# FAUNA OF THE CHILKA LAKE

## MOLLUSCA GASTROPODA AND LAMELLIBRANCHIATA.

*By* N. ANNANDALE, *D.Sc.*, *and* STANLEY KEMP, *B.A.*

(Plates XIV—XVI.)

WITH AN ACCOUNT OF

## THE ANATOMY OF THE COMMON *SOLEN*.

*By* EKENDRANATH GHOSH, *M.Sc.*

(With 3 text-figures.)

# CONTENTS.

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## INTRODUCTION.

Our object in preparing this report has been, not to criticise genera and species from a taxonomic point of view, but to discuss in relation to their biological environment the distribution of the forms that occur in the Chilka Lake, and thus to bring the Mollusca, so far as possible, into line with the other groups dealt with in this volume. So far as nomenclature is concerned, we have in most cases followed that adopted by Mr. H. B. Preston in the series of papers contributed by him to the *Records of the Indian Museum* between 1907 and 1916. Full references to these and to other papers dealing with what von Martens calls the "sub-marine" molluscs of the Indian coasts are given in the bibliography on p. 364.

In the collections from the Chilka Lake that we have sent to Mr. Preston he recognizes no less than 34 species of Gastropods and 45 of Lamellibranchs. Of these he has described 42 species as new. We do not disparage his work, undertaken as it has been with a purely conchological aim, in saying that we expect that many of these species will ultimately prove to be no more than dwarfed or distorted phases of molluscs that occur elsewhere in more normal conditions. Cooke has pointed out with admirable clearness in his volume in the *Cambridge Natural History* (vol. III, p. 82) that a naturalist's concept of species and varieties in Mollusca must be profoundly modified by his point of view. Our point of view is not Mr. Preston's, but unfortunately we lack his special knowledge. We have therefore accepted his conclusions in so far as they do not run counter to the facts we have observed in the field.

In our Introduction to this volume we have dealt at length with the physical conditions of life in the different parts of the lake-system and in particular with the periodic changes in the salinity of the water. It will be as well, however, to recapitulate briefly our statements on these points in so far as they influence the distribution of the Mollusca.

The whole of the lake-system is very shallow, rarely more than 2 fathoms in

depth, and the variations of level that occur at different seasons, though relatively great (about 5 or 6 ft.), are not sufficient to have any appreciable direct effect on the fauna. The bottom of the main area of the lake is covered with soft mud, which probably overlies a deep layer of clean sea-sand, while along the outer shore of this area and round some of the lower islands, sand and mud are mixed. At most places at which this occurs the water becomes excessively shallow in the dry season and is so heated by the sun that conditions are inimical to most forms of animal life; but the admixture is a marked feature of the bottom round the island of Nalbano and a belt of gritty mud extends in fairly deep water out into the channel by means of which the lake is connected with the sea. The outer part of this channel, near the sea-mouth, is scoured by currents at certain seasons and its bottom consists of clean sand. At several points along the inner shore of the main area and on some of the islands there are rocks, partially or entirely submerged in summer and autumn, but in spring exposed and dry owing to the sinking of the water-level. In sheltered spots, where the water near the shore is relatively deep, dense thickets of weed grow up in autumn, dying out almost completely in the rainy season. They consist for the most part of a species of *Potamogeton* that sometimes attains a height of at least five feet in order to flower on the surface. A fine-branched alga also forms somewhat lower thickets at a few places in both parts of the lake-system.

For the greater part of the year the whole of the main area is filled with water that may be called brackish, having a specific gravity (corrected) that reaches a maximum of 1·0150. At this period there is an abrupt change in salinity at the point where the outer channel opens into the main area, the water in the former being, at the height of the season, as salt, or very nearly as salt as that of the Bay of Bengal outside the sea-mouth (sp. gr. 1·02650). Between August and October floods of fresh water pour in from the rivers at the north, driving before them the salter water, until the northern part of the main area and the whole of the outer channel become entirely fresh. In a comparatively small area at the southern end of the lake into which no rivers open, the floods have less effect and the water remains brackish throughout the year, the specific gravity varying from 1·003 to 1·015. The northern boundary of this area is situated close to the island of Kalidai, which forms a land-mark in the distribution of species.

The specific gravities recorded in the table on pp. 332, 333 represent not the full range of salinity in which the species may occur, but merely that in which we found living specimens in the Chilka Lake.

In the collection of the Indian Museum there are specimens of some 37 named species of Gastropods and 47 of Lamellibranchs from the lake. Certain shells that we believe to have been introduced by man or other agents may be dismissed very briefly. We have no reason to include these species among the living fauna, for the Gastropods are merely represented by dead shells, most of which were occupied by hermit-crabs, while of the Lamellibranchs only single valves were obtained, in circumstances which suggested that they had been brought from the coast by man. These introduced shells are:—

GASTROPODA.

Nassidae.
*Bullia vittata*, Linn.

Strombidae.
*Strombus isabella*, Lk.

Viviparidae.
*Vivipara bengalensis*, Lk.

Ampullariidae.
*Ampullaria globosa*, Swains.

Naticidae.
*Natica marochiensis*, Gmel.
,, *maculosa*, Lam.

LAMELLIBRANCHIATA.

Veneridae.
*Meretrix morphina*, Lk.
*Meröe scripta*, Gray.
,, *chilkaënsis*, Preston.
,, *satparaënsis*, Preston.

Donacidae.
*Donax pulchella*, Hanley.

Tellinidae.
*Tellina barhampurensis*, Preston.

Dead shells of the freshwater Gastropods that live in pools and rice-fields are common on the shores of the lake and are occasionally carried into it by winds, by birds and by hermit-crabs of the semi-terrestrial genus *Coenobita*, which also bring marine shells, such as those of *Natica* and *Strombus*, across the sand-hills from the sea. Marine shells, especially those of Lamellibranchs, are commonly collected on the sea-shore by Uriya fishermen and used for the manufacture of lime, lime from this source being highly esteemed as an ingredient in *pán*. Such shells are often dropped in the neighbourhood of villages. They must be carefully distinguished from the sub-fossil shells found at certain places (see p. 338).

The living Mollusca of the lake, omitting Nudibranchs and introduced shells, are listed on pp. 332, 333 and comprise, so far as our knowledge goes, 73 species, 31 of Gastropods and 42 of Lamellibranchs. The Gastropods are distributed among 14 families and 19 genera, the Lamellibranchs among 20 families and 25 genera. No less than 28 species, with one genus (*Chilkaïa*)—that is to say, about 38% of the total number—appear at present to be endemic in the lake-system.

The great majority of the genera are certainly of marine origin, the only exceptions being *Potamides*, *Chilkaïa* (*?*), *Hydrobia* and *Stenothyra*. *Potamides* is essentially an estuarine genus and the two species by which it is represented occur commonly in brackish water all over the Oriental region, in Australia and in Japan. The genus ***Chilkaïa***, as at present known, is represented by a single minute species belonging to a family the other members of which are marine. On the other hand *Hydrobia* and ***Stenothyra*** belong to a family of which most of the species inhabit fresh water, but many make their way into estuarine tracts and are found only in brackish water. This is the case with most of the Indian species. More than half of those of *Stenothyra* known from India have been found in the Chilka Lake.

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[1] The figures in the second column of this table indicate the specific gravity of the water in which living specimens were obtained. Species which, so far as is yet known, are endemic in the lake-system are distinguished by an asterisk.

| | Specific gravity of water. | Distribution in Lake. | | Further Distribution. |
|---|---|---|---|---|
| | | Main area. | Outer channel. | |
| **Gastropoda.** | | | | |
| TORNATINIDAE. | | | | |
| *Tornatina estriata*, Preston .. .. | 1·000—1·0265 | X | X | Cochin backwaters. |
| BULLIDAE. | | | | |
| *Bulla (Haminea) crocata*, Pease .. | 1·000 [1]—? | .. | X | Indo-pacific. |
| NASSIDAE. | | | | |
| *Nassa sistroidea*, G. & H. Nevill .. | 1·000—1·0265 | .. | X | Andamans. |
| ,, *labecula*, A. Ads. .. .. | 1·000—1·0265 | X | X | Philippines. |
| ,, *marrattii*, Smith .. .. | ? | .. | X | Mekran coast to Solomon Is. |
| ,, *denegabilis*, Preston .. .. | 1·000—1·0265 | X | X | Cochin and Madras backwaters; Gangetic delta. |
| ,, *orissaënsis*, Preston .. .. | 1·000—1·0265 | X | X | Madras backwaters; Gangetic delta. |
| MURICIDAE. | | | | |
| *Thais carinifera* (Lam.) .. .. | 1·005—1·0265 | X | X | E. Africa to Australia. |
| CERITHIIDAE. | | | | |
| *Potamides (Tympanotonos) fluviatilis*, Pot. & Mich .. .. | 1·000—1·0265 | X | X | India to Australia and Japan. |
| ,, *(Telescopium) fuscum*, Schum. | 1·0265 | .. | X | ,, ,, ,, |
| TURRITELLIDAE. | | | | |
| *Vanesia rambhaënsis* (Preston).. .. | 1·000—1·015 | X | X | Cochin backwaters |
| FOSSARIDAE. | | | | |
| *Chilkaïa imitatrix*,* Preston .. .. | 1·000—? | .. | X | |
| LITIOPIDAE. | | | | |
| *Litiopa (Alaba) kempi*,* Preston .. | 1·000—1·015 | X | X | |
| ,, ,, *copiosa*,* Preston .. | 1·000—1·0265 | X | X | |
| HYDROBIIDAE. | | | | |
| *Hydrobia (Belgrandia) myliacea*, Nevill .. | ? | ? | ? | Gangetic delta. |
| *Stenothyra blanfordiana*, Nevill.. .. | ? | ? | ? | Gangetic delta; Madras. |
| ,, *minima* (Sowerby) .. .. | 1·000—1·0265 | X | X | Western India; Ceylon. |
| ,, *chilkaënsis*,* Preston .. | 1·000—1·0265 | X | X | |
| ,, *orissaënsis*,* Preston .. | 1·000—1·0265 | X | X | |
| ,, *trigona*,* Preston .. .. | 1·000—1·015 | X | X | |
| ,, *obesula*,* Preston .. .. | 1·000—? | .. | X | |
| SCALARIIDAE. | | | | |
| *Epitonium hamatulae*,* Preston .. | ? | .. | X | |
| PYRAMIDELLIDAE. | | | | |
| *Pyrgulina humilis* (Preston) .. .. | 1·000—1·0265 | X | X | Cochin backwaters; Ceylon. |
| *Chrysallida (Mormula) ecclesia*,* Preston .. | ?—1·015 | X | .. | |
| ,, ,, *nadiensis*,* Preston | 1·000—? | .. | X | |
| *Odostomia chilkaënsis*,* Preston .. | 1·0265 | .. | X | |
| NERITIDAE. | | | | |
| *Neritina (Theodoxus) souverbiana*, Montr. | 1·000—1·0265 | .. | X | China Sea; New Caledonia. |
| CYCLOSTREMATIDAE. | | | | |
| *Cyclostrema (Tubiola) innocens*,* Preston .. | ? | .. | X | |
| *Tinostoma variegatum*,* Preston .. | 1·0265 | .. | X | |
| TROCHIDAE. | | | | |
| *Umbonium vestiarium* (Linn.) .. .. | 1·0265 | .. | X | Warm and tropical seas. |
| *Solariella satparaënsis*,* Preston .. | 1·000—1·0265 | .. | X | |
| **Lamellibranchiata.** | | | | |
| OSTREIDAE. | | | | |
| *Ostrea virginiana*, Gmel. .. .. | 1·000—1·0265 | X | X | W. coast of N. America; ? all tropical seas. |
| ,, *cucullata*, Born. .. .. | 1·000—1·0265 | .. | X | Indo-pacific. |
| ,, *lentiginosa*, Sowerby .. .. | 1·0265 | .. | X | ? |

[1] A single dwarfed specimen.

SPECIES.

| | Specific gravity of water | Distribution in Lake. Main area. | Distribution in Lake. Outer channel. | Further Distribution. |
|---|---|---|---|---|
| **MYTILIDAE.** | | | | |
| *Mytilus smaragdinus*, Chemn. | ? | .. | X | Arabian Sea to Hongkong; ? N. Zealand. |
| *Modiola undulata* (Dunker) | 1·000—1·0265 | X | X | Moluccas; Gangetic delta. |
| ,, *striatula*, Hanley | 1·000—1·0265 | X | X | Arabian Sea to Philippines. |
| **ARCIDAE.** | | | | |
| *Arca* (*Anadara*) *granosa* (Linn.) | 1·003—1·015 | X | ? | Arabian Sea to Japan and Australia. |
| ,, (*Fossularca*) *lactea* (Linn.) | 1·0265 | .. | X | E. Atlantic to Burma; ? Philippines. |
| **ERYCINIDAE.** | | | | |
| *Kellya chilkaënsis*,* Preston | 1·000—1·0265 | X | X | |
| ,, *mahosaënsis*,* Preston | 1·007 | .. | X | |
| **GALEOMMIDAE.** | | | | |
| *Scintilla chilkaënsis*,* Preston | 1·000—? | .. | X | |
| **CARDIIDAE.** | | | | |
| *Cardium* (*Fulvia*) *rugatum*, Gronov. | 1·0265 | .. | X | Bay of Bengal to New Britain. |
| **VENERIDAE.** | | | | |
| *Meretrix meretrix* (Lam.) | 1·000 ?—1·0265 | .. | X | |
| ,, *casta*, Chemn. | 1·000 ?—1·0265 | .. | X | Indian Seas; Ceylon; Singapore. |
| ,, *ovum*, Hanley | 1·000 ?—1·0265 | .. | X | Indian Seas. |
| *Tivela dillwyni* (Deshayes) | 1·000—? | .. | X | |
| *Tapes pinguis*, Chemn. | 1·000 ?—1·0265 | .. | X | Eastern Indian Ocean. |
| ,, *ceylonensis*, Sowerby | 1·000 ?—1·0265 | .. | X | Indian Seas; Ceylon. |
| *Clementia annandalei*, Preston | 1·000—1·0265 | X | X | Gangetic delta. |
| **PETRICOLIDAE.** | | | | |
| *Petricola esculpturata*,* Preston | 1·000—1·0265 | .. | X | |
| **UNGULINIDAE.** | | | | |
| *Diplodonta satparaënsis*,* Preston | 1·009—1·0265 | X | X | |
| ,, *barhampurensis*,* Preston | ? | .. | X | |
| ,, (*Felania*) *annandalei*,* Preston | 1·009—1·0265 | X | X | |
| ,, ,, *ovalis*,* Preston | 1·0265 | .. | X | |
| ,, ,, *chilkaënsis*,* Preston | 1·0265 | .. | X | |
| **PSAMMOBIIDAE.** | | | | |
| *Psammobia mahosaënsis*,* Preston | 1·000—1·0265 | X | X | |
| **SOLENIDAE.** | | | | |
| *Solen* ? *fonesi*, Dunker | 1·000—1·0265 | X | X | Cochin backwaters; Philippines; Cebu. |
| ,, *annandalei*,* Preston | ? | X | X | |
| ,, *kempi*,* Preston | ?—1·0265 | X | X | |
| **MACTRIDAE.** | | | | |
| *Standella annandalei*,* Preston | 1·008—? 1·0265 | X | X | |
| **MYIDAE.** | | | | |
| *Corbula chilkaënsis*,* Preston | *ca.* 1·010 | X | .. | |
| **PHOLADIDAE.** | | | | |
| *Martesia striata* (Linn.) | ? | ? | ? | Cosmopolitan. |
| **TEREDINIDAE.** | | | | |
| *Xylotrya stutchburyi*, Sowerby | 1·000—1·0265 | .. | X | Malay Archipelago. |
| **TELLINIDAE.** | | | | |
| *Tellina chilkaënsis*,* Preston | ? | .. | X | |
| ,, *confusa*,* Preston | ? | ? | ? | |
| **SCROBICULARIIDAE.** | | | | |
| *Theora opalina* (Hinds) | 1·000—1·0265 | X | X | Indian coasts to Philippines. |
| *Cumingia hinduorum*,* Preston | 1·000—1·0265 | X | X | |
| **CUSPIDARIIDAE.** | | | | |
| *Cuspidaria annandalei*, Preston | 1·000—1·0265 | X | X | Madras and Cochin backwaters; Gangetic delta. |
| **LYONSIIDAE.** | | | | |
| *Lyonsia samal-insulae*,* Preston | 1·000—1·0265 | X | X | |
| **ANATINIDAE.** | | | | |
| *Anatina granulosa*,* Preston | ? | ? | ? | |
| ,, *barkudaensis*,* Preston | 1·000 ?—1·0265 | X | X | |
| ,, *barkulensis*,* Preston | 1·000—1·010 | X | X | |

Several of the genera represented in the lake fauna, though essentially marine, include species characteristic of an estuarine environment. As examples of these we may mention *Nassa* and *Thais* among the Gastropods and, among the Lamellibranchs, *Modiola*, *Arca*, *Meretrix*, *Corbula*, *Martesia*, *Clementia* and *Theora*. The species of Pholadidae, Teredinidae, Arcidae and Solenidae are, however, quite distinct from those that have established themselves in the Ganges and other Indian rivers.

## GEOGRAPHICAL DISTRIBUTION.

With the exception of *Chilkaïa*, all the genera that comprise the molluscan fauna of the Chilka Lake have a very wide geographical distribution, whereas, as we have already pointed out, more than one third of the species at present appear to be endemic. Apart from apparently endemic species the Mollusca of the lake fall, with one or two possible exceptions, into two categories, (*a*) those that are found only in other localities of a similar nature on the Indian coasts and (*b*) those of wide distribution. The number of the former is comparatively small, but with further exploration it is probable that many of the apparently endemic species will be transferred to this category. The following forms are known to occur both in the Chilka Lake and in estuarine tracts in other parts of India, but have not been found elsewhere:—

GASTROPODA.

*Tornatina estriata.*
*Vanesia rambhaënsis.*
*Nassa denegabilis.*
,, *orissaënsis.*
*Hydrobia* (*Belgrandia*) *myliacea.*
*Stenothyra blanfordiana.*

LAMELLIBRANCHIATA.

*Clementia annandalei.*
*Cuspidaria annandalei.*

A considerable amount of work has been done by Nevill, W. T. Blanford, Benson, Stoliczka, von Martens and Preston on the aquatic shells of estuarine tracts in India and the Malay Archipelago; but (except in the case of the last author) most of their papers refer exclusively to species found at the edges of creeks and backwaters or in small pools of brackish water. This is probably one of the reasons why our collection from the Chilka Lake differs very greatly from those previously described from similar localities, a very large proportion of the species having been obtained by dredging. A real difference, namely the scarcity in the lake of certain thick-shelled amphibious forms, such as *Neritina*, *Littorina* and *Pythia*, is probably explained by the absence of mangroves and semi-aquatic palms to the stems of which such species frequently attach themselves. It is less easy to explain the entire absence of the almost terrestrial mud-loving genus *Onchidium* and the absence or scarcity of the aquatic genera *Iravadia* and *Corbula*, which are remarkably abundant in the Gangetic delta. The occurrence of *Cyclostrema* is, however, interesting, as we believe that Nevill's "*Valvata? microscopica*," a species very abundant at Port Canning, also belongs to this genus.

Some years ago a considerable collection of shells was made in shallow water off

the coast of Orissa by the S.S. 'Golden Crown,' but not a single species is common to this collection and to our own, while most of the genera are different, a fact due perhaps in the main to the nature of the bottom on which the two collections were obtained.[1] So far as we have been able to discover, the molluscan fauna of the Chilka Lake, at any rate in the matter of Lamellibranch genera, is nearer to that collected, in shallow water and mainly on muddy ground, by the Danish Expedition to Siam[2] than to any other on which a comprehensive report has yet appeared. Eighteen Lamellibranch subgenera and genera are common to the two collections, representing two thirds of those found in the lake.

## BIOLOGICAL DISTRIBUTION.

Less than 50 % of the living Mollusca of the lake are found in the main area, and even this percentage is somewhat reduced if we omit the island of Nalbano. With two exceptions, *viz. Corbula chilkaënsis* and *Chrysallida ecclesia*, each represented by a single specimen, all species found in the main area were also found in the outer channel, but the great majority did not occur on the clean sandy bottom of the seaward part of the latter. By far the richest tract in the whole lake-system is the southern end of the outer channel between Barhampur I. and Satpara Point (see map, Pl. II of this volume).

The following species have a great numerical preponderance throughout the main area, except where the water is excessively shallow:—

| GASTROPODA. | LAMELLIBRANCHIATA. |
|---|---|
| *Tornatina estriata.* | *Modiola undulata.* |
| *Nassa denegabilis.* | *Clementia annandalei.* |
| ,, *orissaënsis.* | *Solen ? fonesi.* |
| *Stenothyra* spp. | *Theora opalina.* |

With the exception of the species of *Nassa* and *Stenothyra*, all of these are much less abundant in the outer channel. In the channel the following species may perhaps be regarded as predominant:—

| GASTROPODA. | LAMELLIBRANCHIATA. |
|---|---|
| *Nassa labecula.* | *Meretrix casta.* |
| *Potamides fluviatilis.* | ,, *ovum* |
| *Litiopa copiosa.* | *Tapes pinguis.* |
| *Pyrgulina humilis.* | ,, *ceylonensis.* |

In this part of the lake it is much more difficult to select predominant species than in the other, for a large number of forms are represented by considerable numbers of individuals, whereas in the main area most of the species are either very rare or else extremely abundant.

[1] Jenkins, *Rec. Ind. Mus.*, VII, p. 51 (1912).

[2] Lynge, *Danske Vid. Selsk. Skrift.* (7) Nat. og. Math., V, pp. 100-299 (1909).

The chief reasons for the difference between the molluscan fauna of the two regions appear to be two,—differences in salinity and differences in the nature of the bottom, the latter factor being perhaps more important in the case of Mollusca than in that of some other groups.

Apart from these distinctions between the two regions, there are other divisions in the fauna dependent on other causes: certain species are abundant in restricted localities. *Potamides fluviatilis*, for example, is extremely common in very shallow water on all ground in which the mud is mixed with sand, being apparently able to endure a high temperature fatal to other species, but avoiding soft mud. The same kind of bottom is also the only one that attracts the species of *Lyonsia* and *Anatina*, but they are burrowing forms not so easily observed.

The number of rock-haunting molluscs is very small; indeed, only two species, *Modiola striatula* and *Thais carinifera*, can be assigned definitely to this category. Both of these are abundant, but their distribution in the main area of the lake is not the same; for while the mussel is found in large numbers on all rocks that are submerged for more than a few months in the year, the *Thais* is restricted to those south of Kalidai, being found only in water the specific gravity of which never falls below 1·003. This species is also found on the oyster-beds at Manikpatna in salt water; its distribution in the lake evidently depends not only on salinity, but to some extent on the presence of mussels or other thin-shelled molluscs on which it preys.

The oysters that occur in the Chilka Lake belong to at least three species, but only one, *Ostrea virginiana*, is at all common Oyster-beds are found only in the neighbourhood of Manikpatna. At this place several small sandy islands are so arranged as to form a bay sheltered from currents that would prevent the deposition of spat, while the fact that the bay is situated at no great distance from the sea-mouth is of importance, both because the greater part of the silt from the flood-waters has already settled before the floods reach it, and because it obtains immediate benefit from the irruption of sea-water that occurs when they subside.

In March we occasionally found single living individuals of *O. virginiana* attached to rocks in the neighbourhood of Patsahanipur; in some of them the shell was as much as 3 cms. in diameter. Later in the year apparently fresh but empty shells of a similar size were noted in the same place. We believe that this indicates that a certain number of larvae make their way into the main area of the lake, on the rocks of which, as we will show later, the oyster was once abundant. They are able to settle down and to grow considerably, but are ultimately killed by the summer floods. If this is so, the rate of growth must be very rapid, but the Uriya fishermen state that when the oyster-beds at Manikpatna are overwhelmed with sand, as sometimes occurs in the flood-season, they are entirely renovated in a single year. The bulk of the beds are formed of living and dead shells of *O. virginiana*, to which a few individuals of *O. cucullata* and *O. lentiginosa*, with large numbers of *Modiola striatula*, attach themselves, while *Petricola esculpturata* esconces itself in cavities between them. So far as we were able to observe, the last-named species was entirely free from the necessity of constructing borings of its own.

Two species of molluscs were found only in or on wooden posts set up to mark the fairway in the outer channel near Satpara. These were the ship-worm *Xylotrya stutchburyi* and an oyster (*Ostrea* sp.) of which a few large individuals were obtained but have unfortunately been mislaid.

The periodic growth and decay of the thickets of weed to which we have alluded above is an important factor in the distribution of the Lamellibranchs *Modiola undulata* and *Cuspidaria annandalei*. The former is known to breed in the lake at all seasons and is found on filamentous algae growing on stones, but by far the greater number of the individuals observed were attached to thicket-forming weeds. Almost as soon as these weeds begin to grow up they are covered with young mussels, which increase in size rapidly and evidently become mature before the plant dies down. The same fact was noted to a less extent in the case of *Cuspidaria*. It is of importance to the fisheries of the lake, in that several of the more abundant edible species of fish haunt the thickets and devour weeds and molluscs together.

Several Gastropods also frequent weeds, notably the species of *Stenothyra*, *Litiopa*, *Pyrgulina* and *Chrysallida*; but these are also found in large numbers among algae of less luxuriant growth and do not form so characteristic a feature of the thickets. *Nassa denegabilis* and *N. orissaënsis* apparently crawl indifferently among weeds or on bare mud.

The great majority of the Mollusca found in the lake inhabit it throughout the year; but it was observed in the case of several of the commonest species, *e.g. Tornatina estriata*, *Clementia annandalei* and *Theora opalina*, that a very large number of individuals died in the latter part of the freshwater season—a fact of particular interest in view of the marine origin of the fauna. It would seem that in the Mollusca, as also in other groups, certain individuals are more tolerant of changes in salinity than the majority of their kind, and that the effect of fresh water on the organism, in at least some forms, is cumulative rather than suddenly fatal. The small Opisthobranch *Bulla crocata* affords interesting evidence. It was originally described from sheltered positions in the sea and is not uncommon, at any rate in certain seasons, in the Madras backwaters. The only living specimen we found in the Chilka Lake was taken in fresh water (in September, 1914), but was scarcely half the normal size, though the shell was fully formed. Full-sized specimens that had not long been dead were obtained, in the same month and in the same part of the lake, among decaying weed cast up on the shore. It would seem probable that the species makes its way into the lake either in the larval stage or before its growth is completed and that the majority of the individuals which have attained their full size in the salt-water season succumb to the freshwater floods. An unusually hardy individual, however, occasionally survives throughout the year, but is dwarfed by the unfavourable character of its environment.

A number of other species are represented in our collection only by fresh but empty shells, found in the outer channel in September in circumstances that did not suggest their having been introduced artificially. As examples we may mention *Cyclostrema* (*Tubiola*) *innocens* and *Epitonium hamatulae*. In several cases, notably

that of the species of *Diplodonta*, living molluscs were found in the salt-water season, but only dead shells in that of fresh water.

Several species, notably *Cardium* (*Fulvia*) *rugatum* and *Mytilus smaragdinus*, evidently make their way at a young stage from the sea into the outer channel, but are unable to survive until maturity; they must be classed merely as occasional visitors of no faunistic interest in so far as the lake-fauna is concerned.

Many species belonging to freshwater genera, such as *Ampullaria*, *Vivipara* and *Planorbis*, are very abundant in rice-fields and even in small pools of rain-water near the margin of the lake; but we did not observe a single instance in which molluscs of this kind made their way into the lake itself, even when its waters were quite fresh. This fact is particularly remarkable in the case of *Melania tuberculata*, which is common in pools of both fresh and brackish water near Rambha and occurs in great abundance in water of considerable salinity in the Gangetic delta.

## SUBFOSSIL SHELLS.

The late Dr. W. T. Blanford drew attention in 1859 to the fact that there were large beds of subfossil estuarine molluscs in the neighbourhood of Rambha. The species best represented in these beds, as he noted, are *Arca granosa*, Linn., and *Meretrix casta*, Chemn. *Thais carinifera* is also fairly common. Worn shells of *A. granosa* and *M. casta* are also very abundant on the shore of Barkuda I.; the latter species, though common in the outer channel, is now extinct in the main area, in which *A. granosa* is very scarce.

Another species found in the main area in a subfossil condition is the common "window-pane oyster", *Placuna placenta* (Linn.), beds of which, of very limited extent, were proved to have existed near Samal I. and at other points. This mollusc no longer lives in any part of the lake, though it is collected for commercial purposes in lake Tamblegam (Tampalakaman), a smaller lagoon on the coast of Ceylon, the water of which probably also undergoes great seasonal changes in salinity.[1] A detailed comparison of the conditions in the two lagoons in this and in other respects would be of great interest.

We have already alluded to the young oysters occasionally found on rocks in the main area; at the southern end of the lake single valves, evidently long dead, were frequently observed, while at the edge of the water near Ganta Sila we found the remains of an oyster-bed. The species (*O. virginiana*) was the same as that now found living at Manikpatna, but the beds differed in that shells of the genus *Chama* were abundant on the oysters. On the rocks at the same place skeletons of solitary corals belonging to the family Turbinolidae were occasionally seen (pl. xiv, fig. 3). *Chama* was not found on the Manikpatna beds, but is usually associated with oysters taken in shallow water off the coast of Orissa, while the Turbinolidae are characteristically marine and are particularly abundant off the same coast.

[1] Hornell, *Ceylon Marine Biol. Reps.*, I, p. 41 (1906). According to Mr. Hornell the specific gravity of the water of this lake in the dry season varies from 1·015 to 1·019 at temperatures from 86° to 90° F. No observations have been made as to the conditions in the wet season.

It is probable that these subfossil species do not all belong to the same period in the history of the lake, though all are undoubtedly recent. The oyster-bed at Ganta Sila (in the presence of *Chama*) and the corals on the rocks evidently date from a time when this part of the lake was in direct communication with the Bay of Bengal; Ganta Sila and the hills near it then forming an island or group of islands in the sea. On the other hand the beds of *Arca* and *Meretrix* at the head of Rambha Bay mark the position of a channel or creek of later date, probably containing brackish water and representing all that then remained of the sea-passage that once separated the islands from the mainland. The beds may possibly have been laid down when the lake-area, though closed to the south, still remained an open bay with a purely marine fauna; but doubt is cast on this view by the existence of precisely similar shells in a subfossil condition on the shores of Barkuda I.

The only case in which we have been able to observe a difference between subfossil and living shells is that of *Arca granosa*. The subfossil shells of this species exhibit considerable variety of form (some being much more nearly bilaterally symmetrical than others) and are never of more than moderate size, the largest having a breadth of 50 mm. The few living examples we obtained were much smaller, the greatest breadth being 26 mm. They differ somewhat in form from any of our subfossil examples in being relatively broader and less inflated (*cf.* figs. 3-6, pl. xvi). Von Neumayer has described a variety of this species under the name "*Arca granulosa* var. *minuta*",[1] from a point some distance up the Yang-tse-Kiang river. It was taken with shells of freshwater genera such as *Vivipara*, *Bythinia*, *Melania* and *Corbula*; the specimens were found in silt and were apparently in a subfossil condition.[2] Our own examples from the main area of the Chilka Lake bear a general resemblance to his figures, but are a little larger and more symmetrical. The variation in *A. granosa* may thus be compared with that recorded by Bateson in the case of *Cardium edule*[3]; but, except in the points noted, we are unable to correlate it definitely with changes in environment.

## SPECIAL CHARACTERISTICS OF THE MOLLUSCAN FAUNA.

In the general facies of the molluscs of the lake the most noteworthy characters are small size, lack of bright pigment and thinness of shell.

Among the Gastropods the only shells that commonly attain a length of more than 1 cm. are *Nassa labecula*, *N. marrattii*, *Potamides fluviatilis*, *P. fuscum* and *Thais carinifera*; of these only three occur in the main area, the majority of the shells in this region being less than 5 mm. long. In the case of Lamellibranchs a few fairly

[1] *Wiss. Ergebn. Reise Béla Széchenyi in Ostasien*, 1877-80, II, p. 641, pl. i, fig. 4 (1898).

[2] In the markets of Shanghai, Soochow and the smaller towns in the same district a dwarfed form of *A. granosa* is commonly on sale in a living condition. It is said to come from near Ningpo. The shells are covered with fine mud and sometimes bear dead or living *Balani*. With them I found mixed, in some instances, shells of Cerithiidae and Nassidae of distinctly brackish-water facies. The largest *Arca* shells of this form are about 30 mm. broad and about 20 mm. high.—*N. A.*; *Soochow*: 7-xii-15.

[3] *Phil. Trans. Roy. Soc.*, CLXXX (B), p. 297 (1889).

large forms, such as the species of *Ostrea*, *Meretrix*, *Tapes* and *Standella*, occur in the outer channel and in some cases make their way in small numbers into the northern part of the main area. The only species of even moderate dimensions that occur in the southern part of this area are, however, the almost extinct *Arca granosa* and the species of *Modiola* and *Anatina*.

It is only in a few cases that it is possible to compare individuals from the lake with those from more favourable localities, but in those instances in which this can be done, as in *Modiola striatula*, *Arca granosa* and *Nassa orissaënsis*, a distinct dwarfing can be detected. In *Arca granosa* all individuals are affected in the same way, and the dwarfing may be due entirely to changes in salinity, while in *Modiola striatula* different individuals are influenced in different ways and other causes, such as confined position and periodic desiccation, seem sufficient to account for the results observed (see pp. 362, 363). We have provisionally accepted Mr. Preston's identification of the small *Solen* common in the lake on a muddy bottom as *S. fonesi*, Dunker. If this be correct, the race is evidently dwarfed, for shells of sexually mature individuals are always under 30 mm. in length, whereas specimens of nearly 6 cms. have been found in the sea. Shells from the lake are relatively much broader than any of those noticed by von Martens, who remarks that larger shells are proportionately narrower than smaller ones. *Nassa orissaënsis* is represented in backwaters near Madras and also in canals of brackish water in the Gangetic delta by a form (var. *ennurensis*, Preston) with a considerably larger and more deeply sculptured shell; but it is difficult to see in what respects the conditions in these localities are more favourable.

None of the shells from the lake, with the exception of those of *Modiola*, are brilliantly coloured and dense pigmentation is the exception rather than the rule. Its absence is particularly noteworthy in the Lamellibranchs, among which colourless forms such as the species of *Kellya*, *Clementia*, *Petricola*, *Diplodonta*, *Psammobia*, *Standella*, *Theora*, *Cumingia*, *Cuspidaria*, *Lyonsia* and *Anatina*, greatly predominate. Among the Gastropods the commonest colours are dull brown and dull green, as in *Vanesia*, *Litiopa*, *Nassa*, *Stenothyra* and *Potamides*. The number of colourless species is comparatively small, comprising those of *Tornatina*, *Pyrgulina* and *Chrysallida*. The only species in which well-defined and conspicuous markings occur on the shell[1] are *Neritina souverbiana*, *Tinostoma variegatum* and *Umbonium vestiarium*; even in these the markings are almost microscopic. The only mollusc in which the living tissues are brilliantly coloured is *Scintilla chilkaënsis*, in which the mantle is yellow and orange.

In the absence of bright colours the fauna resembles that of fresh water and differs from that of the coast immediately outside the lake, where brilliantly painted species such as *Siliqua radiata*, *Eburna* and *Sunetta scripta* are abundant. The complete lack of colour in many of the Lamellibranchs is doubtless correlated with their burrowing habits.

It is among the Lamellibranchs also that thinness of shell is most noteworthy.

[1] Young shells of *Meretrix ovum* are marked with radiating lines of conspicuous brown spots, but these practically disappear in adults.

Such forms as those of *Kellya*, *Scintilla*, *Diplodonta*, *Solen*, *Standella*, *Theora*, *Cumingia*, *Cuspidaria*, *Lyonsia* and *Anatina* are remarkable in this respect, while the shell of the *Clementia* is so fragile that we had great difficulty in preserving perfect specimens. Thick-shelled species such as those of *Arca*, *Meretrix* and *Tapes* are few and have almost completely disappeared from the main area. Except possibly in the case of *Modiola*, we have, however no evidence that individuals from the lake have thinner shells than those of the same species living elsewhere. Among the Gastropods, *Thais* and *Potamides* are exceptional in the thickness of their shell; there is no form comparable in the opposite direction to *Clementia*.

The thinness of shell in the lake species can hardly be due to lack of dissolved calcareous matter, for considerable quantities of *kankar*' (nodular concretions of carbonate of lime) are dug from the bed of the lake when the level of the water is low. In the case of many of the Lamellibranchs (*e.g. Clementia* and *Theora*) it is associated with life in peculiarly soft and adhesive mud, through which the animals progress with considerable rapidity. It is noteworthy, moreover, that all the thick-shelled burrowing Mollusca found in the lake inhabit sand or sandy mud and that there is no evidence that the shells of such forms are thinner than those found in pure salt water.

These facts are of some interest because instances are well known in the Baltic and elsewhere, in which the shells of marine species related to the Chilka forms become greatly attenuated in brackish water. Gibbons[1] has, however, pointed out that though this is the general rule, the shells of true brackish water species may tend to become thicker in correlation with decrease of salinity.

We have already alluded to the fact that, especially in the main area, a comparatively small number of species predominate greatly in respect to number of individuals. It is probable that if a census of the Mollusca of the main area could be taken, the great majority would fall into some eight or nine species and some half dozen genera. This feature is also characteristic of other groups of animals found in the lake and, indeed, generally of animals living in abnormal conditions.

## LIST OF SPECIES.

### Class GASTROPODA.

### Order *OPISTHOBRANCHIATA*.

### Family Tornatinidae.

*Tornatina estriata*, Preston, 1914, p. 303, figs. 7, 7*a*; 1915, p. 297; 1916, p. 27 (as *Retusa*); syn. *T soror*, Preston, 1914, p. 303, figs. 8, 8*a*.

This is one of the commonest Gastropods on a muddy bottom in both sections of the lake-system. Shells from the outer channel tend to be a little larger than those from the main area and to have a less ovately cylindrical form. Mr. Preston separated the latter under the name *T soror* in 1914, but has now found inter-

[1] Gibbons, *Quart. Journ. Conch.*, I, p. 339 (1878.)

mediate specimens in our collection and regards this name as a synonym. The species is found in a living condition at all seasons of the year, but at the end of the freshwater season dead shells are extremely abundant. *T estriata* has also been found in backwaters on the west coast of India.

### Family **Bullidae.**

*Bulla (Haminea) crocata*, Pease, *Proc. Zool. Soc. London*, 1860, p. 19.

This species, which is common among weeds in the backwaters near Madras, does not appear to have become thoroughly acclimatized in the Chilka Lake. Dead shells, some of which contained remains of the soft parts, were found among drift weed on the shore at Satpara in September, and a single small but apparently full-grown living individual was taken in the same month in Seruanaddi. A dead and much eroded shell was found on the shore of Barhampur I. in March.

Our largest shell is about 14 mm. long, but the one from Seruanaddi is less than 5 mm. long. We have discussed the significance of these facts on p. 337.

The species was described from the Sandwich Is., where it was found "usually on sand-flats, but occasionally on seaweed." It was noted by Pease that shells were much more abundant on the leeward than on the windward islands.

## Order *PROSOBRANCHIATA.*

### Family **Nassidae.**

This family is represented by five species of the genus *Nassa*, all of which are small, none exceeding 16 mm. in length. Only two of the species, *N. orissaënsis* and *N. denegabilis*, are widely distributed in the main area, but *N. labecula* is not uncommon on sandy ground at Nalbano. The other two were taken on a few occasions in the outer channel. The shells were frequently inhabited by the hermit-crabs *Diogenes avarus* and *Coenobita cavipes.*

*Nassa sistroidea*, G. and H. Nevill, *Journ. Asiat. Soc. Bengal* (2), XLIII, p. 24 pl. i, fig. 6 (1874).

A few living specimens of this species were taken in the outer channel in March and September. *N. sistroidea*, which was described from the Andamans, is probably only an occasional visitor from the sea, though it is apparently able to survive the freshwater season.

*Nassa labecula*, A. Ads., *Proc. Zool. Soc. London*, 1851, p. 98.

This species is common in the outer channel at all times of the year and was found in abundance with *Potamides fluviatilis* on the shore of Nalbano in March. It is apparently an arenicolous form.

*Nassa marrattii*, Smith, *Journ. Linn. Soc., Zool.*, XII, p. 543, pl. xxx, fig. 4 (1876).

A single shell was dredged, in a fresh condition, in the outer channel off Satpara Point in September. The species, which has been recorded from the western Pacific,

the Malay Archipelago, the Andamans and the Maldives, is perhaps a casual visitor but the shell may have been brought from the sea by a hermit-crab.

*Nassa denegabilis*, Preston, 1914, p. 297, fig. 9; 1915, pp. 290, 480; 1916, p. 28.

This species occurs all over the lake-system on a bottom of mud or muddy sand. The type, which was named, but not described by the late Mr. G. Nevill, is in the British Museum. *N. denegabilis* is found at all times of the year in an active condition. The species is evidently common in estuaries and backwaters on the Indian coasts.

*Nassa orissaënsis*, Preston, 1914, p. 299, figs. 10, 10*a*; 1915, p. 290.

This is perhaps the commonest and most widely distributed Gastropod in the main area and in the inner part of the outer channel, occurring on a muddy bottom usually among weeds. When placed in a dish of water, specimens often float shell downwards adhering to the surface film by means of the expanded foot. The foot does not conform to the description of the genus given by Fischer[1], for the two posterior lobes, instead of being produced and pointed, are very short, broadly rounded and separated merely by a shallow notch (see fig. 1). This peculiarity may be correlated with the softness of the mud on which the animal frequently crawls. We are under the impression that the foot of *N. denegabilis* is similar, but have no definite note on the subject.

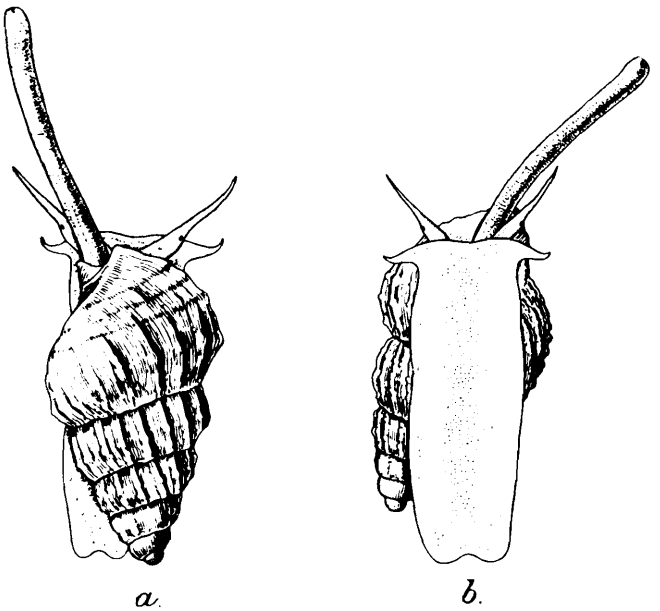


FIG. 1.—*Nassa orissaënsis*, Preston.
Living specimens: *a*, from above: *b*, from below.
(*From sketches made by Mr. G. M. Henry.*)

*N. orissaënsis* is represented in the Madras backwaters and in canals of brackish water at Calcutta by a large and well-developed variety (var. *ennurensis*, Preston, *Rec. Ind. Mus.*, 1915, p. 479; 1916, p. 28, fig. 2).

## Family **Muricidae.**

*Thais carinifera* (Lam.), Reeve, *Conch. Icon.*, III, *Purpura*, pl. vi, fig. 26 (1845).

In the main area of the lake this species is confined to the rocks at the southern end and to the islands south of Kalidai. It was also found in the outer channel in the salt-water season, but was apparently unable to live in pure fresh water and is not found on the rocks near Patsahanipur. On the oyster-beds at Manikpatna it is fairly abundant in March, but in other places is usually found crawling on rocks. A few

[1] *Manual de Conchyliologie*, p. 633, fig. 389, Paris, 1887.

living individuals were dredged in the middle of the southern part of the lake, perhaps making their way from one set of rocks to another.

*T carinifera* is the only Gastropod obtained in the main area whose shell is of any considerable size; the range of the hermit-crabs of the genus *Clibanarius* is therefore co-terminous so far as the main area is concerned with that of *Thais*. The boring sponge *Cliona vastifica* sometimes attacks living shells and the Polyzoa *Alcyonidium mytili* and *Membranipora hippopus* are sometimes found on its surface.

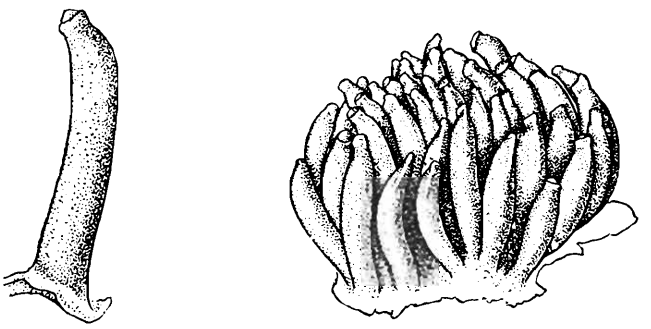

FIG. 2.—*Thais carinifera* (Lam.).

A cluster of egg-capsules ( × $2\frac{3}{4}$), with a single capsule more highly magnified.

Eggs, of which we figure a cluster, were observed on the rocks at Ganta Sila in February and on oyster-shells at Manikpatna in March. They were of a dirty yellowish colour when living, but their contents became deep purple when they were placed in alcohol.

## Family **Cerithiidae.**

*Potamides* (*Tympanotonos*) *fluviatilis*, Pot. and Mich., *Gal. de Moll.*, p. 363, pl. xxxi, figs. 19, 20; 1838 (as *Cerithium*).

*P. fluviatilis* occurs in great abundance along the outer shore of the main area, at Nalbano and in the outer channel. A few specimens were also seen in a small ditch opening into Rambha Bay; but the species is very scarce along the inner shore of the main area. It seems to prefer a bottom of sand or sandy mud and to be able to endure temperatures that are fatal to most other species; it occurred in enormous numbers near the mouth of the outer channel in the freshwater season. Its shell is very commonly occupied by the hermit-crab *Diogenes avarus* and living individuals were occasionally found to which young oysters (*Ostrea* sp.) or small examples of a barnacle (*Balanus amphitrite*) were attached. The hydroid *Clavactinia gallensis* was found on several shells occupied by hermit-crabs, while others, still occupied by their proper owners, were covered by the Polyzoon *Alcyonidium mytili*.

The species is widely distributed in the Indian Ocean and the western parts of the Pacific, occurring usually in brackish water; but according to Mr. Townsend is a distinctly marine form in the Persian Gulf.[1] It was described from the Malabar Coast.

*Potamides* (*Telescopium*) *fuscum*, Schum., Reeve, *Conch. Icon.*, XV, fig. 1 (1866).

Living specimens were common on some of the islands in the outer channel in March. They appeared to be comatose and many of them were half buried in

[1] See Melvill and Standen, *Proc. Zool. Soc. London*, 1901, p. 375.

caking mud. No specimens were seen in the freshwater season. Mr. Townsend draws attention to the tenacity of life exhibited by this mollusc.[1]

The species is abundant in mangrove swamps on the coasts of India and the Malay Archipelago: in the Gangetic delta the shell is one of those most commonly used for making lime. Dead shells in the outer channel of the Chilka Lake were sometimes occupied by the hermit-crab *Clibanarius padavensis*.

The distribution is similar to that of the former species.

## Family **Turritellidae**.

*Vanesia rambhaënsis*, Preston, 1914, p. 297, figs. 5, 5*a* (as *Terebra*); 1915, p. 289; 1916, p. 32.

*V. rambhaënsis* is widely distributed on the bed of the main area of the lake and was also taken at the inner end of the outer channel. Although it was originally described from a single specimen the species appears to be gregarious. It was found in large numbers among dead vegetation in Madarchua Bay at the south end of the lake in July. We obtained no specimens in the outer channel in the salt-water season. The species is also known from the Cochin backwaters.

## Family **Fossaridae**.

*Chilkaïa imitatrix*,* Preston, 1915, p. 291, figs. 1, 1*a*.

Four specimens, including the type of the genus and species, were taken in the inner part of the outer channel in September. Preston remarks on the superficial resemblance of the shell to that of certain forms of *Paramelania* characteristic of the fauna of Lake Tanganyika; but there can of course be no real affinity. The species is evidently very scarce.

## Family **Litiopidae**.

*Litiopa* (*Alaba*) *kempi*,* Preston, 1914, p. 300, figs. 3, 3*a*; 1915, p. 292.

This species occurs sparingly all over the main area of the lake and was found in the outer channel in the freshwater season. It lives among weeds on either a sandy or a muddy bottom.

*Litiopa* (*Alaba*) *copiosa*,* Preston, 1915, p. 292, figs. 2, 2*a*.

*L. copiosa* was found in enormous numbers at both seasons of the year in the channels between Barnikuda and Satpara, between the latter place and Mahosa and in Seruanaddi. It also occurred more sparingly in the neighbourhood of Nalbano.

## Family **Hydrobiidae**.

This family is represented by one species of *Hydrobia* and six forms of *Stenothyra*, all of which Mr. Preston regards as distinct species. Eleven Indian species of *Stenothyra* are now recognized by him[2], most of which were described from brackish water. It seems not improbable to us that, when large series from different localities

[1] See Melvill and Standen, *Proc. Zool. Soc. London*, 1901, p. 375.

[2] *Faun. Brit. Ind., Freshwater Mollusca*, p. 79 (1915) and *Rec. Ind. Mus.*, XII, p. 31 (1916).

are compared, the number will suffer reduction. It is noteworthy that we found no specimens of *Hydrobia myliacea* or *Stenothyra blanfordiana*, both of which were recorded many years ago from the Chilka Lake and are abundant in other localities. Unfortunately we have no information as to the part of the lake in which they were found.

*Hydrobia* and *Stenothyra* are the only genera of Molluscs represented in the fauna of the lake that can be said to have limnic affinities.

*Hydrobia* (*Belgrandia*) *myliacea*, Nevill, *Journ. As. Soc. Bengal* (2), XLIX, p. 161 and L, p. 158, pl. vii, fig. 7 (1880-1881).

Nevill records from the Chilka Lake specimens of a form of this species to which he gave, without description, the name "subvar. *subangulata*." Both this form and the typical one were found at Port Canning in the Gangetic delta.

*Stenothyra blanfordiana*, Nevill, *Journ. As. Soc. Bengal* (2), XLIX, p. 160 (1880) and L, p. 156, pl. vii, fig. 10 (1881).

This species, which was not recognized by Mr. Preston among the specimens we sent him from the Chilka Lake, was described from it by Nevill in 1880. The same author also recorded the species from Port Canning in the Gangetic delta and from Madras. He noted that specimens from the former locality agreed more closely with individuals from the lake than did those from Madras. In parts of the Gangetic delta it is very abundant among weeds.

*Stenothyra minima* (Sowerby), Preston, *Faun. Brit. Ind., Freshw. Moll.*, p. 81 (1915).

We found this species common among weeds in both parts of the lake-system on both a muddy and a sandy bottom and at all times of the year. It was originally described from western India.

*Stenothyra chilkaënsis*,* Preston, 1914, p. 300, fig. 1; 1915, p. 293.

*S. chilkaënsis* is even more common in the lake than the preceding species, together with which it occurs.

*Stenothyra orissaënsis*,* Preston, 1914, p. 300, fig. 2; 1915, p. 293.

This form occurs with the two preceding; it is perhaps no more than a variety of *S. chilkaënsis*.

*Stenothyra trigona*,* Preston, 1915, p. 293, fig. 3.

Occurred with the preceding species, but was not found in the outer channel in the salt-water season.

*Stenothyra obesula*,* Preston, 1915, p. 293, fig. 4.

*S. obesula* is represented in our collection by a single specimen only; it was obtained in the outer channel in the freshwater season on a bottom of muddy sand.

## Family **Scalariidae.**

*Epitonium hamatulae*,* Preston, 1915, p. 294, fig. 5.

A single dead shell of this species (the type) was found in the outer channel off Barhampur I. in the freshwater season. Its small size renders its introduction by a

hermit-crab improbable and we may suppose that the species is a marine one that occasionally enters the channel in the salt-water season.

### Family **Pyramidellidae.**

*Pyrgulina humilis* (Preston), *Journ. Malacol.*, XII, p. 6, pl. ii, fig. 27; 1905 [as *Pyramidella* (*Mormula*)]; 1915, p. 294 [as *Chrysallida* (*Mormula*)]; 1916, p. 32.

*P. humilis*, with its variety *chilkaënsis*, Preston (*loc. cit.* 1915) was found in large numbers in the outer channel at all times of the year. A few specimens were also taken S. of Kalidai and off Nalbano. The variety appears to be more common, at any rate in July, than the typical form.

*Chrysallida* (*Mormula*) *ecclesia*,* Preston, 1915, p 295, figs. 7, 7*a*.

A single living specimen was taken in Madarchua Bay at the south end of the lake in July.

*Chrysallida* (*Mormula*) *nadiensis*,* Preston, 1915, p. 296, figs. 8, 8*a*.

This species was only found in the outer channel in the freshwater season; it is, however, very scarce and probably occurs at all times of the year in this part of the lake.

*Odostomia chilkaënsis*,* Preston, 1914, p. 301, fig. 4; 1915, p. 296.

Only two specimens were obtained, both in the outer channel, one at Manikpatna in March and one near Mahosa in September; the latter, however, was a dead shell.

### Family **Neritidae.**

*Neritina* (*Theodoxus*) *souverbiana*, Montrouzier, Montr. and Souverb., *Journ. Conch.* (Paris), XI, pp. 75, 175, pl. v, fig. 5 (1863).

Specimens were found in the outer channel both in March and in September; they were common near Mahosa in the freshwater season, living among weeds. The species, which was described from the China Sea and New Caledonia, is apparently a marine one that in the sea lives among algae.

### Family **Cyclostrematidae.**

*Cyclostrema* (*Tubiola*) *innocens*,* Preston, 1915, p. 296, figs. 9, 9*a*, 9*b*.

A single dead shell (the type of the species) was obtained in Seruanaddi in the freshwater season.

[The shell described by G. Nevill[1] as *Valvata*? *microscopica*, of which we have examined a long series of co-types, clearly belongs to the same genus as *C. innocens*. It appears to differ from that species only in its smaller size, reddish colour and in the sculpture on its surface; but the type of Preston's species is bleached and perhaps somewhat eroded. We figure (fig. 3) one of the co-types of Nevill's species.]

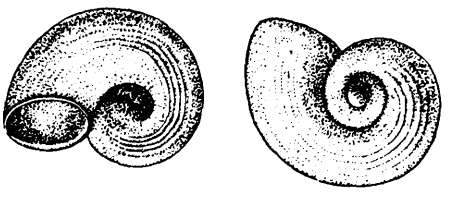

FIG. 3.—*Cyclostrema microscopica* (Nevill).

[1] *Cat. Moll. Ind. Mus.*, fasc. e, p. 21 (1877).

*Tinostoma variegatum*,* Preston, 1914, p. 302, figs. 6, 6*a*, 6*b*.

A few specimens (including the type) were obtained at Manikpatna in the outer channel in March.

### Family **Trochidae.**

*Umbonium vestiarum* (Linn.), Preston, 1915, p. 297.

Several specimens were found in the outer channel in the salt-water season on sandy ground near the mouth of the lake.

*Solariella satparaënsis*,* Preston, 1914, p. 302, figs. 11, 11*a*, 11*b*; 1915, p. 297.

This species occurs in the outer channel in the vicinity of Satpara and Barhampur I. at all times of the year, but is rather scarce.

## Class **LAMELLIBRANCHIATA.**

### Order *TETRABRANCHIATA.*

### Family **Ostreidae.**

*Ostrea virginiana*, Gmelin, Reeve, *Conch. Icon.*, XVIII, *Ostrea*, pl. vi, fig. 9; 1873 (as *O. rostrata*). Plate xiv, fig. 2.

We have already discussed the beds formed by this oyster in the outer channel of the lake (p. 336). It is an extraordinarily hardy species and can endure desiccation, even when exposed to a tropical sun, for considerable periods as well as immersion in fresh water. We have also observed it living in similar conditions in backwaters near Madras, at the head of Port Blair harbour in the Andamans and in a lagoon on the Gulf of Siam.

We have to thank Mr. E. Vredenburg of the Geological Survey of India, who is engaged in a study of the oysters of this group, for the information embodied in the following note.

The specimens from the four localities referred to above seem to belong to a smaller race of a very large oyster (probably the largest living species) which is known to occur abundantly at many points along the south coasts of Asia, from the Mekran to the Malay Peninsula. Mr. Vredenburg is of opinion that, taking into account the variability in the shape of oysters generally, it is not possible to discover in the shape, the build, the ornamentation, the proportions or the dimensions of these shells, any differences sufficiently precise to afford an excuse for separating the form specifically from *Ostrea virginiana*, Gmelin, a very common shell along the Atlantic coast of North America. The species seems to be practically cosmopolitan throughout the warmer seas.

Certain forms occurring in the Bay of Bengal, including that named *O. gryphoides* var. *cuttackensis* and found on the Orissa coast, were separated from *Ostrea virginiana* by Messrs. Newton and Smith (*Rec. Geol. Surv. Ind.*, XLII, pp. 1-15; 1912) (*a*) on account of differences in shape or build which Mr. Vredenburg considers inadequate for specific distinction in such variable organisms, and (*b*) on account of the absence of the deep purple-black or purple-brown colour which, in North

American shells, suffuses parts of the valves, especially the muscular scar. This pigment is certainly absent in the large variety from Cuttack, but it is developed[1] to a most pronounced degree in the specimens which we have lately obtained from the Chilka Lake, the Andamans, Madras and Siam. The absence or presence of the colour is probably due to circumstances of environment. Amongst many species of *Ostrea* the colour is very variable.

The Cuttack shell is regarded by Newton and Smith as specifically identical with a fossil form from the miocene of Europe, *Ostrea gryphoides*, Schlotheim (better known as *Ostrea crassissima*, Lamarck) the close affinity of which to the species living along the coast of North America has been commented upon by every palaeontologist who has had occasion to deal with the form. In most instances specific identity between the fossil form and the living *Ostrea virginiana* has not been admitted. The identity would, nevertheless, have to be conceded, if, on the one hand, we accept Mr. Vredenburg's identification of the living Indian shell with the North American *Ostrea virginiana*, and, on the other hand, Messrs. Newton and Smith's reference of the living form to a miocene species. Mr. Vredenburg, while admitting that there exists the closest relationship between the living and tertiary forms, is not prepared to admit actual specific identity without further research. In any case, as regards nomenclature, if the identity of the Indian and American species is accepted, the specific name *virginiana* is older than any of the others bestowed upon its fossil relatives.

Mr. Preston regards the small Indian form with deep pigmentation of the inner surface as specifically distinct and has described it under the name *O. madrasensis*.[2]

*Ostrea lentiginosa*, Sowerby, Preston, 1910, p. 36.

A few shells of this species from Manikpatna have been identified by Mr. Preston.

*Ostrea cucullata*, Born, *Test. Mus. Caesarei Vindobon.*, p. 114, pl. vi, figs. 11, 12 (1780).

Individuals of this common oyster are sometimes found attached to clumps of *O. virginiana* on the beds at Manikpatna (see pl. xiv, fig. 2).

*Ostrea* sp.

Several shells of a flat circular form were found attached to the post in the channel off Satpara to which reference has already been made. Unfortunately they have been mislaid, but there can be no doubt that they represent a species different from any of those recorded above.

## Family **Mytilidae**.

*Mytilus smaragdinus*, Chemnitz, Reeve, *Conch. Icon.*, X, *Mytilus*, pl. vii, fig. 28 (1858).

A single small shell, in a fresh condition but empty, was found on the oyster-beds at Manikpatna in fresh water. The animal had evidently entered the lake in a larval condition, but had been unable to survive the floods. The species is very com-

[1] The corresponding soft parts of the animal are similarly pigmented.

[2] *Rec. Ind. Mus.*, XII, p. 33, figs. 11, 11*a* (1916).

mon on the east coast of India and grows in great luxuriance on the stone-work of Madras Harbour. The distribution extends from Hong Kong to the Arabian Sea.

*Modiola undulata* (Dunker). *See* p. 358.

*Modiola striatula*, Hanley. *See* p. 360.

## Family **Arcidae.**

*Arca* (*Anadara*) *granosa*, Linn., Lamy, *Journ Conch.*, LV, p. 210 (1907). Plate xvi, figs. 3-6.

Shells are abundant in a subfossil condition at the head of Rambha Bay, on Barkuda I. and at many other places in both parts of the lake; but the animal is extremely scarce in a living condition. Living and fresh specimens with the epidermis still complete were taken on only three occasions,—off Samal I., off Kalidai and near Barkul, in March and September. The largest of these is only 26 mm. in breadth, whereas a large shell from the Nicobars exceeds 75 mm. The subfossil specimens are intermediate in size, not exceeding 50 mm., while shells of about this size were seen with the epidermis still present in the outer channel in March.

We have referred above (p. 339) to von Neumayer's observations on a dwarfed form of this species that occurs in a subfossil condition in the Yang-tse-Kiang delta. *A. granosa* is frequently found living in brackish water on the coasts of India and Malaysia, but the larger specimens in the Indian Museum all seem to come from marine localities. It may therefore be assumed that dwarfing is correlated in this species with decrease in the salinity of the water; in the Chilka Lake the process seems to have been progressive and to have commenced while the south end of the lake was still in communication with the sea. The case is one of the best illustrations with which we have met, of the gradual change that has taken place in the fauna of the lake in the course of its comparatively short geological history.

The species has a distribution extending from the Arabian Sea to Japan and Australia.

*Arca* (*Fossularca*) *lactea*, Linn., Lamy, *Journ. Conch.*, LV, p. 97 (1907).

A few living specimens were dredged in the channel between Satpara and Barhampur I. in March and a dead shell was taken at the same locality in September. They occurred on a bottom of muddy sand. It seems probable that the species is killed off annually towards the close of the monsoon by the irruption of fresh water. *A. lactea* is a common European and E. Atlantic mollusc and has been recorded from Ascension I., S. Africa, the Red Sea and various Indian localities; also somewhat doubtfully from the Philippines.

## Family **Erycinidae.**

*Kellya chilkaënsis*,* Preston, 1915, p. 298, figs. 10, 10*a*.

This species is apparently scarce, but living specimens were found in both parts of the lake,—near Kalidai and Patsahanipur in March and in the inner part of the outer channel, both in this month and in September.

*Kellya mahosaënsis*,* Preston, 1915, p. 298, fig. 11.

*K. mahosaënsis* is represented in our collection by the type specimen only, a minute shell found with typical *K. chilkaënsis* in the outer channel.

## Family **Galeommidae.**

*Scintilla chilkaënsis*,* Preston, 1915, p. 299, figs. 12, 12*a*.

*S. chilkaënsis* was not uncommon near Satpara and Barhampur I. in the freshwater season on a bottom of mixed sand and mud, but was not found in salt water.

The mantle closely resembles that of *S. hydatina*, Deshayes, as figured by Lynge[1]; the papillae on its margin being long and finger-shaped. The mantle was yellow and the tentaculiform marginal papillae were pale with deep orange tips, those of *S. hydatina* being described as deep red.

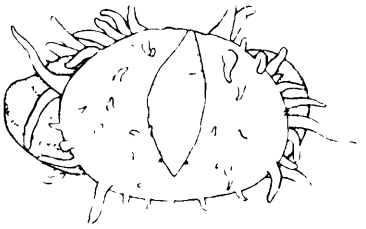

FIG. 4.—*Scintilla chilkaënsis*, Preston.

Specimen with mantle expanded, covering the greater part of the shell (from an example preserved in spirit).

## Family **Cardiidae.**

*Cardium* (*Fulvia*) *rugatum*, Gron., Reeve, *Conch. Icon.*, II, *Cardium*, pl. xii, fig. 63 (1843).

A few young molluscs of this species were taken just inside the mouth of the lake in salt water. *C. rugatum*, like *Mytilus smaragdinus*, is doubtless an occasional visitor to the outer part of the lake-system in the salt-water season.

## Family **Veneridae.**

This family is represented by no less than seven species (four genera), but only one form, *Clementia annandalei*, now occurs living in the main area of the lake. At least one other, *Meretrix casta*[2], is abundant in a subfossil condition at the head of Rambha Bay and on Barkuda I.

*Meretrix meretrix* (Lam.), Reeve, *Conch. Icon.*, XIV, *Cytherea*, pl. iii, fig. 10; 1864 (as *C. impudica*).

Common in the outer channel.

*Meretrix casta*, Chemn., Reeve, *Conch. Icon.*, XIV, *Cytherea*, pl. vii, fig. 25 (1864); syn. *Corbicula* (*Velorita*) *satparaënsis*, Preston, 1914, p. 306, fig. 22.

Blanford[3] states that this species is characteristic of estuarine waters on the Indian coasts. It is still fairly common in the outer channel of the Chilka Lake, where it buries itself in a bottom of mixed sand and mud, and probably occurs

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[1] *Danske Vid. Selsk. Skr.* (7), *nat. og math.*, V, iii. p. 186 (1909).

[2] There seems to be great confusion as to the Indian species of this genus and it is possible that a further systematic study will considerably alter the synonymy at present accepted.

[3] *Rec. Geol. Surv. Ind.*, V, p. 61 (1872).

throughout the year. Its habits render it difficult to obtain except when the water is low. Both young and old individuals were found.

*Meretrix ovum*, Hanley, Reeve, *Conch. Icon.*, XIV *Cytherea*, pl. vi, fig. 19 (1864).

This species is more common than the preceding in the outer channel, both young and old individuals occurring in great abundance on the same ground and also on clear sand nearer the mouth of the lake. *M. ovum* was described from Malabar.

*Tivela dillwyni* (Deshayes), Reeve, *Conch. Icon.*, XIV, *Cytherea*, pl. vii, fig. 24 (1864).

A single small living specimen was obtained in Seruanaddi in the freshwater season.

*Tapes pinguis*, Chemn., Mart. and Chemn., *Conch. Cab.*, *Veneracea*, p. 126, pl. v, figs. 3-5, 8-10; 1869 (as *Vernes*).

The species is fairly common in the outer channel with *M. casta* and *M ovum* in March and probably at other times of the year.

*Tapes ceylonensis*, Sowerby, Mart. and Chemn., *Conch. Cab.*, *Veneracea*, p. 236, pl. xl, figs. 10, 11 (1869).

The same remarks apply to this species as to the last.

*Clementia annandalei*, Preston, 1914, p. 306, figs. 14, 14*a*, 14*b*; 1915, p. 301.

All over the main area of the lake this is one of the commonest molluscs, occurring in mud with *Theora opalina*. In the inner part of the outer channel it is less abundant, its place being taken to some extent by species of *Diplodonta*. Living individuals were dredged at all times of the year, but it was noticed that dead shells were relatively very abundant at the end of the freshwater season. The shell is so brittle that it is difficult to obtain perfect specimens, but is much less transparent than that of the *Theora*.

The species also occurs at Port Canning in the Gangetic delta and has long been represented in the collection of the Indian Museum by large numbers of specimens from this locality labelled with the *nomen nudum* "*Clementia blanfordii*, Benson." The genus is characteristic of estuarine waters in the tropics of Africa and Asia.

## Family **Petricolidae.**

*Petricola esculpturata*,* Preston, 1915, p. 301, figs. 13, 13*a*.

This mollusc was found only in crevices between oyster-shells on the beds at Manikpatna in the outer channel. It was obtained both in fresh and in salt water.

## Family **Ungulinidae**

Only two of the five species of *Diplodonta* by which this family is represented were found in the main area of the lake. Considering the fact that several species are known from the Gulf of Siam, all of which have a wide Oriental distribution, it is remarkable that all the Chilka forms should prove to have been undescribed. The first three species in the following list seem to prefer a bottom of sandy mud, but *D. ovalis* and *D. chilkaënsis* live chiefly on clean sand.

*Diplodonta satparaënsis*,* Preston, 1915, p. 302, figs. 14, 14*a*, 14*b*.

Dead shells of relatively large size were abundant in the inner part of the outer channel at all times of the year. A few living specimens of smaller size were taken in this channel in the salt-water season, and at the same season a few small living individuals were found near Kalidai I.

*Diplodonta barhampurensis*,* Preston, 1915, p. 302, figs. 15, 15*a*.

Represented only by a pair of empty valves (the type) taken in the inner part of the outer channel in the freshwater season.

*Diplodonta* (*Felania*) *annandalei*,* Preston, 1914, p. 307, figs 20, 20*a*, 20*b*; 1915, p. 303.

An abundant species at the inner end of the outer channel and also found in the main area in the neighbourhood of Nalbano, off Patsahanipur, near Kalidai and at Maludaikuda. As is the case with *D. satparaënsis*, living specimens were found only in the salt-water season, while fresh but empty shells were obtained in fresh water in September.

*Diplodonta* (*Felania*) *ovalis*,* Preston, 1914, p. 308, figs. 19, 19*a*, 19*b*; 1915, p. 303.

A few individuals were found at Manikpatna and near the mouth of the lake, while one was taken in the inner part of the channel near Barhampur I. No specimens were obtained in the freshwater season.

*Diplodonta* (*Felania*) *chilkaënsis*,* Preston, 1914, p. 308, figs. 21, 21*a*, 21*b*; 1915, p. 303.

Except for one living specimen taken on the southern side of the Satpara peninsula, all our examples of this species, which are not numerous, were obtained towards the seaward end of the outer channel on clean sandy ground. A single living individual was found with a number of dead shells in September, 1913. Most of the shells dredged in the freshwater season were dead.

## Family **Psammobiidae.**

*Psammobia mahosaënsis*,* Preston, 1915, p. 303, figs. 16, 16*a*, 16*b*.

This species is not uncommon in the inner part of the outer channel. Living individuals were found in both the salt and the freshwater season.

## Family **Solenidae.**

In the Chilka Lake we found three forms of *Solen* that must be provisionally regarded as distinct species, but we believe that until the anatomy of the Oriental forms of the genus has been investigated, it will remain impossible to assign specific limits with any degree of certainty. Our reason for making this statement is the fact that in the collection of the Indian Museum, only a small proportion of which is named so far as this genus is concerned, we find many forms that seem to grade one into the other. Moreover at several localities on the Indian coasts pairs of forms occur, resembling one another closely except in the proportions of their shell, the relative dimensions being less different at some places than at others. Two forms of this

kind, which Mr. Preston has called *S. annandalei* and *S. kempi* occur in the outer channel of the lake and at Nalbano, while a third (*S.* ? *fonesi*) which is relatively shorter than either, is one of the most abundant species of Lamellibranchs in the main area. Shells of the two former are found together and both would seem to burrow only in sandy ground, whereas the third is essentially an inhabitant of soft mud. *S. annandalei* and *S. kempi* are comparatively scarce and, with the exception of a single small specimen of the latter, are represented in our collection by dead shells only. Dr. Ekendranath Ghosh describes the general structure of *S.* ? *fonesi* in considerable detail in the appendix on pp. 367-374.

? *Solen fonesi*, Dunker, Preston, 1916, p. 37; syn. *S. truncatus*, Preston, 1914, p. 309. Plate xvi, fig. 7.

In his paper of 1914 Mr. Preston regarded this shell as a young form of *S. truncatus*, Wood, which it resembles in outline. Many sexually mature individuals were, however, found that were no larger than those examined by him.

We obtained in the Chilka Lake no shell more than 28·5 mm. long and, in a series of specimens that we have measured, we find that the length varies from $3\frac{1}{3}$ to a little more than $3\frac{1}{2}$ times the breadth.

Von Martens[1], who regards *S. fonesi* as synonymous with *S. woodwardi*, Dunker, notes that Dunker's specimens were from 51 to 53 mm. long and 11 to 12 mm. broad; Reeve's figure is 59 mm. long and 12 mm. broad. Von Martens concludes that small specimens are about $4\frac{1}{2}$ times as long as broad, and larger ones as much as 5 times. If Mr. Preston's identification is correct, the Chilka race is evidently a dwarfed one.

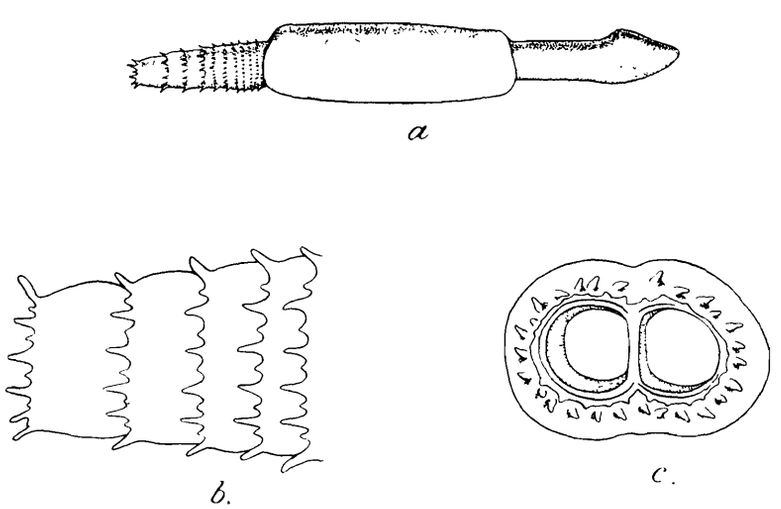


FIG. 5.—Chilka race of *Solen* ? *fonesi*, Dunker.

*a*. A living specimen, slightly enlarged, with extruded foot and siphon.
*b*. A portion of the siphon, more highly magnified, lateral view.
*c*. A cast-off section of the siphon, end view.

The question of proportions in this and closely allied species is, however, one of great difficulty. Three valves found on a sandy beach at the mouth of the Ennur backwater near Madras and identified by Mr. Preston as *S. fonesi*, are respectively about 86, 72 and 71 mm. long. The first of these is $5\frac{3}{4}$ times as long as broad and the other two about $4\frac{1}{2}$ times—measurements and proportions that do not by any means tally with those given by von Martens.

[1] Weber's *Zool. Ergebn. Ned. Ost.-Ind.*, IV, p. 270 (1897).

For the greater part of the year the little *Solen* is extremely abundant in the lake and numbers were brought up in most hauls of our nets. Even when the shells were absent, the peculiar siphons to which we refer below were often found. At the end of the wet season, however it was difficult to obtain living specimens, and only a few were seen at this time of the year.

The animal excavates, in the ordinary manner a vertical burrow that is not very much deeper than its own length, inserting its foot into the mud in a contracted condition and then expanding it so as to force an entrance. If laid on its side it can right itself instantaneously by turning its foot round at an angle and thus getting a purchase on the bottom. It can dart rapidly for some inches backwards by squirting water from its siphon and can also swim forwards with moderate ease, compressing its foot laterally and using it as a paddle.

The most remarkable feature in the structure of the species lies in the great development of the siphons, in their very distinct segmentation, in the arrangement by which the segments are thrown off either singly on in groups by a process of autotomy, and in the existence of a ring of minute tentacles round the distal end of each segment. Apart from the actual shortening effected by the autotomy of one or more segments, it produces no apparent structural or functional disablement of the siphons, and if, as seems not improbable, the tentacles have a sensory function, the new tip is as well equipped as the old.

The small form of *Solen ? fonesi* occurs in the backwaters of Cochin as well as in the Chilka Lake. The species is recorded from the Philippines and Cebu, but without particulars.

*Solen annandalei*,* Preston, 1915, p. 304, figs. 17, 17*a*. Plate xvi, fig. 8.

The shell of this form is easily distinguished from Chilka specimens of *S. ? fonesi* by its larger size and relatively greater length; in the only two specimens we have seen the length is respectively 4·7 and practically 5 times the breadth. The shells were found on sandy beaches at Nalbano and Satpara, in both cases with examples of *S. kempi*.

*Solen kempi*,* Preston, 1915, p. 305, figs. 18, 18*a*. Plate xvi, fig. 9.

The shell is still narrower than in *S. annandalei*, the length being from 6·4 to about 7 times the breadth. Several fresh shells were found at Satpara and Nalbano and a single living example was dug from pure sea-sand near the mouth of the lake. The siphons resembled those of *S. fonesi*, but the animal, instead of being practically colourless, had a distinct greenish tinge.

## Family **Mactridae.**

*Standella annandalei*,* Preston, 1915, p. 305, figs. 19, 19*a*, 19*b*.

This species is common on sandy ground at Nalbano, burrowing to a depth of several inches. It also occurs in the outer channel, in which, however, we took only dead shells. The only living specimens we obtained were taken in March, but the habits of the species render it difficult of capture except when the level of the lake

is very low. A polychaete worm of the genus *Diopatra* frequently fixes a single valve of the shell to the upper extremity of its tube, which projects in the form of a vertical funnel above the surface of the sand.

### Family **Myidae.**

*Corbula chilkaënsis*,* Preston, 1911, p. 39, fig. 2.

This species is represented in our collection by a single specimen, the type, taken living under a stone at the edge of the lake near Rambha in March, 1910. It bears a remarkably close resemblance to some species of *Cuspidaria*. The interior of the shell has not been examined and we are by no means certain of the true systematic position of the species.

### Family **Pholadidae.**

*Martesia striata* (Linn.), Reeve, *Conch. Icon.*, XVIII, *Pholas*, pl. viii, figs. 32, *a*, *b*, *c*. (1873).

In the old collection of the Indian Museum there are several small and distorted valves of this species, labelled "Chilka Lake." It is a cosmopolitan form common in drift-wood in the Bay of Bengal and the specimens probably came from a log that had drifted into the mouth of the lake.

### Family **Teredinidae.**

*Xylotrya stutchburyi*, Sowerby, Reeve, *Conch. Icon.*, XX, pl. ii, figs. 5, 5*a*, *b*, *c* (1878).

A post standing in the lake near Satpara was bored through and through by this ship-worm. Many of the tubes were empty and one of them was occupied by a small blenny of the genus *Petroscirtes*; some were lined by the Polyzoon *Membranipora hippopus*.

## Order *DIBRANCHIA*.

### Family **Tellinidae.**

We obtained no living representatives of this family; but the shells of the following two species were apparently quite fresh at the time they were collected.

*Tellina chilkaënsis*,* Preston, 1915, p. 306, figs. 20, 20*a*, 20*b*.

A single pair of fresh valves was obtained in the inner part of the outer channel in the freshwater season.

*Tellina confusa*,* Preston, 1914, p. 309, figs. 18, 18*a*.

We obtained no specimens of this species, which has long been represented in the Indian Museum by examples from the late Dr. Blanford's collection, labelled *T aequistriata*, Sowerby. They are probably from the outer channel of the lake.

### Family **Scrobiculariidae.**

*Theora opalina* (Hinds), *Proc. Zool. Soc. London*, 1843, p. 78.

This is quite the most abundant bivalve mollusc in the main area of the lake. It occurs more sparingly in the inner part of the outer channel. The shell lies buried

in mud, or muddy sand, and the siphons are capable of elongation to at least three times its length; but so far as we could discover the burrow is always quite superficial. The animal is capable of giving sudden leaps by ejecting water. The shell when not eroded is of a glassy transparency (see fig. 6) but becomes somewhat clouded after death

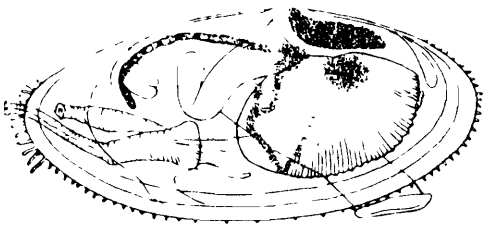

FIG. 6.—*Theora opalina* (Hinds).
Living animal, with siphons contracted and foot partially extruded. From a sketch by Mr. G. M. Henry.

*Theora opalina* was originally described from a muddy bottom in shallow water in the Philippines. It probably occurs in all estuaries and backwaters on the Indian coasts, at any rate it is fairly common in those of Bengal, Madras and Cochin.

*Cumingia hinduorum*,* Preston, 1915, p. 308, figs. 22, 22*a*.

This species was found living at the inner end of the outer channel at all times of the year. Living specimens were also obtained off Parikudh in the main area in November in water of very low salinity (sp. gr. 1·00225), the bottom at this point being somewhat sandy.

## Family Cuspidariidae.

*Cuspidaria annandalei*, Preston, 1915, p. 308, figs. 23, 23*a*, p. 482; 1916, p. 39.

This species is common all over the lake-system except at the seaward end of the outer channel. It sometimes occurs on bare mud, but is particularly abundant in thickets of *Potamogeton*, to which young shells are frequently found attached. It seems to flourish equally well in fresh, salt and brackish water. Many shells have a number of small greyish spots on the swollen part; these are more conspicuous in fresh examples. The species has also been found in backwaters at Madras and Cochin and in the Gangetic delta.

## Family Lyonsiidae.

*Lyonsia samalinsulae*,* Preston, 1914, p. 310, figs. 16, 16*a*; 1915, p. 309.

There are not many specimens of this species in our collection; but they were found living at widely separated places in the outer channel and the main area both in the salt and fresh-water seasons. Their scarcity is probably due to the fact that they burrow in sandy mud near the shore and were therefore rarely taken in our nets.

## Family Anatinidae.

Broken shells belonging to the genus *Anatina* were observed in considerable numbers on the shore, when the level of the lake was low, wherever a certain amount of sand was mixed with the mud of the bottom. Good specimens were difficult to obtain on account of the fragility of the shells and of the fact that the animals burrow to a depth of at least two feet.

Lynge draws attention to the variability of *A. anatina* (Linn.) and expresses the opinion that many species of the genus will ultimately have to be withdrawn. We

have found it very difficult, with all the types before us, to distribute fresh specimens among Preston's three species.

*Anatina granulosa*,* Preston, 1914, p. 310, figs. 17, 17*a*.

The species was described from a specimen long in the Indian Museum and labelled merely "Chilka Lake." We attribute to it with some doubt a much larger shell found dead on the shore at Ganta Sila in March.

*Anatina barkudaënsis*,* Preston, 1915, p. 309, figs. 25, 25*a*.

Under this name Preston includes the majority of our specimens; they were found in all parts of the lake except the sandy area of the outer channel. All our living examples were taken in the salt-water season, but the only manner in which we were able to obtain them was by digging on the shore when the water level was low.

*Anatina barkulensis*,* Preston, 1915, p. 309, figs. 24, 24*a*.

A living specimen was dug up at Ganta Sila in February, and another was dredged near Mahosa in the outer channel in September. The type, obtained at Barkul Point in March, was dead but in a fresh condition.

## NOTE ON VARIATION IN *MODIOLA*.

The great abundance of *Modiola* in the Chilka Lake and the conspicuous nature of the variability exhibited by its species has enabled us to prepare notes on this genus of a more elaborate kind than those we have given on other Mollusca.

*Modiola* is a genus of cosmopolitan distribution and wide bathymetric range. *M. watsoni* is common in the Bay of Bengal at a depth of over 100 fathoms and several forms have been found in inland lakes in eastern Asia. In the estuaries of Indian rivers at least one species is abundant, *viz.* that referred to below as *M. striatula*, Hanley.

In the large series of specimens we obtained in the Chilka Lake it is possible to select individual shells corresponding with those referred by Mr. Preston to nine species and one variety; but, for the reasons stated below, we are convinced that at most only two variable species of different habits are represented. We should mention that only a comparatively small proportion of the shells were available at the time that the collection was examined by Mr. Preston.

### **Modiola undulata** (Dunker).

(Plate XV, figs. 1—6: plate XVI, fig. 1.)

1856. *Volsella undulata*, Dunker, *Proc. Zool. Soc. London*, XXIV, p. 363.
1858. *Modiola undulata*, Reeve, *Conch. Icon.*, X, *Modiola*, pl. v, fig. 18.
1911. *Modiola chilkaënsis*, Preston, *Rec. Ind. Mus.*, VI, p. 41, fig. 6.
1914. *Modiola undulata* and var. *crassicostata*, Preston, *ibid.*, X, p. 304, fig. 15.
1915. *Modiola undulata* and var. *crassicostata*, Preston, *ibid.*, XI, p. 298.

This species is abundant in the Chilka Lake, occurring at all seasons and in all parts of the lake-system. It is almost invariably attached either to *Potamogeton*, to filamentous or delicately branching algae or to the ropes of fishing traps; in other

words to objects that sway freely in the water. The algae may be growing on stones and of no great length and a few living shells were found apparently lying free on a muddy bottom, but they may have been shaken from weeds by the net. Large numbers of dead shells were noted in December on the shore at Rambha after a strong breeze.

The shell in specimens of *M. undulata* from the Chilka Lake is thin, as a rule semi-transparent and lightly tinged with yellowish-green; markings when present, as they usually are, are of a bright reddish-purple. There is considerable variation in outline; but the upper margin is always strongly elevated at or near the middle and is sometimes subangulate: the exact position of this point is not always the same. On account of the elevation the proportional depth of the shell is always considerable, but in this character also there is much variation. The lower margin of the shell is often quite straight, but perhaps more frequently very slightly concave: it is never emarginate. In some specimens one valve is a little more inflated than the other, but this peculiarity is sometimes so slight as to be almost imperceptible and may exist in either valve. The type of Mr. Preston's *M. chilkaënsis* (pl. xv, fig. 5) is an individual in which it is particularly well marked, but his figure exaggerates the asymmetry.

The surface of the shell is usually devoid of radiating ridges, except immediately in front of and below the umbo, where there are distinct transversely-striated costae. Faint traces of similar costae are, however, often to be observed on the posterior edge of the shell and occasionally extend along its whole length in a well-developed condition. It is to this form that Mr. Preston has given the name var. *crassicostata* (pl. xv, fig. 6).

In the commonest type of colouration the shell is marked with zig-zag purple lines, which run transversely and are frequently interrupted, and also with finer straight radiating lines of the same colour. Lines of both kinds frequently disappear almost completely on the lower half of the shell and the longitudinal ones are almost always most strongly developed on the posterior half. Both kinds of lines may be obsolete or even entirely absent and the whole surface of a uniform pale yellowish-green; shells of this type are not uncommon. On the other hand the purple lines often develop into irregular blotches, and occasionally the whole surface, except the extreme margin, becomes deeply suffused with purple pigment, definite markings being indistinguishable. This type of colouration is, however, very rare. Photographs illustrating variation in colour-pattern are reproduced on Plate xv, figs. 1-4.

The shells described by Dunker evidently belong, so far as colouration is concerned, to the form commonest in the Chilka Lake, but Reeve has figured and described a unicolourous specimen which appears to have been browner than any in our collection. Our descriptions of colour have, however, been drawn up from specimens preserved in spirit, in which the differences are much better seen than in dried shells.

Neither in colouration, shape, degree of asymmetry or presence or absence of ribs on the surface are we able to find correlation of any kind, and specimens from

the same handful of weed may possess any combination of the peculiarities mentioned. It is very probable that the inequality of the valves characteristic of Mr. Preston's *M. chilkaënsis* is due to unequal pressure at an early stage of growth, the crowded condition of the shells (pl. xvi, fig. 1) easily explaining how this may have occurred.

There seems to be very little difference between our specimens of *M. undulata* and those described by Dunker and Reeve. The former author gives the length of the shell as 11 lines (about 23 mm.) and our largest specimens are of exactly the same size. Only a few individuals, however, attain these dimensions, the circumstances in which they live making it impossible for the majority of them to exist for a prolonged period. A large number of those individuals that are attached to the stems of *Potamogeton* must perish with that plant, which dies down in June or July, though it is possible that some are able to transfer themselves to the roots, which of course persist. In this position there is great danger of their being overwhelmed by mud. Those individuals, on the other hand, that are attached to filamentous algae growing on stones are mostly killed by desiccation in spring or early summer.

We have no evidence, therefore, in the case of this species that its abnormal environment in the Chilka Lake has produced anything of the nature of a racial dwarfing or distortion. It is naturally a variable species, as is proved by the apparent discrepancies in Dunker's and Reeve's descriptions, both authors having had before them specimens from the same locality (the Moluccas) and collection. We are not aware that the species has been recorded from any other Indian locality but the Chilka Lake, but we have specimens from Port Canning in the Gangetic delta.

## **Modiola striatula**, Hanley.

(Plate XV, figs. 7-18 ; plate XVI, fig. 2.)

1842-56. *Modiola striatula*, Hanley, *Cat. Recent Bivalve Shells*, p. 241, pl. xxiv, fig. 29.
1858. *Modiola striatula* and *emarginata* (Benson MS.), Reeve, *Conch. Icon.*, X, *Modiola*, pl. x, figs. 72, 73.
1909. *Brachyodontes emarginatus*, Lynge, *Danske Vid. Selsk. Skr.* (7) *nat. og. math.*, V, p. 135.
1909. *Modiola cochinensis*, Preston, *Rec. Ind. Mus.*, III, p. 278, fig. 2.
1910. *Modiola jenkinsi*, Preston, *ibid.*, V, p. 36, fig. 5.
1911. *Modiola annandalei* and *celator*, Preston, *ibid.*, VI, pp. 40, 41, figs. 4, 5.
1914. *Modiola emarginata*, Preston, *ibid.*, X, p. 304.
1915. *Modiola taprobanensis*, Preston, *Ann. Mag. Nat. Hist.* (8), XVI, p. 84, fig.
1916. *Modiola taprobanensis*, Preston, *Rec. Ind. Mus.*, XII, p. 35.

The synonymy of this species presents great difficulties, owing, we are convinced, to the extreme variability of the shell. Among the specimens from the Chilka Lake Mr. Preston has recognized no less than four species, while in our more recent collections we find selected shells that agree precisely with his types of two others. We are by no means certain that the synonymy we give is exhaustive, for it seems not at all improbable that, when large series from estuarine tracts and lagoons in the Oriental region are compared, it will be found that other forms at present regarded as distinct fall well within the limits of variation of *M. striatula*. It is noteworthy, moreover,

that in a small series of *M. lacustris*, von Martens, from the Tung-ting Lake in China, we find variations in the shape of the shell comparable to those that occur in the species from the Chilka Lake.

*M. striatula* differs from *M. undulata* so far as habits are concerned in that it is usually found attached to rocks, stones, wooden posts or other solid objects. This is the case in the Gangetic delta as well as in the Chilka Lake. Shells are occasionally found in both places fastened to algae growing on stone, but seem to be unable to attain their full development in this position. In the Gangetic delta a favourite situation is on posts partly destroyed by *Xylotrya*; but the mussel is also found on brick-work in the Calcutta docks, where it is stated to do considerable damage by settling in cracks in the bricks and splitting them by its growth. In the Chilka Lake it prefers to settle in crevices in rocks or among oyster-shells. We have noticed on many occasions that the young molluscs show a marked tendency to congregate round the adults (pl. xvi, fig. 2).

In the lake it is extremely abundant in both the outer channel and the main area and occurs at all times of the year, being very common in all suitable places whenever the rocks and oyster-beds are covered with water.

Near Calcutta, where it is very abundant, it is frequently overwhelmed by the sponge, *Spongilla alba*, in which we occasionally found shells in the Chilka Lake. On the bottom of our steam-launch large numbers were also discovered in the sponge *Suberites sericeus*.

The shells that we have included under the name *M. striatula* vary very greatly in shape, sculpturing, size and colouration, but we find from the old collection of the Indian Museum that all, or practically all, were included by G. Nevill under the name *M. emarginata*, Benson. This name seems to have existed in manuscript some time before it was published by Reeve, and it was the one by which the common mussel of the estuaries of the Bay of Bengal was known to Blanford [1] and his contemporaries. Nevill gives *striatula* as a synonym on his labels.

From *M. undulata* the species appears to be distinguished by the following characters, though in certain cases we have found it very difficult to separate individual shells of small size. The shell is always more opaque and as a rule much more densely pigmented, the pigment being of a duller shade. The upper margin is as a rule less strongly elevated and more evenly arched, the proportional depth of the shell being therefore less. The postero-dorsal margin is as a rule more declivous and the posterior extremity more narrowed and less strictly horizontal. In a large number of shells the ventral margin is boldly excavated or emarginate. Radial ridges, which are exceptional in *M. undulata*, are usually present; but the anterior margin is sometimes quite smooth.

The nominal species that we include under *M. striatula* may be divided into two groups, (i) those in which the lower margin of the shell is practically straight and (ii) those in which it is distinctly excavated. The former consists of *M. cochinensis* and

[1] Blanford, however, distinguished some specimens as *M. striatula*.

*M. jenkinsi*, Preston, the latter of *M striatula*, Hanley; *M. taprobanensis*, Preston; *M. emarginata*, Reeve; *M annandalei* and *M. celator*, Preston. In practically every series of specimens we have examined, either from the Gangetic delta or from the Chilka Lake, there is a complete transition between these two groups, and many of the specimens identified by Blanford and by Mr. Preston as *M. striatula* have the lower margin straight, while in Reeve's figure it is much more nearly so than in Hanley's. In fact, so far as it is possible to say without seeing those of *M striatula* and *M. emarginata*, we believe that the types could be arranged in the following order so as to form an almost complete series in this respect:—

1. *M. jenkinsi.*
2. *M. cochinensis.*
3. *M. striatula.*
4. *M. taprobanensis.*
5. *M. emarginata.*
6. *M. celator.*
7. *M. annandalei.*

With the concavity of the lower margin in these forms a relative narrowing and elongation of the whole shell is often correlated and in those types in which this margin is straightest, the relative depth of the shell is greatest. *M taprobanensis*, however, is a rather broad form.

The type of *M. celator* is remarkable for its abnormal outline as seen in dorsal view and for the thickened and eroded condition of the antero-superior region of the shell. We find precisely similar shells in a number of our series and also others in which abnormalities of a similar nature occur in other parts. Photographs of abnormal shells and of the types of four species described by Mr. Preston are included in the series figured on pl. xv, figs. 7-18.

The development of radial costae is an extremely variable character, but the surface is less frequently quite smooth than in *M. undulata*. In many specimens the costae are quite as fully developed as in the var. *crassicostata* of that species, but they are never branched as in *M. subramosa*, Hanley. Another variable character is the development of concentric growth-lines; abnormal specimens occur, especially in forms resembling *M. celator*, in which they are greatly accentuated. Sculpturing of the shell is not, however, correlated in any way with its shape. It seems to us impossible to recognize *Branchyodontes*, Swainson, even as a subgenus.

The colouration is also very variable, but the variation is not quite of the same nature as in *M. undulata*, the different colours being as a rule more diffused as well as duller. In some specimens, however, zigzag transverse purple lines and longitudinal striae can be detected, but the purple is usually less red and the ground-colour of a bluer green. Young specimens are as a rule brighter than adults and fully developed shells are sometimes of an almost uniform dull brown.

Perhaps the best illustration we possess of correlation between different forms of shell and their environment is a worm-eaten log covered with mussels of this species. It has long been in the Indian Museum and almost certainly came from the Gangetic delta. Among the shells from this log are some that are relatively short and broad and have the lower margins perfectly straight, while others exhibit every degree of

length of shell and concavity of margin. The former are those which repose in comparatively short cavities with a smooth lining and straight or nearly so, while the latter are esconced in deeper holes of irregular shape and are pressed either against one another or against the walls. In each case the shell takes the shape of the space it occupies; in some instances it forms practically a cast of that space and the degree of concavity of the lower margin is most strictly correlated with the degree of curvature of the surface against which it is pressed.

In the Chilka Lake we noticed exactly the same phenomenon. Shells with a straight margin, like the types of *M. jenkinsi* and *M cochinensis*, were those which were attached to flat objects such as the inner surfaces of oyster-shells, while extreme forms such as *M. annandalei* were living in crevices in rocks or on uneven stones. The byssus is always very short and the shell is pressed closely against the object of attachment. In the case of forms resembling Mr. Preston's *M. celator*, we believe that we are dealing merely with abnormalities produced by growth in unusally confined spaces. The shell is always greatly thickened and eroded on the surface, either all over or in parts.

Colouration is to some extent correlated with environment, shells from rocks or logs overgrown with algae being paler and greener than those on bare stone of a dark shade, while those on the inside of oyster-shells are often quite pale; the correlation, however, is not of a precise nature. Specimens from some localities, *e.g.* the Cochin and Madras backwaters, are browner than those from the Chilka Lake. They have been named by Mr. Preston, *M cochinensis* and *M. taprobanensis* respectively.

The shell seems to be thicker in specimens from marine localities than in those from estuaries and backwaters.

All our specimens from the Chilka Lake are small, exceptionally large shells not exceeding 20 mm. in length, while in many series none reach 15 mm. The largest specimen from the log of wood to which we have referred above is 31·5 mm. in length, others from the Andamans are scarcely smaller, while Reeve figures an individual 39 mm. long and von Martens[1] notes that the largest he examined was 36 mm.

It is clear, therefore, that all the individuals we found in the Chilka Lake are dwarfed and we are convinced that our investigations were sufficiently exhaustive in this respect to include the whole range of variation. There is, however, a small series of specimens in Blanford's collection, labelled as coming from the Chilka Lake, some of which are more than 35 mm. in length. It is unfortunate that no precise information is available as to their *provenance*, but in general appearance they bear a remarkably close resemblance to those on the log of wood referred to above; we have good reason to suspect that they may have been introduced on driftwood.

Specimens from the backwaters of Cochin and Madras are even smaller than those from the Chilka Lake, rarely, if ever, exceeding 10 mm. in length, but in these places they live in confined spaces between the valves of dead oyster-shells. Those from the Chilka Lake oyster-beds are almost as small. Among those we have our-

[1] Weber's *Zool. Ergebn. Nied. Ost-Ind.*, IV, p. 227 (1897).

selves found in small pools near Calcutta liable to desiccation, none exceed 23 mm. in length. There are several other series in the collection of the Indian Museum from the Gangetic delta which include shells 31 mm. long, but we are ignorant of the precise circumstances in which they were found.

From all these facts it would seem that the small size of the mussels of this species found in the Chilka Lake is in no sense a racial character, but is due to the direct effect of environment on the individual. We must remember that by far the greatest part of the rock-area available on the shores and islands of the lake is completely dried for several months in the year, at any rate from March until the latter part of June. At the end of the dry season extremely few living individuals are to be found and these are situated in close proximity to the muddy bottom and are therefore liable to be buried. From the situation in which the young mussels establish themselves it necessarily follows that the chief, though not the only, breeding season must occur shortly before the adults are killed by the sinking of the water-level and that the larvae settle down when the lake is full. It is interesting to notice that they do so at a time when the water is quite fresh or but very slightly saline.

The situation most favourable to the growth of *M. striatula* seems to necessitate the following conditions,—(i) a firm support provided with cavities in which the animals may attach themselves; (ii) the absence of any risk of being engulphed in mud or in living sponges and (iii) an uninterrupted supply of water. There is of course the question of food-supply also, but on this we have no information. To judge from the specimens we have examined, ideal conditions are to be found on worm-eaten logs of wood, either fixed beneath the lowest water-level or floating.

It is not improbable that the species is essentially an estuarine one, but in spite of this fact, ideal conditions exist very rarely, if at all, in the Chilka Lake. We are of the opinion that dwarfing in the case of *M. striatula* in the lake is not due to the low salinity of the water and that there is no evidence that the unfavourable conditions noted in the preceding paragraphs have affected the race as distinct from the individual.

*M striatula* was originally described from the Philippines and has been recorded from the Gulf of Siam, Singapore, Ceylon, Burma and from both sides of the Indian Peninsula (Calcutta, Madras, Cochin, Bombay).

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