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FAUNA OF THE CHILKA LAKE.

THE HYDROGRAPHY AND INVERTEBRATE FAUNA OF RAMBHA BAY IN AN ABNORMAL YEAR.

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(Plates XXXII–XLIII.)

CONTENTS.

	Page
Part I. Hydrography. By R. B. SEYMOUR SEWELL	679
Observations in August, 1919	681
Observations in April, 1920	686
Part II. Fauna. By N. ANNANDALE	
Porifera	690
Coelenterata	691
Ctenophora	692
Polyzoa	692
Annelida	693
Crustacea	693
Insecta	697
Mollusca	697

OBSERVATIONS IN RAMBHA BAY.

The main object of this paper is twofold; firstly to describe the differences in density found in the water of the inner part of the Chilka Lake at different levels and secondly to put on record changes in the composition of the invertebrate fauna noted in the same locality, in a year in which the density of the water as a whole was considerably below normal.

It was noted in August, 1919, that the water of Rambha Bay, which forms the south-western extremity of the Chilka Lake, was apparently much less salt than it had been at the same season or a little later in 1914, when Annandale and Kemp concluded their investigation of the fauna of the lake. For various reasons it was impossible to carry out another survey of the lake as a whole, but arrangements were made for observations on the bay at different seasons with Barkuda Island as our headquarters.

We were unable to visit the mouth of the lake, but trusted to obtaining information from official sources as to its condition at the time. In this we have been to some extent disappointed. We have to thank the Director of Fisheries, Bengal, Bihar and Orissa, and also the Executive Engineer, Cuttack, for supplying us with such facts as were known to the departments concerned. They have spent much time and labour in doing so, but unfortunately no inspection seems to have been made at the critical period at which we believe that channel became closed, *i.e.* towards the end of the dry season. The mouth is known to have been open in April, 1919 and in the same month of 1920, and changes in its position are known to have occurred in the former year. We have little doubt that it was closed for a considerable period in the summer or autumn of 1919, in which low density was associated with exceptionally high water in a season of by no means excessive rainfall. We were informed by the serang of the Rajah of Kallikota's steam launch, who is well acquainted with all parts of the lake, that the channel was entirely blocked in November, 1919, but this is contradicted by other statements. In the rainy season of 1920 conditions apparently became normal again.

PART I. HYDROGRAPHY.

By R. B. SEYMOUR SEWELL.

The present investigations were undertaken by me in order to supplement the work done by Dr. N. Annandale and Dr. S. W. Kemp[1] during their survey of the Chilka Lake in 1914. The conclusions at which these investigators arrived were

[1] Annandale and Kemp: "Fauna of the Chilka Lake, Introduction, Hydrography of the Lake," *Mem. Ind. Mus.* pp. 5-12, Vol. V (Calcutta, 1915).

based entirely upon observations made on the surface waters, and it was felt that this was not altogether satisfactory. I therefore undertook to carry out a series of observations on the water at different levels, but as in the time at my disposal it would have been quite impossible to conduct such a hydrographic survey of the whole lake, I decided to confine my investigations to a small area, and Rambha Bay at the extreme south end was selected as being the most convenient locality.

The water-samples were taken by means of an 'Ekman' reversing water-bottle and temperatures were simultaneously recorded by a reversing thermometer and were subsequently reduced in accordance with the formula given by W. Walfrid Ekman.[1] The density of the water-samples was estimated—usually on the day following their collection—by a 'Buchanan' hydrometer and the findings were subsequently reduced to 0°C, Standard Temperature, and temperature *in situ* by means of Knudsen's Tables. I have throughout adopted 25·0°C as Standard Temperature, so that my results are not directly comparable with those given by Annandale and Kemp who reduced their results to 15°C.[2]

The various stations—numbered consecutively—were made as nearly as possible in lines, running roughly at right angles to the main length of the bay and more or less parallel with each other, so that the results obtained could be plotted out in sections. The positions of the stations were in every case taken by means of a prismatic compass, and, in order to fix them as accurately as possible, three observations were taken at each station of the bearings of prominent land-marks; their positions are shown in Chart 1.

The results obtained by Dr. N. Annandale and Dr. S. W. Kemp in 1914 showed very clearly that there was during the course of that year a very considerable range of variation in the degree of salinity of the surface water, correlated with and in the main due to two causes, namely, the influx of fresh water from the Mahanaddi River system during the S.W. monsoon season and the influx of sea-water during the winter months. To quote their own words (*loc. cit.*, pp. 11–12), the conclusions at which they arrived were that "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 feet 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

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[1] W. Walfrid Ekman: "On the use of insulated water-bottles and reversing thermometers," *Pub. de Circonstance*, No. 23. (*Conseil permanent Internat. pour l'explor. de la mer.* Copenhagen, April, 1905.)

[2] Table IV (p. 710) shows the corresponding values of the different densities at 25°C and 15°C respectively.

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."

In order, therefore, to obtain so far as was possible an insight into the annual changes that take place in the salinity of the water in Rambha Bay, two series of observations were carried out, in August, 1919, and in April, 1920, respectively. These months were selected as being the most likely periods in which to get the desired information, since in August the influx of fresh water would be causing a rise in level and a fall in salinity, while in April, there should be a large influx of salt water entering the lake from the sea.

In the following pages I propose first to consider these two periods separately and afterwards to compare and correlate the results obtained.

I. Observations in August, 1919.

During the early part of my visit to the Chilka Lake, from August 11th to 16th, 1919, the local conditions were more or less constant and, on the whole, the weather was fine with light winds from the south and south-west; there were occasional light showers of rain and a somewhat heavier shower, accompanied by a north-easterly wind, occurred on August 16th, and lasted for about an hour. On August 17th, however, there was a heavy storm with strong wind from the north-east which caused a considerable rise in the height of the lake. The reverse effect, of a strong wind from the south-west lowering the level of the water in Rambha Bay, has been recorded by Annandale and Kemp (*loc. cit.*, p. 11). Unfortunately I had no means available of measuring the actual amount of the rise of level that occurred, but it must have been several inches, and simultaneously the waves raised by the wind must have caused a considerable disturbance and admixture of the water in the upper levels. Obviously then observations taken after this date (August 17th) are not comparable with those recorded earlier, and I have therefore considered them separately.

Wherever it was found possible, three observations—on the surface, at 5 feet and 10 feet depth—were made at each station, but where the shallowness of water did not permit of observations at this latter depth, I took two observations, at the surface and at 6 feet depth respectively, and the results obtained are given *in extenso* in the Appendix, Table 1. As my investigations were of necessity made on different days and therefore under slightly different conditions of temperature, etc., it might be argued that the results obtained are, in view of the shallowness of the water in the Bay and the varying effects of radiation and conduction of heat through the different layers of water, not strictly comparable with each other. I have, therefore in addition to giving the densities at the temperature *in situ* in the various sections also given corresponding sections after all densities had been reduced to standard temperature, 25·0°C. In an investigation of the physical conditions of so small an area of water it was expected that it would prove necessary somewhat to reduce the usual intervals between contour lines, and this proved to be correct especially as regards temperatures and I have in places drawn them as close as 0·25°C; but as regards the densities obtained, these were found to differ so widely and in such short distances that as a rule I have given them in 0·5 intervals.

Annandale and Kemp (*loc. cit.*, p. 5) give the depth of water in Rambha Bay as having a maximum of 8 feet during the dry season, with a rise of 5 to 6 feet during the floods. In September, 1914, the density of water in this area was found to be 6·5 [they give it as 1·0065, distilled water being 1·000 (*loc. cit.* p. 8)] and again in November of the same year they found the density to be 6·0, though on this occasion they state that "water of appreciable salinity was, however, not so closely restricted to the southern area (of the lake) for a sample obtained off Kalidai[1] gave a reading of 1·0035 and others off Barkul[1] of 1·003. The flood waters 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."

At the time of my visit to the lake the depth of water in the middle of the Bay was 11 feet and during September it rose still higher. On August 11th, 1919, a sample of water taken at the surface at Barkuda Island showed a density of 9·29 in situ at a temperature of 29·9°C or of 10·78 at standard temperature.

Throughout the whole period between August 11th and December 16th, 1919, there seems to have been a steady fall in the density of the surface layers (*vide* Appendix, Table II), and a sample taken near Breakfast Island on this latter date and sent to me for examination gave a density at standard temperature of only 2·19. Allowing for such annual variations as are bound to occur owing to variations in the annual rainfall, my results up to this point seem to agree fairly well with those obtained by Annandale and Kemp in 1914. It was, however, found that the surface conditions of the water in the bay in August were by no means constant. In plate XXXVIII I have given the densities of the various water-samples taken *at the surface* at the temperatures that existed *in situ*, and it shows very clearly the way in which the density *decreases* as we pass from the mouth of the bay between Barkuda and Chiriya Islands in a south-westerly direction towards the village of Rambha, situated a the head of the bay to which it gives its name. This distribution of the water in the bay in 1919, is the exact opposite of that found by Annandale and Kemp in November, 1914, who record (*loc. cit.* p. 10) that "throughout the southern part of the lake the water in the middle was of lower specific gravity than that nearer the shores." During the period of my observations between August 11th and 18th, 1919, surface-

[1] As neither Kalidai or Barkul are shown on my charts I may mention that the former is an island some 8 miles away to the north-east of the entrance to Rambha Bay, while the latter lies on the mainland about 2 miles to the north of Kalidai.

water having a density of 9·0 or over was found only at the mouth of the bay and in a small area in the southern prolongation of the head of the bay to the south-east of Rambha village; throughout the whole length of the bay the density was found to decrease steadily as we approach Rambha village, and the contour lines of equal density drawn on the plate show very clearly that this fall is due to an influx of fresh water. The map shows that at the head of the bay in the vicinity of the village two streams enter the lake and at this period of the year, and even on into December a quantity of warm fresh water was being brought down, which flowed out into the lake over the top of the more dense water below. As this current of water passes out into the lake its own density is raised by gradual admixture with the denser water of the lake, while at the same time the salinity and consequent density of the lake-water is diminished, and the effects can be traced even as far as the mouth of the bay. The effect of this surface current of fresh and comparatively warm water is seen extremely well in sections 1 and 2, plate XXXII, at stations 14 and 20 respectively. The current runs from near Rambha village across the mouth of the southern continuation of the bay towards Ganta Sila, and in August its course was plainly marked by floating leaves and scum. At this point the current alters its course and sweeping round the northern promontory of Ganta Sila appears to divide. A study of section 4, plate XXXII, shows that we have two areas of lower density situated at the two sides of the entrance to the bay, at stations 8 and 11 respectively, and, furthermore, in both these areas the temperatures recorded are higher than that of the surrounding water. That the lowered density is not merely the result of this raised temperature is, however, clearly shown in section 4, plate XXXIII, in which I have plotted out the densities after reduction to standard temperature. One area of lowered density occur on the surface at station 11, and it has a temperature of 0·2°C higher than the surrounding water, while at a depth of 6 feet the temperature is as much as 0·61° higher than the water at the corresponding level at station 10. This area is a direct continuation of the surface current noted above and on a calm day the course of the current could be easily traced from Ganta Sila to the south-west corner of Barkuda Island by the presence of the leaves and scum referred to above; it is obvious that any breeze from the S.W. or S.S.W. will very materially assist, even if it is not the actual determining factor, in the causation of this current. A strong breeze will cause a flow of surface water of low density out of the bay and this must naturally be compensated for by an influx of water from outside the bay at the deeper levels. At station 8, the second area of lowered density is found, not on the surface, but at a depth of from 5 to 6 feet, and in order to account for its presence at this depth we must first study the conditions existing in the deeper waters of the lake.

One of the earliest points that attracted my attention during my survey was the extremely rapid rise in the density of the water of the bay as we pass from the surface towards the bottom. This alteration of density is most marked, as one would expect, at stations 13, 14 and 15 at the head of the bay where owing to the influx of fresh-water the surface density is markedly lowered, and in this region a reference to section I, plate XXXII, shows that the density *in situ* increases from 4·46 on the surface at station 14 to over 7·0 at 5 feet and to nearly 10·0 at 9 feet depth; but even at the mouth of the bay we still find a very considerable rise in density as we pass from the surface to the 10-feet depth-level. If now we examine the density contour lines at the three levels—surface, 5 feet and 10 feet depth—shown in plates XXXVIII, XXXIX and XL respectively, we see that there is at all levels, but especially at the 10-feet depth-level, a distinct curvature indicating a slow but steady flow of water into the bay. This is particularly noticeable at the 5–10 feet depth-levels, where the inflowing current can be traced throughout the whole length of the bay except in its southerly prolongation near Rambha village.

This inflowing deep current, after passing through the comparatively narrow channel to the south-east of Samal Island, enters Rambha Bay and flows along the bottom till it strikes the shore in the neighbourhood of Chiriya Island and Ganta Sila, and is then deflected towards the surface. This deflection is well seen in section 4, plate XXXII. On reaching the surface the denser water spreads out and flows over the top of the southern branch of the surface current of low-density water that we saw was coming from the head of the bay, where the streams enter the lake, and in this way we get the formation of the area of low density at a depth of 5 feet, that we found to be present at stations.

The only feature in the conditions existing during the first part of my observations prior to August 17th, 1919, that remains to be considered is the area of higher density that was found in the southern extremity of the bay near Rambha village at stations 16, 17 and 18. This patch of water appears to lie outside the influence of the circulation of water that was going on in the rest of the bay, and station 18 showed particularly clearly an area of raised density on the surface. I attribute the comparatively high densities found in this area to the effects of evaporation; as Annandale and Kemp have pointed out (*loc. cit.*, p. 11) "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."

I now pass on to the conditions observed after the occurrence of the storm on August 17th.

During the time when my observations were made on August 18th, a wind was blowing from the south and south-west and this gradually increased in strength so that I was eventually compelled to discontinue my work. The results obtained are shown in section 3, plate XXXIII, and the first fact that strikes one is that in the centre of the bay extending from station 23 to station 25 and having a depth in the centre of about 6 feet is an area of water having a lowered density—7·0 and under—and raised temperature—29·5°C and over. It seems to me that owing to the wind the surface current coming from the southern end of the lake, which we have already studied, is modified, so that instead of dividing into two areas, the whole of the low-density water is now carried in a north-easterly direction across the bay. We have here a condition of affairs very similar to that recorded by Annandale and Kemp in 1914 (*loc. cit.*, p. 11) except that in this case the effect on the density of the water is the reverse of that seen by them, because, as I have already pointed out, the water at the head of the bay in 1919 had a lower density than that in the centre.

At the same time I found that the density of the lower layers of water near the bottom showed a considerable diminution below what had been found in corresponding situations previously, the bottom water at a depth of 10 feet being now only a little over 9·0 in density *in situ* or a little over 10·0 at standard temperature of 25°C, whereas previously in sections 2 and 4 I had found that at this depth it was 10·0 or over *in situ*, or 11·0 and over at standard temperature. Furthermore, the temperature of the water at this depth showed an increase of more than 1·0°C above that

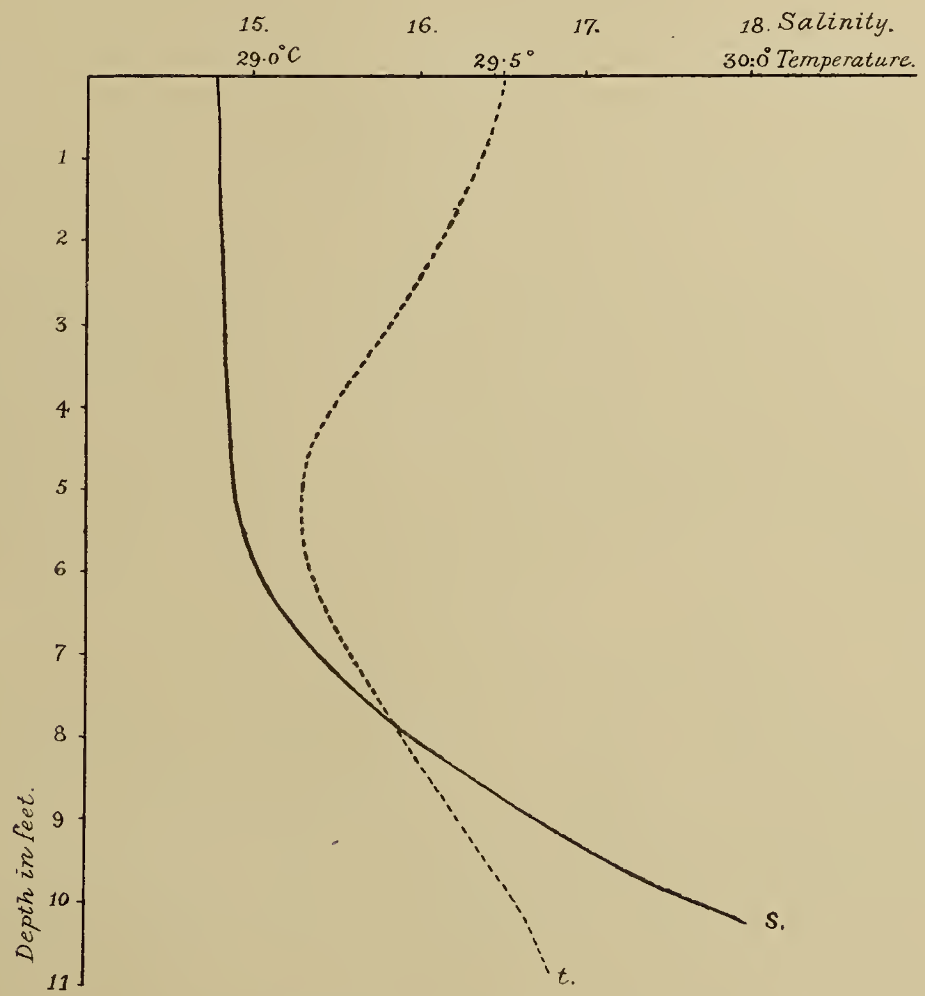

FIG. 1.—The vertical distribution of temperature (t) and salinity (s) at station 23, August 18, 1919.

previously noted. The cause of these changes is by no means obvious, and it is probable that more than one factor has contributed towards their production; the purely mechanical effect of the waves raised by the storm must have caused a considerable amount of admixture between the various layers and would thus tend to cause a fall in density and rise in temperature, but if this had been the sole cause the temperature at 5 feet depth would have been higher than that at 10 feet depth which is not the case. It seems, therefore, that it must be due to an influx along the bottom of water having a higher temperature than that of the mid-water. It is possible that this flow may be merely an increase in the inflowing deep current that we have already seen to be normally taking place at the 10 foot level, brought about in order to compensate for the increased outflowing surface-current caused by the wind, since there seemed to be no appreciable fall in the surface level of the water of the bay; but I am inclined to think that we have here an additional inflow from a source not indicated in my previous observations, namely from the extensive and somewhat enclosed area lying between the mainland and Cherriakuda, Barkuda, and Samal Islands. The surface current due to the wind must have blown a quantity of water into this area through the passages between the mainland and Cherriakuda Island and between this latter and Barkuda Island, and this must produce a corresponding outflow.[1]

A study of the temperatures and salinities found at stations 2 and 3 in section 2, August, 1919, and again at station 23, section 3, August 1919, further seems to indicate that we have present in the lake at this season of the year a condition of affairs that is very similar to that which is known to exist in the Oyster 'Polls' in Norway. The depth of the water in the lake is considerably less than that present in a typical 'Poll', such as the Kverne-Poll, but a comparison of the vertical distribution of temperature and salinity at the above stations in the Chilka Lake with the distribution present in the Kverne-Poll in June as given by Murray and Hjort (1912, p. 226)[2] reveals many features in common: and this is particularly well shown in the chart of station 23 which I give above. In both cases the water on the surface is of appreciably higher temperature and slightly higher salinity than that present at a depth of about 4–5 feet and below this level both temperature and salinity steadily increase. The differences present in the Chilka Lake are not so marked as those in the Kverne-Poll but the conditions present are essentially similar.

2. Observations in April, 1920.

My second visit to the Chilka Lake was from the 27th–29th April, 1920. Throughout this period the weather was fine. Each morning there was little or no wind, but, as the day wore on, light airs sprang up from the S.S.W. and by midday a strong breeze was blowing from this direction. As the weather conditions on all three days were exactly similar, the results obtained are all comparable with each other.

A very considerable change had occurred in the level of the lake since my visit in August, 1919, and the depth of water in the bay instead of being about 11 feet was now only 5 feet—that is to say *was 3 feet lower than the maximum depth given by Annandale and Kemp for the dry season* (*vide loc. cit.*, p. 5). In consequence it was

[1] From observations made in August, September, October, and December 1919, and in April June and July, 1920, Dr. Annandale tells me that he is convinced that the normal direction of the wind at Barkuda island is approximately S.W. throughout the year. This wind blows the water of the bay past the island during the day so that the water-level of the lake sinks appreciably. The breeze tends to fall in the evening, however, and is usually less strong at night. The water then returns to the bay, with the result that the level is usually higher in the morning than it is in the evening.

[2] Murray and Hjort, "The Depths of the Ocean" (London, 1912).

only possible to obtain two samples of water at the great majority of the stations namely at the surface and at a depth of four feet.

As before, observations were taken in a series of traverses across the bay, and the positions of the various stations—numbered 26 to 40—are shown in plate XLI. On this occasion, the prismatic compass used for taking bearings was not so satisfactory as the one employed in August, 1919, and in several cases the bearings do not meet very satisfactorily, so that the positions of the stations shown on the plate are to be regarded as approximate only. The results obtained are given *in extenso* in the Appendix, Table III.

The first point to be considered is the general density of the water in the bay, and here at the outset we find a most surprising difference from the results obtained in April, 1914. In that year Annandale and Kemp (*loc. cit.*, p. 8) found that the density in Rambha bay was 10·0 except at the southern prolongation near Rambha village, where it was as high as 11·0. A reference to plate XLII shows that in 1920, the surface water of the bay was everywhere less than 5·0, except just at the mouth and in the southern extension at the head of the bay where it was only little over 5·0.

As was found to be the case in August, 1919, the surface density shows an appreciable range of variation in different areas. In plate XLII, I have plotted out the various densities, at the temperature *in situ*, of the surface samples taken at each of the stations. To the north-east of Chiriya Island is an area of higher density that appears to be slowly making its way into the bay. The source of this area is by no means obvious for two observations taken to the north and east of Samal Island (*vide* samples 94 and 95, Appendix 8, Table III), show that in that region the density of water is on the whole less than that in Rambha Bay. Another area of higher density occurs in the southern extension of the head of the bay, between Rambha village and Ganta Sila, and this I attribute, as before, to evaporation. In the centre of the bay at stations 32 and 33 we find a peculiar circumscribed area of lowered density, 4·5 and under, and a similar lowering of density of the surface water was found at station 35 in the channel between Cherriakuda Island and Barkuda Island, though separated from the area in the centre of the bay by a band of water having a density of 4·58. A reference to the corresponding stations in section 2, plate XXXVI, in which I have shown the densities at standard temperature, shows that at station 32 the lowering of the density on the surface is due entirely to a rise in temperature, for the density at standard temperature in this area is uniform with those on each side. As to the cause of this very local rise in temperature I am unable to offer any explanation.

Turning now to the results obtained from samples taken at a depth of 4 feet, I have plotted the results, as before, in plate XLIII and here again we find the same areas of increased density both at the entrance and at the extreme head of the bay, while we still get evidence of the area of low salinity in the centre of the bay at station 32. But, unlike the surface area, the lowered density at this depth is not the result of a raised temperature. It is still clearly seen in section 2, plate XXXVI, after the density has been reduced to standard temperature. No sign of any similar lowering of density is seen in either sections 1 or 3 so the condition is obviously local, and it seems to me that the most probable explanation is that there is in the neighbourhood of this station an under-water spring. If this be so, the spring appears to be an intermittent one, for no trace of it is visible in the results obtained in August, 1919. We now find that in the channel between Cherriakuda and Barkuda Islands there is an area of higher salinity and raised temperature. The sample was taken at 12-20 p.m. on the 17th April, 1920, when a strong breeze was blowing across the bay from the S.S.W. and it seems to me that we have here corroborative evidence of the view put forward by me above that a strong breeze from this direction in addition to causing a surface outflow from the bay also sets up a counter-current flowing along the bottom *into* the bay from the shallow area enclosed by Cherriakuda, Barkuda, and Samal Islands.

A sample of water sent to me by Dr. Annandale in June, 1920, showed that yet another great change had taken place in the density of the water. This example was taken at 10-30 a.m. at the end of the jetty on Barkuda Island and at the time a strong breeze was blowing from the S.S.W. Unfortunately, no record of the temperature was taken simultaneously, but the density of the sample at standard temperature was 9·66 so that it is obvious that there had been a great increase in the salinity of the water in the lake since April.

A comparison of my observations in 1919 and 1920 with those made by Annandale and Kemp in 1914, shows clearly that the conditions existing in Rambha Bay during these two periods were vastly different. At the commencement of my work in August, 1919, my results agree very fairly well with those obtained five years previously; but between August, 1919, and June, 1920, changes occurred in the Lake that were quite unlike anything observed in 1914. I have already given Annandale and Kemp's account of what, judging from their experience, is the normal sequence of events in the lake during successive seasons of the year, and a comparison with my results show that the abnormal features present during the end of 1919 and early part of 1920 are: (1) the steady and progressive diminution in the density of the lake-water long after the close of the monsoon season, so that in December the density was only a little over 2·0; (2) the steady fall in the level of the lake up to and possibly even beyond April, 1920; and (3) the subsequent rapid rise in salinity in May-June, 1920. These changes in the density and salinity of the water in the lake produced a very noticeable effect on the fauna, which Dr. Annandale has dealt with in the second part of this paper, and we are here merely concerned with the changes themselves.

As I have already mentioned the height of the lake was steadily rising throughout the whole period of my survey in August, 1919, and for some weeks afterwards. As Annandale and Kemp have pointed out, by far the most potent factor in producing changes of level and reduction of density is the monsoon flood-water brought down by the Mahanaddi river-system and poured into the north end of the lake, and as a result of this influx the water in the greater part of the north-east end of the lake becomes fresh or almost fresh. According to their view (*loc. cit.*, p. 8) "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, the changes are not due to admixture so much as to the expulsion of one volume by another." They appear to have overlooked the possibility that the fresh-water coming into the lake might flow over the top of the denser water, and thus produce the diminution in the density that they found during the monsoon months, and since all their observations were confined entirely to samples taken from the surface, it is impossible to say whether the same rapid rise in density as we pass from the surface to the bottom, such as we have seen to be present in Rambha Bay in August, 1919, and to a less extent though still recognisable in April, 1920, existed at all in 1914, though I see no reason to suppose that it was not present at any rate to some degree, or that it is a phenomenon confined to the area at the south-west end of the lake.

On the occasion of both my visits we obtained evidence that this bottom layer of denser water is steadily flowing into Rambha Bay from the main area of the lake. This inflow was vastly greater in August, when the lake was rising, than it was in April, and it seems probable that there are two factors concerned in its production. The first of these factors is in my opinion the steady and continuous breeze that blows throughout the greater part of the year across the lake from the south-west or south-south-west. We have already seen that the effect of this breeze is to produce a strong *surface* current out of the bay, and it is to this that I attribute the deep influx of water of higher density into the bay along the bottom that was occurring in April, 1920. In August, 1919, however, the effect was too great to be accounted for by this agency, and was, moreover, accompanied by a rise in the surface level, and it seems to me that we have here evidence of the 'banking up' of the more saline water, as far as the deeper layers are concerned, such as Annandale and Kemp (*loc. cit.*, p. 11) postulated in 1914.

The steady influx of fresh water from the Mahanaddi and local streams causes a correspondingly steady fall in the density of the lake water so that the minimum appears in a normal year to be reached about February when the influx of salt water from the sea takes place, and a corresponding rise in density follows, reaching its maximum about July, during which month Annandale and Kemp found the density in Rambha Bay to be as high as 14·5 to 15·0. During the period of my observations in 1919–1920, we have two outstanding features of great interest. As I have already mentioned between the months of August–December, 1919, the density of the water in the bay had fallen very considerably, till at the end of the year the density at standard temperature of a sample taken off Breakfast Island was only 2·19. In April, 1920, the density of the water off Barkuda Island at standard temperature had risen to more than twice this and varies from 5·5 to 6·1. There had, therefore, been no appreciable influx of *fresh water* into the bay and presumably into the whole lake, and the explanation of the raised density combined with a marked lowering of the surface level that existed in April seems to be found in the absence of the normal inflow from the sea, which usually occurs in February and March, combined with extensive evaporation from the surface. As Annandale and Kemp point out (*loc. cit.*, p. 11). "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." Any inflow from the sea must, however, depend on the existence of a free channel between the two areas, and although I have been unable to obtain any direct evidence that such was actually the case, the serang of the launch informed me that this channel was closed in November, 1919.

Part II. FAUNA.

By N. Annandale.

The chief object of these notes is to put on record changes in the invertebrate fauna of the south-western extremity of the Chilka Lake that took place between the years 1914 and 1919–20. I have also added one or two particulars that supplement statements made in former parts of this volume. My observations were made in August, September, October and December, 1919, and in April and June, 1920. A few notes were also obtained in July and August of the latter year.

Porifera.

Three species of sponge were found in Rambha Bay in 1914, namely *Cliona vastifica* Hancock, *Suberites sericeus* Theile, and *Laxosuberites lacustris* (Annandale). All of these belong to marine genera. In the rainy season and in December, 1919, *Laxosuberites lacustris* was still common on the lower surface of stones in the landing stage at Barkuda, but no specimens of the other two sponges were found, and by April, 1920, the *Laxosuberites* had also disappeared. One of the most noteworthy changes in the fauna of the bay was the appearance in it of the freshwater sponge *Spongilla alba* Carter in great abundance. In 1915 I wrote of this sponge, "In the Chilka Lake its distribution is somewhat remarkable. It occurs on all the rocks of the northern region, often growing luxuriantly and covering considerable areas, and is found among loose algae in the outer channel. In sheltered inlets among the rocks its gemmules often form a scum on the surface. South of Kalidai I. it is not present in the lake, although many rocks apparently suitable for its growth are situated round Rambha Bay. . . . We found it growing actively and producing larvae in water of sp. gr. of 1·0065, but it cannot exist in water that never becomes fresh or practically fresh."

At the end of July, 1919, and on several occasions in the next month I found dead sticks on both the north and the south shore of Barkuda covered with dead sponge of this species containing numerous gemmules. In September and October small sponges were common on the lower surface of stones on both sides of the bay, and my nets were on several occasions completely blocked up by masses of weed coated with *Spongilla alba*. In the dry season of 1919–20 it died down, as it also did in a small pool of nearly fresh water on Barkuda, but dead sponges containing gemmules were common on the under side of stones at the edge of the lake. At the end of June, 1920, when the water had again become much salter, gemmules, which showed no tendency to germinate, were common in the same position and also on the surface of the bay. A single young sponge was, however, found on *Potamogeton* on June 26th.

COELENTERATA.

The following species of coelenterates were found in Rambha Bay in 1913 and 1914: *Gyrostoma glaucum, Phytocoetes*[1] *chilkaeus, Pelocoetes exul, Halianthus limnicola, Edwardsia tinctrix, Virgularia* sp., *Acromitus rabanchatu, Dicyclocoryne filamentata* and *Bimeria fluminalis*. Of these species, all of which but the *Virgularia* were originally described by myself, the first five are, in a wide sense, Actiniaria, the sixth is an Alcyonarian, the seventh a Rhizostomatous medusa, while the eighth and ninth are gymnoblastic Hydrozoa. Most of the species belong to marine genera and all to marine families, but *Phytocoetes, Pelocoetes* and *Dicyclocoryne* have been taken only in brackish water.

In 1919–20, the only species included in this list that were observed were *Halianthus limnicola, Acromitus rabanchatu, Dicyclocoryne filamentata* and *Bimeria fluminalis*. These I will discuss in order, but first I must put on record additions to the coelenterate fauna of the bay. On August 14th, 1919, Major Sewell took, in a sample of water from the surface, a single medusa of *Campanulina ceylonensis* (Browne) of the typical form. This medusa was obtained in the outer channel of the lake in 1914, but not in the main area. In the neighbourhood of Calcutta the hydroid is abundant in canals of brackish water at the beginning of and just before the rainy season and produces medusae in great abundance in water having a low specific gravity. Both hydroid and medusae disappear when the specific gravity sinks below 1·006 C. (corrected to standard temperature of 15°C) owing to increase in the rainfall. In the Gangetic delta this usually takes place about the end of July. On June 26th, 1920, numerous specimens of the medusa *Phialidium cruciferum*, a form hitherto known only from the outer channel of the Chilka Lake, were taken in a tow-net round Barkuda. In one of them one of the radial canals branched a short distance from the proximal extremity. The branch, which reached the edge of the umbrella, bore an imperfectly formed subsidiary manubrium. On the inner surface of the umbrella the Protozoon *Trichodina* was abundant. The medusae were feeding on pelagic fish-eggs, which were observed in the stomach of several.

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[1] Mr. T. A. Stephenson has just published an important paper on the classification of the Actiniaria (*Quart. Journ. Mic. Sci. LXIV, No.* 256) in which he discusses the brackish-water species assigned by me to the Sagartiidae, subfamily Metridiinae. He considers these species as constituting a new family (Diadumenidae) with *Sagartia schilleriana* Stoliczka, as type, under the name *Diadumene* (gen. nov.) *schilleriana*. He further separates my *Phytocoetes chilkaens* from *P. gangeticus* generically under the name *Mena* (gen. nov.) *chilkaea*. As to the generic distinction of Stoliczka's species he is undoubtedly right, but I am not at present prepared to follow him in the other changes suggested.

Halianthus limnicola.—No sea-anemones were dredged in the rainy season of 1919, but several specimens of this species were obtained in April, 1920. They were much less active and not so contractile as those observed in the cold weather of 1914.

Acromitus rabanchatu.—This medusa was common in the bay in December, 1919, but none were observed in April or the early part of June, 1920. In the latter half of June young and half-grown individuals were common, including specimens in the Semostoman stage.

Dicyclocoryne filamentata.—A young medusa was taken on the surface of the bay in August, 1919, by Major Sewell and Dr. Baini Prashad. It is about twice the size of those previously described, which were killed when just set free in an aquarium, and agrees with them in all but two important characters. These two characters are (1) that an eye-spot is well developed in the sensory mass at the base of each tentacle, and (2) that each tentacle bears, about half-way along its length, a pair of lateral branches precisely like itself. It is, therefore, probable that the adult medusa of this species has branched ambulatory tentacles and resembles *Cladonema.* Less important differences from the original specimens observed are that the manubrium is narrowly bell-shaped and situated on a short peduncle, the mouth being now open in the form of a small pore, and that the umbrella expands a little towards the base. The subquadrate cross-section and minutely tuberculate surface are preserved. There is still no trace of the gonads. The medusa of this species had not been hitherto observed in the Chilka Lake, or indeed, anywhere in natural conditions, the youngest stage having been described from captive specimens.

Bimeria fluminalis.—The dwarfed form of this species was common on the lower side of stones near the edge of the lake with the sponge *Laxosuberites lacustris* as late as December, 1919, but I was not able to find any specimens in the early part of June, 1920. By the end of that month, however, very small colonies were abundant on the lower side of stones on the landing-stage on Barkuda. The species is able to live for short periods in fresh water, but apparently not permanently.

CTENOPHORA.

The only member of this group that occurs in the bay is *Pleurobrachia globosa bengalensis,* which, however, in 1914 was found only when the water was fairly salt. It was not found in December or April, 1919, but was common at the end of June with *Phialidium cruciferum* and the young of *Acromitus rabanchatu.*

POLYZOA.

The only Polyzoon I saw in the lake in 1919–20 was *Membranipora hippopus* Levinsen. *Loxosomatoides laevis,* which was common on stones at Barkuda in 1914, was not found. Small colonies of the *Membranipora* were common on *Potamogeton pectinatus* as late as December, 1919, but I could find none in April, 1920. At the end of June in the latter year it was fairly common on *Potamogeton.*

Annelida.

Hirudinea.—Two species of Hirudinea were found in Rambha Bay in 1914, viz. *Glossosiphonia ceylonensis* (Harding), and a new species of *Piscicola.* They have been described by Mr. W. A. Harding, whose report on the leeches, as well as further remarks by Dr. T. Kaburaki, have been already published in this volume. None were collected in 1919–20, but no special search was made for them. I saw the *Piscicola* in June, 1920, among algae at the end of the landing-stage at Barkuda and obtained specimens in August from a pool on the island. The *Glossosiphonia* was collected in 1914 in flooded country at the head of the bay and is a true freshwater species closely allied to *G. heteroclita* (Linn.) of Europe and N. America.

Oligochaeta.—The following species of oligochaete worms were taken on the shores of Rambha Bay below water-level in 1914:—*Enchytraeus barkudensis* Stephenson and *Pontodrilus bermudensis* Beddard, f. *ephippiger* (Rosa). To these was added in July, 1916, *Monophylephorus parvus* Ditlevsen, which was found in masses of rotting weeds just afloat. This species has not been found since 1916, but conditions for its propagation, apart from changes in salinity, were perhaps unsuitable in 1919–20, owing to storms which washed away the dead weeds. The other species are apparently still common, as was to be expected.

Polychaeta.—Mr. R. Southern has recently published in this volume a full description of the species collected in 1914. The littoral Nereidae mentioned in his paper as occurring in the main area do not seem to have been affected by the physical changes that have taken place in the lake since that date, and no change has been observed in the common species dredged off shore.

Crustacea.

Amphipoda.—The species collected in 1914 have been worked out by Prof. Charles Chilton, whose account has been published recently in this volume. Two amphibious species are common as "sandhoppers" on the shores of Rambha Bay, namely *Orchestia platensis* Kröyer, and *Talorchestia martensii* (Weber), the former being much the more abundant of the two. Nine true aquatic species occur. Of these at least three are easily recognized and are well known to me. They are, the new species of *Niphargus, Quadrivisio bengalensis* Stebbing, and *Grandidierella megnae* (Giles). In saying that I am acquainted personally with the last I should state that I have not attempted to distinguish between it and a closely allied new species described in Prof. Chilton's paper. The two forms, however, occur commonly together. *Niphargus*, *Quadrivisio* and *Grandidierella* are all very abundant among algae and stones on the shore of Barkuda Island and I noticed no diminution either in their numbers or in those of the sandhoppers in 1919 or 1920.

Isopoda.—The aquatic isopods collected in 1914 have not yet been identified, but I may note some further facts about the terrestrial but strictly littoral species, *Ligia exotica* Roux, which Prof. Chilton has already described in great detail in our report on the fauna of the lake. In the rainy season of 1914 we observed this species on the shore of Barkuda I. in great droves. They were also present in

August and for the greater part of September, 1919. About the end of that month they began to disappear and by the end of October not a single specimen could be found. In December also the species appeared to be entirely absent, but in April a few young individuals were seen on rocks and stones at the edge of the lake[1]. At the beginning of June the species was again becoming fairly common and fairly large, but no full-grown individuals occurred, while at the end of that month full-grown individuals were abundant. In August the individuals were as large and the droves as populous as in the same month in 1919. These phenomena are evidently seasonal and it is improbable that they are affected by changes in the salinity of the water, for *L. exotica*, though it takes to water readily and is a good swimmer, habitually lives on dry land. Our former notes on its habits were made in the rainy season of 1914.

Cumacea.—Only two species of Cumacea (*Iphinoe sanguinea* and *Paradiastylis culicoides* Kemp) were taken in the lake in 1914, and of these only the latter was found in Rambha Bay. In April, 1920, Major Sewell and I dredged specimens, probably belonging to the *Iphinoe*, just outside the bay.

Stomatopoda.—Dr. Kemp found only one species of Stomatopod in Rambha Bay, namely *Squilla scorpio* Latreille. The very great majority of the specimens belonged to this var. *immaculata*. In 1914, many adult individuals of this variety were observed under stones on the shore of Barkuda I. and in similar situations, but none were found in 1919 or 1920. In the rainy season of the former year, however, and as late as December, young specimens, an inch or more in length, were commonly dredged from the bottom of the bay. None were obtained in April, 1920, but a few larvae were observed on the surface with *Lucifer hanseni*.

Mysidacea.—Dr. Tattersall has recorded three species of this group as occurring in Rambha Bay. They are *Rhopalopthalmus egregius* Hansen, *Macropsis orientalis* and *Potamomysis assimilis* Tattersall. These species, which are easily recognized, were abundant in 1914, and equally so in 1919 and 1920. The first has been taken in the open sea and belongs to a marine genus, but the two latter are brackish-water forms occasionally found in fresh water at a considerable distance from the sea, but not as a rule in isolated bodies of water.

Decapoda.—No less than 23 sepcies of Crustacea Decapoda were taken in Rambha Bay in 1914, and, thanks to Dr. Kemp's enthusiastic study, we know more about the distribution in the lake of this group than about that of any of the other larger groups of animals represented in its fauna. Of the 23 species 10 belong to the Reptantia, 6 are crabs in the ordinary sense of the word, 3 hermit crabs and one a burrowing shrimp-like form belonging to the tribe Thalassinidea.

Of the six crabs, two (*Ebalia malefactrix* and *Philyra alcocki* Kemp) are small and rather scarce species dredged occasionally in 1914 from the bottom of the lake. My investigations in 1919 and 1920 were not sufficiently comprehensive to demonstrate their absence in these years beyond doubt, but I am convinced that they were at any rate scarcer than before. A single specimen of the *Philyra* was dredged off Nalbano, which lies some little distance to the north-east of Rambha Bay near the opening into the outer channel of the lake, in December, 1920. Two other species

[1] I have observed this also in February, April, May and June 1922.

(*Varuna litterata* (Fabr.) and *Pachygrapsus propinquus* de Man) are littoral, in damp weather practically amphibious, species. In 1914, they were common on the shore of Barkuda I., which I made my headquarters in 1919 and 1920 on several occasions for several weeks at a time. I found neither at any season in these years. The two remaining crabs, *Scylla serrata* (Forsk.) and *Neptunus pelagicus* (Linn.), are both free-swimming species, but *Scylla serrata* at any rate is often found in holes at the bottom. In the Chilka Lake both are caught for food. A fisherman I employed at Barkuda occasionally brought me the *Scylla* both in the rainy season of 1919 and in the hot weather of 1920. I saw fresh claws of *N. pelagicus* dropped by a fishing-eagle on Barkuda in December, 1919.

The three hermit-crabs (*Clibanarius padavensis* de Man, *C. longitarsis* (de Haan) and *C. olivaceus* Henderson) are all conspicuous species, partly amphibious in habits, and were found in 1914 on the landing-stage at Barkuda and among the rocks at the base of Ganta Sila across the bay. In the main area of the Chilka Lake the only Gastropod shell large enough for the body of adults is that of a species of *Cuma* closely allied to *C. carinifera* (Lamarck). Subfossil shells of this mollusc, found living in Rambha Bay in 1914, are still abundant all round Barkuda, but the hermit-crabs entirely disappeared as the lake became fresh.

Upogebia heterocheir Kemp, the only other representative of the Reptantia found in Rambha Bay, burrows in the soft mud in the open parts of the lake. It was if anything more abundant in April, 1920, than it was at any season in 1914.

The thirteen species of Decapoda Natantia collected in Rambha Bay in 1914 belong to five families, which it will be convenient to deal with separately to some extent. These families are the Palaemonidae, the Alphaeidae, the Atyidae, the Penaeidae and the Sergestidae. I shall discuss these not in taxonomic order but rather in reference to their habits.

The Palaemonidae and Atyidae may be considered together first, as they are in the main freshwater Crustacea whose presence in the lake provides perhaps the chief lacustrine or fluviatile element in its fauna. The Palaemonidae were represented in the bay in 1914 by three species of the freshwater genus *Palaemon* and by one of *Urocaris*, which is mainly marine. The names of the species are *Palaemon lamarrei* Milne-Edwards, *P. rudis* Heller, *P. scabriculus* Heller and *Urocaris indica*[1] Kemp. The three former were seasonal visitors to the lake, which they probably entered from bodies of fresh water for the purpose of breeding. *P. rudis* did so regularly and in large numbers, while the other two species were rarely met with. *P. rudis*, indeed, was one of the common prawns of the lake in a commercial sense in the rainy season. I have no reason to think that any change took place in this respect in the monsoon of 1919, in which the prawn-fishery was said to be particularly good. The specimens of prawns I saw in Rambha Bay at this season seemed to me to be *P. rudis*. The habits of *Urocaris indica*, which has also been taken in the sea, are different. It is a

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[1] Dr. Kemp has recently revised the subfamily to which this species belongs and considers that it should be known as *Periclimenes* (*Periclimenes*) *indicus*. See *Rec. Ind. Mus.* XXIV, p. 144 (1922).

permanent inhabitant of the thickets of *Potamogeton pectinatus* that occur all over the Chilka Lake. What I take to be this prawn was common in these thickets in Rambha Bay in the rainy season of 1919, and I have no reason to think that it is less so now.

The two species of Atyidae found in Rambha Bay in 1914 were *Caridina nilotica* (Roux) and *C. propinqua* de Man. Their genus is fluviatile and lacustrine, but both species have been found at more than one locality in brackish as well as fresh water. *C. nilotica* is represented in India by a race that was called *bengalensis* by de Man[1] in 1908, but Dr. Kemp[2] has recently shown that this race cannot be separated from the same author's var. *gracilipes* from Celebes and China. Both *C. nilotica gracilipes* and *C. propinqua* are still abundant in the *Potamogeton* thickets of Rambha Bay.

The family Alpheidae was represented in Rambha Bay in 1914 by two species of *Alpheus*, namely *A. crassimanus* Heller and *A. paludicola* Kemp, the former a marine species, the latter only known from brackish water. In 1919 and in April, 1920, *A. paludicola* was dredged in considerable numbers in the bay with *Upogebia heterocheir*, which it resembles in habits. *A. crassimanus* was not obtained, but in 1914 this species was less abundant and less liable to be caught in our nets than the other.

As regards the Penaeidae my observations are very incomplete. This is the more unfortunate as we obtained evidence in 1914 that these prawns did not breed in the lake. Four species were obtained in the bay in 1914, viz. *Penaeus carinatus* Dana (de Man), *P. indicus* Milne-Edwards, *Peneopsis monoceros* (Fabr.) and *P. dobsoni* Miers. I am not sufficiently well acquainted with these species to distinguish them in the field and can only say that Penaeidae were found in the bay in the cold weather of 1919–20.

The last Decapod Crustacean to be mentioned is the little Sergestid *Lucifer hanseni* Nobili, the only completely pelagic species of its class found in the Chilka Lake. It was enormously abundant on the surface of Rambha Bay in 1914 on certain occasions but could not always be obtained. Its appearance and disappearance were not correlated with changes in season or salinity. This was observed also in the rainy season of 1919, in December of the same year and in April and June, 1920. There was, however, certainly no diminution in the abundance of the species on the whole. The genus *Lucifer* is marine, but *L. hanseni* is known to be very tolerant of changes in salinity.

It will be evident from what has been said that there was a considerable reduction in the Crustacean fauna of Rambha Bay in the dry season of 1919–20 as compared with that of 1914-15, doubtless in correlation with the reduction of the salinity of water demonstrated by Major Sewell. Some species, moreover, proved more tolerant than others and while, as might be expected, those of freshwater origin suffered less than those belonging to marine families and genera, it is somewhat remark-

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[1] de Man, *Rec. Ind. Mus.* II, p. 265, pl. xx, figs. 6, 6*a*, 6*b* (1908).

[2] Kemp, *Mem. As. Soc. Bengal* VI, p. 275 (1918).

able that the amphibious and littoral forms seem to have been affected more than any others. It is also interesting to note that none of the pelagic species (except those only found previously when the water was at its saltest) have apparently diminished in numbers, though one of the most abundant (*Lucifer hanseni*) belongs to a marine genus. I have been able to obtain no evidence of any fresh invasion of lacustrine or fluviatile species to take the place of those that have died out.

INSECTA.

Ephemeroptera.—A swarm of large may-flies was observed on the surface of the lake off Barkuda on Sept. 23, 1920. They were, however, fully mature and may have emerged from some body of fresh water in the neighbourhood and have been blown out on to the lake. They were evidently in a moribund condition. No members of this order were observed in the bay in 1914.

Odonata.—The dragon-fly *Pseudagrion microcephalum* (Ramb.) was as common in 1919–20 in Rambha Bay as it was in all parts of the lake in 1914. It was observed to breed in the lake in preference to the pond on Barkuda. The imago is common at all seasons, but particularly so at the beginning of the rains. The nymph emerges in the evening, as a rule on masses of dead weed on the shore, and there undergoes its final metamorphosis. Numbers of teneral adults, only able to flutter, can often be seen in the early morning at the edge of the water. *Anax guttatus* (Burm.) also breeds in the lake and probably *Brachythemis contaminata* Brauer, which skims along the shore in the evening, catching the sandhoppers (*Orchestia platensis*) as they leap into the air.

Rhynchota.—*Eurates formidabilis* Distant, was just as common on the surface of the bay in 1920 as it was in 1914. A single winged specimen of *Gerris spinolae* was observed from the landing-stage at Barkuda on the first day of the rains, June 11th. It was first noticed on a stone at the margin and may have just alighted from flight.

Diptera.—*Anopheles rossii* Giles, as in 1914, was the only mosquito found breeding in the lake in 1919–20. Imagines were enormously abundant on Barkuda, apparently coming from the lake, in the latter part of the rains of 1919 and the hot weather of 1920. Fortunately they are very easily affected by movements of the air and do not become really active till fairly late in the evening. In the day-time they hide in hollow trees, in crannies among the rocks and in corners of badly-ventilated rooms.

MOLLUSCA.

Twenty species of living Mollusca were taken in Rambha Bay in 1914, 12 species belonging to the Gastropoda and 8 to the Pelecypoda. Among the gastropods no less than 8 families are represented, and among the bivalves 6 families. Of the 20 families only one (the Hydrobiidae) is not essentially marine, and *Stenothyra*, the genus present, is essentially estuarine. The Mollusca, therefore, afford particularly good material for estimating the results of changes in salinity of the water of the Chilka Lake on the fauna, the more so as many of the species were extremely abundant in 1914 and are easily recognized.

Unfortunately several changes in nomenclature, affecting both genera and species, have been rendered necessary by further investigations undertaken since the publication by Dr. Kemp and myself of our report on the Mollusca in this volume (1916). These changes I will explain in footnotes.

Gastropoda.—Two of the species found in Rambha Bay in 1914, *Cuthona henrici* Eliot (fam. Aeolidae) and *Litiopa kempi* Preston (fam. Litiopidae) were of such rare and sporadic occurrence that they need not be considered further. Neither was found in 1919–20. At the end of this paper Dr. Baini Prashad and I describe a Nudibranch mollusc of the family Hermaeidae discovered in the bay in June, 1920.

The Opisthobranchia, apart from the *Cuthona*, were represented in 1914–15 by a single species (*Tornatina estriata* Preston, fam. Tornatinidae). This in 1914 was one of the commonest molluscs all over the lake. In August, 1919, I dredged numerous dead shells of this species, especially between Cherriakuda and the mainland. Among them I found two exceptionally small living individuals. In September and December of the same year I still found dead shells, but no living specimens, and in April, 1920, even empty shells seemed to have disappeared.

The Nassidae are represented in the bay by two very abundant species, *Nassa denegabilis* and *N. orissaensis* Preston. These were among the most abundant molluscs in 1914, and in 1920 showed no marked diminution in numbers.

By far the largest living gastropod in the main area of the lake in 1914 was a species (*Cuma disjuncta*) closely allied to *C. carinifera* (Lamarck)[1] of the family Muricidae. It was not uncommon on the landing-stage at Barkuda and among the rocks at the base of Ganta Sila, where the egg-capsules were found in February. Subfossil shells are still abundant on the shore at Barkuda but living individuals have completely disappeared.

The Cerithiidae, though many species live in brackish water, were represented in 1914 in the main area of the Chilka Lake by a single species, *Potamides cingulata* (Gmelin)[2]. This species was found living at only one spot in Rambha Bay, viz. in a ditch at Rambha. I have not been able to find it at this spot recently, but considerable changes have been made artificially in the ditch.

A small elongate shell from Rambha Bay, the true systematic position of which s still somewhat doubtful, was placed in the genus *Vanesia* and the family Turritellidae by Preston. Living specimens were found, occasionally in some abundance, in 1914. In 1919–20 only dead shells were obtained.

Preston recorded four species of the genus *Stenothyra* (family Hydrobiidae) as occurring in Rambha Bay. A re-examination of his material has convinced Dr. Baini Prashad and myself[3] that great confusion prevails in his identifications. We believe that the following species actually occurred in the Bay in 1914. *Steno-*

[1] Identified by Preston as *Thais carinifera*, but really distinct. I have described it in the *Memoirs of the Asiatic Society of Bengal* VII, pp. 266–8, fig. 2 (1922).

[2] Named *Potamides* (*Typanotonos*) *fluviatilis* Pott. and Mich. by Preston. The name given above seems to be the correct one, as Dr. Baini Prashad has demonstrated to me.

[3] Annandale and Prashad, *Rec. Ind. Mus.* XXII, pp. 121–136, pl. xvi (1921).

thyra blanfordiana Nevill, *S. minima* (Sowerby) and *S.* (*Astenothyra*) *miliacea* (Nevill). No change in the numbers of these abundant forms, comparative or actual, was observed in April, 1920.

Pelecypoda.—All the bivalve molluscs taken in Rambha Bay in 1914 were abundant forms.

The Mytilidae were represented by two closely allied species of *Modiola*, *M. undulata* (Dunker), which was found attached to algae and other floating objects, and *M. striatula* Benson, which was taken on stones and other solid fixed objects. Both were extremely abundant, as they still are. Practically every stone at the edge of the bay, if not buried in mud, has several or many individuals of *M. striatula* fixed to it tightly, while in stormy weather innumerable shells of *M. undulata* are washed ashore. In suitable situations masses of living individuals are found attached to weeds. There has certainly been no diminution in the numbers of these species. *M. striatula*, an extremely plastic species, is known to be very tolerant of changes in salinity and allied forms are found in freshwater lakes in the centre of China.

The Veneridae include certain species of the genus *Meretrix* that are eminently characteristic of estuarine and similar waters and *M. casta* Chemnitz is abundant in a subfossil condition with *Arca granosa* (Linn.) at several places on the shores of Rambha Bay. The only species of the family found living in the bay in 1914 was, however, one of the genus *Clementia*, which is also characteristic of brackish water but differs from *Meretrix* in having an extremely delicate shell. This species (*C. annandalei* Preston) was one of the commonest molluscs all over the main area of the Chilka Lake. In September, 1919, I found many dead shells and a few living individuals, the latter all of small size. In December of the same year only dead shells were found, while in the following April very few even of these were left.

The Solenidae, a marine family with one freshwater genus, *Novaculina* Benson, were also represented by a single species, which was identified by Mr. Preston as possibly a form of *Solen fonesi* Dunker. We, therefore, referred to it as ? *Solen fonesi*, being doubtful as to the identification. Dr. Ekendranath Ghosh[1] has recently shown that it belongs to a new genus and species, which he has called *Neosolen aquaedulcioris*. This was another very common mollusc in the bay in 1914, and nearly every haul of our nets brought up, if not complete specimens, at any rate fragments of the very characteristic double siphon, which is segmented and very readily cast off. In the rainy season of 1919 no specimens were obtained ; in December a couple of broken siphons were observed, while in April, 1920, no specimens of any kind were seen.

Theora opalina (Hinds), belonging to the family Scrobiculariidae, was the most abundant of all the bottom-haunting molluscs of the bay in 1914. It survived in greatly diminished numbers at any rate till April, 1920, when a few small individuals were taken with many dead shells.

The Cuspidariidae also were represented in 1914 by one abundant species, *Cuspi-*

[1] Ghosh, *Rec. Ind. Mus.* XIX, p. 57 (1920).

daria annandalei Preston. It was usually taken with *Modiola undulata* on weeds or algae. Until December, 1919, it was still common, but in April only a few individuals were found alive.

The two remaining species, or nominal species, of the Pelecypoda taken in 1914 belong to the family Anatinidae and are doubtfully distinct. Mr. Preston has named them *Anatina barkudensis* and *A. barkulensis*. These molluscs can as a rule be secured alive only by digging in sand when the lake is low, *i.e.* in the cold season and the hot weather. None were obtained in 1919–20, but no special search was made for them. Fairly fresh shells were observed on Cherriakuda in April, 1920.

Considering the molluscs as a whole, we observed in 1914 that, in them as in other groups of animals, changes in the physiography and hydrography of the lake had a selective influence. This was also so in 1919–1920. Some species have disappeared, while others have survived without decrease of reproductive vigour. The species moreover, that have survived are not always those that might have been expected to do so *à priori*. Those of *Modiola* are, we know, tolerant, but *Nassa* is mainly a marine genus.

The changes observed in the invertebrate fauna of Rambha Bay in 1919–20 were doubtless correlated with the occurrence of abnormally low salinity of the water, and were almost certainly of a temporary nature. It is improbable that all individuals of the species that were not observed in these years had perished, and, indeed, observations made in June, July and August, 1920, proved that several of the more conspicuous forms were already recovering their old status.[1]

It will be convenient to add here the description of a new species of Nudibranch-mollusc discovered in Rambha Bay by Dr. Baini Prashad and myself.

Stiliger pica Annandale & Prashad, sp. nov.

The mollusc we call *Stiliger pica* is a very small aeolidiform Hermaeid with simple ungrooved rhinophores and without other tentacular processes on the head or foot.

The total length of the living animal in an expanded condition was 8·7 mm. and the breath of the foot 1·5 mm. The foot was long and narrow with parallel sides and sharply pointed but not produced into a filamentous process behind. In front it was somewhat expanded and its antero-lateral angles formed small, broad, blunt lobes separated by a deep emargination in front. The snout was truncate as a whole and depressed over the front of the foot; its anterior margin was separated into two lobes like those of the foot but smaller. The dorsal surface of the anterior part of the head was deeply concave. The rhinophores were long, slender, pointed and filiform; the eyes small but distinct and situated immediately behind the bases of the rhinophores. The cerata were relatively long and slender, almost filiform and sharply pointed at the tip. The longest were of about the same length as the rhinophores. They were arranged in two bands, one running down each side of the notum from a little behind

[1] In October, 1920, *Pachygrapsus propinquus* and a species of hermit-crab reappeared at Barkuda.

the eye to the posterior extremity. Each band of cerata consisted approximately of three or four rows, but the arrangement was irregular. As a rule the longest cerata were those of the innermost row. Some very small cerata, broader in proportion than others, were situated in the anterior third of each band. The central region of

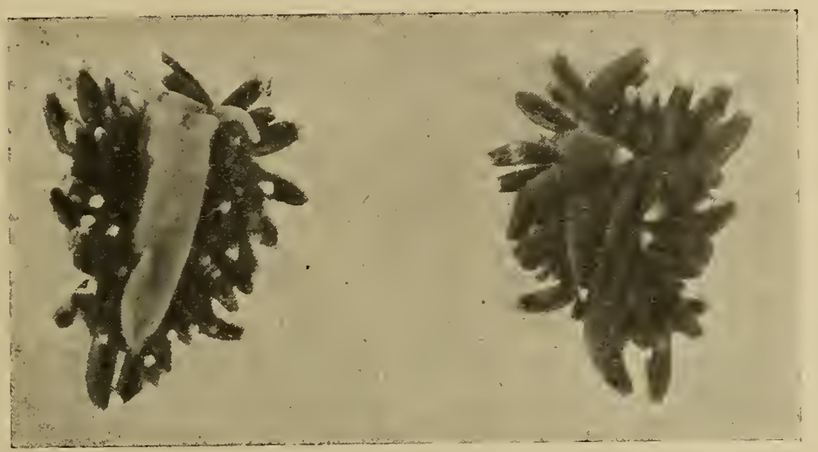

FIG. 1.—Photographs of the ventral and dorsal views of the type-specimen of *Stiliger pica* Annandale & Prashad (magnified).

the notum was bare and the anus opened on this region in the anterior third of the body. The sides were vertical and a little concave. The male pore lay below and a short distance behind the right tentacle, the female pore immediately behind it.

The penis was observed extruded in the living specimen. It was a slender organ about as long as one of the rhinophores and terminating in a slightly asymmetrical cup-shaped structure. The stylet was not observed in the living animal.

In life the back and sides were dull olive-green tinged with black between the rhinophores and obscurely vermiculated on the antero-lateral regions. There was a small pale spot round the anus. The sole of the foot was white, clouded with olive-green. The tip of the snout, rhinophores and a broad stripe extending backwards from their bases on either side to a point a little behind the eye, which was included, were translucent white with minute specks. The cerata were sooty black, obscurely speckled with grey, and had conspicuous white tips.

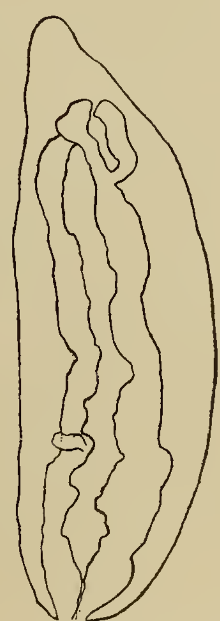

FIG. 2.—A ceras showing the arrangement of the hepatic diverticulum.

The animal was killed with boiling formalin (5 % sol.) and has retained the form and colouration described, except that the foot and head are slightly contracted and the latter somewhat depressed.

With a single minute specimen in our hands we have not been able to make out details of the internal anatomy. The genital system in general agrees with Bergh's description and figures of *Stiliger mariae* (M. & M.),[1] but the stylet of the penis is extremely short, slender and minute. The cup-like structure of the tip is withdrawn in a strongly muscular sheath. The alimentary system is also of the same type as in *S. mariae* and the radula is closely similar. The hepatic diverticula in the cerata (fig. 2) are not much coiled and bear only a few short branches.

S. pica differs from most species of *Stiliger* in its slender cerata, but otherwise seems to be a typical member of the genus. The only other species described from brackish water is *S. tentaculatus* Eliot. This peculiar form differs greatly from other species in having well-developed oral tentacles and also tentacle-like processes at the antero-dorsal angles of the foot.

The only specimen of *S. pica* we have seen was found in the latter part of June, 1920, in a small aquarium containing stones from the end of the landing-stage at Barkuda in the Chilka Lake. These stones were covered with both green and dark purple algae and it was not until they had been under observation for some days that the mollusc was observed, owing largely to the chance that it had strayed into a mass of green filamentous algae in which its dark colouration rendered it very conspicuous.

The number of Nudibranch molluscs known from brackish water in the Oriental Region is still small, but is increasing with our knowledge of the estuarine faunas and of those of maritime lakes. The following list may be of interest :—

Tribe Cladohepatica.

Family Aeolididae.

Cuthona annandalei Eliot; Gangetic Delta. *Rec. Ind. Mus.* V, pp. 248, 249, pl. xix (1910).

Cuthona henrici Eliot; Chilka Lake, east coast of India. *Mem. Ind. Mus.* V, p. 377, fig. 1 (1916).

Family Hermaeidae.

Stiliger tentaculata Eliot ; Talé Sap, Gulf of Siam. *Mem. As. Soc. Bengal* VI, pp. 179–182, figs. 1, 2 (1917).

Stiliger pica, sp. nov., Chilka Lake.

Family Elysiidae.

Elysia chilkensis Eliot; Chilka Lake. *Mem. Ind, Mus.* V, p. 378 (1916).

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[1] Semper's *Reisen in Phillipinen, Wiss. Res.* Th. II, Cd. II, pp. 139–144, pl. xxvi, figs. 1–17 (1870-1875). See also Eliot, *Brit. Nud. Moll*, pt. VIII (suppl. pp. 136-137). According to Eliot, the species should be known as *S. bellulus* M. & M.

22	,,	,,	12-45 p.m.	9	1. Breakfast Isl. 250° 40′	11 feet	Surface	29·0°	9·20	29·85°	14·26	10·42	9·225	
23	,,	,,			2. Cherriakuda Isl. (west point) 34° 0′.		5 feet	28·93°	9·13	30.5°	14·72	10·85	9·67	
24	,,	,,			3. Chiriya Island 210° 0′.		10 feet	28·185°	9·15	30·3°	14·64	10·77	9·93	
25	,,	,,	1-15 p.m.	10	1. Breakfast Isl. 241° 40′	$11\frac{1}{4}$ ft.	Surface	29·0°	8·80	30·0°	14·15	10·315	9·115	
26	,,	,,			2. Cherriakuda Island (west end) 305° 0′.		5 feet	28·27°	8·86	30·6°	14·43	10·58	9·61	
27	,,	,,			3. Chiriya Island 208° 40′		10 feet	28·29°	9·33	30·85°	15·03	11·135	10·15	
28	,,	,,	2-10 p.m.	11	1. Breakfast Isl. 231° 0′	11 feet	Surface	29·2°	8·74	30·0°	14·09	10·26	9·00	
29	,,	,,			2. Cherriakuda Isl. (west end) 283° 0′.		5 feet	28·88°	8·375	30·15°	13·74	10·14	8·78	
30	,,	,,			3. Chiriya Island 206° 0′		10 feet	28·29°	9·26	30·3°	14·76	10·89	9·91	
31	,,	16	10-30 a.m	12	1. Mr. Minchin's House 212° 20′.	$6\frac{3}{4}$ feet	Surface	29·2°	7·74	29·3°	12·76	9·02	7·78	
32	,,	,,			2. Ganta Sila 167° 0′ ..		6 feet	28·98°	8·88	30·25°	14·33	10·49	9·29	
					3. Chiriya Island 139° 20′									
33	,,	,,	10-50 a.m.	13	1. Mr. Minchin's House 211° 20′.	9 feet	Surface	29·4°	6·80	29·15°	11·69	8·03	6·72	
34	,,	,,			2. Ganta Sila 154° 20′ ..		6 feet	28·96°	8·76	29·35°	13·88	10·07	8·89	
					3. Chiriya Island 128° 20′									
35	,,	,,	11-25 a.m.	14	1. Mr. Minchin's House 214° 20′.	,,	Surface	30·2°	4·99	28·5°	9·51	6·01	4·46	Slight rain.
36	,,	,,			2. Ganta Sila 133° 0′ ..		6 feet	29·06°	9·06	28·06°	13·76	9·96	8·745	
					3. Barkuda Island (east end) 62° 20′.									
37	,,	,,	11-50 a.m.	15	1. Mr. Minchin's House 227° 0′.	10 feet	Surface	30·0°	7·97	28·25°	12·65	8·92	7·42	Raining heavily.
38	,,	,,			2. Ganta Sila 112° 20′ ..		5 feet	29·09°	9·05	30·4°	14·56	10·70	9·47	
39	,,	,,			3. Barkuda Island (east end) 59° 41′.		$9\frac{1}{2}$ feet	28·99°	9·42	31·4°	15·33	11·42	10·22	
40	,,	,,	12-20 p.m.	16	1. Mr. Minchin's House 283° 0′.	$7\frac{1}{2}$ feet	Surface	30·0°	8·81	31·5°	14·69	10·82	9·30	Slight rain.
41	,,	,,			2. Ganta Sila 80° 40′ ..		6 feet	28·98°	9·05	31·4°	14·97	11·08	9·88	
					3. Barkuda Island 52° 40′									
42	,,	,,	12-40 p.m.	17	1. Mr. Minchin's House 308° 40′.	5 feet	Surface	30·2°	9·01	31·7°	14·76	10·885	9·295	
					2. Ganta Sila 71° 20′ ..									
					3. Rambha Railway Station 9° 40′.									
43	,,	,,	1-0 p.m.	18	1. Mr. Minchin's House 314° 20′.	$7\frac{1}{4}$ feet	Surface	30·0°	9·73	29·7°	15·05	11·16	9·635	
44	,,	,,			2. Ganta Sila 41° 20′ ..		6 feet	29·78°	9·53	29·6°	14·81	10·83	9·48	
					3. Rambha Railway Station 343° 20′.									

Number of Sample.	Date. Month.	Date. Day.	Hour.	Number of Station.	Bearings of Land.	Depth of water.	Depth from which sample was collected.	Temperature of water at time sample was collected.	Density of sample as found by Buchanan's Hydrometer	Temperature of sample during experiment.	Density of sample at 0°C.	Density of sample at 25°C.	Density of sample *in situ.*	REMARKS.
45	August	19	1-25 p.m.	19	1. Mr. Minchin's House 293° 40′. 2. Ganta Sila 48° 20′ .. 3. Rambha Railway. Stn. 336° 40′.	9½ ft.	Surface	30·6°	9·02	29·5°	14·22	10·38	9·67	
46	,,	,,					6 feet	29·46°	9·58	29·2°	14·72	10·85	8·50	
47	,,	,,	1-50 p.m.	20	1. Mr. Minchin's House 271° 40′. 2. Ganta Sila 76° 40′ .. 3. Cherriakuda Isl. (east end) 32° 20′.	10¼ ft.	Surface	32·0°	7·915	29 55°	13·03	9·28	7·11	
48	,,	,,					5 feet	29·77°	9·34	28·4°	14·16	10·33	8·885	
49	,,	,,					10 feet	29·18°	9·16	32·0°	15·27	11·36	10·10	
52	,,	18	10-0 a.m.	21	1. Breakfast Isl. 311° 0′ 2. Cherriakuda Isl. (west end). 7° 20′. 3. Chiriya Island 109° 0′	9¼ ft.	Surface	29·3°	7·09	30·25°	12·35	8·68	7·25	
53	,,	,,					6 feet	29·39°	8·04	30·3°	13·44	9·66	8·34	
54	,,	,,	10-15 a.m.	22	1. Breakfast Island 258° 40′. 2. Chiriya Island 131° 0′ 3. Cherriakuda Isl. (west end) 5° 0′.	10½ ft.	Surface	29·3°	7·265	29·45°	12·30	8·59	7·31	
55	,,	,,					5 feet	29·09°	7·28	30·1°	12·535	8·82	7·60	
56	,,	,,					10 feet	29·49°	8·905	30·35°	14·39	10·53	9·19	
57	,,	,,	10-45 a.m.	23	1. Breakfast Isl. 234° 0′ 2. Chiriya Island 160° 0′ 3. Cherriakuda Isl. (west end) 353° 0′.	10¾ ft.	Surface	29·5°	6·60	30·3°	11·87	8·20	6·86	
58	,,	,,					5 feet	29·09°	6·80	29·9°	11·94	8·26	7·05	
59	,,	,,					10 feet	29·59°	8·90	30·3°	14·37	10·52	9·13	
60	,,	,,	11-30 a.m.	24	1. Breakfast Isl. 223° 40′ 2. Chiriya Island 175° 20′ 3. Cherriakuda Island (west end) 335°0′.	11 feet	Surface	29·9°	6·77	29·25°	11·69	8·03	6·57	
61	,,	,,					5 feet	29·175°	6·79	29·35°	11·74	8·08	6·84	
							10 feet	29·59°	8·78	29·9°	14·10	10·27	8·88	
62	,,	,,	12-15 p.m.	25	1. Ganta Sila 213° 0′. .. 2. Chiriya Island 185° 0′ 3. Barkuda Isl. (east end) 73° 0′.	10¼ ft.	Surface	29·5°	7·00	29·95°	12·18	8·49	7·14	
63	,,	,,					5 feet	29·59°	7·65	29·3°	12·66	8·93	7·55	
64	,,	,,												

TABLE II.—*Showing the Density of Water taken from the Surface in Rambha Bay between August and December*, 1919.

Number of Sample.	Date. Month.	Date. Day.	Position.	Depth from which sample was taken.	Temperature at time sample was taken.	Density of sample as found by Buchanan's Hydrometer.	Temperature of sample during experiment.	Density of sample at 0°C.	Density of sample at 25°C.	Density of sample *in situ*.	REMARKS.
..	1919 August	11	Barkuda Island end of Jetty.	Surface	29·9°	9·13	30·4°	14·65	10·78	9·29	
50	,,	17	,, ,, 3-15 p.m.	,,	29·8°	6·70	29·5°	11·70	8·04	6·60	At the commencement of and after a storm wind and rain from the N.E.
51	,,	,,	,, ,, 5-15 p.m.	,,	29·1°	6·26	28·75°	10·97	7·36	6·15	
65	Sept.	5	,, ,,	,,	..	4·61	29·5°	9·09	5·615	..	Temperature of water at time sample was taken was not recorded
66	Oct.	19	,, ,,	,,	..	4·12	21·7°	6·575	3·35	..	
67	Dec.	16	Breakfast Island	,,	..	3·05	21·6°	5·40	2·19	..	
96	1920 June	7	Barkuda Island end of Jetty.	,,	..	8·11	30·1°	13·44	9·66	..	

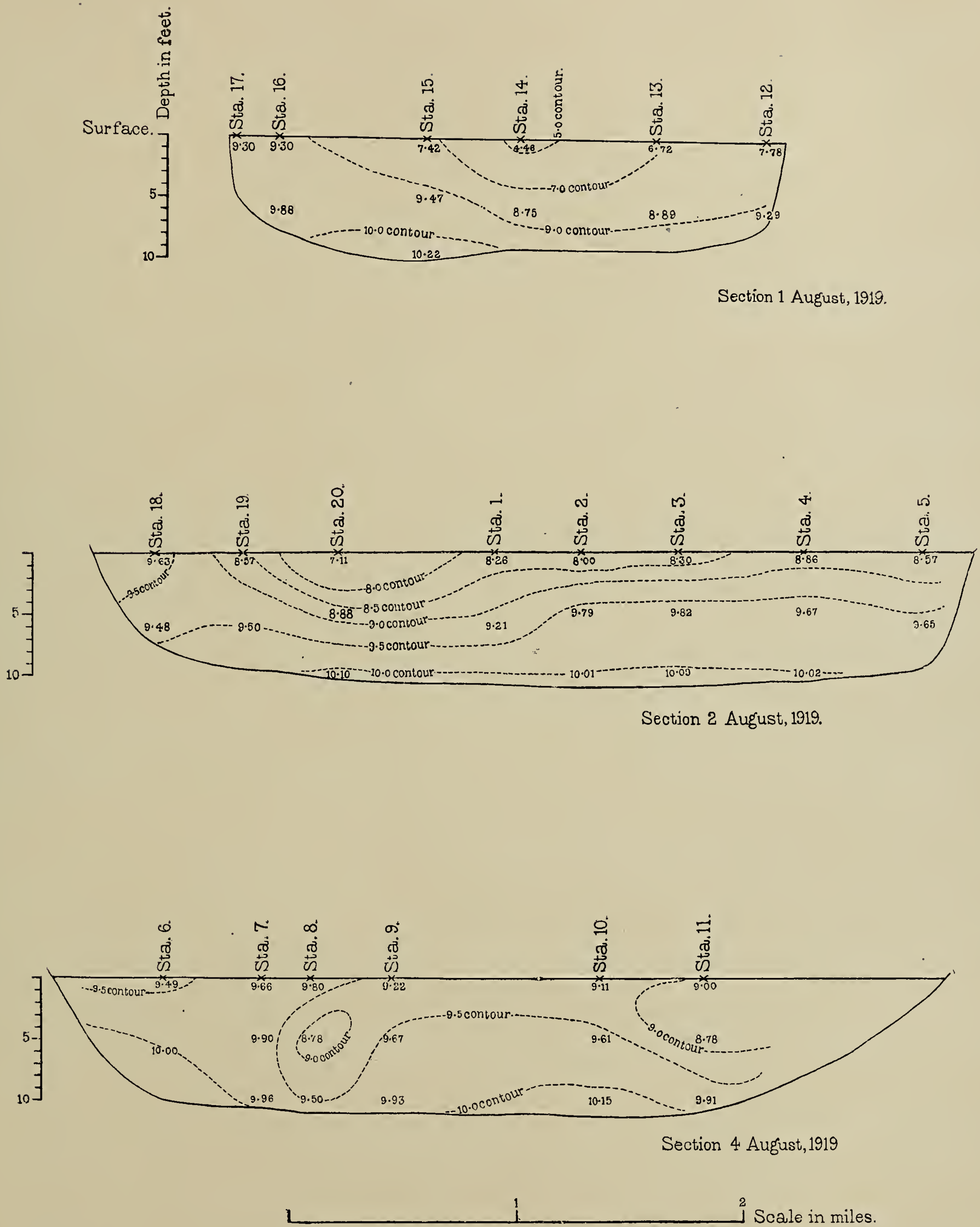
TABLE III.—*Hydrographic Observations taken at Stations 26–42, April, 1920.*

Number of Sample.	Date. Month.	Date. Day	Hour.	Number of Station.	Bearings of Land.	Depth of Water.	Depth from which sample was collected.	Temperature of water at time sample was taken.	Density of sample as found by Buchanan's Hydrometer	Temperature of sample during experiment.	Density of sample at 0°C.	Density of sample at 25·°C.	Density of sample *in situ.*	REMARKS.
68 68A	April ,,	27 ,,	9-25 a.m.	26	1. Chiriya Island 207° .. 2. Ganta Sila 225 .. 3. Barkuda Isl. due E ..	5 ft.	Surface 4 feet	28·25° 28·25°	·3·70 3·74	31·0° 31·0°	8·97 9·01	5·50 5·54	4·58 4·62	
69 70	,, ,,	,, ,,	9·40 a m.	27	1. Chiriya Island 208° .. 2. Breakfast Isl 235° .. 3. Rambha 265° ..	5 ft. 3 in.	Surface 4 feet	28·2° 28·0°	3·66 3·64	31·2° 31·5°	8·99 9·08	5·52 5·55	4·60 4·69	
71 72	,, ,,	,, ,,	10-0 a.m.	28	1. Chiriya Island 215° .. 2. Breakfast Isl. 246° .. 3. Rambha Station 273°	5 ft. 9 in.	Surface 4 feet	28·2° 28·2°	3·19 3·24	53·9° 33·9°	9·49 9·53	5·98 6·03	5·06 5·10	Slight breeze from S.S.W.
73 74	,, ,,	,, ,,	10-40 a.m.	29	1. Chiria Island 222° .. 2. Rambha Station 286° 3. West end of Cherriakuda Island 312° ..	5 ft. 9 in.	Surface 4 feet	28·2° 28·2°	3·39 3·61	34·1° 31·5°	9·65 9·05	6·14 5·58	5·21 4·70	
75	,,	,,	10-45 a.m.	30	1. Chiriya Island 278° .. 2. West end of Cherriakuda Island 333°. 3. E. end of Barkuda Island 5°.	4 ft.	Surface	28·2°	3·67	31·7°	9·19	5·70	4·78	
76	,,	,,	11-0 a.m.	31	1. Chiriya Island 157° .. 2. Ganta Sila 245° .. 3. East end of Barkuda Island 37°.	4 ft. 9 in.	,,	28·6°	3·65	31·5°	9·09	5·62	4·58	
77 78	,, ,,	,, ,,	11-15 a.m.	32	1. Chiriya Island 180° .. 2. Ganta Sila 229° .. 3. Rambha Station 93° ..	5 ft.	,, 4 feet	29·6° 28·7°	3·66 3·72	31·5° 30·3°	9·10 8·71	5·63 5·30	4·28 4·23	
79 80	,, ,,	,, ,,	11-40 a.m.	33	1. W. end of Cherriakuda Island 328°. 2. Rambha Station 263° 3. Ganta Sila 218° ..	,,	Surface 4 feet	28·8° 28·8°	3·63 3·72	31·5° 31·5	9·06 9·16	5·59 5·68	4·49 4·58	
81 82	,, ,,	,, ,,	12 Noon	34	1. East end of Barkuda Island 42°. 2. West end of Cherrikuda Island 308°. 3. Rambha Station 250°	,,	Surface 4 feet	28·9° 29·1°	3·65 3·39	31·8 34·1	9·20 9·77	5·72 6·24	4·58 5·04	Breeze steadily freshening.

83	April	27	12-20 p.m.	35	1. Barkuda Jetty 81° .. 2. Chiriya Island 184° .. 3. Mr. Minchin's House 229°.	4 ft. 6 in.	Surface	29·1°	3·60	31·5°	9·03	5·56	4·37	Strong breeze from S.S.W.
84	,,	28	11-0 a.m.	36	1. Chiriya Island 117° .. 2. W. end of Barkuda Isl. 53°. 3. Mr. Minchin's House 255°.	5 ft.	,,	29·3°	3·65	33·9	9·97	6·43	5·17	Dead calm.
85	,,	,,					4 feet	28·2°	3·63	33·7	9·88	6·35	5·43	
86	,,	,,	11-15 a.m.	37	1. Chiriya Island 136° .. 2. Ganta Sila 177° .. 3. Mr. Minchin's House 237°.	,,	Surface	29·4°	3·58	32·8	9·49	5·98	4·69	
87	,,	,,					4 feet	28·6°		Sample	not kept			
88	,,	,,	11-40 a.m.	38	1. East end of Barkuda Island 56°. 2. Ganta Sila 190° .. 3. Rambha Station 271°	,,	Surface	29·2°	3·50	33·1°	9·52	6·01	4·78	Slight breeze from S.S.W.
89	,,	,,					4 feet	29·1°	3·62	32·9°	9·56	6·06	4·86	
90	,,	,,	12 Noon.	39	1. Chiriya Island 166° .. 2. Ganta Sila 204° .. 3. Mr. Minchin's House 242°.	,,	Surface	29·4°	3·68	32·0°	9·30	5·81	4·52	Breeze freshening.
91	,,	,,					4 feet	29·4°	3·61	33·0°	9·60	6·09	4·79	
92	,,	,,	12-25 p.m.	40	1. Chiriya Island 133° .. 2. Ganta Sila 167° .. 3. Mr. Minchin's House 233°.	,,	Surface	29·4°	3·64	32·0°	9·25	5·77	4·48	Strong breeze from S.S.W.
93	,,	,,					4 feet	29·4°	3·63	31·9°	9·21	5·73	4·44	
94	,,	29	10-40 a.m.	41	1. East end of Samal Isl. 159° (?) 2. Kespool village 296° .. 3. Hill Section Grand Trunk Road 253°.	6 ft.	Surface	29·6°	4·35	30·2°	9·39	5·90	4·54	,,
95	,,	,,	11-45 a.m.	42	1. Chiriya Island 218° .. 2. S.E. corner Samal Isl. 181°. 3. E. corner Samal Island 320°.	5 ft. 6 in.	,,	30·0°	4·13	30·0°	9·08	5·61	4·13	,,

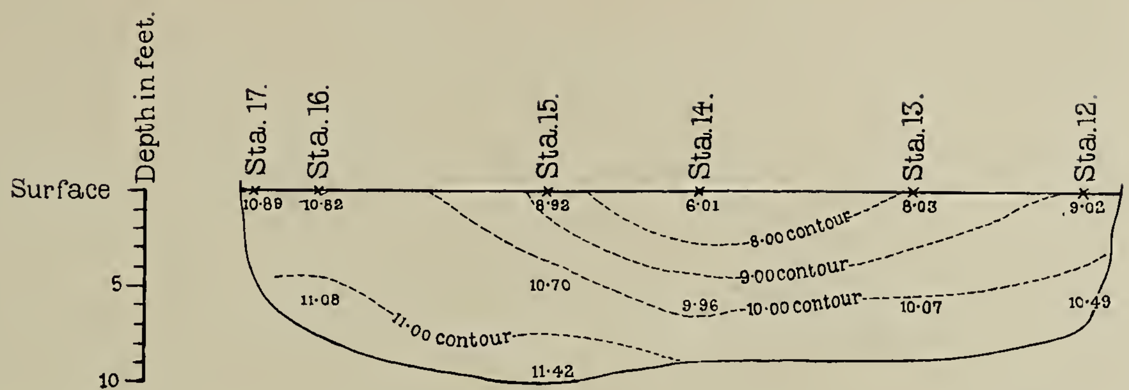
TABLE IV.—*Showing the corresponding densities of water at 0°, 15° and 25°C. respectively.*

At 0°C.	At 15°C.	At 25°C.
1002·000	1001·164	999·044
1002·500	1001·619	999·506
1003·000	1002·093	999·969
1003·500	1002·567	1000·432
1004·000	1003·041	1000·895
1004·500	1003·514	1001·358
1005·000	1003·988	1001·822
1005·500	1004·463	1002·285
1006·000	1004·937	1002·749
1006·500	1005·411	1003·212
1007·000	1005·885	1003·676
1007·500	1006·360	1004·140
1008·000	1006·834	1004·604
1008·500	1007·308	1005·068
1009·000	1007·783	1005·532
1009·500	1008·257	1005·996
1010·000	1008·732	1006·461
1010·500	1009·207	1006·925
1011·000	1009·682	1007·390
1011·500	1010·157	1007·854
1012·000	1010·632	1008·319
1012·500	1011·107	1008·784
1013·000	1011·582	1009·249
1013·500	1012·067	1009·714
1014·000	1012·533	1010·179
1014·500	1013·008	1010·644
1015·000	1013·483	1011·110
1015·500	1013·958	1011·575
1016·000	1014·434	1012·041
1016·500	1014·910	1012·506
1017·000	1015·386	1012·972
1017·500	1015·862	1013·438
1018·000	1016·337	1013·904
1018·500	1016·823	1014·370
1019 000	1017·289	1014·836
1019·500	1017·766	1015·302
1020·000	1018·242	1015·769
1020·500	1018·718	1016·235
1021 000	1019·194	1016·702
1021·500	1019·670	1017·168
1022·000	1920·147	1017·635

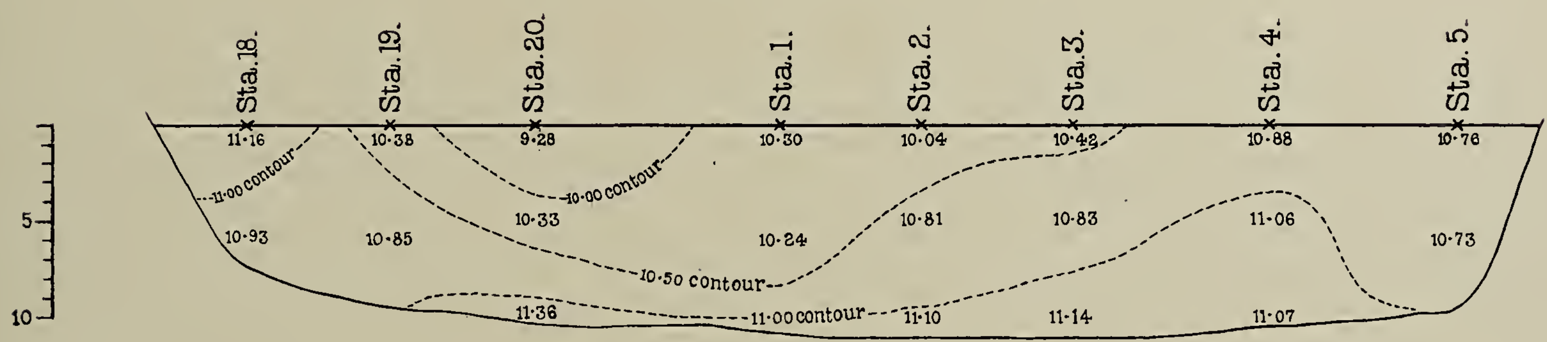


R. B. S. S. del.

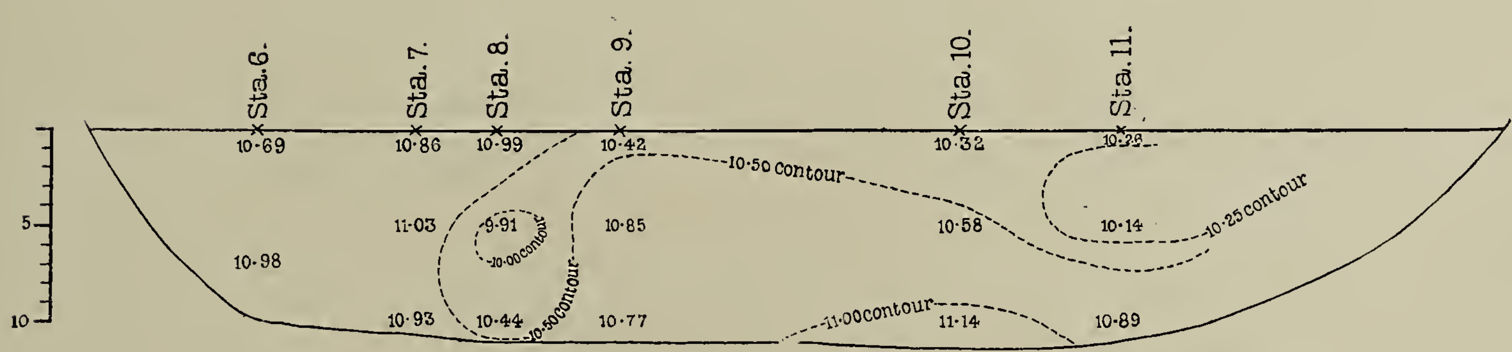
Sections of Rambha Bay, August 1919, showing densities *in situ*.



Section 1. August, 1919.



Section 2. August, 1919.

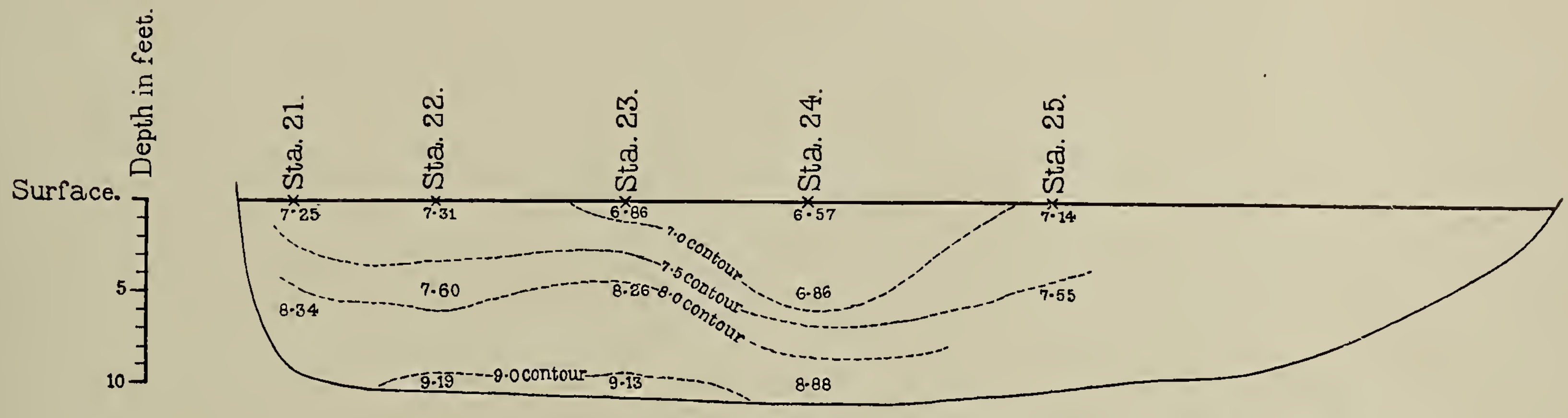


Section 4. August, 1919.

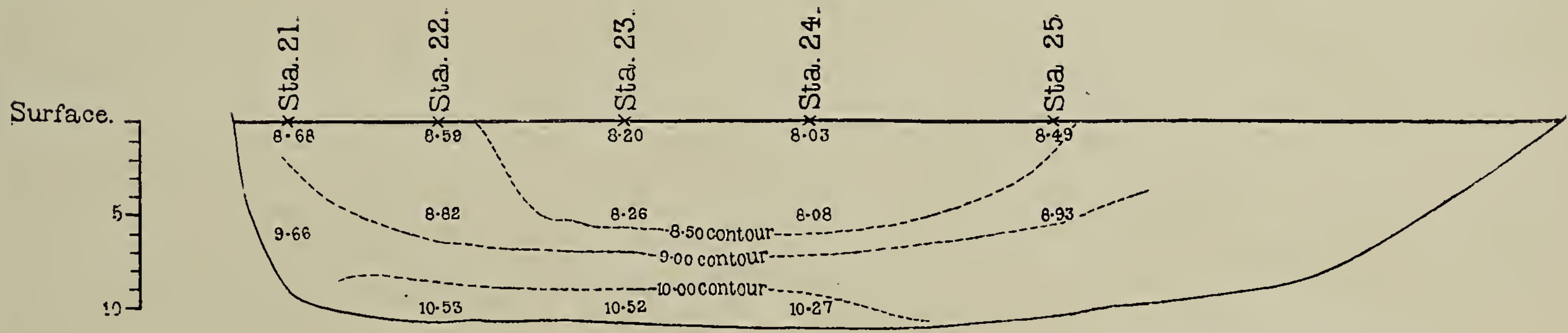
1 2 Scale in miles

R. B. S. S. del.

Sections of Rambha Bay, August 1919, showing densities reduced to standard temperature [25. 0°C.]



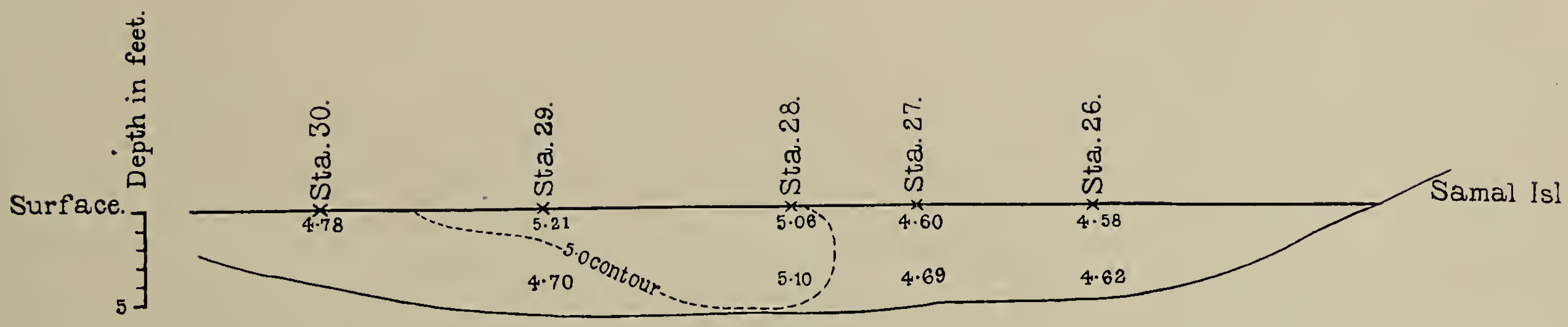
Section 3. August, 1919.



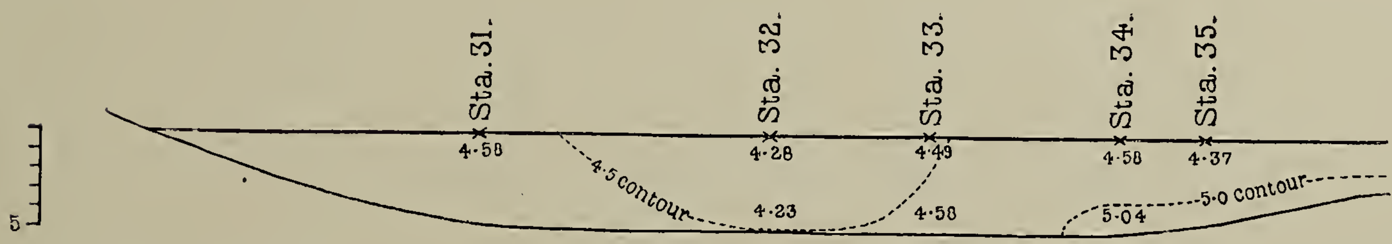
Section 3. August, 1919.

R. B. S. S. del.

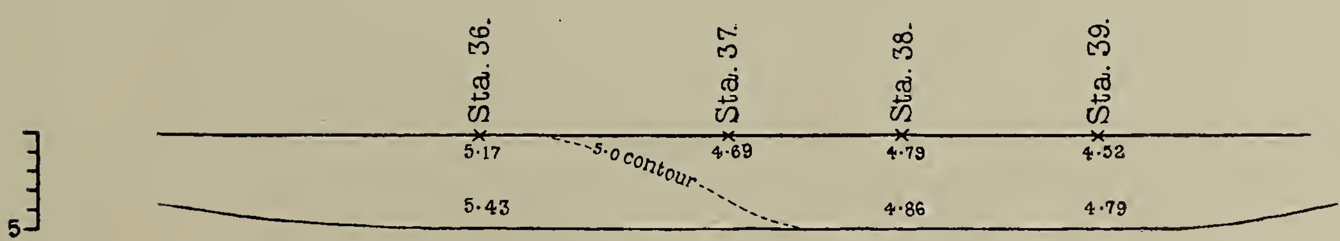
Sections of Rambha Bay, August, 1919, showing (above) density *in situ*, (below) density reduced to standard temperature [25. O°C.]



Section 1. April, 1920.



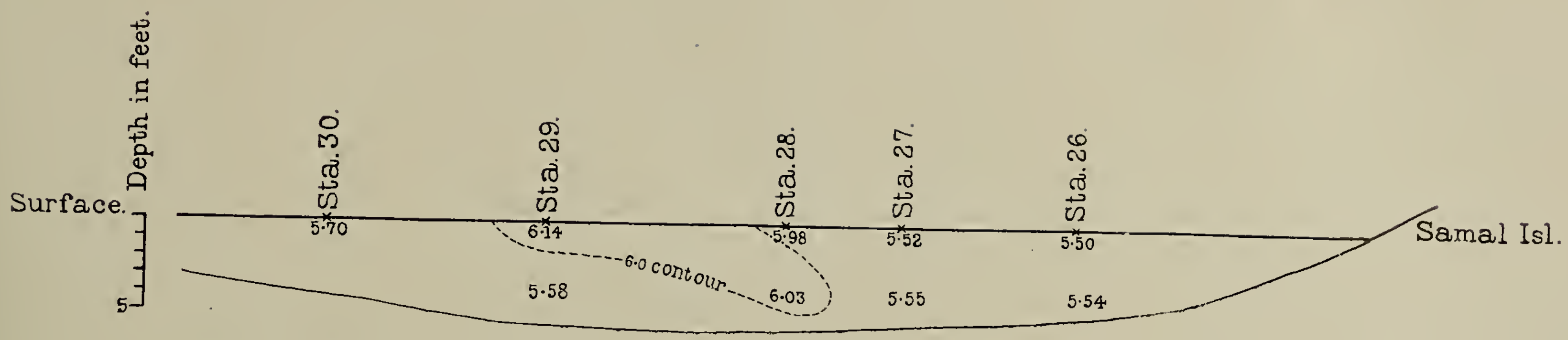
Section 2. April, 1920.



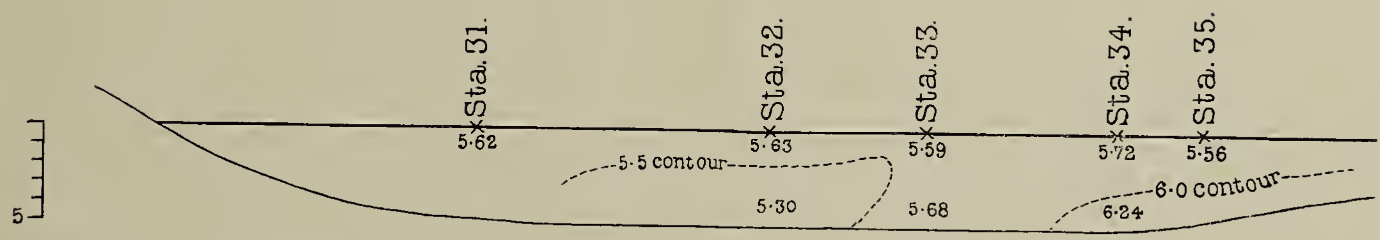
Section 3. April, 1920.

R. B. S. S. del.

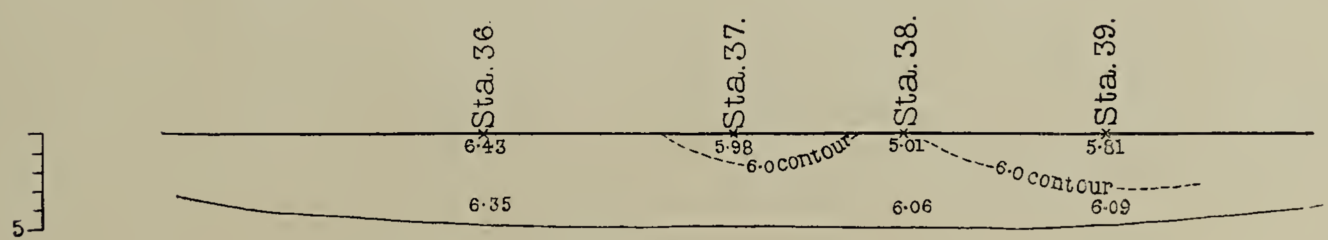
Section of Rambha Bay, April 1920, showing densities *in situ*.



Section 1. April, 1920.



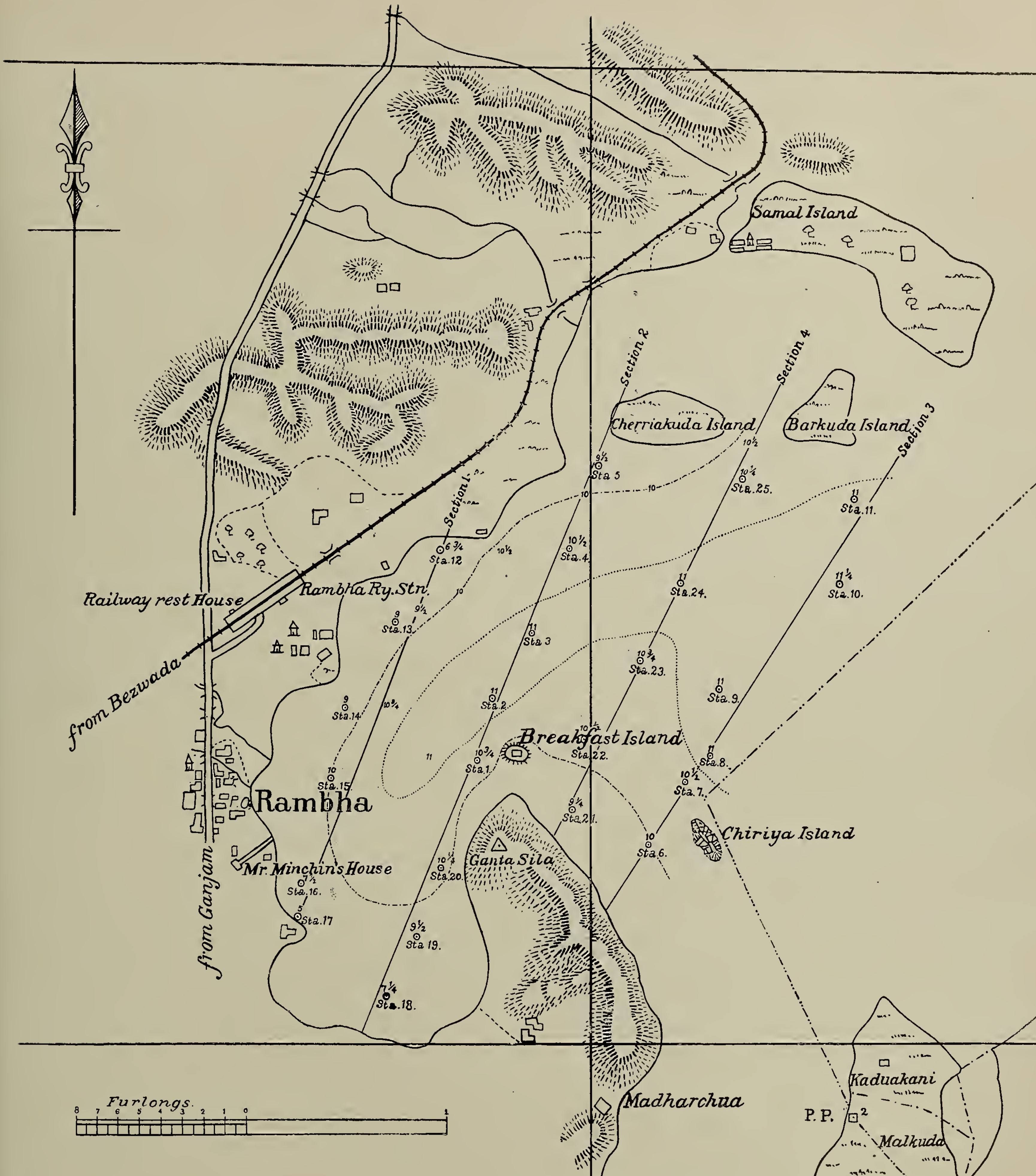
Section 2. April, 1920.



Section 3. April, 1920. 1 2 Scale in miles.

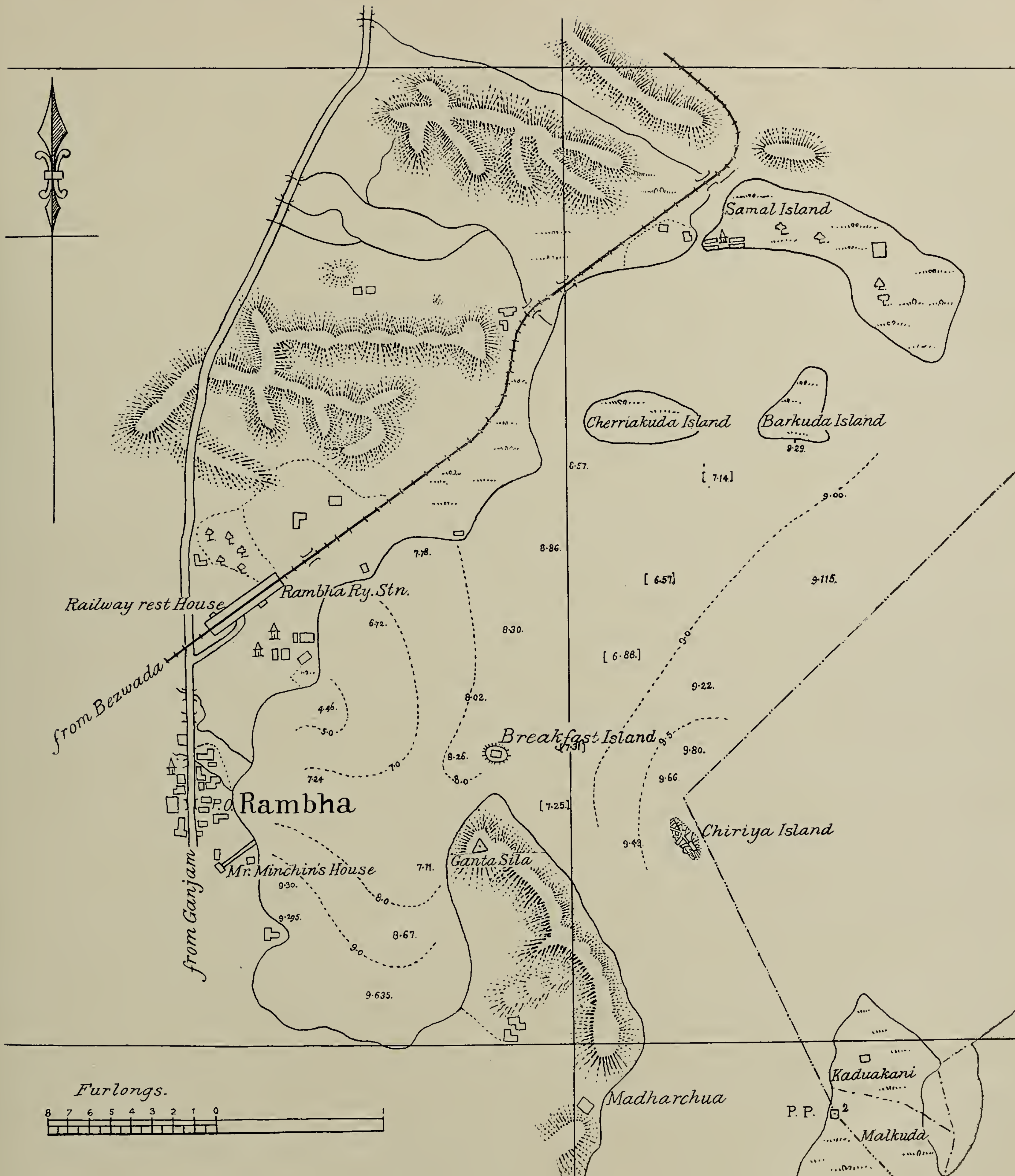
R. B. S. S. del.

Section of Rambha Bay, April 1920, showing densities reduced to standard temperature [25. O°C.]



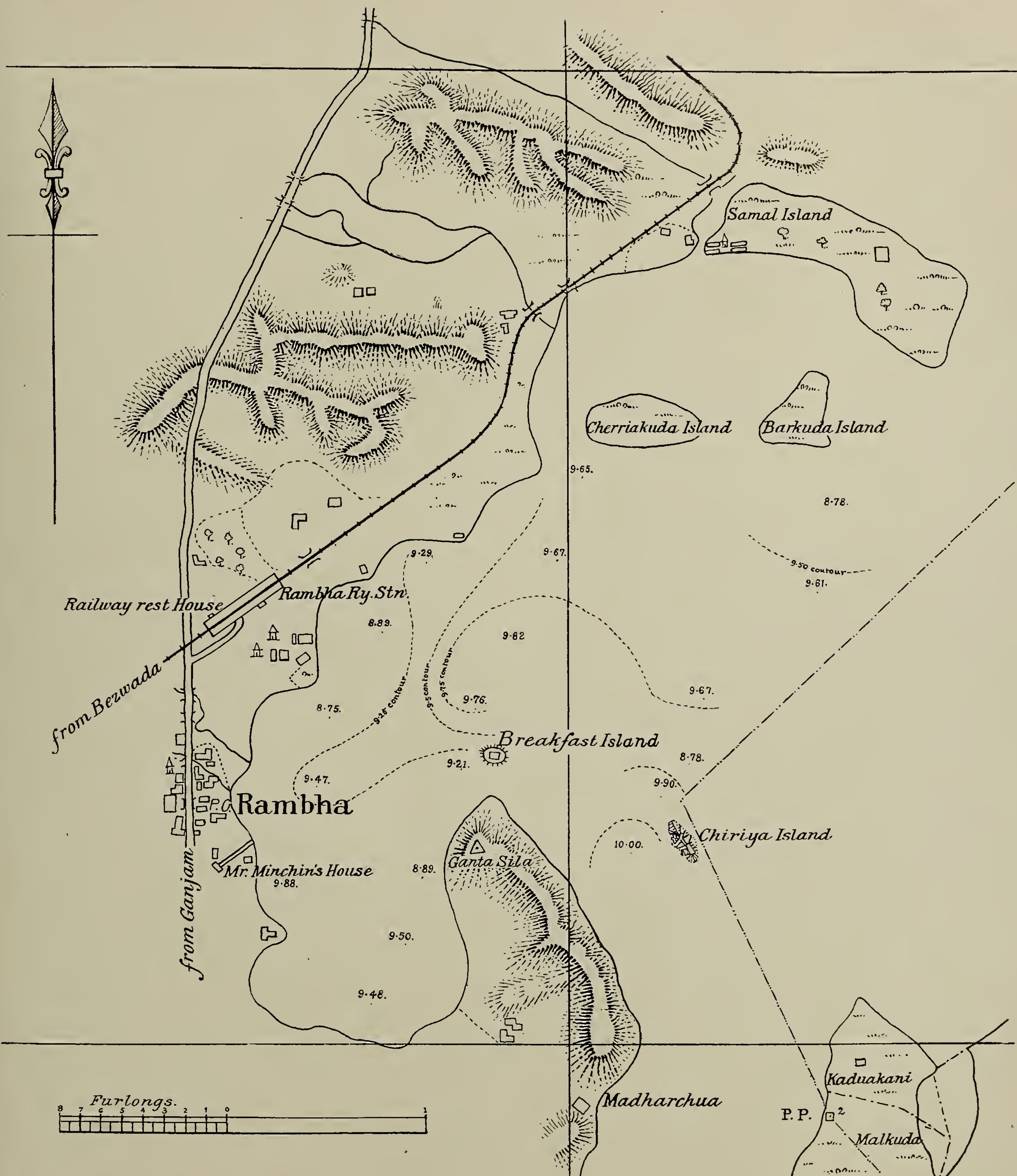
R. B. S. S. del.

Chart showing position of stations 1—25. August 1919.



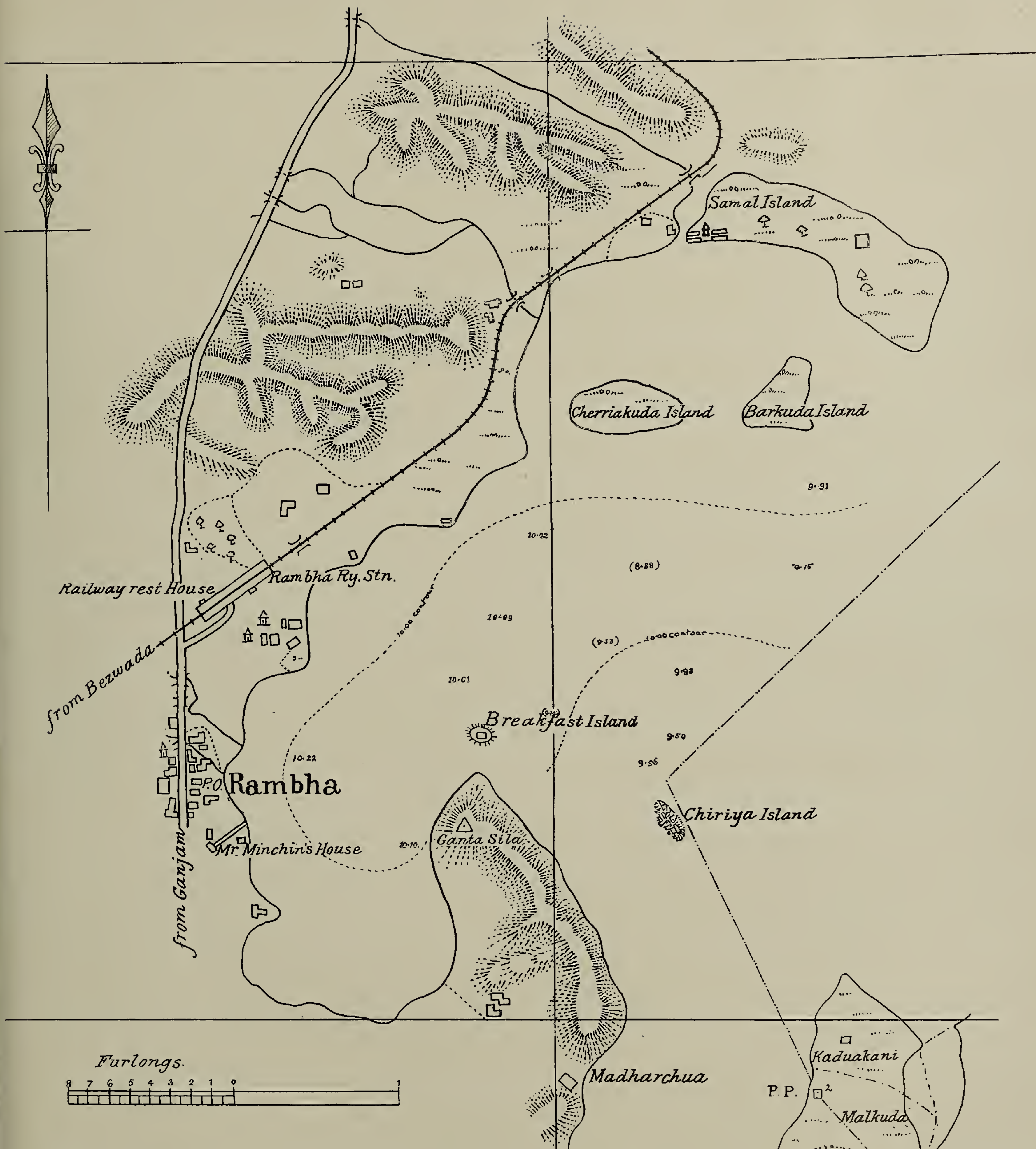
R. B. S. S. del.

Chart showing density at surface, August 1919.



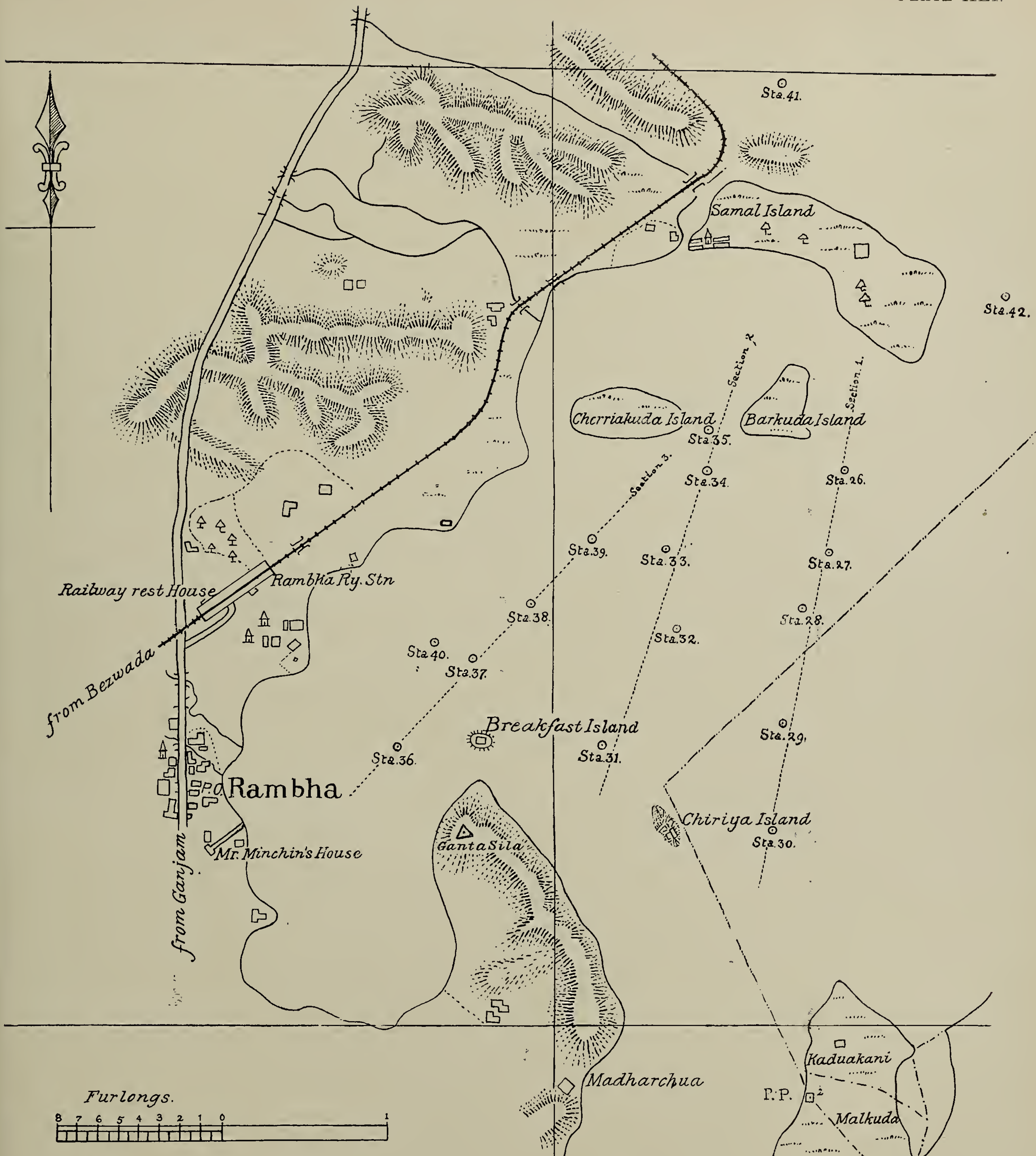
R. B. S. S. del.

Chart showing density at 5 feet depth, August 1919.



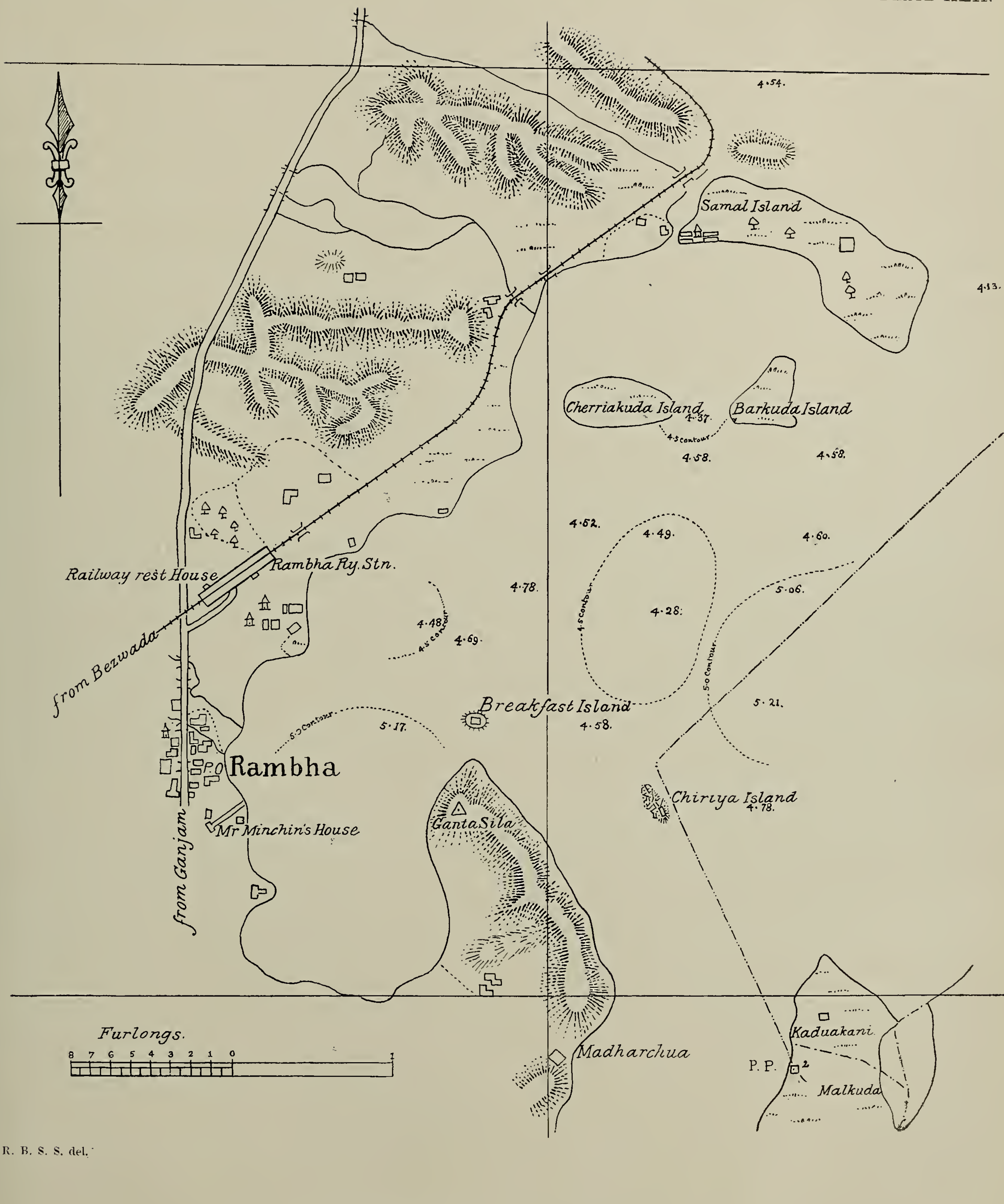
R. B. S. S. del.

Chart showing density at 10 feet depth, August 1919.



K. B. S. S. del.

Chart showing position of stations 26—40, April 1920.



R. B. S. S. del.

Chart showing density on the surface *in situ*.

R. B. S. S. del.

Chart showing density at 4 feet depth *in situ*.