INTRODUCTION.

By N. ANNANDALE.

Among the districts on the frontiers of Burma few have greater interest for the zoologist than Manipur, the position of which is thus defined by Mr. B. C. Allen in the official Gazetteer of the Naga Hills and Manipur (Calcutta: 1905).

"The Native State of Manipur is situated between 28° 50′ and 25° 41′ N. and 93° 2′ and 94° 47′ E. and covers an area of 87,456 square miles. On the north it is bounded by the British district of the Naga Hills, on the west by Cachar, on the south by the Lushai Hills and Burma, and on the east by Burma."

The greater part of the State is occupied by mountainous country, which, though of great zoological interest, is less important from the point of view of the study of the freshwater molluscs than the comparatively small valley that forms the richer and more civilized part. I propose, therefore, to say no more than a few words about the hill-streams and their fauna and to devote the greater part of this introduction to a succinct account of the valley.

Hill-streams of Manipur.

Within the limits of the State of Manipur small hill-streams that belong to several different water-sheds occur, viz. (1) those that flow down into the valley; (2) those that flow northwards to join the Brahmaputra system; (3) those that flow eastwards to Burma and (4) those that flow westwards towards Sylhet. The fact that the hill-tracts of the state are much more extensive though less valuable than the valley renders the number and direction of their streams large and varied. Hill-streams, however, rarely have a rich molluscan fauna and the only ones in which my party was able to make collections were those that entered the valley and those that flowed northwards to the other side of the Naga Hills.

The streams closely resemble those of other hill-ranges in north-eastern India. They are as a rule little more than mountain torrents, though in some of the valleys among the hills they may assume for a time a placid and even course. Their beds are for the most part rocky or stony and there is little aquatic vegetation.

Fauna of Oriental Hill-streams.

The fauna of such streams has a very similar facies all over south-eastern Asia from Nepal to HongKong and probably to Formosa and the Philippines. Its main characteristics are: (1) the production of special adhesive apparatus, more particularly in the Batrachian larvae, fish and insects, all of which provide numerous and highly interesting instances of convergence in this respect, and

(2) the scarcity of molluscan life, to which, however, there are exceptions at certain places. These features may be observed in the fauna of the hill-streams of Manipur as clearly as in that of the streams of Sikkim or southern China, but as the main character of the Mollusca is negative, the peculiarities can naturally be discussed more appropriately when dealing with the fish than when describing this group.

Manipur Valley.

The Manipur valley is a flat swampy plain lying 2,600 feet above sea-level and 50 miles long by 25 miles broad. It is surrounded by mountains considerably higher than itself and is thus completely isolated from the rest of Assam, to which the Manipur State is attached politically. The river system has no connection with that of the Brahmaputra, but drains through a narrow pass into the Chindwin, the largest tributary of the Irrawadi.

The climate is comparatively temperate and equable. The highest and lowest shade temperatures recorded in Imphal, the capital, which is situated in the central part of the valley, are 92° and 30° Fahr. The rainfall is moderate as compared with that of some parts of Assam, but varies greatly from year to year. The average at Imphal is about 70 inches, but while in 1896-97 it was only 57 inches, in 1899-1900 it was over a hundred inches. The winter and early spring are usually dry, but in 1920 a considerable amount of rain fell at the beginning of March. About half the annual rainfall normally takes place between June and August inclusive. The prevailing winds are from the south and the west. In February and March a strong westerly breeze, apparently originating in the ranges of mountains that separate the Manipur from the Sylhet valley, almost invariably arises about 10 a.m. and blows until the evening, putting a stop to all fishery operations and transport by boat in the open part of the larger swamps, except at night and in the early morning and evening.

The greater part of the valley is cultivated and is very fertile, rice being the principal crop, while even the hill-slopes are also utilized in agriculture by the Naga tribes, who burn down the jungle in patches, which they use for one year only. On a few of the smaller hills that crop up like islands in the valley there is fairly high and dense jungle, but the vegetation even here is not so luxuriant as perhaps might be expected, the soil being extremely friable and apparently incapable of supporting large woods or a great profusion of creepers, bamboos being frequently the dominant form of plant-life.

The River-system of the Valley.

The river-system of the valley is derived mainly from small streams that arise in the Naga Hills in the northern part of the State. These flow down in an almost straight course. A few small streams also come from the western slopes, but they are of no great importance. No water reaches the valley from Burma and none from the Sylhet or Brahmaputra Valley.

The whole of the basin is covered by a net-work of water

courses and swamps and after prolonged rain a great part of it is under water. Several different rivers have local names, but their course as indicated on the maps seems to be imperfectly understood. Indeed, no part of the State has been properly surveyed except the hills to the north and west. It will be sufficient for my purpose to say that these streams unite to form the Imphal River, which flows out through the hills at the south-east of the valley down into the Chindwin. They are all sluggish and turbid and even after uniting form, at any rate in the dry season, but a comparatively small stream.

Depressions of various sizes are found all over the valley. In the flood-season several of these might be legitimately called lakes, but in winter the majority are almost or quite dry and the only one of them to which this term can be applied is the Loktak Lake, which occupies a considerable but very variable area in the southern part of the valley.

The Loktak Lake.

Even the Loktak Lake is little more than a large, deep swamp. In places the water is as much as 10 feet deep, but even in such spots it is blocked up almost to the surface with submerged vegetation, while a very large part of its area is covered with floating islands formed of living and decayed plants. The bottom is composed of evil-smelling soft mud containing much rotten vegetable matter. In the dry weather the lake is normally about 8 miles long by 5 miles broad, but its extent probably varies greatly in different years.

Towards the eastern side of the Loktak a chain of small rocky islands, the chief of which is called Thanga, rise from the surface to a height of several hundred feet. In February, 1920 these islands were separated from a broad peaty area, occupying the eastern part of the valley, only by a stream of running water. At that season only a few small pools remained in the peaty area, but in the flood season it must be entirely submerged.

At no point has the lake definite shores, and even the rocky islands are surrounded in winter by flat mud-banks which slope down under the water very gradually. On the northern and western sides the floating islands become, as it were, gradually stranded and changed into grass-land.

Water of the Lake.

Owing largely to the strong breezes which blow across the surface and disturb the water it is more or less turbid. At spots where the submerged vegetation is particularly dense it is, however, clearer than elsewhere.

I have to thank Sir H. H. Hayden, F.R.S., Directer of the Geological Survey of India, for having samples of the water analyzed in the laboratory of his department. These analyses show that there is no great amount of dissolved mineral matter. They may be compared in detail with the analyses of the water of the Inlé Lake printed on pp. 2 and 4 of Vol. XIV of the *Records of the Indian Museum.* A general comparison is given later in this Introduction.

	Water from channel s. of Thanga I., Manipur. Total amount received 554 c.c.; solid suspended matter found therein ·0148 gm.	Water from open part of Loktak Lake. Total amount received 1107 c.c.; solid suspended matter found therein ·0189 gm.	Water from stream flowing into Loktak Lake s. of Potsengbam, Manipur. Total amount received 1079 c.c.; solid suspended matter found therein ·0134 gm.
Total Solids per litre	·0670	·1010—·1240	·1050—·1040
Organic matter ,,	·0240	·0128—·0237	·0240—·0251
Sulphate (SO_4) ,,	·0079	·0063	·0041—·0057
Carbonate (CO_3) ,,	·0180	·0480—·0495	·0450—·0435
Chloride (Cb) ,,	·0028	·0023—·0024	·0039—·0042
Silicia (SiO_2) ,,	·0027	·0020—·0062	·0030—·0035
$Fe_2O_3Al_2O_3$,,	*nil*	·0075	*nil*
Calcium (Ca) ,,	·0049	·0148	·0118
Magnesium (Mg) ,,	·0053	·0068—·0134	·0110—·0105

Comparison between the Loktak Lake and the Inlé Lake.

As one of the chief objects of my visit to Manipur was to obtain material for a comparison between the fauna of the Loktak and that of the Inlé Lake, a short summary of the physical characters of these two bodies of water may be given.

Both are situated in isolated valleys at altitudes between 2,500 and 3,000 feet. Their river-systems are connected with adjacent watersheds, that of the Irrawadi in the one and that of the Salween in the other. The climate of the two valleys also is similar, and they are only some 340 miles apart as the crow flies. Even the appearance of the two lakes is not dissimilar, for both lie in open plains between ranges of rather bare mountains running almost due north and south, and both are remarkable for the floating islands which cover a considerable part of their surface. Both, moreover, are shallow, and neither has well-defined shores or a definite permanent area.

On detailed comparison, however, it becomes clear that, in this, as in so many instances the physical differences, though much less apparent, are actually of greater importance from a biological point of view than the physical resemblances. The structure of the two valleys and of the hills surrounding them, as we shall see when discussing the origin of the Loktak Lake, is very different, the most important feature characteristic of the Manipur valley being probably the absence of limestone, for as a result of this the composition of the water of the two lakes is quite unlike.

This chemical divergence occurs in every particular. The percentage of calcium and magnesium salts is very much smaller

in the Loktak Lake, in the more open parts of which calcium occurs only to the extent of 0·0148 per cent as compared with 0·022 per cent in the Inlé Lake, and magnesium to that of 0·0068 to 0·0134 as compared with 0·0279. On the other hand, the amount of organic matter in the much more congested Loktak Lake is considerably greater than it is in the clear water of the central region of the Inlé Lake, while the amount of carbonic acid is more than four times as great in the former as in the latter. The percentage of silica, further, is much greater in the Loktak Lake, and this is also so, as might be expected, with SO_4. These differences are due doubtless, so far as most of the mineral salts are concerned, mainly to the composition of the surrounding rocks and of those amongst which the water-supply of the lakes flows before entering them. The larger amount of organic matter, of carbonic acid, of SO_4 and possibly of silica may be accounted for, on the other hand, partly by differences in the vegetation, but these again are correlated with the chemical composition of their environment.

Origin of the Loktak Lake.

It is impossible to consider the origin of the Loktak Lake without considering also that of the Manipur valley in its present condition. Two different views have been held on this point, one, that the whole valley is a comparatively recent lake-bed and that the Loktak once filled it and has shrunk to its present size, perhaps even in historical times; the other, that the valley is of comparatively ancient date and has been filled in gradually to its present level by debris brought down from the hills by the tributaries of the Imphal River. As I have already said, the valley has never been properly surveyed. From a geological point of view its structure is practically unknown, but the rocks of the surrounding hills appear to resemble closely those of the Naga Hills to the north. I have to thank Dr. E. H. Pascoe of the Geological Survey of India for the following note on rock-specimens from islands in the Loktak Lake.

"The rocks consist for the greater part of hard shale but two of the specimens are of siliceous sandstone. They belong in all probability to the Disang series, about the age of which we know nothing definite beyond the fact that it is pre-Tertiary. The Disang series is essentially argillaceous and the rocks thereof would produce somewhat muddy water but not so muddy as softer argillaceous deposits.

"As to any organic connection of Lake Loktak with Assam, there is not sufficient evidence to go upon. An idea which I believe is a very old one and mentioned by La Touche makes the present Chindwin-Irrawadi the former continuation of the Tsang-po or Tibetan-Brahmaputra, the upper waters of this large river being afterwards captured by the Assam-Brahmaputra. Whether Lake Loktak was connected with the Chindwin at the time it was a continuation of the Tsang-po I cannot say, nor do I know whether this would help you in any way."

The most important facts about the specimens from my point of view are that they certainly represent rocks common all round the valley, and that those which represent the rocks most abundant in the neighbourhood are extremely friable and readily crumble to form a fine soil precisely like that in which the cultivated parts of the Manipur valley are deeply buried. Soil of this kind extends on the north and west sides of the lake well down to high water-level and it is only on the east, and probably also on the south side, that large deposits of peat are being formed. The peat in these deposits is less coherent than, and not quite so black as that found round the Inlé Lake. There is no sign whatsoever of raised beaches at any point.

This last fact induced Col. Godwin-Austen, who was the first man with any knowledge of geology to visit Manipur, to doubt whether the lake had ever extended much beyond its present high-water limits. The peaty deposits on its eastern shores are very like those found in other parts of the valley and known to represent swamps that were recently larger than they are now, but even if the whole of these swamps were completely submerged the greater part of the valley would still be above water.

All of these facts seem to me to support Col. Godwin-Austen's views, to which Mr. R. D. Oldham gave his adherence. The Manipur valley, moreover, although at first sight it closely resembles a lake-bed, with its dead level only broken by small island-like hills rising abruptly from the plain; nevertheless, on closer examination seems to differ in little but its greater extent from other swampy valleys in the Naga and Khasi hills which have certainly never been lakes but have been filled in to an almost equal level by the silt brought down in streams that now meander through them with sluggish waters in which flow has been diminished by a gradual filling in of their old beds and consequent diminution in fall.

Vegetation of the Loktak Lake.

No factor is more important in influencing the fauna of any body of water than its vegetation, and it seems to be a general rule, at any rate in warm countries, that over-abundant submerged plant-life, especially if it includes a luxuriant growth of small sessile algae, is inimical to many forms of animal life, partly doutbless on account of actual toxins produced by the vital activities of certain species and partly on account of the poisonous nature of the rotting material at the bottom. The latter feature, however, is of a very complex character, evidently depending at least in part on the activities of microscopic organisms. But these again are dependant largely on the physical and chemical characters of the water. As we shall see later, the fauna of the Loktak Lake, and especially the invertebrate fauna, is a rather poor one. I associate this fact with the extreme luxuriance of the vegetation.

As has already been stated, this luxuriance of the vegetation, both submerged and floating, gives the lake the character of a large swamp. The submerged weeds are of various kinds, but

perhaps the most abundant of all is the Water-chestnut (*Trapa bispinosa*)[1], which has leaves floating on the surface as well as a profuse growth under water. The floating leaves dot the whole surface of the more open parts of the swamp, growing up through dense thickets of *Potamogeton* and *Hydrilla*. The leaves and stems of these completely submerged plants are as a rule densely covered with small algae, and it is quite exceptional to find beds of any kind of water-weed that have a clean appearance.

In the channels among the floating islands surface-plants such as *Pistia*, *Azolla* and *Lemna* are often fairly abundant, but not sufficiently so to play a great part in the formation of the islands.

These islands are not so coherent and do not support so varied and luxuriant a flora as do those of the Inlé Lake. The chief agent in their formation is a comparatively small grass which sends out long trailers on the surface of the water. A *Caladium*, several species of *Polygonum* and a fern are common upon them, but the bulk of the vegetation consists of grasses and sedges.

The islands are not used for horticulture or stock-keeping as are those on the Inlé Lake, but occasionally small fishing-huts are built on the firmer islands, and pieces are frequently cut off from them and towed away to be utilized in forming fishing-enclosures.

General characters of the fauna of the Loktak Lake.

A whole volume of these *Records* was devoted to the fauna of the Inlé Lake and the help of a number of specialists was invoked in its preparation. It is unnecessary to deal with the fauna of the Loktak Lake in the same detail, because it is a much less isolated association and does not consist for the most part of highly specialized species of animals. It will, therefore, be sufficient to have the molluscs and the fish completely worked out and to mention here a few salient representatives of other groups. The molluscs will be described in full in the succeeding paper, and has already Mr. Sunder Lal Hora dealt in detail with the fish. Here I shall merely refer to these groups as constituting the most important elements in the fauna and give a few facts of a general kind about them.

Conditions in the Loktak Lake are favourable to the growth and reproduction of Protozoa and many water-plants were observed that bore a profuse growth of Vorticellids. Small masses of sponge were found in considerable abundance on the weeds of the open parts of the lake. On examination they proved to belong to but one species, *Spongilla carteri*, the commonest and most generally distributed of the Indian Spongillidae. They differed, however, from the typical form of the species in the small size and irregular shape of individual sponges. No Hydrozoa were observed and the only polyzoon collected was immature—evidently a species of

[1] This plant is utilized as a vegetable in large quantities by the people of Manipur, who unlike most Indian races, employ the leaves as well as the roots as an article of food.

Pectinatella and probably *P. burmanica*, but still in a stage in which the individual colonies had not become embedded in a common jelly. There were no statoblasts in these colonies. Small Oligochaete worms were abundant among the weeds and a larger form with gills on the sides of its posterior region was obtained from mud at the bottom. Leeches of various species were collected, but only one, a *Glossosiphonia* parasitic on *Vivipara oxytropis*, was at all common.

The Crustacea were less well represented than might perhaps have been expected. Small Ostracods were abundant at certain spots among the weeds, but few other Entomostraca were observed. The Decapoda were singularly scarce, the only species collected being a small *Palaemon*. Crabs were apparently absent, and so also were Atyidae, which might have been expected to abound among the weeds. Aquatic insects were also rather scarce, the commonest being dragonfly larvae of the families Agrionidae and Libellulidae. In the smaller channels among the floating islands large numbers of mosquito larvae (both Culicinae and Anophelinae) were often seen, and larvae of *Chaoborus* were dredged from the bottom of the lake. Several large species of Dytiscidae were fairly common, but water-beetles generally were scarce. Although the molluscs were rich in number of individuals, the number of species that occurred actually in the lake was small. Several typically non-lacustrine forms, notably *Limnaea acuminata* and *Indoplanorbis exustus*, were found all over the lake and the only Gastropods that could be regarded as really characteristic were two exceptionally large species of Viviparidae (*Vivipara oxytropis* and *Lecythoconcha lecythis*), both of which are also paludine. Dead shells of *Lamellidens corrianus* were picked up at the northern end of the lake, but Unionidae were evidently very scarce. A species of *Sphaerium* (*S. indicum*) was, however, fairly common among the weeds. All heavy-shelled forms were naturally absent.

Fish were very abundant, but unlike those of the Inlé Lake, they were not highly specialized. Few very small species were seen, but the great majority do not grow more than 5 or 6 inches long. Except eels, indeed, few fish in this lake attain the length of one foot. Cat-fish (Siluridae, *sensu lato*) are particularly well represented in our collection. A large proportion of the species of this and other families are provided with highly developed tactile organs, and the enlarged eyes so characteristic of the Inlé fish-fauna are not found among them. The general facies of the specimens is that of swamp-fish, and genera peculiar to swamps and similar bodies of water are present.

Frogs and toads are not abundant, at any rate in March and April, but *Rana limnocharis* and *Bufo melanostictus*, two of the most abundant Indian species, were observed on the shores of the lake and the tadpoles of the toad were found in a small pool of water on one of the islands. We saw no kind of water-tortoise and the local fishermen assured us that they were not acquainted with any.

It is not in my power to give an account of the water-birds of the Loktak Lake, on and around which both swimming and wading birds are extraordinarily abundant. On this subject Hume's paper in *Stray Feathers*, Vol. XI, should be consulted. I have not seen any other place in India where such enormous swarms of ducks and geese could be observed on the water as was the case in February on this lake, and wading birds were almost as abundant in the surrounding swamps. Some of the latter, notably the smaller Herons, the Open-bill (*Anastomus oscitans*) and the Glossy Ibis (*Plagadis falcinellus*), were proved by examination of their stomach-contents to be feeding mainly on aquatic molluscs, and even the ducks and geese must destroy enormous quantities of molluscan spawn and young with the weeds on which they depend mainly for their food-supply.

Otters are said to be abundant, but no specimens were obtained.

The fauna of the Loktak Lake must, therefore, be regarded as paludine rather than lacustrine. It is comparable to that of the marginal zone of the Inlé Lake rather than to that of the central region. Even from the former, however, it differs notably. The great abundance of different species of small bottom-haunting fish, the greater poverty of the arthropod fauna and the absence of several molluscan genera (*Pachylabra*,[1] all the Hydrobiidae, *Segmentina*, etc.) usually found in such situations are noteworthy features, and may be correlated directly with the superabundance of vegetation and indirectly with the composition of the water and therefore, still more indirectly, with the geological formation of the surrounding country and the meteorology of the valley. The absence of extreme specialization in the aquatic fauna may be put down partly to the same causes and partly to the absence of complete geographical isolation, while the curious fact, amply illustrated in the following paper, that, though the Imphal River belongs to the Irrawadi system and is cut off by high ranges of mountains from those of Assam, nevertheless the aquatic molluscs are essentially Assamese and include very few Burmese species—this fact would at any rate suggest that comprehensive physiographical changes have taken place in the Manipur valley and the surrounding hills at a date geologically not remote.

THE PROSOBRANCHIA.

By N. ANNANDALE.

This order is represented in the aquatic and amphibious fauna of Manipur by eleven species, belonging to the families Hydrobiidae, Viviparidae, Melaniidae and Ampullariidae. With one exception, that of the Viviparid genus *Lecythoconcha*, the genera are those usually found in the tropical districts of India, and this section of

[1] The place of this genus is taken to a large extent by gigantic Viviparidae.