

FAUNA OF THE CHILKA LAKE

INTRODUCTION.

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GEOGRAPHY OF THE LAKE.

The Chilka Lake is a lagoon situated on the east coast of Peninsular India and connected with the Bay of Bengal. Its area is about 350 sq. miles; its depth rarely exceeds two fathoms; its water undergoes great changes of salinity in the course of the year and at any one season differs greatly in this respect at different places. The precise geographical situation of the lake is between latitudes $19^{\circ}28'$ and $19^{\circ}54'$ N. and longitudes $85^{\circ}6'$ and $85^{\circ}35'$ E.; the greater part of it lies in the Puri District of the Province of Bihar and Orissa, while one corner extends into the Ganjam District of the Madras Presidency.

Its position and character.

A glance at the map (plate II) will show that the lake consists of two parts,

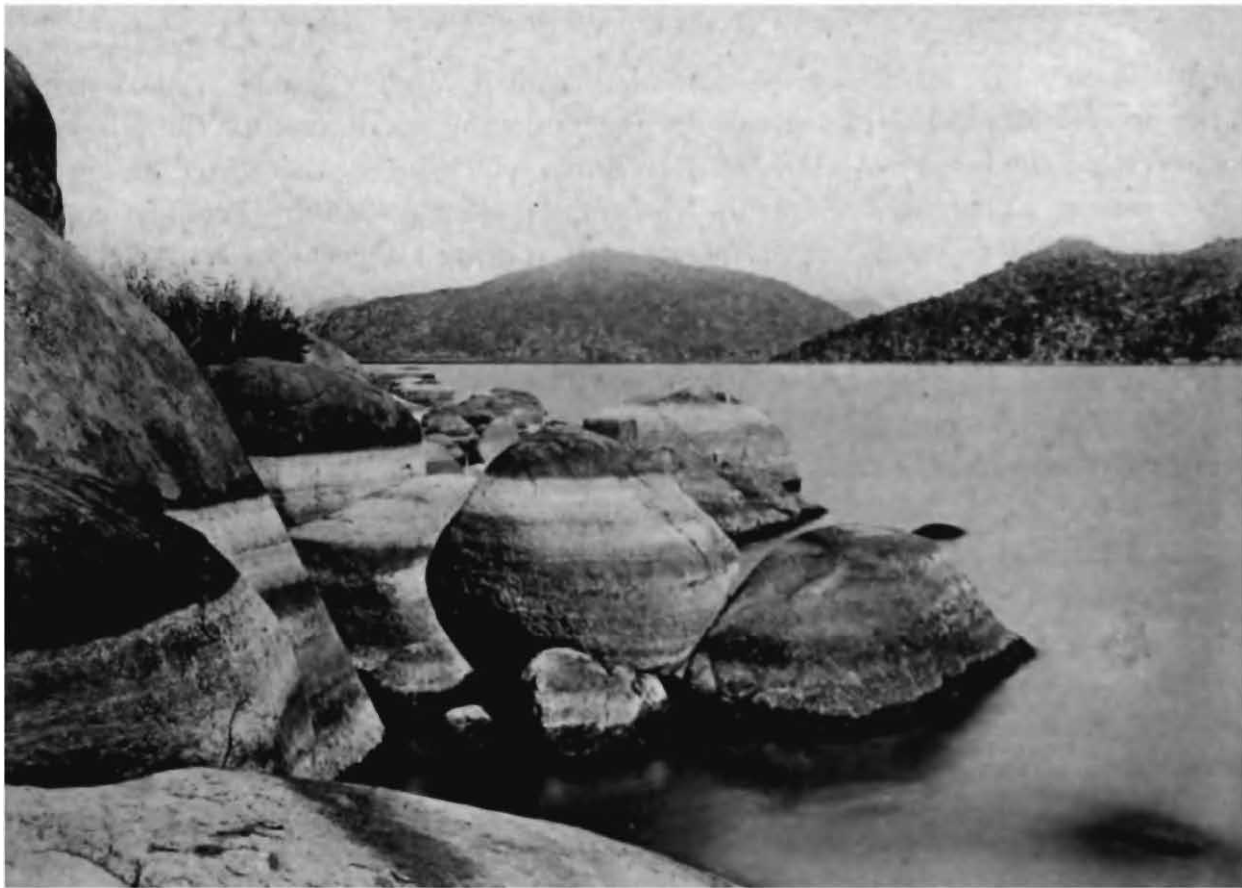
Its divisions.

(i) an outer channel opening to the sea and (ii) what may conveniently be called the main area.

The outer channel is peculiar in that its course is not direct from the sea to the lagoon, but runs parallel to both for some miles. Its total length is about twelve miles and the breadth of the outer part nowhere more than one and a quarter. The actual mouth of this channel changes from time to time both in position and in breadth; in 1914 it was situated opposite the village of Arakhuda and was not more than 300 yards broad. Near the opening the channel turns abruptly at right angles to its former course and communicates with the sea by a narrow passage several hundred yards in length and apparently of no great depth. There are records that on several occasions the mouth has been completely blocked up by sand carried along the coast by northerly currents, especially in the south-west monsoon.¹ It has then been opened artificially by digging to prevent flooding of the surrounding country.

From the inner opening of the sea-passage the channel runs almost directly south-west. On one side it is separated from the sea by a narrow sand-spit and on the other from the main area of the lake by a series of comparatively broad peninsulas and islands. On reaching the apex of the Satpara peninsula the channel divides into two branches, one of which continues in the original course until it becomes gradually merged in a network of swamps and narrow water-ways. The broader branch, however, turns at a right angle and, continuing round Satpara peninsula,

¹ The origin and direction of the local currents on this coast are still very imperfectly known, and it is probable that more than one factor plays a part in the phenomenon to which we refer.



Nov 1914

Rocks near Patsahempur



Nov 1914

Foreshore near Bapat

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VIEWS OF THE CHILKA LAKE

finally reaches the main area at the point called Mugger-Mukh¹ (Shark mouth). In the flood-season this is one of two openings into the main area, for there is another south-west of the large flat island of Barnikuda which lies in the midst of the inner part of the channel; but even the opening at Mugger-Mukh becomes extremely shallow in the dry season, while the other disappears altogether. In March there is not more than a foot and a half of water on the bar² at the former point.

The main area of the Chilka Lake is the real lagoon and occupies by far the greater part of the lake-system. It is roughly pear-shaped, the longer axis running south-west and north-east. Its length is about forty miles in the height of the dry season and its greatest breadth about twelve and a half miles. The broadest point is situated toward the north-east extremity.

The shores of the Chilka Lake have considerable variety of character. Smooth green lawns, diversified by clumps of trees, slope down to the water's edge: rocky headlands rise as pyramids, seemingly composed of loose boulders piled one on another with bamboos and other vegetation springing up in the interstices; islands, some bare and rocky, others like the headlands, others again low and sandy, rise from the surface of the water; naked sand-hills contrast with the dark green foliage in which fishing villages lie hidden.

On a near approach the green lawns are not attractive, for in dry weather their margins are edged with decaying weed and in the rainy season lie deep in evil-smelling mud: the headlands and islands are difficult of access at all times of the year. Our present business, however, is not to discuss the beauties or the discomforts of the Chilka Lake but to describe the features of its shores that have a bearing, direct or indirect, on the nature and distribution of its fauna.

At the northern end of the main area the silt brought down by several branches of the Mahanaddi system, of which the most important is the Dayanaddi, has formed a margin so ill-defined that, when the floods are high and the water in consequence fresh, there is no perceptible boundary between rice-fields and lake; the former terminate only at the point at which the water becomes too deep for rice to grow. As the water-level sinks in late autumn wide stretches of muddy foreshore are left bare.

Along the outer side of this area, as the distance from the mouth of the streams increases, a large quantity of sea-sand is mixed with the mud, and even where the proportion of alluvium present is very small, the periodic decay of vegetation and the fine silt usually held in suspension in the water but deposited when a dead calm prevails, produce a thinner or thicker layer of mud above the sand. Along the whole of this shore the extent of mud or sand left bare when the water sinks is considerable and the depth of the lake at and near the margin extremely small, to be measured in inches rather than feet.

¹ In several Indian dialects the word "mugger" (more correctly *magar*) means crocodile; but the Uriya fishermen of the Chilka Lake use it to signify either a crocodile, a porpoise or a shark. The last is sometimes distinguished as *magar-mach* and the porpoise (*Orcella brevirostris*) as *sus-magar*.

The inner side of the main area has a far more varied character. For some miles north-east of Barkul, almost to the point at which the delta of the branches of the Mahanaddi may be said to commence, the shore consists of a series of little bays separated by headlands of the kind described above. Most of these headlands are spurs running out from a range of rocky hills that lies almost parallel to and at no great distance from this shore; others are isolated fragments of the same formation. Between the promontories the edge of the lake is flat and resembles that of the outer shore of the same area, except that the proportion of mud to sand is greater at most points and the slope a little less gentle; single rocks and groups of stones, most of which are left entirely bare in winter, occur sparingly; the grass that covers the shore is short and coarse.

South-west of Barkul point, which forms a lower and less pyramidal promontory than those that lie to the north-east, there are several wider bays in which the margin is of a similar kind, but without the headlands

The south (strictly south-west) end of the lake is occupied by two long and rather narrow bays separated by a mass of rocky hills, the highest of which, a regular pyramid named Ganta Sila, rises almost straight from the water to a height of over 500 feet and is one of the most conspicuous land-marks over the greater part of the whole area. Round its base single rocks of considerable size form what may almost be called small cliffs; when the lake is flooded or moderately full the water round them is several feet deep, but in spring and early summer a narrow muddy foreshore is left bare in front of them. The shores of the two bays resemble those adjacent to them.

Near the south-western corner of the outer bay lies the mouth of a small canal that formerly ran to the town of Ganjam, which is connected by another canal with the Bay of Bengal. The Chilka-Ganjam canal is now, however, completely blocked up and the locks with which it was provided must always have rendered any direct communication between the lacustrine fauna and that of the sea practically impossible.

The inner shore of the outer channel, except in the immediate neighbourhood of the sea-opening, resembles the outer shore of the lagoon. The bar that separates the channel from the Bay of Bengal is, however, composed almost entirely of clean sea-sand sloping down into the water, and it is only at the point at which the channel turns landwards, and in particular opposite Barhampur Id., that the margin becomes muddy or swampy.

The only streams of any size that find their way into the lake are the branches of the Mahanaddi that enter the north-eastern part of the main area, for the hills that run parallel to the inner shore are practically waterless for the greater part of the year and even at the southern end the small water-courses dry up more or less completely by the beginning of the hot weather.

In the main area of the lake there are a number of rocky islands of different sizes, none of them really large, that have a certain biological importance in that

their bases remain under water throughout the year. In this area there are also a few flatter and more sandy islands the margins of which slope gradually, but the most remarkable and the largest island in the whole lake is Nalbano, which lies not very far within the Mugger-Mukh. Nalbano is a great sand-bank completely covered with tall reeds, the roots of which are submerged when the water is high, so that only the leaves and inflorescences are visible above the surface.

The islands of the outer channel, including Barnikuda, are also sand-banks, but at most support in the way of vegetation no more than a scanty growth of short grass with, in the case of Barnikuda, a few stunted shrubs.

Generally speaking the bottom of the main area is muddy, while that of the outer part of the outer channel is sandy. In the former its nature is so uniform, notwithstanding the admixture of a certain amount of sand at some places, that the small actual differences have as a rule little effect on the fauna, and it is only in the neighbourhood of Nalbano and on the shores of some of the other islands that true arenicolous species occur in this area. The mud forms two quite distinct layers, one of which remains practically undisturbed except in very rough weather, while the other is usually held suspended in the water and only deposited in very sheltered places or at times of unusual calm. This floating layer is of course very finely divided and habitually stains the water a dirty clay-colour. Its occasional deposition is an unfavourable factor in the life of many sessile organisms. The permanent layer is gray and of a clayey consistency, but not so tenacious or so heavy as that of creeks and canals in the Gangetic delta. It is mixed with a considerable amount of decayed vegetable matter, which sometimes stains it black, and often with a large number of small dead shells of genera such as *Clementia*, *Theora*, *Nassa*, *Stenothyra*, etc. These apparently do not remain long intact; but at certain points, notably in the neighbourhood of Gopkuda Id., there are fairly large deposits of dead *Placuna*-shells, which are evidently more permanent, while at the edge of Rambha Bay masses of crude lime are dug from the mud when the water sinks and with them occur large numbers of dead shells of *Arca* and *Meretrix*. These deposits of calcareous matter do not, however, seem to have any direct effect on the fauna found amongst them.

In the inner part of the outer channel there is a great mixture of mud and sand, some of the latter being black and extremely heavy. Mr. G. H. Tipper of the Geological Survey of India informs us that this is due to the presence of monazite in small quantities.

In the part of the outer channel that runs parallel to the Bay of Bengal, the bottom is composed of almost pure yellow sand similar to that which forms the beach along the greater part of the eastern shore of Peninsular India. The only natural solid bodies found in this part of the lake are the large masses of dead and living oyster-shells that lie in beds round the small islands opposite the village of Manikpatna. The faunistic importance of the absence of solid bodies is illustrated by the fact that on a small post set up to mark the channel near Satpara we found several species not obtained anywhere else in the lake.

The main area of the Chilka Lake is exceedingly shallow. In the dry season, when the water-level is at its lowest, the depth rarely exceeds 8 ft. at the southern end ; while over an immense area towards the northern extremity it nowhere reaches 4 ft. The deepest sounding we obtained at this season was 10 ft., at a point close to the eastern end of Kalidai Id., whence a comparatively deep trough extends towards the shores of Parikudh. At many places we found it impossible to approach within a mile of the shore even in a small row-boat.

We have already referred to the shallowness of the water at Mugger-Mukh and to the depth of the outer channel at this season. The deepest water is said to be situated off Arakhuda and our boatmen talked of five fathoms ; but the deepest soundings we ourselves obtained did not exceed 20 ft.

In the flood-season all depths are increased by 5 or 6 ft., the exact amount probably varying from year to year.

It is evident that the differences in depth, relatively great though they may be, are actually insufficient to produce any appreciable effect on the fauna of different parts of the lake, except in so far as they imply a great rise of temperature in extremely shallow water.

The origin of the Chilka Lake was thus explained by the late Dr. W. T. Blanford in his "Sketch of the Geology of Orissa"¹ :—

"The lake itself is a part of the sea first rendered shallow by deposits from the mouths of the Mahanaddi and from silt carried up the bay round the hills near Ganjam by the violent southerly winds of the monsoon, and then entirely cut off by a spit, formed, by the same agency, of sand drifted along the coast. Near the south-western extremity of this spit there is a considerable deposit of estuarine shells, at a height of 20 to 30 feet above the present flood level of the Chilka."

For our special purpose it is unnecessary to elaborate this concise statement, with which we are in general agreement.² We may point out, however, that even stronger evidence for the belief that the lake was once an open bay than that adduced in the passage quoted, is to be found in the occurrence on the rocks at the base Ganta Sila of the remains of solitary corals, organisms that flourish only in a pure sea-water. The beds of dead *Placuna*-shells to which we have already alluded provide evidence less strong, for *Placuna* flourishes in the Tampalakaman (Tamblegam) Lake³ on the coast of Ceylon, in which conditions are not very dissimilar to those of the Chilka Lake.

HYDROGRAPHY OF THE LAKE.

Of the varied elements that compose the physical environment of the fauna of the lake by far the most noteworthy is the great periodic change in salinity to which

¹ *Rec. Geol. Surv. India*, V, p. 56 (1872).

² Hunter, in his "Orissa" (p. 25; 1872) cites a legend which implies that the bed of the lake was dry land as late as the 4th century A.D.

³ Hornell, "Report on the *Placuna Placenta* Pearl Fishery of Lake Tampalakaman": *Rep. Ceylon Marine Biol. Lab.*, I, p. 41 (1906).

its waters are subject. This factor undoubtedly exercises a continual selective influence on the animals of the lake and it is to it, in the main, that the special interest of the fauna is due.

The methods which we adopted in determining the salinity of the water are explained on p. 17.

As is pointed out below (p. 18) our investigations were made chiefly at two periods, in each of which we attempted, so far as was possible, to visit all parts of the lake. Observations were, of course, made at other seasons and we have in fact, in 1914 and in previous years, paid visits to the lake in practically every month; on these occasions, however, our investigations were of a more or less restricted nature, concerning only a portion of the area to be investigated.

The more comprehensive surveys effected in the two periods mentioned above were made respectively in the salt- and the freshwater seasons. In the first, in which our observations extended from February 12th to March 18th, the entire lake was filled with water of varying but comparatively high density, while in the second, from September 1st to September 23rd, the water throughout a great part of the system was quite fresh, owing to the floods which enter the lake at the close of the monsoon.

The charts on p. 9 showing the corrected specific gravity of the water will give a good idea of the enormous variation in density at these two periods. It is of course improbable that they represent the maximum and minimum with any exactitude. Somewhat higher specific gravities are doubtless to be found in early summer, that is to say in the period immediately preceding the monsoon, and subsidiary investigations made in July tend to prove that this is the case. It is also possible that the general density indicated in fig. 2 is capable of further reduction in exceptionally high floods so far as the southern end of the lake is concerned.

In giving an account of the general configuration of the lake-system, we noticed that it could be divided into two parts, the main area, which comprises the bulk of its waters, and the outer channel that forms the communication with the sea. This division is not founded entirely on geographical considerations; there are also very marked differences in the range of density of the water in the two regions and therefore notable faunistic distinctions.¹ The division is consequently based on both physical and biological features of considerable importance.

In March we found that the specific gravity of the sea, taken at a point some miles below the mouth (and therefore, owing to the strong north-easterly currents that prevail along the coast, uncontaminated by any discharge from the lake) was 1.0270. An additional observation made a few days later just inside the mouth gave a reading of 1.02825. At this period there was no appreciable outflow from the lake and the water in the channel over an area extending from Barnikuda Id. to Arakhuda yielded specific

¹ The prevalence of a sandy bottom over a large part of the outer channel must also of course be taken into account in considering the faunistic differences.

gravities varying from 1.02625 to 1.02650.¹ It is clear that in this region, during March, the water was for all practical purposes as salt as the sea.

In September the conditions were markedly different. The level of the water was some five feet higher than in March and many of the low-lying islands in the channel were almost or entirely submerged, a strong current was flowing out of the lake and the water throughout the length of the channel was entirely fresh up to the point where it entered the sea. Ebb and flow at this period made no alteration in salinity and the maximum effect even of a high spring tide could only have been a slight banking of the water at the mouth. The specific gravity of the sea a little to the south of the entrance to the lake was at this period 1.01675, a reading considerably lower than those obtained in March of the same year.

By December the freshwater floods had in a large measure subsided and samples taken in the early part of this month at Satpara and near Manikpatna gave readings respectively of 1.00325 and 1.01250. At this time a small outflow from the lake probably still persisted, salt water entering the channel only at high tide or under specially favourable conditions of wind.

In the outer channel, then, the range of salinity is the greatest possible, and animals that live permanently in this region are able to exist for some eight months in water almost or quite as salt as the neighbouring sea (sp. gr. 1.0270) and for at least three months in water that is entirely fresh.

The change from salt to fresh water that takes place annually towards the close of the monsoon season is probably effected gradually. The discharge from the rivers at the northern end of the lake must in the first place drive before it the saline water with which the main area was previously filled, and there can be no doubt that the first slow currents that pass down the outer channel have a comparatively high salinity, which slowly decreases with the augmenting volume of the flood. The change from fresh to salt water, on the other hand, probably takes place more suddenly. After the floods have subsided and the head of water in the lake has disappeared, there must, under suitable conditions of tide and perhaps also of wind, come a time when a volume of salt water enters the sea-mouth and it is possible that far-reaching alterations take place in the channel in the course of a single day.

Both periods of change must have marked effects on the fauna of the outer channel and on each occasion there is probably a high mortality; freshwater forms must be largely exterminated on the entrance of salt water, while many marine species that have established themselves during the salt-water period must succumb in the flood season. We have direct evidence that this occurs.

Though less extensive than is the case with the outer channel, the changes of density to which the waters of the main area are subject are nevertheless great; the specific gravity varying, according to our observations, from 1.000 to 1.0150.

¹ A sample taken in a swamp south-east of the northern extremity of Barhampur Id. and separated by a bar from the main channel gave a reading 1.02376. The water in this place was probably mixed with a certain amount of surface drainage from land in the vicinity.

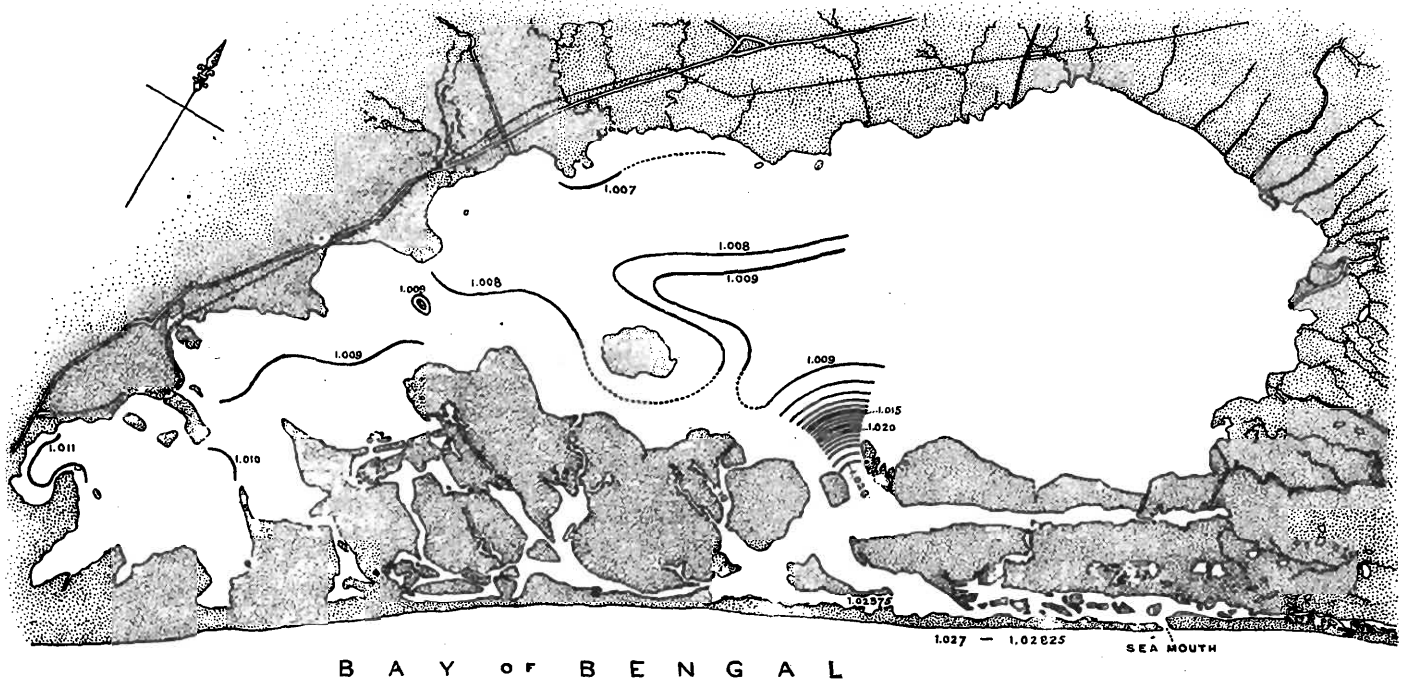
In February and March, as will be seen from the chart on p. 9, an abrupt change in density was encountered at Mugger-Mukh on the bar that separates the main area from the outer channel—a bar covered at this period by water only some eighteen inches or two feet in depth. The specific gravities in little more than a mile changed from 1.026 to 1.010. The floods of the previous year's monsoon had not only altogether subsided, but a considerable quantity of salt-water had entered from the Bay of Bengal. The most noteworthy feature of the specific gravities in this large region was that the denser water was accumulated at the south end. The highest readings were obtained at the southern extremity of Rambha Bay and from this point to Nalbano the specific gravities regularly decreased. North of Nalbano, water of greater density was again met with, while the lowest readings were obtained along the north-western shore in the vicinity of Patsahanipur. At this period the specific gravities we obtained ranged from 1.00675 to 1.01150. Owing to the extreme shallowness of the lake we were unable, however, to visit a considerable region at the northern end and the comparatively small amount of water that enters from the rivers probably produces specific gravities lower than any we actually recorded.

Subsidiary observations made in the middle of April at the southern end of the lake seem to indicate that no great change in the conditions had taken place, though the position of the isohalines (as indicated by the lines of equal specific gravities) had probably altered to a certain extent. Samples taken in Rambha Bay and off Breakfast and Chiriya Ids. gave readings identical with those of February; but off Barkuda the specific gravity was lower (1.00975) and off Maludaikuda higher (1.00975). By July, however, a notable change had occurred and there is little doubt that during May and June a considerable volume of salt water had entered the lake; the specific gravities were higher than any previously observed and the entire area southwest of Samal Id. was filled with water varying from 1.0145 to 1.0150. At Barkul the specific gravity was still much the same as in February, *viz.*, 1.00750.

The conditions in the main area were very different in September, 1914. In this month, as shown in fig. 2, p. 9, the greater part of the area was filled with fresh or almost fresh water.

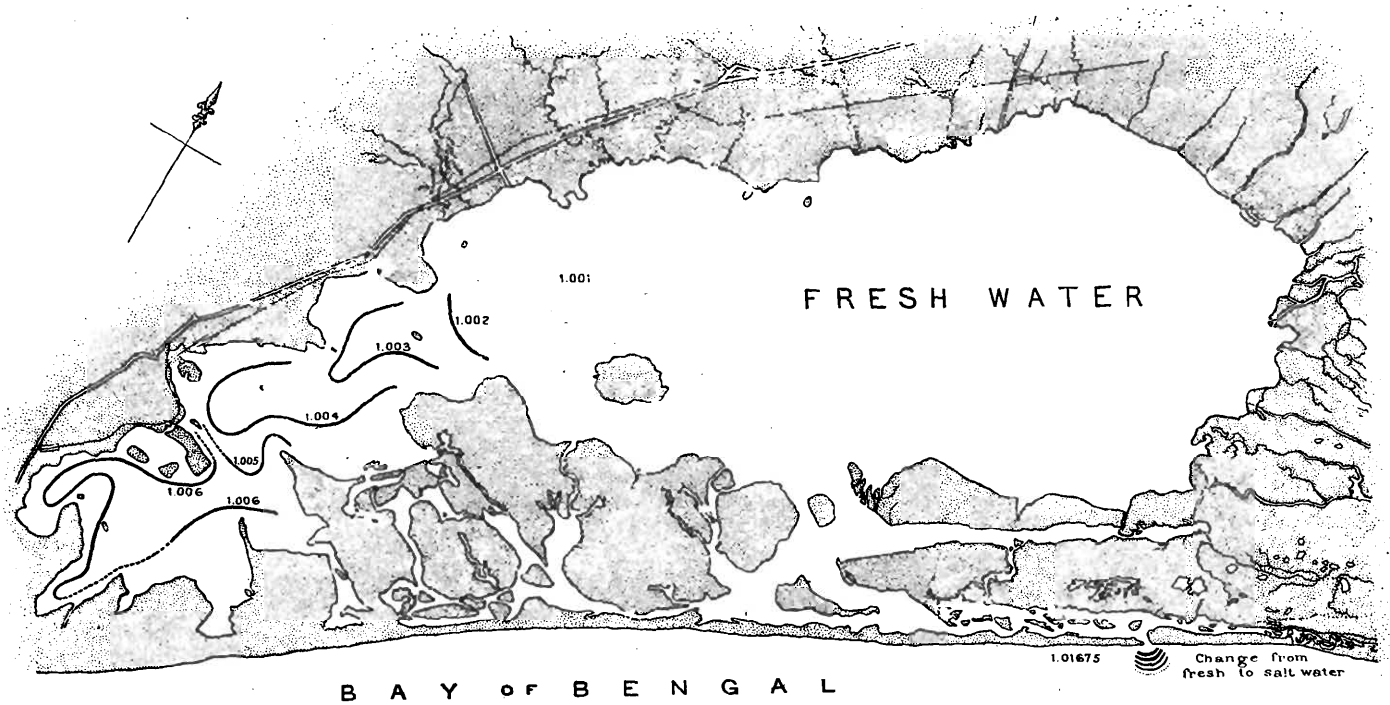
The great volume of silt-laden water brought down into the northern end by the branches of the Mahanaddi system had expelled all that of higher salinity—a phenomenon already noted with reference to the outer channel. It is evident that, in these parts of the lake at any rate, the changes are not due to admixture so much as to the expulsion of one volume by another.

In September slight traces of a higher specific gravity were met with between Nalbano and Patsahanipur, the water varying from fresh to 1.001, and southwards of this line there was a gradual rise in density up to sp. gr. 1.0065 in Rambha Bay. The latter reading, the maximum observed in September, is about the same as the minimum recorded in the salt-water season. It will be noticed that specific gravities of 1.006 and over were only met with near the shore in the extreme south and that



TEXT-FIG. 1.—The specific gravity of the water of the lake in February and March, 1914.

At this period we were unable to visit the north-east end of the lake owing to the shallowness of the water. The specific gravities recorded in the main area varied from 1.00575 to 1.0115. A sudden change occurred at Muggur-Mukh,¹ the outer channel being filled with water as salt as that of the Bay of Bengal.



TEXT-FIG. 2.—The specific gravity of the water of the lake in September, 1914.

During this month the water-level was some 6 ft. higher than in February and March; Nalbano¹ and several of the islands in the outer channel were submerged. The north-eastern part of the main area was filled with fresh water, as was also the outer channel as far as the sea-mouth. In the south-western end of the main area the specific gravities ranged from 1.002 to 1.0065.

¹ See detailed map, Plate II.

throughout the southern part of the lake the water in the middle was of lower specific gravity than that nearer the shores.

A short series of observations made in November indicates that the conditions in this month did not differ largely from those observed two months earlier, the highest specific gravity (1.006) being obtained at the south end of Rambha Bay. Water of appreciable salinity was, however, not so closely restricted to the southern area, for a sample obtained off Kalidai gave a reading of 1.0035 and others off Barkul of 1.003. The flood-water, had somewhat abated, with the result that the level had decreased and the saline water, confined during September at the extreme south, had spread further north.

It is noteworthy that the rocks on the inner shore of the main area appear to indicate that the water sinks mainly in a series of sudden falls, for, as will be seen from the upper photograph on Plate I, the stone is marked in the dry season with three or four horizontal bands of a superficial nature. The distinct demarcation of these bands is apparently due to the fact that the upper limit of each has indicated the highest water-line for some considerable period, and after a high south-westerly wind we noticed in one case that a band actually represented an area of half-dried alga just left bare by a sudden reduction of level.

An attempt to discuss in detail the various other agencies that affect the salinity of the lake would be beyond the scope of our present enquiry and would certainly demand an experience of hydrography and meteorology which neither of us possesses. It has been our object to obtain, so far as was practicable within the limits of a single year, a general idea of the alterations in salinity to which the fauna of the lake is subject and of the more important causes to which these changes are due.

It is evident that the changes are to a large extent correlated with differences in water-level and that the monsoon floods are by far the most potent of the agencies at work. Other causes must, none the less, have a marked effect. Although the rivers at the north bring with them by far the greater part of the fresh water that enters the system, the streams which occur in the monsoon at other points but are for the most part dry during the remainder of the year, must also have some influence on the conditions and during periods of heavy rain surface drainage even from the small watersheds at the southern end must be considerable.

Unfortunately no precise data are available as to the amount of rain that falls actually on the lake, in our experience it was decidedly less (in 1914) than that which fell on the surrounding country. Storms coming up from the south often either followed the hill ranges to the north-west of the lake, or else split in two before they reached it, one part skirting these hills while the other keeps to seaward, following the line of sand-hills along the coast.

An important factor in local changes in salinity is the direction of the wind. Owing probably to the topography of the surrounding country the monsoon currents are to some extent diverted and the prevalent wind throughout the greater part of the year is south-westerly. From this quarter it often blows with considerable

force and for protracted periods. We are informed that on occasions, when its violence is extreme, the greater part of Rambha Bay is entirely emptied of water and in February, 1914, the effect of even a moderate breeze was brought home to us by a sudden lowering of the water-level so great that the "Lady of Chilka" grounded at her moorings. Sudden changes of the kind must result in the water being banked up towards the northern end and must produce a considerable admixture of volumes hitherto distinct. Observations made at Barkuda Id. in February, before and after several days' strong breeze, showed a definite rise in density, the salter water having doubtless been brought from the southern end by the wind.

Tides have of course no effect during the flood season, as at this period the outer channel is filled with fresh water to a level some feet above that of the sea. Even when the lake was at its lowest we were unable to observe any regular ebb and flow in the main area. The influence of wind, indeed, seemed to us sufficient to account for any diurnal changes in level that were actually noted. Any effects that the tides may have had were doubtless masked by this agency, while we made no attempt to investigate less obvious movements.

In the outer channel tide had of course a slight effect at this season; but the rise and fall, owing to the narrowness of the sea-mouth, was probably much smaller than in the Bay of Bengal immediately outside. It is clear, nevertheless, that the tides, assisted probably by changes in the wind, must have a much greater effect on the isohalines than is indicated by diurnal changes in water-level, for to this agency in a large measure must be assigned the influx of salt water at the time when the autumn floods have subsided.

In a lagoon of the size and shallowness of the Chilka Lake evaporation must, especially in a tropical climate, be more than considerable and doubtless plays a great part in the phenomena we have been discussing. We have no means of estimating the exact influence of this factor, but it is not unreasonable to suppose that beyond compensating for the comparatively small amount of fresh water that comes from the Mahanaddi system in the dry season, it also plays an important part in inducing an inflow from the sea.

The great changes in the salinity of the Chilka Lake are due, as has already been explained, to the floods of fresh water which enter it each year at the northern end from several branches of the Mahanaddi system; the annual sequence of events, as it concerns the lake as a whole, may be stated briefly as follows:—

The floods that enter the lake at the close of the monsoon from the Mahanaddi delta expel all salt water from the northern portion, driving it through the outer channel to the sea, and are of sufficient volume to raise the level of the lake some 5 or 6 ft. above the mean of the dry season. There being no outlet at the southern end, the comparatively saline water which had accumulated there is banked up by the flood, becoming, however, diluted to a considerable extent both by admixture with water from the north and by surface drainage from the land in the vicinity. Towards the end of the year the floods subside. The first effect of the alteration

in level is that the water of low salinity, hitherto confined at the southern end, spreads further north. In course of time the level sinks to a minimum and subsequently, under suitable conditions of wind and tide, volumes of salt water enter from the sea and entirely fill the outer channel. This in 1914 had already taken place before the month of February. Under normal conditions the waters of the main area probably rise in salinity, owing to successive inflows from the Bay of Bengal, until a maximum is reached in July. By August the monsoon floods have commenced, the water-level rises rapidly and a repetition of the annual cycle begins.

The important subject of salinities may therefore be summarized as follows:—

- (1) In the dry season the water of the outer channel is practically as salt as that of the Bay of Bengal, while that of the main area is distinctly brackish.
- (2) At the end of the wet season the water of the whole of the outer channel and of a great part of the main area is fresh, while that of the south-western part of the latter is but slightly saline.
- (3) At all times of year the change from water of low to that of comparatively high salinity take places abruptly in a very limited area, so that the isohalines are closely crowded together.
- (4) In the dry season this area of abrupt change is situated at the junction of the outer channel with the main area, but by the end of the wet season it has shifted to the sea-mouth.

Variations in the temperature of the water of the lake have probably, except in extreme cases, but little influence on the distribution of the fauna. According to our observations, the surface temperature ranges from 25° to 35°C. and is probably higher to a marked extent than that of the Bay of Bengal. The cooler water is naturally found in the more central parts, while nearer the shores, and especially in the vicinity of rocky headlands, the temperature is noticeably higher. Even comparatively short periods of hot weather must obviously have a marked effect in raising the surface temperature and the maximum must be reached in very shallow water or in small more or less isolated pools at the margin. In one such spot we obtained, in March, a reading of 43°C.; this temperature must be inimical to many forms of life and as a matter of observation few living animals are to be found in situations of the kind. Seasonal variation in temperature is certainly not very great: but our data are not sufficiently extensive to permit of a more precise statement.

VEGETATION

In most parts of the lake the aquatic vegetation is scanty, but in a few sheltered bays in the main area a species of *Potamogeton*¹ with slender, grass-like leaves grows

¹ Probably *P. pectinatus*, Lam. We have to thank Dr. D. Hooper for the name of this plant.

luxuriantly, forming dense thickets that extend upward from the bottom to the surface for a height of at least four feet. This plant dies down in the rainy season and masses of dead and dying weed then break loose, float on the water and are thrown up on the shore or entangled amongst rocks at the edge. The new growth makes its appearance in autumn and is well advanced by the middle of November, when the plant is in flower on the surface. Its maximum luxuriance is not, however, reached until February or March, after the flowering season is practically over.

A plant more widely distributed in both parts of the lake, but much less conspicuous and luxuriant, is *Halophila ovata*, a species that creeps along the bottom sending up stems of four to six inches high at short intervals. These bear relatively large ovate leaves which form a favourite basis for a few simply organized sessile animals. *Halophila*, which is practically confined to a muddy bottom, is found all over the main area and in the inner part of the outer channel, in patches that often reach a considerable size. Small masses of this plant are constantly being detached, probably by diving ducks and other water-birds, and float from place to place. The plant is found in an active condition at all times of the year.

Several other aquatic Phanerogams occur in the lake, but are not of sufficient abundance to have any faunistic interest.

Among semi-aquatic flowering plants by far the most conspicuous is the reed (*Phragmites*) that covers Nalbano and grows among the rocks on many of the promontories. It reaches a height of at least 10 feet. Several other smaller grasses and at least one species of rush also grow in the shallows of the main area, but not in sufficient quantities to attract a special fauna.

The higher algae are absent from the lake and those of the less specialized groups that occur are not as a rule of any great zoological interest. Several unicellular forms are found, however, in considerable quantities in the plancton at some seasons, notably species of Dinoflagellata, while a certain number of diatoms live on the bottom or elsewhere. Submerged rocks and stones are usually coated with simple and branched filamentous algae of a bright green or a brown colour, but the growth is never very luxuriant. A slimy dark green species with an offensive odour sometimes covers small patches of the bottom in the main area and is fairly common along the shore of the Satpara peninsula. Its presence seems to be peculiarly inimical to animal life. As the water sinks after the rains, this alga, in drying, forms a thin felt-like substance and is gathered by the villagers at Satpara and used by them instead of paper for wrapping up parcels.

From a zoological point of view the most important feature of the vegetation on the shores of the lake is the total absence of mangrove swamps. Except where the beach is sandy, as along the outer parts of the outer channel, or stony, as around many of the islands and promontories of the main area, cultivated fields or grazing grounds extend down to the water's edge, if the former do not actually encroach upon the water. There are, therefore, comparatively few trees close to the margin; firewood is also scarce and trunks and branches are not allowed to go to waste or to float away. This fact is of faunistic importance in reference to the

general scarcity of solid bodies to which attention has already been called with respect to the outer channel. The hedges of screw-pines by which the fields are protected from trespassing cattle are, however, when the water is high, sometimes partially submerged; they then afford shelter to many Decapod crustacea, while broken fragments stranded on the shore give lodgment to amphibious insects and crustacea, as well as to several terrestrial vertebrates that feed on these animals.

GENERAL CHARACTER OF THE FAUNA

When all the reports contributed by specialists to this volume have been completed we propose to discuss the fauna of the Chilka Lake in considerable detail. It will be well, however, to preface these reports by a brief statement as to the general nature of the fauna with which they will deal. To do so it will be convenient to consider the animals first under the following headings:—

- | | |
|-----------------|--|
| (1) Mud fauna | (4) Weed fauna |
| (2) Sand fauna. | (5) Free-swimming organisms. |
| (3) Rock fauna. | (6) Plankton and surface fauna generally |

1. The organisms that live in mud or crawl on its surface form what is perhaps from a zoological point of view the most conspicuous element in the fauna of the lake. Considering the great proportion of the bottom that is covered with mud this fact is not surprising. Among the mud-dwellers are included several coelenterates, several polychaete worms, a large proportion of the molluscs, several Decapod and other crustacea, a few small Teleostean fish and several comparatively large rays. In nearly every case the number of species present in any one group is extremely small, indeed it is probable that in many cases even families are each represented by a single form. The number of individuals on the other hand is as a rule very large. In this section of the fauna we find many noteworthy adaptations for burrowing and for protecting the gills or other breathing apparatus from being clogged with particles of silt.

2. The arenicolous animals of the lake are mainly confined to the outer part of the outer channel and have as a rule a less specialized character than the mud-dwellers. Among them are to be found at least one species of sponge, two species of oligochaete worms, several polychaetes, and the majority of the Decapod crustacea and molluscs. This element is not entirely confined to the outer channel, for several of its representatives are found on the shores of Nalbano Id. and a few even so far inland as Barkuda Id. near the mouth of Rambha Bay.

3. The rock fauna is much more restricted as to number of species and genera than might at first sight seem probable. The sponges are represented by two abundant forms, the coelenterates by a single hydroid, the crustacea and worms by a few small species that crawl among sponges and algae or hide under stones; the molluscs by one or two sessile Lamellibranchs and one or two Gastropods. The poverty of this element is due very largely to two facts, firstly that most of the rocks are only covered by water for a small part of the year, and secondly that any animal

which settles on a flat surface is liable to be smothered by the deposition of fine silt in calm weather.

4. The majority of the animals that can be classed under the heading of weed fauna are associated either with *Potamogeton* or with *Halophila*. Young fish of many species take shelter amongst the dense thickets of the former plant, to which the insects of the lake are, at any rate in the salt-water season, almost entirely confined. Several species of Decapod crustacea and at least one very abundant Lamellibranch mollusc are also characteristic of these thickets. The comparatively large leaves of *Halophila* act as a base for several small sponges, coelenterates and polyzoa. On the whole the scantiness of the fauna associated with weeds is a little surprising.

5. Under the heading of free-swimming organisms we must include the majority of the fish, as well as a few medusae and at least one Ctenophore, also several Decapod crustacea and at least three species of Mysidacea. As a rule the animals falling under it are perhaps the least interesting with which we have to deal, and it has been impossible, except in a very few instances, to add materially to our knowledge of their biology or distribution.

6. We are hardly in a position as yet to say much about the plancton beyond stating that in the main area of the lake it is never abundant and almost disappears for a time in the earlier part of the rainy season, while in the outer channel it becomes, in the salt-water season, both more abundant and more varied than it ever is inside Mugger-Mukh. One point may be noted, however, *viz.*, that in most of our samples from the main area Copepods and larval molluscs greatly predominate.

We have not included among the headings tabulated above that of 'amphibious fauna,' as perhaps we might have done. There are of course a certain number of crustacea, insects and other animals that would naturally fall into this category; but the amphibious fauna fades so gradually into the terrestrial one, with which we do not propose to deal, that it has seemed best to consider separately the status of each species that lives only partially in water.

Regarded as a whole, the fauna of the lake may be described as mainly of marine origin. A few freshwater forms have, however, established themselves, while there is also a marked faunistic element that appears to have originated actually in estuaries or backwaters subject to great changes of salinity and temperature. This element is also well represented in the Gangetic delta and in lagoons on both coasts of Peninsular India. A fourth element consists of species that immigrate at appropriate seasons either from the sea or from neighbouring streams, ponds and rice-fields, while a fifth—of little importance—is composed of mere casual visitors that drift, swim or crawl into the lake and exist there for a period without establishing their species among its permanent inhabitants.

The abundance of individuals and poverty of species noticed under the heading of mud fauna is to a very large extent characteristic of the fauna generally and in particular of that of the main area.

Perhaps the most striking feature of the biology of the permanent residents in the lake is the extraordinary power of individual adaptability to physical changes

in environment that most of them possess. It seems strange to find a *Rhizostomous* medusa or an *Oxystome* crab living in lacustrine conditions, but it is even more remarkable that individuals of such forms are able to flourish at one season in fresh and at another in salt water.

AIMS OF THE ZOOLOGICAL SURVEY OF THE LAKE.

The origin of our zoological survey of the Chilka Lake has been explained in the note prefixed to this volume; the main object we have had before us in its execution has been to lay a foundation for the study of the fauna of brackish water and of water of variable salinity on the coast of India on the same lines as our predecessors in the Indian Museum have done for that of the abyssal fauna of Indian seas. For this object it has seemed necessary in the first place to make our collections as comprehensive as possible, noting the circumstances of each capture and deducing from our notes facts as to the biology of the commoner species. It has not been possible, and perhaps it has been hardly desirable, to make any attempt at a detailed biological or morphological study of any particular group or species. That can come later, and if our researches prove useful to future naturalists who may undertake investigations of the kind, we feel that our labours will be amply rewarded. In a field so little explored we think it is as well not to specialize too soon.

The methods employed and the apparatus used in the survey may be described in some little detail.

METHODS AND MATERIAL.

In making our investigations we were fortunate in obtaining from the *Kallikotara* the use of a small launch, the "Lady of Chilka", the only steamship on the lake. From this launch we were able to trawl systematically over a considerable part of the main area and, in the flood-season, over the whole of the outer channel. In the latter area, in the salt-water season, we worked from a row-boat kindly lent us by the Salt Department.

The very soft mud of which the bottom is for the most part composed proved a considerable difficulty, and we believe that a really satisfactory instrument for the zoological investigation of regions such as the Chilka Lake yet remains to be devised. A net with mesh fine enough to retain small bottom organisms, such as *Cumacea* and minute *Mollusca*, does not permit the mud to escape and in a very short space of time becomes filled to bursting point.

For bottom work we used chiefly two sorts of net. The first of these was a miniature beam-trawl, six feet in breadth, of a size that could be fished comfortably from the stern of the launch. At the cod-end the mesh of this net was $\frac{1}{2}$ in. (stretched) and it therefore permitted the greater part of the mud to escape, except in particular places where it was of a lumpy character. To the back of this net, on the outside, we attached a shaped bag of mosquito-netting or coarse-meshed canvas, placed in the path of the swirl caused by the foot-rope. This net caught numbers of small

animals which would otherwise have escaped, and compensated in some measure for the large mesh of the main bag: none the less it was frequently drawn up half full of mud.

The second type of net employed for bottom work was a \square -net, that is to say a light frame of $\frac{5}{8}$ in. iron (shaped in the form of a \square and towed by three bridles) to which by means of brass rings a long bag of coarse-meshed canvas was attached. This net produced excellent results; but it was only possible to make very short hauls as the bag rapidly filled with mud.

Mud we dealt with by means of a series of large rectangular sieves with brass meshing, fitted in a frame to keep them above the level of the deck.

A larger net, an otter-trawl with head-rope 28 ft. in length and 3 in. mesh at the cod-end, was also employed occasionally and was successful in obtaining large fish that were able to avoid the smaller nets, especially in thickets of *Potamogeton* near the shore.

The larger free-swimming organisms were obtained by towing the \square -net in midwater and at the surface; but for many of the fish we were dependent on indigenous methods, which will be described in a special paper in this volume. Plancton we collected in silk tow-nets of the ordinary type supplied by the Marine Biological Station at Plymouth. Hand-nets were of course employed in shore-collecting, in which we found a hammer and chisel an essential part of our outfit.

As regards determinations of salinities it seemed unnecessary, in view of the enormous seasonal changes, to employ the elaborate titration method advocated by the Bureau International pour l'Exploration de la Mer, a method designed to demonstrate extremely slight differences in oceanic and coastal waters. We realized at the outset that to obtain a complete or even an approximate knowledge of the varied physical conditions that affect the salinity of the lake would be beyond our powers and that it was improbable that observations carried out in a single year, however complete, would render possible a true account of the actual changes that take place. Variations in rainfall, temperature, wind, tide and possibly other factors must all produce different effects in different years.

In making our observations on the density of the water we used a hydrometer kindly lent us by Capt. R. B. Seymour Sewell, Surgeon-Naturalist to the Marine Survey of India, and our results are therefore expressed in the form of specific gravities. The scale of the instrument, which is calibrated for 15°C., is about 7 cms. in length and is graduated from 1.00 to 1.04 in 40 divisions. Readings were taken to the nearest 0.00025. In order to give corrected readings of specific gravities of 1.0015 and under it was necessary, at the temperature at which we were working, that the hydrometer should be scaled below 1.000. This unfortunately was not the case and we are in consequence unable to insert the line representing sp. gr. 1.001 in the chart reproduced in fig. 2 on p. 9.

Water-samples were collected in bottles provided with a spring top and rubber washer and were, as a rule, tested the day they were taken. The determinations quoted are in every case reduced to 15°C. by the use of a correction table. This table is based on a series of laboratory experiments made with the same instrument

in waters of different salinities at temperatures ranging from 10° to 35°C. We are under great obligation to Dr. W. A. K. Christie, Chemist to the Geological Survey of India, for advice and practical assistance in this matter.

The positions of our stations in the lake were determined by the use of a sounding quintant and station-pointer kindly lent us by the Survey of India.

The specimens on which the reports in this volume are based are at present in the Indian Museum, in which all the types of new species described, as well as a complete set of all other forms, will be preserved. The oldest specimens from the Chilka Lake that we possess are a few shells collected by the late Dr. W. T. Blanford and his agents, mostly, as is evident from the species represented, in the outer channel. The Museum collector obtained a considerable number of fish in the neighbourhood of Gopkuda Id. in 1907, while Dr. J. Travis Jenkins made collections, also mainly of fish, in the outer channel in 1908. One of the present authors paid a short visit to Rambha in the following year and obtained there, among other material, the types of several new shells described by Mr. H. B. Preston. It was not, however, until August, 1913, that any concerted attempt was made to investigate the bottom-fauna. In that year we used bottom-nets for the first time in the lake, mainly in the immediate neighbourhood of Barkul. In October of the same year we commenced preliminary work at Satpara and Rambha, and subsidiary trips were made in November and in the following January. Our actual survey commenced in February, 1914. Apart from a number of short visits to one or other region of the lake, it was conducted, as has already been stated, mainly at two periods, representing respectively the middle of the salt-water and that of the fresh-water season. In February and March we spent altogether about six weeks on the lake, on which we trawled practically every day, while in September a period of about three weeks was occupied in the same manner. Our own shorter trips were made in April, July, November and the beginning of December, while Dr. B. L. Chaudhuri collected fish at Barkul and elsewhere in December of the same year and in January, 1915.

We have in our log particulars of 171 collecting stations. In some cases the data of two or more stations refer to the same place at different seasons, but many specimens were collected, on the subsidiary trips and at other times, in circumstances not noted in the log, though recorded on the labels.

The bulk of the collections is of course very considerable and it will therefore be possible for us to distribute to other museums by the only means open to us (*i.e.*, that of exchange) a number of sets of duplicates.

LIMITATIONS OF THE WORK.

Neither the time nor the funds at our disposal were unlimited and even within the somewhat narrow boundaries to which the survey was confined, we were obliged to observe certain limitations in collecting. Generally speaking we made no special effort to capture and preserve representatives of microscopic groups such as the

Protozoa and Rotatoria. The smaller Entomostraca were collected merely as they occurred in tow-nettings. In the majority of groups larval forms, with a few specific exceptions, were also neglected, while certain other small and inconspicuous organisms (*e.g.*, the free-living Nematodes) were obtained only in small numbers.

We regret that we were unable to study the ornithology of the lake, which is remarkably attractive at different seasons to different kinds of water-birds, though comparatively few breed there habitually.

In a few groups of animals of which we did make fairly comprehensive collections, it has not been possible in the present state of international affairs to find specialists able and willing to investigate the specimens. The most noteworthy of these groups are the Nemertea and the aquatic beetles. Of the former at least three species are common in the main area of the lake, while both the Dytiscidae and the Hydrophilidae are represented by a considerable, but not a large, number of forms. We failed to get the two species of Nudibranch molluscs that occur identified, while the single Tunicate we obtained (an immature Appendicularian common in the outer channel in March) is probably not determinable specifically.

Among internal parasitic species we preserved a certain number of Helminthes, especially Cestoda from the alimentary canal of sting-rays. Mr. T. Southwell has also collected specimens of this group in the lake and is preparing a report upon his and our collections.¹ The parasitic Nematodes are poorly represented and there is only one Acanthocephalon, which was found in the intestine of a Teleostean fish. The Trematodes are represented by at least three species, a large and common form from the body-cavity of a ray and two minute Distomids, one occurring in the canals of a Ctenophore and the other in the body-cavity of a Copepod. We do not propose to discuss these internal parasites further except in reference to their hosts.

Of the groups that appear to be actually absent from both the outer channel and the main area, the most conspicuous are the Echinoderms and the Cephalopod² molluscs. Certain other divisions of the latter phylum, *e.g.*, the Pteropoda, seem also to be unrepresented in the fauna, as is the case with several groups of coelenterates, notably the Cubomedusae and the stony corals. The aquatic insects are naturally represented by but a few of those families which possess aquatic larvae.

Apart from such limitations, there are also others dependent on mechanical difficulties in collecting. Our collections from the main area of the lake, considering the multitude of individuals and the paucity of forms, are probably almost complete; a few rare species may have escaped our notice, but it is doubtful whether this is the case with the common animals, which are, of course, very much more important from a faunistic point of view. If any of the latter are missing it is probably among the fish that gaps occur. In the fauna of the outer channel on the other hand there are probably many gaps both in the vertebrates and in the invertebrates. All

¹ *Rec. Ind. Mus.*, *ined.*

² Goodrich (*Trans. Linn. Soc., Zool.* (2) VII, pp. 5, 7, 1896) records specimens of *Sepiella inermis* (van Hasselt) and *Loligo indica*, Pfeffer, from the "Chilka Bight" but they were probably obtained outside the mouth of the lake, as they are from the 'Investigator' collections.

the evidence available points to the fact of there being a large number of species in both divisions of the animal kingdom which occasionally enter this part of the lake from the sea in the salt-water season, and it would not be unreasonable to expect to find in the channel at that season stray individuals of any member of the littoral fauna of the adjacent parts of the Bay of Bengal.

The shallowness of the water on the bar at Mugger-Mukh and in the northern part of the main area generally makes it impossible for any but a small boat to enter the outer channel or to proceed much north of Nalbano between October and August, and consequently we were unable to make use, except in September, of our larger nets either in the channel or in the shallows of the northern region. A considerable number of the marine species found in the former part of the lake in September but not in March probably escaped our notice in spring for this reason, and it is also probable that our series of fish and possibly of reptiles would have been considerably augmented if we had had the use of the launch between Satpara and the mouth of the lake at all seasons. The freshwater season (roughly the middle of August to the middle of October) is, however, the critical period in the study of those animals that are able to withstand great changes in salinity and September is therefore perhaps the most interesting month in the year so far as the outer channel is concerned. There is, moreover, no reason to postulate any great difference between the faunas of the northern and central parts of the main area, except in so far as extreme shallowness of water is indirectly destructive of animal life owing to increased temperature. So far as the main area is concerned, the only faunistic boundary that we are able to distinguish extends from Kalidai Id. towards Parikudh.

In our own papers we have included notes on and descriptions of species allied to those from the Chilka Lake but found in the Gangetic delta or in lagoons on the Indian coasts, in cases in which this course seemed desirable.

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In the first place we have to thank both the specialists abroad who are helping us in the preparation of this report and our colleagues in Calcutta who have assisted us in the field and in the laboratory. The artists of the Museum and of the Marine Survey of India, Babus A. C. Chowdhury, S. C. Mondul and D. N. Bagchi, have devoted their usual skill to the preparation of the plates and figures that illustrate our papers, while Mr. G. M. Henry of the Colombo Museum has prepared several sketches of living animals that have been of great use in describing the species. To our assistant in the field, Mr. R. Hodgart, much of the success of our collecting is due. Mr. C. Dodsworth, agent for the Kallikota estates, helped us considerably at Rambha and elsewhere, and we have to thank the Superintending Engineer, Orissa Circle, and the Inspector of Salt Revenue at Satpara for the use of bungalows or boats on the lake. Last but not least of our obligations are those to Colonel Sir S. G. Burrard, F.R.S., and other officers of the Survey of India, who gave us invaluable technical advice and placed at our disposal the scientific instruments that rendered the necessary physical observations possible.