seven plates of maps; Nos. 7-9, pp. 521-541, with five plates of maps; No. 10, vol. xxiii., pp. 32-61, with six plates of maps, and geological map.

distant more than a mile from the lower end, and more than two miles from the upper end. The bottom falls below the 300 feet level in two basins, the larger extending from about two miles from the lower end for a distance of 7½

water in the loch occupying the wider southern portion, where, about 3½ miles from the lower end, there is a small area exceeding 500 feet in depth. The areas between the contour-lines, and the percentages, are:—

Feet	Acres	Per cent.
0 to 100	1575	34
100 ,, 200	1160	25
200 ,, 300	875	19
300 ,, 400	476	10½
400 ,, 500	474	10½
more than 500	58	more than 1
	<hr/> 4618	100

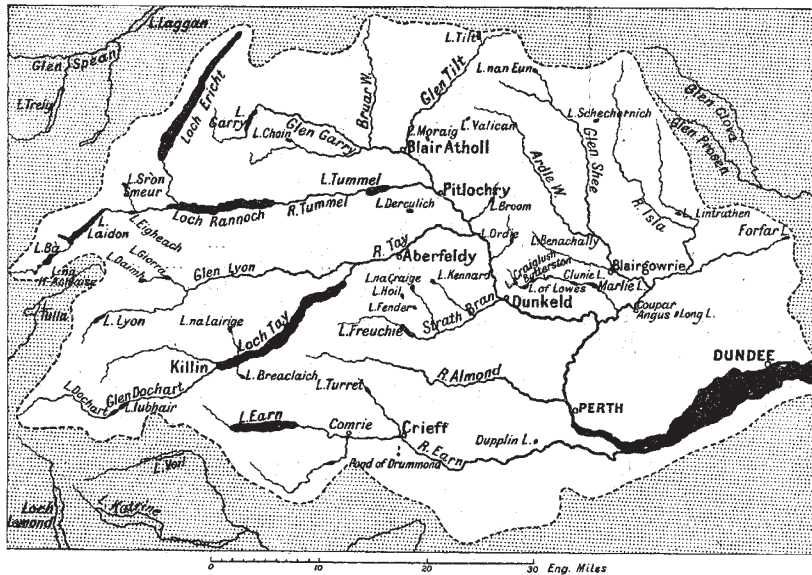


FIG. 1.—Index Map of the Tay Basin.

Loch Rannoch is widest and deepest in the eastern half, narrowing and shallowing towards the west. It consists of one large deep basin, with two subsidiary small basins exceeding 50 feet in depth near the west (upper) end, the maximum depths in which are 84 and 54 feet respectively. The 100-foot basin approaches close to the lower (east) end, extending for nearly seven miles up the loch, while the 200-foot basin is six miles, and the 300-foot basin four miles in length, distant respectively about a quarter of a mile and half a mile from the lower end. The bottom sinks in three places along the central axis of the loch below the 400-foot level, the easternmost basin being the largest and

miles up the loch, and separated by a slight shoaling of the water over an interval of a mile from the smaller basin, which is half a mile in length. The 400-foot basin lies in the northern half of the loch, approaching to within less than four miles from the lower end, and is 3½ miles in length, while the deepest part of the loch (exceeding 500 feet) is situated about 5½ miles from the lower end, between Skiagar on the south and Cragganruar on the north, the maximum depth occurring (roughly) about one-third of the length of the loch from the lower end. A view of Loch Tay, as seen from Kenmore Bridge, is shown in Fig. 2. The areas between the consecutive contour lines, and the percentages to the total area of the loch, are:—

deepest, the maximum depth of the loch (440 feet) having been observed less than two miles from the lower end; the deepest soundings recorded in the other two small basins are 404 and 421 feet respectively. The areas between the contour-lines, and the percentages, are:—

Feet	Acres	Per cent.
0 to 100	1972	30½
100 ,, 200	1532	23½
200 ,, 300	1390	21
300 ,, 400	1017	15½
400 ,, 500	600	9
more than 500	9	less than ½
	<hr/> 6520	100

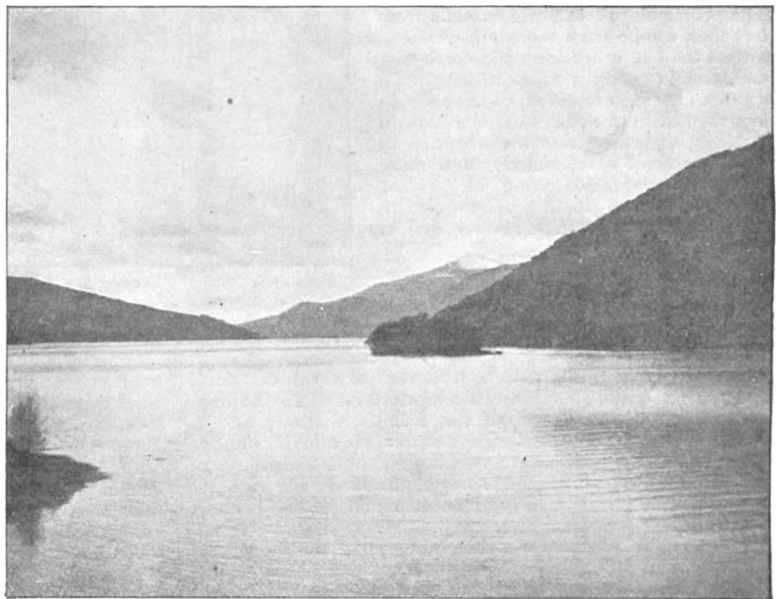


FIG. 2.—Loch Tay.

Loch Ericht is widest near the lower (south-western) end, narrowing towards the upper end. A constriction in the outline of the loch near Loch Ericht Lodge, about 4½ miles from the upper end, cuts it into two deep basins, but, though the width here is less than a quarter of a mile, the depth exceeds 100 feet, so that the 100-foot basin is a continuous area 1¾ miles in length, extending from less than half a mile from the lower to less than a mile from the upper end. The 200-foot and 300-foot basins are each divided into two parts by the constriction referred to, the larger part in each case being found in the southern portion of the loch. The greatest depth observed in the portion of the loch to the north of the constriction is 314 feet, the deepest

Feet	Acres	Per cent.
0 to 100	1950	41
100 ,, 200	877	19
200 ,, 300	950	20
300 ,, 400	875	19
more than 400	65	more than 1
	<hr/> 4717	100

*Loch Earn* is extremely simple in conformation and flat-bottomed in character, the depth of water increasing gradually from the shores down to the deepest part, which is centrally placed, but rather nearer the upper (west) end. A depth of 100 feet is met with less than a quarter of a mile from the west end and less than half a mile from the east end. The 200-foot basin is  $4\frac{1}{2}$  miles in length, distant about three-quarters of a mile from the west end and  $1\frac{1}{2}$  miles from the east end, while the 250-foot basin is nearly two miles in length, being distant  $1\frac{1}{2}$  miles from the west end and 3 miles from the east end. The maximum depth of 287 feet was observed near the centre of the loch, between the mouth of the stream called Allt Bhacaidh on the northern shore and that of the Allt Dhùnain on the southern shore, about  $2\frac{3}{4}$  and  $3\frac{3}{4}$  miles from the west end and east end respectively. The areas between the consecutive contour-lines, and the percentages of the total area, are:—

Feet	Acres	Per cent.
0 to 100	926	38½
100 ,, 200	755	31½
more than 200	700	30
	2381	100

*Loch Laidon*, the largest of the Rannoch Moor lochs, lies on the boundary line between Perthshire and Argyllshire. It trends in a north-east and south-west direction, sending out a long shallow arm towards the west, and with a small shallow distinct basin, called Dubh Lochan, at its north-eastern end. The floor of the loch is rather irregular. The deepest part is in the centre of the loch, where there is a basin three-quarters of a mile in length and more than 100 feet in depth, the maximum depth of 128 feet having been observed about  $2\frac{3}{4}$  miles from the south-west end and  $2\frac{1}{2}$  miles from the north-east end. Outside of this main 100-foot basin, isolated soundings of 104 and 100 feet were obtained to the south-west, and a sounding of 100 feet to the north-east. The principal 50-foot basin extends from less than a mile from the south-west end to less than  $1\frac{1}{2}$  miles from the north-east end, and is nearly 3 miles in length; a smaller basin, one-third of a mile in length, lies in the north-eastern part of the loch, separated from the larger basin by an interval of a quarter of a mile, with an isolated sounding of 50 feet midway between them. Of the entire lake-floor, 74 per cent. is covered by less than 50 feet of water.

*Loch Tummel* is the final one on the Tummel branch of the Tay, and it receives the outflow from all the other lochs on this branch, including Lochs Ericht, Rannoch, and Laidon; its drainage area is thus very considerable—about 306 square miles, or  $3\frac{1}{2}$  times the area of the loch. It is irregular in outline and in the conformation of the bottom. The west (or inflow) end of the loch is shallow, and is being silted up by the large amount of alluvial matter brought down by the river; two large tongues of alluvium project into the loch on both sides of the river, and, indeed, the loch must formerly have extended much farther towards the west, but has been gradually silted up and shortened. Cones of alluvium have also been formed at the mouths of the inflowing streams, both on the northern and southern shores. The loch is divided into three deep basins by two ridges crossing the loch, the depth on the western ridge being 53 feet and on the eastern 56 feet, so that the 50-foot area is continuous, and nearly  $2\frac{1}{2}$  miles in length, approaching to within 100 yards from the east end and a quarter of a mile from the west end. Of the three deep basins, the western one is the deepest, with a maximum depth of 128 feet; the central one has a maximum depth of 119 feet, and the eastern one a maximum depth of 99 feet. A view of Loch Tummel is shown in Fig. 3. The areas between the contour-lines, and the percentages, are:—

*Loch Garry* lies to the east of Loch Ericht, and resembles it in trend and in outline. The 25-foot, 50-foot, and 75-foot areas are continuous, the 50-foot area being nearly two miles in length. There are two 100-foot basins, separated by depths of 82 to 93 feet, the larger one in the southern half of the loch, with a maximum depth of 105 feet, the smaller one in the northern half, enclosing the maximum depth of the loch (113 feet). The areas between the contour-lines, and the percentages, are:—

Feet	Acres	Per cent.
0 to 50	352	56
50 ,, 100	217	34½
more than 100	60	9½
	629	100

*Loch Lyon* is extremely simple in outline and in conformation. It is nearly uniform in width, except for a cone of alluvium laid down by the river on the south-eastern shore. The lower (north-eastern) end is shallow, as though it had

Feet	Acres	Per cent.
0 to 50	200	52
50 ,, 100	170	43
more than 100	19	5
	389	100

been silted up, the 25-foot contour being distant about a quarter of a mile, while at the upper end the 75-foot contour approaches to within 300 yards of the shore. The alluvial cone mentioned causes a constriction in the outline of the loch accompanied by a slight shoaling of the water, the depth here being 77 feet, deepening to 84 feet to the south-west, and to 100 feet to the north-east; the last-mentioned sounding—the maximum depth observed—occurs approximately in the middle of the loch. The areas between the contour-lines, and the percentages to the total area of the loch (which show the flat-bottomed character of the deep basin), are:—

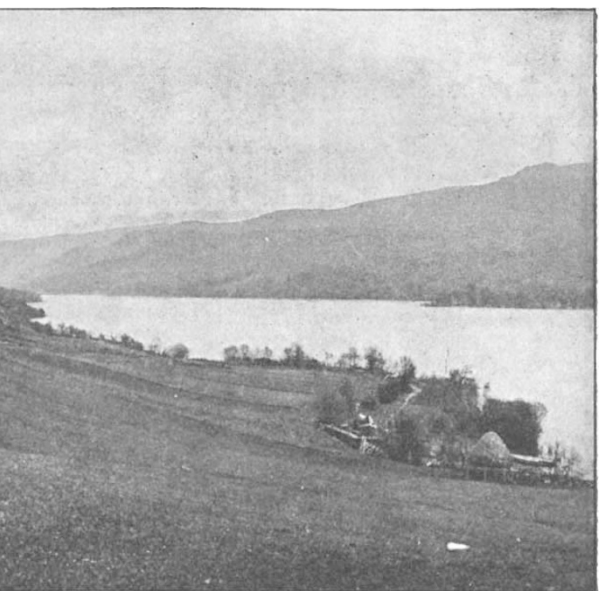


FIG. 3.—Loch Tummel.

The Loch of Lintrathen is the source of the Dundee water-supply, and has been raised 22 feet in connection therewith; Loch Turret similarly supplies the town of Crieff,

Feet	Acres	Per cent.
0 to 25	92	39
25 ,, 50	36	15
50 ,, 75	55	23
more than 75	53	23
	236	100

and Loch Benachally the town of Blairgowrie. The results obtained by the Lake Survey must be of particular interest to these municipalities, as indicating the capacities and the depths of the lochs from which they draw their water-supplies. Lochs Daimh, Kennard, Turret, and Fender, though small lochs, are interesting on account of their relatively great depth. The little Loch Fender, which has an area of only some 22 acres, is especially striking in this respect.

Temperature observations were made at the time of sounding most of the lochs, and the results are given under each loch. In the case of Loch Rannoch, the observations extended over a period of four months, and gave some interesting results as to the march of temperature throughout the waters of the loch from March to July, 1902, but usually the observations are too few to afford material for discussion, though they are available for comparison with any future observations.

The bathymetrical maps illustrating the papers are a distinctive feature, and are excellent examples of chromolithographic work. They are reduced from the Ordnance Survey charts to the uniform scale of 3 inches to the mile. The water-surfaces are tinted in deepening shades of blue, the darkest shades indicating the greatest depths. The land-surfaces are tinted in deepening shades of brown, the darkest shades indicating the highest elevations. Longitudinal and cross sections of the principal lochs are given, the true vertical relief drawn to scale being shown in solid black, while coloured extensions in outline represent the vertical scale exaggerated five times in order to show the relative depth with greater effect. Besides the maps there are numerous woodcuts in the text, some of which are reproduced in this notice.

Appended to the concluding paper are some valuable notes on the geology of the Tay basin, by Drs. Peach and Horne, illustrated by an admirable geological map, and on the biology of the lochs of the Tay basin, by Mr. James Murray, assistant zoologist on the staff of the Lake Survey.

In their concise sketch of the geology and glaciation of the district, Drs. Peach and Horne show that the Tay basin is geologically divided into two parts by the great fault along the Highland border—to the north-west metamorphic rocks pierced by igneous intrusions, to the south-east rocks of Old Red Sandstone age with a small patch of Carboniferous strata. Most of the lochs lie to the north-west of the Highland fault, and the groups of strata are enumerated in the order in which they are met with on proceeding northwards from the fault, their distribution being indicated, and the system of north-east and south-west dislocations which traverse the metamorphic area discussed. After dealing with the lower and upper divisions of the Old Red Sandstone, which occur to the south-east of the border fault, the authors proceed to consider the evidence relating to the glaciation of the Tay basin, which leads to the conclusion that, during the climax of the Ice age, the region must have been covered with one continuous sheet of ice; striæ have been found up to elevations of 3000 feet, showing that the highest mountains were over-ridden by the ice, the movement of which must to some extent have been independent of the existing valley-system. This stage was followed by a period of confluent glaciers, when the ice streamed over passes connecting adjoining valleys, leaving in its track lines of moraines. Finally, there was the phase of corrie-glaciers, when the glacial detritus was borne for no great distance from the local centres of dispersion.

The majority of the lochs within the Tay basin, most of them small and comparatively shallow, lie in the midst of drift deposits; several other lochs, some of considerable size, lie along lines of displacement, for example, Lochs Erich, Garry, Laidon, and Lyon, the long axes of which coincide with the courses of more or less powerful dislocations. As typical examples of rock-basins eroded by ice-action, Lochs Rannoch, Tummel, Earn, Iubhair and Dochart are cited. The two last-mentioned originally formed one sheet of water, and have been separated by alluvial material brought down by the river; Loch Dochart is being rapidly silted up, and must formerly have extended three miles up the valley. Further up Glen Dochart a strip of alluvium five miles in length may probably represent a silted-up rock-basin. Loch Tay presents certain features differentiating it from the rock-basins cited, there being no rocky barrier close to the

lake, and the Loch Tay fault runs along the course of the lake for a distance of  $5\frac{1}{2}$  miles, the deepest part of the basin coinciding with this fault, to which the deflection of the original valley of the Tay must be due. Thus Loch Tay cannot be regarded as a typical example of a rock-basin, but the other rock-basins referred to seem to furnish strong evidence in support of the theory of ice-erosion.

Tow-net collections were taken in most of the lochs in the Tay basin, and have furnished Mr. Murray with material for some interesting notes on the plankton of the open water of the different lochs. The number of species is not very great, and does not vary much; each loch has a distinct character, which, notwithstanding a considerable amount of seasonal variation, is pretty constant. The genera and species usually met with in the open water of the lakes are enumerated, and although all the forms may be present in most of the lakes, the varying proportions in which they occur give rise to great differences in the character of the plankton. This lacustrine type of plankton was found even in the smallest lochs surveyed. Some of the forms are subject to considerable variation, and sometimes a single organism, usually vegetable, will so increase in a loch as to form a "Wasserblut." A brief account of the plankton-organisms observed in some fifty of the lochs visited is given.

#### THE HOPE REPORTS.<sup>1</sup>

THE fourth volume of the "Hope Reports" contains twenty papers bearing upon the study of insects in particular and the theory of natural selection in general. The most important of these is Mr. Shelford's paper on mimetic insects and spiders from Borneo and Singapore.

So long as we had only a few isolated cases of mimetic resemblance between animals belonging to different families or orders, it was possible for the opponents of the theory of natural selection to make light of them or to urge with some force the argument of the influence of similar external conditions, but as the number increases the difficulty of accounting for these wonderful mimetic resemblances by any other theory than that of natural selection becomes insurmountable. Mr. Shelford's list of mimics and their models is a long one, and as his description is accompanied by valuable field notes and is illustrated by five excellent coloured plates, it forms one of the most important contributions to the literature of the subject which has yet been published. The figures were drawn from the dried specimens as they arrived in this country, and in some cases the mimicry does not seem to be a very close one as it may be judged by the illustrations only, but it is in these cases that the value of the field notes lies.

In the description of a fly belonging to the genus *Sepedon* that mimics a hymenopteran (*Collyris emarginata*, MacL.), Mr. Shelford says:—

"Both of the species now under discussion were caught together on the wing on Mt. Serambu, Sarawak, and when seen alive and actively moving about were not readily distinguishable. As cabinet specimens they furnish an instance of the importance of field-work in the study of mimicry, and of the unreliability of dead impaled insects or mere figures unless, indeed, both are prepared with reference to careful observations of the living forms. The fly when alive was of a very brilliant blue like that of the *Collyris*; but the colour has now faded to a dusky indigo, while the abdomen being much shrunk detracts considerably from the previous resemblance. The legs are brilliant red, and constituted one of the most conspicuous features of both fly and beetle."

The tables that Mr. Shelford gives of the arrangement of these insects which mimic and are mimicked into convergent groups should be carefully studied by naturalists who may have the opportunity to study insects in the tropics.

An important series of experiments on the colour relation between lepidopterous larvæ and their surroundings is described by Prof. Poulton. In *Gastropacha quercifolia* the susceptibility to the colour surroundings appears to be restricted to the younger stages of the larva, but in further experiments Prof. Poulton found that in *Amphidasis betularia* every stage except the first and the fifth or sixth is

<sup>1</sup> "The Hope Reports." Vol. iv., 1900-1903. (Printed for Private Circulation.)