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THE BRACKISH-WATER FAUNA OF MADRAS.

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Lake Biwa in Japan, were published in the succeeding years, in Annandale's *Zoological Results of a Tour in the Far East* (1916–1925). In recent years, considerable data have accumulated on the euryhaline fauna of the Gangetic delta mainly by the contributions of Annandale, Kemp, Sewell, and other officers of the Zoological Survey of India. An investigation of the brackish-water areas near the city of Madras was thought desirable as no attempt has been made to advance our knowledge of the brackish-water animals of South India beyond the references in the Chilka Lake reports. Apart from this aspect, the local animals which could be examined first-hand are so little known in many of the educational centres in India that both the student and the teacher are often handicapped owing to the paucity of familiar local species illustrating several biological phenomena; hence this work was planned with the hope that it may benefit College students in general. Comparatively little is known of the bionomics of the brackish-water types of animals, and since the place chosen was suited for close and constant investigation, an intensive ecological study was made extending over a period of three years. As will be seen from the following account, a fairly rich and specialized fauna exists at Adyar, showing interesting peculiarities both in mode of life and life-history.

Material and Methods.

The account of the fauna given here is based upon a number of collections from the Adyar backwater, Adyar River, and the brackish-water localities of the Cooum, made within the course of three years, dating from November 1933. A few collections made previous to this have also been utilized, but these do not include any species that we have not taken subsequently. During the early part of the survey, *i.e.*, for about a year, the Adyar backwater and the river were visited about thrice a month on an average, and regular shore and plankton collections were made. The backwater and the river were less frequently visited during the next year, but special attention was devoted to the upper reaches of the river and the pools of brackish-water near the Boat Club. Observations were also made on the fauna of the small islands in the river near the Elphinstone Bridge, and the brackish tracts of the Cooum. Field observations during the third year have confirmed the previous years' results.

The shallow nature of the backwater and the river was of considerable advantage in that no elaborate equipment was necessary for conducting this study. Shore collections were made by us regularly during our visits. For examining the fauna of the mud, the most useful instrument was a large shovel with which mud could be levered up without causing much

disturbance to the organisms. Mud taken in this manner from the backwater, salt pools, river, etc., was carefully examined in the laboratory and the organisms picked up. The tow-net was used to collect the free-swimming invertebrates, small fish and larvæ. The collection also includes specimens obtained by dredging from the deeper parts of the river.

For the collection of fish, prawns and the larger species of swimming crabs, we have entirely depended upon the implements used by the fishermen of the locality. These were closely meshed nets of various sizes and shapes. Fishing is usually done in the mornings. Catches obtained by the fishermen from the river and the backwater were regularly purchased until representatives of most of the species were obtained. Afterwards, their catches were only examined on the field.

The hydrographical readings given were kindly taken by Dr. M. K. Subramaniam, based on analyses of water-samples from the Adyar River near the bar. We have taken a number of temperature records on subsequent occasions, which have clearly illustrated the wide range of variation that is likely to occur from place to place, and also the extent of diurnal variations.

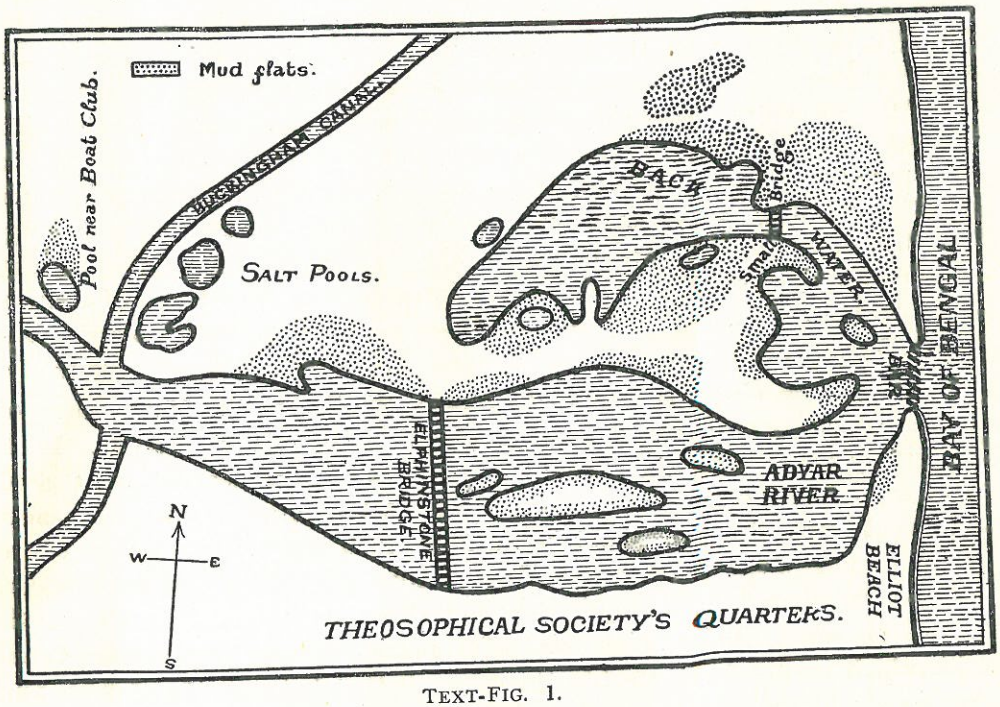
The species have been worked out by us, and in many cases the identifications have been checked with the help of the collections of the Madras Government Museum. Dr. S. L. Hora has kindly identified for us four species of Gobies ; Dr. H. S. Rao, three Gastropods ; and Dr. F. H. Gravely, one spider. We wish to thank all of them for their valuable help.

Description of the Area.

The brackish-waters of the city of Madras (Lat. 13·4′ ; Long. 80·17′ E.) include the backwater at Adyar, and the mouth of the Adyar River which is in close association with the former. To this may be added those portions of the Cooum River and the Buckingham Canal, which are either in communication with the sea or with the Adyar backwater or river. The present study is mainly based on animals collected from the backwater and the river-mouth where the fauna is fairly rich and characteristic. A number of collections have also been made from the bar where the River Cooum opens into the sea. This account is also applicable to the other brackish-water regions of the Cooum and the Buckingham Canal as the macroscopic fauna of these localities consists only of a few of the resistant species that are observed at Adyar.

The Chingleput or the Adyar River opens into the sea five miles south of Fort St. George. The northern side of the river leads into the backwater which is a shallow sheet of water about one square mile in area, lying between

San Thome and Adyar. On the east, the backwater closely borders the sand bank that separates it from the seashore, while its northern and western portions extend into shallow mud-flats, which are covered by water only during high tide, and are more or less permanently dry during the hot months of the year, March to July. There is no sharp separation between the backwater and the river-mouth proper as the former is something like a bay on the northern bank of the river; from the faunistic



TEXT-FIG. 1.

point of view, the portion of the river from the Elphinstone Bridge up to the bar, nearly a mile in length and about quarter to half a mile in width, along with the backwater forms a typical brackish-water zone. As the river is very shallow lower down the bridge, a few island formations occur in the middle of its course.

The peculiarity of the place is brought about by the fact that the Adyar River is not in communication with the sea throughout the year. As the source of the water-supply for the river is the comparatively low rainfall of the Chingleput District (about 49 inches per annum), it is full only during the North-East Monsoon period (October to December) when there is good flow of fresh water into the sea, and the river-mouth is fairly deep and broad during the flood season. This condition exists only for a

period of about two months. As the strength of the current gradually weakens, tidal effects are markedly felt and the rapid flow of water is very much inhibited. The presence of the backwater is of much significance in that it allows a good admixture of sea water and freshwater. These conditions change with the advent of summer. The river becomes gradually reduced to a languid line of water with practically no flow. By about the end of January, the fringes of the backwater get dried up, leaving some of the mud-flats exposed. The immediate effect is an increased flow of water from the sea into the river and the backwater; but this is soon retarded by the action of breakers, which raise up a sand bank at the mouth of the river on a line with the shore. Thus the connection of the river and the backwater with the sea is intermittent during February; but it is completely cut off by the end of March. The sand bank, or the *bar* as it is called, widens out in latter months, reaching a maximum width of about three-quarters of a furlong. The bar is prominent until the next rainy season when the river-current is again strong enough to force its way into the sea. The times of opening and closing of the bar may be considered as approximately occurring between October and November, and between February and April respectively.

The *Cooum River* is only a tidal creek (similar to the Matla River of Lower Bengal) which has a tortuous course in the city of Madras. It is practically dry during the summer months. At the monsoon time, a good amount of rain water collects in the river. A temporary connection is now established with the sea, about half a mile south of Fort St. George, where the river crosses the Buckingham Canal. Soon after the monsoon, however, a bar is raised, but this is quite low and allows the inflow of small quantities of sea-water during high tide. The portion of the Buckingham Canal with which we are concerned in this paper is that between the Adyar and the Cooum, from the point where it cuts the former near the Adyar Boat Club four miles up the river, to the point where it crosses the Cooum near the Napier Bridge to the south of Fort St. George.

Geologically, the whole locality is built by the sea straggling over a large area of the sandy soil characteristic of the greater part of the Coromandel Coast. The soil of the adjoining areas consists of a mixture of sand and red loam. The nature of the soil is such that in the wet weather, many temporary pools of water are formed; this is enhanced by the presence of tidal creeks like the Cooum. In the formation of the backwater, the sand-laden current of the coast coming from the south and grazing the shore in a northerly direction towards the head of the Bay of Bengal, must have played a prominent part since it has caused the sea to recede, and has directed the water and silt of the sluggish river in the direction of the

backwater. A number of marine and estuarine shells in a sub-fossil or fossil state have been recorded from the Adyar locality by Oldham (1893).

The bottom of the river as well as of the backwater is of a muddy consistency, but the sandy element in the soil becomes pronounced as we approach the sea. Excepting on the eastern border, the whole of the backwater-edge is muddy, composed of thick brown mud mixed with black clay, the latter predominating in its northern sides where the bed is almost completely composed of fine, loose clay. In the river-bed, the clay is less marked, but the soil is composed of sand and mud mixed in more or less equal proportions. The boulders of the Elphinstone Bridge and the small bridge near the Adyar Cemetery, and the stony embankment near the Theosophical Society's Quarters on the southern bank of the river are the only hard substrata in this brackish-water tract, giving shelter to typical rock-dwelling species.

The Depth.—The chief difference between the river and the backwater lies in their respective depths. Nowhere in the backwater is the maximum depth more than 4 feet during low tide, except during floods. Two distinct zones may be observed in the backwater: *a middle zone* that never dries up even in the hottest months and extends from the bar up to the small bridge in a curve; and *a marginal zone* on the fringes of the former, consisting of mud-flats, which are completely submerged only during monsoon times and are normally left exposed during low tide. The relative depths of the two zones are such that when the marginal zone is just exposed, the water in the middle zone will be two to four feet deep. In contrast with the backwater, the river is considerably deeper; even during the dry weather, a channel, nearly six feet deep, is noticeable near its southern bank up to about a mile from the sea. This extends right up the river and is navigable for small country crafts. A similar deep channel is seen on the northern bank almost up to the bridge but beyond this up to the Boat Club the river merges into a series of mud-flats and small pools of brackish-water. These pools are brackish although many of them have no direct communication with the river. Their brackish nature is the result of percolation of water through the raised banks. One such pool near the Boat Club is fairly big and will be specially referred to later. Higher up the river, the pools contain only fresh water and are inhabited mainly by freshwater organisms.

The Tides.—The tides are felt only in the months during which the bar is open; their influence is felt up to a distance of about three to four miles up the river. The maximum tidal effect is a little after the monsoon, from about January to the end of February, when the river-current is feeble.

The maximum tidal range is about three feet. As has been mentioned above, the initial drying up of the backwater during the early summer months is followed by an increased flow of water from the sea into the river and backwater until a bar is formed.

The Vegetation.—The vegetation is rather poor in the river as may be expected from the depth and the flow of water; but the backwater is in sharp contrast with this, its shallow stagnant situation being particularly suited to the luxuriant growth of algæ. Numerous forms of algæ inhabit the middle zone of the backwater; chief among them are *Enteromorpha* and *Chætomorpha*. Algal beds are best developed during the summer months of the year when they occur almost everywhere and give shelter to numerous organisms. The bottom of the middle zone of the backwater and the shallow portions of the river is closely covered with *Potamogetons* while marsh plants like *Avicennia* and *Sueda* are quite common in the mud-flats and the islands in the river. As we proceed higher up, freshwater forms like *Spirogyra*, *Ceratophyllum* and others may be found in large numbers.

The Environment.

The salinity, temperature, pH, chlorine and excess base values are given in the accompanying table, from a set of readings taken in 1933. These readings refer to the conditions near the bar. As may be expected from the nature of the locality, the salinity of the water in the backwater and the river is liable to great variation, being not only different in different times of the year, but also varying in different places at the same time. The salinity is highest from January to March when the rains have practically ceased but the bar remains open—a period during which the maximum

TABLE I.

Hydrographical Readings: Averages for 1933.
Adyar River Water, near Bar.

	Bar open					Bar closed				
Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.
Temperature: 26·6 ..	25·4	25·0	26·2	27·7	28·2	29·6	28·8	28·5	28·5	28·2
pH	8·50	8·48	8·55	8·46	8·46	8·65	9·07	9·15	8·82	8·70
Excess Base ..	30·15	20·73	23·20	17·59	25·16	24·90	24·52	25·35	23·50	23·30
Salinity ..	25·10	28·17	30·44	29·92	17·29	19·74	16·91	17·19	18·30	19·38
Chlorine ..	13·84	15·59	16·85	16·56	9·56	10·92	9·35	9·51	10·12	10·72

flow of sea-water into the backwater takes place. At the bar the salinity of the water was 28·17 ; 30·44 ; and 29·92 per mille in the months of January, February and March respectively. The corresponding figures for April, May and June were 17·29 ; 19·74 ; and 16·91 respectively. The greatest variations in salinity occur when the bar is closed since the occasional showers during June–July bring down considerable quantities of freshwater, effecting a notable reduction in salinity. On the other hand, intense heat of the summer results in an increase in salinity of the backwater, especially of the pools in the marginal zone, since the volume of water is very much lowered owing to drought.

In the absence of any large river opening into the sea in the vicinity of the city of Madras, the salinity of the coastal waters here is much higher than the records for the upper limits of the Bay of Bengal. According to Sewell's charts, the maxima and minima are 34·50 (June–August) and 32·00 (September–November) per mille respectively (Sewell, 1929). This is in sharp contrast to what occurs at the head of the Bay, where the surface salinity may be so low as 21·00 per mille, owing to the large volume of freshwater brought down by the Ganges and the Brahmaputra. The change from marine to brackish-water conditions is gradual in the Gangetic Delta, while it is rather abrupt at Adyar.

Temperature.—The maximum and minimum records of temperature of the water are 33·80 and 25·00 degrees Centigrade respectively. The temperature is the lowest during the rainy season when the bar is open, and is highest during the summer months May and June. From January to March, the temperature of the water is slightly higher than that of the air, while in the succeeding months of April, May and June it is below the air temperature. As in the case of salinity, the temperature is also subject to a great amount of fluctuation. In the backwater, there is often difference between the readings for the middle and marginal zones, and the surrounding pools. The deeper central zone has a more uniform temperature than the other regions. The exposed mud-flats with numerous pools show the greatest amount of variation as they are quickly heated up by sunlight. The following readings of surface temperature taken at 12 Noon on a bright sunny day in the month of October (1–10–1934) are illustrative :—

Temperature of the sea-water ..	.. 27°·70 C.
Temperature of the water at bar..	.. 28°·00 C.
Middle zone ..	.. 29°·20 C.
Marginal zone ..	.. 32°·00 C.
Temperature of an isolated pool..	.. 33°·80 C.

The maximum difference noted between morning (8 A.M.) and afternoon (2–3 P.M.) temperatures is 3·5° during the month of June.

The pH values normally vary between 8 and 9. As will be seen from the table, the highest values are observed during the months June and July.

List of Animals Collected from the Brackish-waters of Madras.

The following list does not include the Protozoa and the Rotifera since we have not made any special study of them. Only the commonest species of the Copepods obtained are listed. The other groups are fairly exhaustive. Those species which have been recorded by other authors, but which we have not been able to obtain, are mentioned separately. The latest nomenclature has been followed as far as possible.

Phylum Porifera.

Spongilla sp.

Phylum Cœlenterata.

Class *Hydrozoa.*

Dicyclocoryne filamentata (Annandale). Medusæ only.
Campanulina ceylonensis (Browne). Medusæ only.
(*Phortis ceylonensis* of certain authors.)
Campanularia (*Clytia*) *noliformis* McCrady. Hydroid only.
Laomedea (*Obelia*) *spinulosa* Bale. Hydroid only.

Class *Scyphozoa.*

Acromitus flagellatus (Hæckel). The species is probably the same as *A. rabanchatu* Annandale (*vide* Rao, H. S., 1931).

Class *Anthozoa.*

Order *Actiniaria.*

Sub-tribe *Athenaria.*

Phytocætes gangeticus Annandale.
Phytocæteopsis ramunnii Panikkar.
Stephensonactis ornata Panikkar.
Pelocætes exul Annandale.

Sub-tribe *Boloceroidaria.*

Boloceractis gopalai Panikkar.
Bunodeopsis sp. (not *B. strumosa*).

Sub-tribe *Acontiaria.*

Aiptasiomorpha sp.

Phylum Platyhelminthes.

Order *Acœla.*

Convoluta sp. ?

Phylum Nemertea.

Order *Heteronemertini.*

A species belonging to this order is common in the pools of brackish-water all through the year.

Phylum Nemathelminthes.

Class *Nematoda.*

Family *Oncholaimidæ.*

Oncholaimus sp. Common free living Nematode. The species is different from *O. indicus* and *O. chilkænsis.*

Phylum Annelida.

Order *Polychæta.*

Family *Hesionidæ.*

Ancistrosyllis constricta Southern.

Family *Nereidæ.*

Lycastis indica Southern.

Nereis glandicincta Southern.

Nereis chilkænsis Southern.

Family *Eunicidæ.*

Diopatra variabilis Southern. (Fauvel, 1932, considers the species as being synonymous with *D. neapolitana.*

Marphysa gravelyi Southern.

Lumbriconereis polydesma Southern.

Lumbriconereis sp.

Family *Nephthydidæ.*

Nephthys polybranchia Southern.

Family *Ariciidæ.*

Scoloplos sp.

Scolecolepis sp. Probably *S. indica* Fauvel.

Family *Spionidæ.*

Polydora ciliata Johnston.

Polydora kempi Southern.

Prionospio cirrifera Wiren.

Family *Capitellidæ.*

Heteromastus similis Southern.

Capitella sp.

Family *Sabellidæ.*

Laonome indica Southern.

Potamilla leptochæta Southern.

Family *Serpulidæ.*

Hydroides norvegica Gunnerus.

Order *Oligochæta*.
Family *Megascolecidæ*.
Pontodrilus bermudensis Beddard.

Phylum Polyzoa.

Order *Ctenostomata*.
Family *Vesicularidæ*.
Bowerbankia caudata Hincks.

Phylum Arthropoda.

Class *Crustacea*.
Order *Copepoda*.
Only the commonest species are noted.
Acartia southwelli Sewell.
Pseudodiaptomus annandalei Sewell.
Order *Cirripedia*.
Division *Operculata*. Family *Balanidæ*.
Balanus amphitrite Darwin.
Order *Schizopoda*.
Mysidacea. Family *Mysidæ*.
Rhopalophthalmus egregius Hansen.
Mesopodopsis orientalis (Tattersal).
Order *Amphipoda*.
Amphipoda Genuina. Gammarina.
Grandidierella megnea (Giles).
Grandidierella gilesi Chilton.
Paracalliope fluviatilis (G. M. Thomson).
Order *Tanaidacea*.
Apseudes sp. not *A. chilkæensis*.
Order *Isopoda*.
Isopoda Genuina.
Family *Cirolanidæ*.
Cirolana sp. probably *C. pleonastica* Stebbing.
Family *Sphæromidæ*.
Sphæroma vastator Spence Bate. (*S. terebrans* of certain authors.)
Family *Cymothoidæ*.
Cymothoa indica Schiodte and Meinert. The species is parasitic in the mouth and gill chambers of *Etroplus maculatus*, *E. suratensis* and *Glossogobius giuris* (Panikkar and Aiyar, 1937).
Family *Ligiidæ*.
Ligia exotica Roux.
Order *Decapoda*.

Decapoda Natantia.

Tribe Caridea.

Family *Palæmonidæ.*

Periclimenes indica Kemp.

Periclimenes demani Kemp.

Leander sp.

Palæmonetes hornelli Kemp.

Palæmon lamarrei Milne-Edwards.

Family *Alpheidæ.*

Alpheus malabaricus Fabricius.

Alpheus paludicola Kemp.

Alpheus sp. *A. rapax* ?

Tribe *Penæidea.*

Family *Penæidæ.*

Penæus carinatus Dana.

Penæus indicus Milne-Edwards.

Penæopsis monoceros (Fabricius).

Decapoda Reptantia.

Tribe *Oxystomata.*

Family *Calappidæ.*

Matuta victor (Fabricius).

Tribe *Brachygnatha.*

Family *Ocypodidæ.*

Ocypoda cordimana Desmarest.

Ocypoda macrocera Milne-Edwards.

Uca (*Gelasimus*) *annulipes* (Latreille).

Uca (*Gelasimus*) *triangularis* (A. Milne-Edwards). The species is recorded by Henderson. We have not obtained it so far.

Metaplax distincta (Milne-Edwards).

Family *Grapsidæ.*

Varuna litterata (Fabricius).

Sesarma tetragonum (Fabricius).

Sesarma quadratum (Fabricius).

Grapsus maculatus Catesby (Syn. *G. grapsus.*)

Metasesarma rousseauxii H. Milne-Edwards.

Family *Portunidæ.*

Scylla serrata (Forskal).

Neptunus pelagicus (Linnæus).

Neptunus sanguinolentus (Herbst).

Tribe *Paguridea.*
Family *Paguridæ.*
Clibanarius olivaceous Henderson.
Clibanarius padavensis De Man.
Diogenes sp. *D. avarus* ?

Phylum Mollusca.

Class *Lamellibranchiata.*
Family *Ostreidæ.*
Ostrea arakanensis Sowerby. The species is synonymous with *O. madrasensis* and *O. virginica* of Preston and other authors (*vide* Winckworth, 1931).
Family *Mytilidæ.*
Modiolus striatula Hanley.
Modiolus undulatus (Dunker).
Family *Arcidæ.*
Arca granosa (Linnæus).
Family *Veneridæ.*
Meretrix casta Chemnitz.
Family *Cuspidariidæ.*
Cuspidaria cochinensis Preston.
Class *Gastropoda.*
Family *Hydrobiidæ.*
Stenothyra blanfordiana Nevill.
Amnicola (*Alocinma*) *stenothyroides* Dohrn.
Family *Cerithiidæ.*
Potamides cingulatus (Gmelin).
Melania tuberculatus (Muller).
Family *Nassidæ.*
Pygmæonassa orissænsis (Preston).
Family *Aplysiidæ.*
Aplysia sp.
Family *Hermæidæ.*
Stiliger gopalai Rao.

Phylum Chordata.

Class *Pisces.*
Order *Teleostei.*
Sub-Order *Malacopterygii.*
Family *Elopsidæ.*
Elops indicus Swainson.
Megalops cyprinoides (Broussonet).

Sclerodermi.

Family *Triacanthidæ.*

Triacanthus brevirostris Temm. and Schleg.

Gymnodontes.

Family *Tetrodontidæ.*

Tetrodon patoca Hamilton Buchanan.

Tetrodon inermis Temm. and Schleg.

Class *Reptilia.*

Order *Ophidia.*

Natrix piscator (Schneider).

Cerberus rhynchops (Schneider).

Regional Distribution and Range of Fauna.

Apart from the regional survey of the fauna of Adyar that follows, the range of distribution of many of the species may be indicated here, especially of those that show great restriction or variation in occurrence. Species that have a wide range of distribution from the bar (even seashore in some instances) up to the inner reaches of the river and the backwater where the water is almost fresh during low tide are :—

Acromitus flagellatus.
Lycastis indica.
Heteromastus similis.
Capitella sp.
Modiolus striatula.
Scylla serrata.
Mesopodopsis orientalis.
Tetrodon patoca.

These species have been obtained from collections made from the river near the Teachers' College and the Engineering College. *Acromitus flagellatus* has been observed only during high tide ; probably it comes in with the rising tide and retreats with the tidal flow, without having the necessity to remain in freshwater. Others have been collected irrespective of tidal influence ; *Scylla serrata, Mesopodopsis orientalis, Lycastis indica* and the Capitellids can remain in water that is nearly fresh. Large numbers of young ones of Tetrodons and colonies of Modiola were collected from about two furlongs east of the Saidapet Bridge, the latter in clusters of hundreds from the stony banks of the stream. This was in the month of January, 1935, an abnormal year as the rainfall was rather scanty ; and the bar was about to close even though the rainy season was only just over. Only Modiolas, Mesopodopsis and the Capitellids appear to be able to breed

here in the uppermost reaches of the brackish-water zone among the animals listed previously.

Coming down the river for about a mile and a half from the above locality where the water is almost fresh, the marine element in the fauna becomes more marked; and near the Adyar Boat Club the conditions probably range from oligohaline to mesohaline environments. The fauna is not rich in the river proper, but the adjoining pools that occur on either side harbour a rich fauna. The organisms found in these pools will be considered separately. The 'marine' species that are common in this zone of the river are :—

Phytocœtes gangeticus.
Lycastis indica.
Lumbriconereis polydesma.
Lumbriconereis sp.
Marphysa gravelyi.
Penæopsis monoceros.
Grandidierella megnæ.

The typical brackish-water tract that harbours a rich fauna commences from about half a mile lower down, and consists of that part of the river near the Elphinstone Bridge and the backwater. The animals that are found quite close to the bar include only true marine species and are obviously forms that cannot survive great decrease in the salinity of the environment.

One usually finds the following animals at or near the bar :—

Glycera sp.
Ocypoda cordimana.
Ocypoda macrocera.
Matuta victor.
Neptunus sanguinolentus.
Neptunus pelagicus.
Apylsia sp.
Platycephalus insidiator.

Clibanarius padavensis is also found but its occurrence in this region is not due to its lack of adaptational power to less saline environments, but only to a preference to a sandy bottom. The invertebrate animals that are common in the seashore just opposite the mouth of the river and the vicinity are :—

Cavernularia malabarica.
Sphenopus marsupialis.

Onuphis eremita.
Glycera sp.
Donax sp.
Leiodomus vittatus.
Littorina sp.
Olivia gibbosa.
Albunea semnista.
Emerita (Hippa) asiatica.
Philyra scabriscula.
Ocypoda platytarsis.
Ocypoda macrocera.

Excepting *Ocypoda macrocera*, none of these species has invaded the brackish-water.

The distribution of many of the species is considerably influenced by the nature of the substratum. Species like *Potamides cingulatus, Phytocætes gangeticus, Phytocœteopsis ramunnii, Stephensonactis ornata, Scylla serrata, Uca annulipes, Sesarma quadratum, Sesarma tetragonum* and a few others are not found in completely sandy areas. They show a definite preference to localities where the bottom consists of sand and mud mixed more or less in equal proportions. However, *Sesarma tetragonum, S. quadratum* and *Uca annulipes* are more frequently found in wet mud-banks that are not submerged as all of them are of almost terrestrial habits. The majority of Polychætes are also found in shallow localities of a mixture of sand and mud. *Neptunus pelagicus, N. sanguinolentus, Matuta victor, Clibanarius padavensis, Ocypoda cordimana, O. macrocera* and *Platycephalus insidiator* are species almost invariably restricted to sandy regions. The south-western fringe of the backwater is characterised by soft black clay that emits hydrogen sulphide and the fauna here is rather sparse. There are practically no animals where the clay is thick, but in other regions where the sub-stratum is loose *Lumbriconereis* sp., *Marphysa gravelyi* and *Prionospio cirrifera* are often common among the Polychætes, and *Stenothyra blanfordiana* and *Pygmæonassa orissænsis* among the Molluscs. The Buckingham Canal, the Cooum, and the brackish-water ditches adjoining them have a poor macroscopic fauna as the water in them is much polluted. The animals that are collected usually from these localities are *Sesarma quadratum* and *Lycastis indica* near the water edge ; *Marphysa gravelyi, Melanoides tuberculatus* and *Lumbriconereis* sp. in the mud. Small ditches of water near the Cooum bar harbour large numbers of *Potamides cingulatus. Metasesarma rousseauxii* is often found crawling amidst the stones near the Napier Bridge.

Bionomical Classification of the Fauna.

The backwater and the river may be divided according to the environmental conditions and the habits of the different species into the following groups.

I. Fauna of the Algal Beds.—The backwater and the adjoining pools harbour a rich algal flora consisting of species of *Enteromorpha, Chætomorpha, Gracillaria* and other forms, while the bottom is often covered with dense growths of *Potamogeton* sp. The number of animals inhabiting the algæ and the leaves of Potamogetons is very great and they are here collectively designated as the algal-bed fauna. As the maximum algal growth is during the summer when the bar is closed and the water still, the animals inhabiting the algæ have corresponding maxima periods in summer. The following forms have usually been obtained from the algal beds : —

Boloceractis gopalai.
Bunedeopsis sp.
Planarian (*Convoluta* sp.?)
Oncholaimus sp.
Bowerbankia caudata.
Nereis glandicincta.
Modiolus undulatus.
Stenothyra blanfordiana.
Amnicola (*Alocinma*) *stenothyroides.*
Cuspidaria cochinensis.
Stiliger gopalai.
Grandidierella megnæ.
Grandidierella gilesi.
Paracalliope fluviatilis.

Of these the species of Amphipods are obtained in large numbers all through the year. The Molluscs are usually common only during the summer and a few succeeding months. The *Planarian* has been noted only in the month of August, and that for a short period. None of the other species shows any particular dominance during other periods. The algæ amongst which the animals live form the food for many of them.

II. Fauna of Rocky Substrata.—The animals grouped under this head include (1) attached forms like *Balanus* and *Laomedea* which are found on the boulders of bridges, stones on the banks, etc. ; (2) species that occur in water where the bottom is stony ; and (3) forms that live on stones on the water-edge and are aquatic, amphibious or terrestrial. The following are the common species ;—

Spongilla sp.
Campanularia noliformis.
Laomedea spinulosa.
Aiptasiomorpha sp.
Nereis chilkænsis.
Ancistrosyllis constricta.
Hydroides norvegica.
Modiolus striatula.
Ostrea arakanensis.
Balanus amphitrite.
Sesarma quadratum.
Clibanarius olivaceous.
Grapsus maculatus.
Ligia exotica.
Cirolana sp.

Of these the Sabellid and Hydroids are common only when the bar is open. Goboid fishes like *Acentrogobius viridipunctatus, Ctenogobius meggitti* and *Glossogobius giuris,* and the Ciclid fish *Etroplus maculatus* and *E. suratensis* are often collected from localities with a stony bottom. Their eggs are found attached to the stones, empty shells, etc. The snake *Natrix piscator* is fairly common on the southern banks of the river.

III. The Free-Swimming Fauna.—The following animals constitute the free-swimming element of the fauna :—

Dicyclocoryne filamentata. (Medusæ)
Campanulina ceylonensis. (,,)
Acromitus flagellatus.
Mesopodopsis orientalis.
Rhopalophthalmus egregius.
Periclimenes indica.
Periclimenes demani.
Leander sps.
Palæmon lamarrei.
Penæus carinatus.
Penæus indicus.
Penæopsis monoceros.
Copepods.
Fish.

IV. Fauna of the Marginal Zone.—The animals that inhabit the marginal zone of the backwater include numerous species ; the majority of them are inter-tidal forms found in the mud-flats or the water edge. Most

of the species are either amphibious or terrestrial, or the species are capable of surviving temporary exposure to air. They are highly resistant and are endowed with great powers of adaptability. The following species may be noted :—

Phytocœtes gangeticus.
Clibanarius olivaceous.
Clibanarius padavensis.
Sesarma quadratum.
Sesarma tetragonum.
Metasesarma rousseauxii.
Metaplax distincta.
Varuna litterata.
Uca annulipes.
Stenothyra blanfordiana.
Amnicola stenothyroides.
Potamides cingulatus.
Periophthalmus pearsei.
Periophthalmus kœlreutri.
Boleophthalmus boddœrti.

The species of *Clibanarius, Sesarma quadratum, Uca annulipes, Potamides cingulatus,* the Hydrobiid Molluscs, and *Boleophthalmus boddœrti* are the commonest species found near the edges of the Adyar backwaters, especially when the mud-flats are exposed. The marginal species found near the mouth of the Cooum are *Potamides cingulatus, Melania tuberculatus, Metasesarma rousseauxii, Ocypoda cordimana, Sesarma quadratum* and *Uca annulipes.*

V. Fauna of the Middle Zone.—Passing on to the middle zone of the backwater, the following species are commonly met with :—

Pelocœtes exul.
Marphysa gravelyi.
Diopatra variabilis.
Lumbriconereis sp.
Heteromastus sp.
Meretrix casta.
Pygmæonassa orissœnsis.
Matuta victor.
Scylla serrata.

In addition, most of the free swimming species of Crustaceans, and fishes are also obtained from the middle zone. The anemones *Phytocœteopsis ramunnii, Stephensonactis ornata* and *Phytocœtes gangeticus* are found between

the marginal and middle zones of the backwater. The last mentioned species has also been obtained from exposed mud-flats with very little water.

VI. The Mud-Burrowing Fauna.—Most of the species listed above under the fauna of the marginal and middle zones are either mud-burrowing in habits or are capable of temporarily remaining in the mud. The following species are typical burrowers :—

(*a*) Under water—

Phytocœtes gangeticus.
Phytocœteopsis ramunnii.
Stephensonactis ornata.
Pelocœtes exul.
Marphysa gravelyi.
Diopatra variabilis (also tube-dwelling).
Lumbriconereis sp.
Prionospio sp.
Capitella sp.
Heteromastus sp.

(*b*) Outside water—

Sesarma quadratum.
Sesarma tetragonum.
Metasesarma rousseauxii.
Varuna litterata.
Uca annulipes.
Ocypoda cordimana.
Ocypoda macrocera.
Pontodrilus bermudensis.

Species that can temporarily remain under the mud in the water for varying periods are :—

Apseudes sp.
Meretrix casta.
Scylla serrata.
Alpheus malabaricus.
Alpheus paludicola.
Penæus indicus (Young ones).
Penæus carinatus (Young ones).
Penæopsis monoceros.
Leander sp.
Periophthalmus pearsei.
Boleophthalmus boddærti.
Platycephalus scaber.

The following species creep about near the water-edge :—

Clibanarius olivaceous.
Clibanarius padavensis.
Potamides cingulatus.
Stenothyra blanfordiana.
Amnicola stenothyroides.

VII. Species Capable of Aerial Respiration.—Many of the animals inhabiting the mud-flats are either amphibious or terrestrial in habits. Though they belong to groups of animals that are primarily aquatic, they are capable of varying degrees of aerial respiration. The crabs and the Goboid fishes are the most remarkable among them as they show a series of adaptations designed for aerial respiration, and some of the Crustaceans are thoroughly terrestrial and can respire only outside water. The following species mostly remain outside water :—

Crustacea—

Grandidierella megnæ.
Grandidierella gilesi.
Paracelliope fluviatilis.
Ligia exotica.
Uca annulipes.
Ocypoda cordimana.
Ocypoda macrocera.
Metaplax distincta.
Metasesarma rousseauxii.
Sesarma quadratum.
Sesarma tetragonum.
Grapsus maculatus.
Varuna litterata.
Clibanarius olivaceous.
Clibanarius padavensis.

Among these species, *Ocypoda cordimana, O. macrocera, Grapsus maculatus,* and *Ligia exotica* are almost completely terrestrial.

Fishes—

Periophthalmus pearsei.
Periophthalmus kœlreutri.
Boleophthalmus boddærti.

Other Invertebrates—

Lycastis indica.
Capitellids.

Potamides cingulatus.
Stenothyra blanfordiana.
Amnicola stenothyroides.

In addition, the following species can survive exposure to air for different periods varying according to the species :—

Phytocœtes gangeticus.
Scylla serrata.
Neptunus sanguinolentus.
Palœmon lamarrei.
Penœopsis monoceros.
Oxyurichthys tentacularis.
Ctenogobius (*Oligolepis* ?) *acutipinnis.*
Platycephalus scaber.

VIII. Fauna of Isolated Brackish-water Pools.—The pools of brackish-water in association with the backwater and the river are of three kinds ; they are :—(1) Small pools on the fringes of the backwater, harbouring a rich algal flora during the summer, and at other times having the same environmental conditions as the backwater ; (2) Salt pools that occur on either side of the river up to an extent of about three miles from the river mouth ; and (3) Pools in which the water is only very slightly brackish or completely fresh, occurring higher up the river and containing freshwater organisms in addition to a few brackish-water species that enjoy a wide range of distribution (compare above).

The first type of pools contains the following species, excluding the alga-inhabiting forms which have been given separately.

Phytocœtes gangeticus.
Phytocœteopsis ramunnii.
Campanulina ceylonensis.
Clibanarius olivaceous.
Paracalliope fluviatilis.
Grandidierella megnæ.
Potamides cingulatus.

The temperature fluctuations are rather high in these pools as has already been pointed out.

The pools belonging to the second category are numerous, but a large and typical one is that found near the Adyar Boat Club, the fauna of which during the different seasons was studied by us in detail. This pool is situated in somewhat marshy soil just adjoining the Adyar River on its west and the Buckingham Canal to the south ; and it is about half a furlong

long. The pool gets filled up by the November rains, but the level of the water gradually falls in the succeeding months. The depth of water is about 2–2½ ft. during November–December period (this is about the maximum depth); but by February, the depth is only a few inches. The pools are almost without water by about March. Owing to percolation of water from the river, the water in the pool remains brackish all through the year and the fauna is what is characteristic of the brackish-water. From November to March, the following species are obtained from these pools :—

Acromitus flagellatus.
Phytocœtes gangeticus.
Lumbriconereis polydesma.
Lumbriconereis sp.
Lycastis indica.
Marphysa gravelyi.
Heteromastus similis.
Prionospio cirrifera ?
Mesopodopsis orientalis.
Periclimenes indica.
Palæmon lamarrei (Stray individuals only).
Paracalliope fluviatilis.
Sesarma quadratum.
Sesarma tetragonum.
Aplocheilus melastigma.
Acentrogobius neilli.
Acentrogobius viridipunctatus.

By April, the conditions of the pool change very much since most of the aquatic species perish with the drought. The interesting point about this pool is that unlike the pools in the mud-flats that completely dry up during the summer, the bottom remains slightly moist even in the hottest months of the year as a result of percolation of water from the river. Contrary to what happens in the mud-flats, the muddy substratum does not become cracked up in the usual manner. During this period, the pool has a certain amount of resemblance to a salt marsh; and as is usual with the salt marsh fauna, typical terrestrial species are met with in large numbers. Numerous insects, among which the one frequently encountered is a Forficulid, and a spider belonging to the genus *Olios* (Family Sparassidæ) and probably to the widely distributed Oriental species *Olios lamarcki* (Latreille), are quite common in the marshy mud until about the month of October, when again the pool gets filled up by the rains, thus giving place to the other set of animals. Since the soil is wet in the middle of the pool even

during the summer, species like *Lumbriconereis* sps., *Phytocætes gangeticus*, and the Capitellids do not actually perish during drought, but remain alive and inactive in the wet mud.

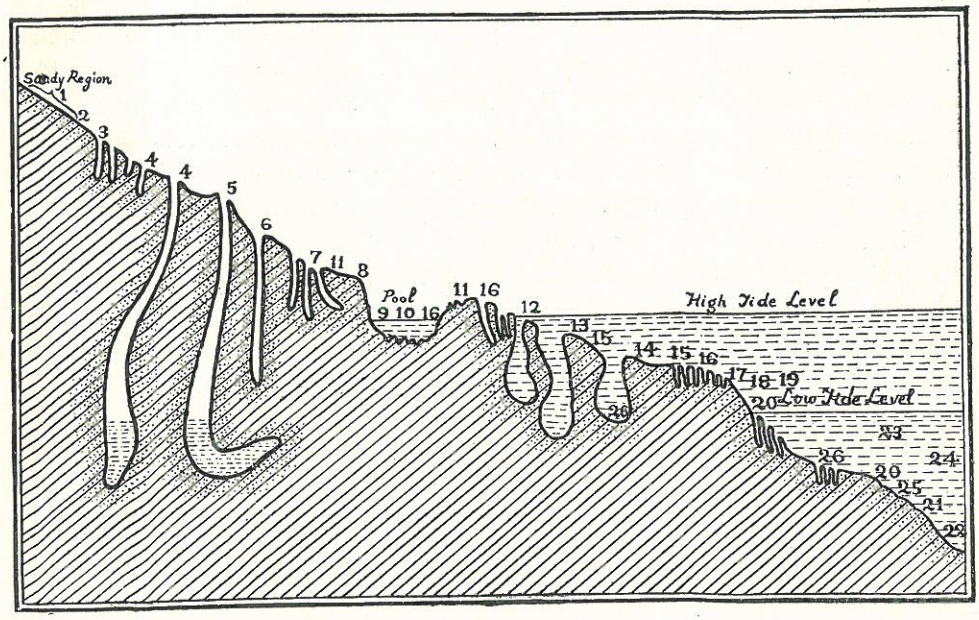
The pools belonging to the third category are much smaller in area and poorer in fauna than those described before. The following species are noted from them :—

Lycastis indica.
Lumbriconereis sp.
Stenothyra blanfordiana.
Amnicola stenothyroides.
Indoplanorbis exustus.
Melania tuberculatus.
Mosquito larvæ (Culex group).
Chironomid larvæ.

In addition to these species, tadpoles and adults of the common frog *Rana cyanophlyctes* Schneider have also been met with in these pools during the rainy weather.

Vertical Distribution of Animals.

I. Inhabitants of the Mud-flats.—The vertical distribution of the inhabitants of the mud-flats is represented in an imaginary section passing



TEXT-FIG. 2.

Copelia. p. 334.

through a mud-flat. The different levels at which the burrowing species occur are indicated in the figure. All the species marked do not occur in any one particular locality. The groups of animals that show a distinct zonation in the inter-tidal zone are the crabs. The Ocypods, *O. cordimana* and *O. macrocera*, are the species that occur farthest from the water-level near the bar ; in other places the corresponding species is *Sesarma tetragonum*, which inhabits deep burrows. The habits of the Ocypods and those of *Sesarma* are by no means similar ; for, while the former mostly remain outside the burrows, retiring into them only for safety, the latter rarely come out. *Gelasimus* (*Uca*) *annulipes* and *Sesarma quadratum* inhabit burrows above water edge. In all the burrowing crabs, the depths of the burrows are such that they run on a line with the low tide level so that there will be a little water in them even during low tide. Among the Polychætes, *Lycastis indica* and the Capitellids are often observed above the water-level. *Clibanarius padavensis*, *C. olivaceous* and *Scylla serrata* are inter-tidal in habits, but the last mentioned is a swimming form and hence cannot be said to have any restricted occurrence.

II. Plankton.—The following notes on the plankton of the Adyar backwaters are based upon a number of collections made between November 1933 and October 1936. An ordinary muslin tow-net was used for making collections, which, on the average, were made once a fortnight. During the August–January period when the planktonic organisms are particularly noticeable, tow-netting was done almost every week during the years 1934 and 1935. On the other hand, the number of collections made during the summer months is rather low ; and often, the tow-net water yielded nothing. Planktonic study not being our main objective, the observations made here are intended only for pointing out some of the more important features of the plankton. We have not paid attention to the study of the Protozoa ; of the Copepods, only the commonest species have been noted. One great difficulty experienced was in tow-netting small pools of brackish-water ; these pools have been eliminated from the study ; but several collections have been made from the large salt pool near the Boat Club. There is not the least doubt that variations take place from year to year in the constituent elements of the plankton in the different months depending upon the changes in the rainy season and their influence on the time of opening and closing of the bar. An approximate idea of the nature of the plankton during the different months may be gathered from the following summary of our records :—

November. Bar just open.
Acromitus flagellatus. Ephyræ. Common.
Campanulina ceylonensis. Rare.
Rhopalophthalmus egregius. Swarms in 1933.
Mesopodopsis orientalis. Swarms.
Penæus carinatus. Post-larval stages. Common.
Penæus indicus. Post-larval stages. Common.
Clupeid larvæ. Common.
Therapon jarbua. Young ones.
Acentrogobius neilli. Larval and Post-larval forms.
Aplocheilus melastigma. Young and adults.

December. Bar open.
Acromitus flagellatus. Ephyræ. Common.
Dicyclocoryne filamentata. Rare.
Penæus carinatus. Post-larval and young ones. Plenty.
Penæus indicus. Post-larval and young ones. Plenty.
Mesopodopsis orientalis. Common.
Peciclimenes indica. Rare.
Cirripede nauplii. (Probably of *Balanus amphitrite.*) Common.
Pseudodiaptomus annandalei. Common.
Ocypode megalopæ (*Ocypoda cordimana* ?).
Therapon jarbua. Young ones.
Therapon quadrilineatus. Young ones.
Clupeid larvæ. (Engraulis and Stolephorus.)
Young mullets.
Aplocheilus melastigma. Post-larval and young ones.

January. Bar open.
Acromitus flagellatus. Young ones. Plenty.
Campanulina ceylonensis. Rare.
Penæus carinatus. Post-larval and young ones. Common.
Penæus indicus. Post-larval and young ones. Common.
Periclimenes indica. Rare.
Pseudodiaptomus annandalei. Common.
Post-larval Goboids. Common.
Aplocheilus melastigma. Young and adult. Common.
Young mullets. Rare.

February. Bar open, but very narrow.
Campanulina ceylonensis. Rare.
Penæus indicus. Young ones. Common.
Penæus carinatus. Young ones. Common.

Young mullets. Rare.
Periclimenes indica. Rare.
Veliger larvæ. Rare.
Mesopodopsis orientalis.

March. Bar almost closed ; but sea-water may get in during high tide.
Aplocheilus melastigma. Young ones. Common.
Acartia southwelli. Common.
Penæids. Young ones. Rare.
Veliger larvæ. Common.

April. Bar closed.
Campanulina ceylonensis. Rare.
Acartia southwelli. Plenty.
Pseudodiaptomus annandalei. Rare.
Veliger larvæ. Common.
Mesopodopsis orientalis. Rare.

May. Bar closed.
Periclimenes indica. Rare.
Pseudodiaptomus annandalei. Rare.
Veliger larvæ. Plenty.

June. Bar closed.
Campanulina ceylonensis. Common.
Veliger larvæ. Common.
Periclimenes demani. Rare.
Periclimenes indica. Common.
Mesopodopsis orientalis. Common.
Palæmonetes hornelli ? Rare.

July. Bar closed.
Campanulina ceylonensis. Common.
Acœlous planarian (*Convoluta* sp.?) Rare.
Acartia southwelli. Common.
Periclimenes indica. Common.
Mesopodopsis orientalis. Common.
Pseudodiaptomus annandalei. Rare.
Leander sp. Young ones. Common.

August. Bar closed.
Campanulina ceylonensis. Common.
Acœlous planarian. Large numbers.
Periclimenes indica. Common.
Mesopodopsis orientalis. Common.
Aplocheilus melastigma. Young ones.
Acentrogobius neilli. Young ones.

September. Bar closed.
Acromitus flagellatus. Ephyræ.
Campanulina ceylonensis. Swarms.
Copepod nauplii. Large numbers.
Pseudodiaptomus annandalei. Common.
Acartia southwelli. Rare.
Acœlous planarian. Rare.
Penæopsis monoceros. Very young ones. Common.
Mesopodopsis orientalis. Common.

October. Bar usually closed, but may open during this month.
Acromitus flagellatus. Ephyræ. Common.
Campanulina ceylonensis. Common.
Copepods. Numerous. (Several species.)
Mesopodopsis orientalis. Common.
Acentrogobius neilli. Young ones. Common.
Acentrogobius viridipunctatus. Young ones. Common.
Periclimenes indica. Rare.
Penæopsis monoceros. Young ones. Common.

General Conclusions on the Fauna.

The list of animals given previously will clearly illustrate the predominantly marine character of the fauna of Adyar and the adjoining brackish-waters of Madras. Of about 92 species of Invertebrates noted, more than eighty species belong to groups of animals that are typically marine. The freshwater species which have more or less acclimatised to the brackish-water conditions are thus comparatively few here ; this constitutes the most important difference between the fauna of an estuarine brackish-water tract and that of a salt marsh. In the latter, the animals which are of typical freshwater habitat, and terrestrial species that have secondarily taken to an aquatic mode of life are quite numerous and show varying degrees of adjustment to saline environments. In the Adyar fauna, the noteworthy groups of freshwater animals which have secondarily taken to brackish-water life are the members of the family Hydrobiidæ among the Mollusca and some of the Palæmondiæ among the Crustacea.

Among the 54 species of fishes, only seven freshwater forms are noted. The others include several casual or seasonal migrants from the sea, while the majority of them are more or less permanent inhabitants of the back-water. The true brackish-water species have been caught when the bar is open and when it is closed ; and in most of them, the young as well as the adult fish have been met with. Marine species like *Stolephorus commersoni,*

Sphyræna jello, Serranus sexfasciatus, Lutjanus sp., *Therapon quadrilineatus, Therapon puta, Upeneus sulphureus, Scatophagus argus, Caranx ciliaris, Pseudorhombus javanicus, P. arsius* and *Triacanthus brevirostris* have been obtained only during the months when the bar is open and the salinity high. The freshwater species are the two Chiclids, *Etroplus maculatus* and *E. suratensis, and Macrones vittatus, Panchax parvus, Aplocheilus melastigma, Barbus sophore* and *Barbus dorsalis.* All of these species breed in brackish-water.

Breeding Habits.

Many species inhabiting the Adyar backwaters are capable of breeding all through the year, but a period of intense reproductive activity is seen in many of the inhabitants. This is determined by the extent to which the environmental conditions are suitable for the breeding of any particular animal. Thus most fish cannot breed when the backwater and the river are partially dried up ; nor can the Gastropods with their densely packed gelatinous egg masses breed under flooded conditions. Ripe sex cells or embryos have been observed in the following animals during all months of the year :—

Pelocœtes exul.
Phytocœtes gangeticus.
Phytocœteopsis ramunnii.
Stephensonactis ornata.
Marphysa gravelyi.
Lycastis indica.
Lumbriconereis sp.
Diopatra variabilis.
Mesopodopsis orientalis.
Grandidierella megnæ.
Grandidierella gilesi.
Paracalliope fluviatilis.
Clibanarius padavensis.
Clibanarius olivaceous.
Potamides cingulatus.
Stenothyra blanfordiana.
Amnicola stenothyroides.
Stiliger gopalai.
Meretrix casta.
Cymothoa indica.
Cirolana sp.
Aplocheilus melastigma.

Panchax parvus.
Etroplus maculatus.
Etroplus suratensis.
Acentrogobius neilli.
Acentrogobius viridipunctatus.

The groups of animals that show great intensity in reproductive activity during particular seasons are the crabs, Molluscs and the fishes. Among the Brachyura, only the Grapsoid and Ocypod crabs breed in the brackish-waters of Madras. Ovigerous females belonging to different species have been collected from December to March. The Pagurids are perennial spawners. Among the Caridea, ovigerous females of *Periclimenes indica* have been obtained only from April to July. Very young ones of *Alpheus malabaricus* are very common in the backwater during January and February, and this species also appears to breed under brackish-water conditions. *Penæus indicus* and *P. carinatus* do not attain sexual maturity in the backwater; but their young ones are noticed in fairly large numbers during the months when the bar is open (compare plankton records).* In contrast with this is another Penæid, *Penæopsis monoceros*, which appears to breed in the brackish-water as judged by the fact that numerous young specimens 15 to 20 mm. long are obtained in tow-net collections taken in September and October, about six months after the bar is closed.

Most of the fish show an intense reproductive activity soon after the monsoon in November. Large numbers of young ones of *Acentrogobius neilli*, *A. viridipunctatus*, *Gobius* sps. and *Mugil* sps. have been obtained in tow-nets during November and December. Along with them are found larval and post-larval stages of Clupeid fish which are brought into the backwater from the sea. Young ones of *Aplocheilus melastigma* are obtained during almost all the months of the year, especially a day or two after any shower. Rains have a remarkable influence over the breeding in most fishes. Species like *Acentrogobius neilli*, *A. viridipunctatus*, *Etroplus maculatus*, *E. suratensis*, *Panchax parvus*, *Aplocheilus melastigma*, etc., spawn intensively even during the summer months if there be occasional heavy rains.

The optimum season for breeding of Molluscs is the summer. During the months March, April, May, June and July, the egg cases of many Gastropods are common in the backwater. Large numbers of young ones of *Potamides cingulatus* and *Meretrix casta* are noticed in July and August. *Stenothyra blanfordiana*, *Amnicola stenothyroides* and *Stiliger gopalai* exhibit

* For habits of brackish-water prawns, *vide* Panikkar, 1937 *b*.

enormous powers of reproduction ; though they breed all through the year, they have periodical phases of intensive propagation determined by the monsoon, salinity and other environmental conditions.

The subject of breeding in the common brackish-water species of Madras is dealt with in detail in another study by us.† The summary of our observations is given below :—

1. Breeding of animals of the brackish-waters of Madras is not particularly confined to any definite part of the year ; actively reproducing species are met with during all seasons.

2. The following types of breeding are noted :—

(*a*) Continuous breeding throughout the year occurring more or less uniformly and irrespective of seasons.

(*b*) Continuous breeding with a marked season of higher activity during one part of the year than the remainder.

(*c*) Breeding season confined to some definite part of the year.

(*d*) Discontinuous breeding occurring all through the year, spawning often taking place irregularly, mostly determined by the rains.

Discussion.

General Considerations.—The interesting feature of the fauna of the brackish-water is the intimate association of animals of the sea, backwater and freshwater for life in a common habitat. The animals of marine origin constitute the largest number of species as most of them are either present in the sea or are represented there by closely related species. The number of marine animals that have invaded the brackish-water is greater in the tropics than in temperate regions. Annandale (1922) mentions that the aquatic fauna of Europe is easily divisible into the freshwater and marine faunas ; and that with the exception of *Palæomonetes varians* in brackish-water in North Europe, and *Mysis relicta* and a few other species of estuarine Molluscs in different parts of Europe, the separation of marine and freshwater faunas is a constant feature. Recent studies of the brackish-water fauna of Europe have shown, however, that this statement of Annandale is not altogether correct. The contributions of Redeke (1933) on the fauna of the Zuider Sea, of Remane (1934) on the Baltic Sea, of Sick (1933) on the brackish ditches of North Germany, and of Brandt, Wundsch (1933), Lundbeck (1932), Sergestale (1934) and others on the different brackish tracts of Europe have shown that a fairly large number of characteristic marine and euryhaline species exist in Europe inhabiting waters of low

† "Observations on Breeding in Brakish-water Animals of Madras." By N. Kesava Panikkar and R. Gopala Aiyar (Unpublished).

salinity. The conditions in England are also more or less similar as shown by the studies of Allen and Todd (1900 and 1902), Percival (1929), Stammer (1928), Ellis (1932), Robson (1925) and Fraser (1932) on the estuarine fauna, of Nicol (1936) on the fauna of the brackish lochs of Scotland, and of Lambert (1930) and Nicol (1935) on the animal life of the salt marshes adjoining sea coasts or estuaries. It is clear from all these papers that a more or less distinct brackish-water fauna is present in the temperate regions as well. It must, however, be admitted that as compared to the tropics, the brackish-water species are fewer in numbers and less in variety in the land-locked seas, estuaries, backwaters and salt marshes of the temperate regions. As pointed out by several observers, the penetration of a large number of marine animals into waters of low salinities is a characteristic feature of the tropics, and the numbers of species inhabiting brackish-water are so many and representative of almost all the major marine invertebrate phyla except the Echinodermata. An interesting fact regarding the tropical brackish-water fauna is the occurrence of numerous adaptations in the mode of life of animals of marine origin, which serve to facilitate their life in these peculiar environs.

Acclimatisation of Marine Animals to Fresh and Brackish-Waters.—It is almost universally accepted that the present freshwater fauna has been derived to a large extent from ancient marine animals. Many of them have penetrated into freshwater through media of progressively decreasing salinity as found at the meeting places of large volumes of freshwater and sea water like the openings of big rivers or backwaters. Most of the modern brackish-water organisms are forms that migrated from the sea into the brackish-water at a very recent geological epoch ; often, we find along with them, numerous marine species capable of surviving in the brackish-water. We find in every tropical backwater, tidal creek, or estuary, an active and aggressive attempt on the part of many marine species to secure a permanent foot-hold either in the semi-aquatic mud-flats and mangrove swamps or in the salt marshes with peculiar environmental conditions of fluctuating salinity, temperature and hydrogen-ion concentration. Many explanations have been suggested to explain this peculiar phenomenon of the tropics ; but as pointed out by Annandale (1922) the factors contributing to this must necessarily be varied, and it is perhaps necessary to study the known instances individually before any definite view is taken. The conditions necessary for the successful colonisation of the brackish-water are many and may now be considered.

Sollas (1883 and 1905) in his classical discussion on the origin of freshwater faunas, emphasized the current strength of rivers as the chief obstacle

to the progress of marine animals into freshwater. He pointed out that an animal must either be fixed or strong enough to withstand the current of streams if it should establish itself in fresh-water. This must be true of the larvæ as well as the adults, the epiplanktonic ciliated larvæ of marine Invertebrates being extremely unsuitable for life in a flowing stream. Hence, only those animals as have got rid of the free-swimming larval stages, by an abbreviation of the life-history, were successful in establishing in the freshwater. The absence of free eggs and larvæ from the freshwater plankton is explained by this theory, and the larger sizes of eggs of freshwater animals as compared with their marine relatives is also explained as an attempt at further acquisition of yolk to cope with the curtailment of life-history. While explaining some of the important differences between freshwater and marine animal life, this theory does not explain the difference between the temperate and tropical conditions. This was attempted much earlier by von Martens (1858) who emphasized that the freshwater environment with its alternative liability to periods of freezing and desiccation, is more severe than that of the sea. The difference between the cold and hot seasons is very great in the cold countries, while a more even temperature conditions prevail in the tropics ; hence acclimatisation was easier here than in the cold countries where extreme temperature conditions prevail. In addition to these two explanations, Needham (1930) made the interesting suggestion that there is a third factor limiting the penetration of marine animals into freshwater, *viz.*, that of the inorganic deficiency of the freshwater from the point of view of the larval development of marine animals. Based on the experiments of Pouchet and Chabry (1889), Herbst (1897), Rapkine (1927), Ranzi (1930) and his observations on the phosphate contents of developing eggs, he pointed out that the developing planktonic larvæ of marine Invertebrates depend upon the inorganic contents of sea-water for certain items of nutriment. Proper development and metamorphosis would be impossible without the supply of calcium, phosphates, etc., inorganic materials not available in freshwater. Penetration into freshwater is possible only for those marine animals that have so perfected their development as to be independent of the environment for their inorganic requirements.

The three theories summarised above overlooked another important aspect of the problem—the question of osmotic regulation of marine animals on which attention has been focussed in recent years by the work of Schleiper (1929, 1929 *a*, 1930 and 1935), Dakin (1908, 1908 *a*, 1931 and 1935), Schwabe (1933), Adolph (1925, 1926 and 1930), and others. The most important physiological difference between freshwater and marine organisms is that in the osmotic pressure relative to the external medium. The body fluids

of marine invertebrates have almost the same osmotic pressure as that of the sea-water in which those animals live (Schleiper, 1930); in many instances, this pressure is slightly higher than that of the surrounding medium as shown by recent investigations (Dakin, 1935). These animals allow a free interchange of body fluids with the sea-water, and changes in salinity of the external medium hence affect the osmotic concentration of the body fluids. All freshwater and numerous brackish-water animals, as also the marine fishes, have developed a power of regulation of osmotic pressure that keeps their body fluids in a permanent state of hypertonicity irrespective of the low concentration of the medium that bathes the animal. When the salt content of the environment is lowered, the higher osmotic pressure of the body fluids of marine invertebrates is not maintained owing to the passage of water into the interior and loss of salts by diffusion. This would go on until a state of isotonicity is reached, a condition in which the animal may not survive unless a greater concentration of the body fluid is maintained by some regulating mechanism. Thus the colonisation of brackish-water and freshwater is made possible only with the development of osmoregulatory powers as poikilosmoticity would be fatal in hypotonic media.

Exact data are not yet available regarding the energy requirements for the maintenance of osmoregulatory powers in aquatic animals. In several cases, however, there is a relationship between the salt content of the external medium and the oxygen consumption. As shown by Schleiper (1931), Beadle (1931), Lowenstein (1935) and others, there is a rise in the amount of oxygen consumed when marine animals are transferred to media of lower concentrations; the rise gradually goes on until it reaches a maximum and then remains constant at a level above the normal. The deleterious effects of oxygen tension combined with reduction in salinity of the environment have been clearly demonstrated by Schwabe (1933) for the crab *Carcinus mœnas*. This increase in oxygen requirements has a great bearing on the problem of survival in the brackish-water. Integumental regulation plays an important rôle in the maintenance of the steady state. Pantin (1931) has observed that the presence of calcium in the water is of considerable advantage to the estuarine Platyhelminth *Gunda ulvæ* in overcoming the adverse effects of salinity fluctuations. All these point to the conclusion that the factors involved in the entry of marine animals into brackish-water and freshwater are many and cannot easily be reduced to any single theory.

In the light of what has been said above, the relative advantage of the tropics for the inward migration of marine organisms may be explained a

being due to various reasons. We consider that the temperature factor is of the greatest importance, for, in addition to the relative evenness as suggested by von Martens, the differences between the air, freshwater and ocean temperatures are comparatively small in the tropics. Not only was this advantageous in the successful colonisation of brackish and freshwater, but also in the assumption of amphibious and terrestrial modes of life by several littoral marine animals (*cf.* Pearse, 1929 and 1936). The greater rainfall of the tropics and the presence of large rivers bringing down an immense amount of fresh water into the sea, have considerably altered the coastal salinities of the tropics and this has endowed the tropical marine animals with great powers of adjustment as they are under the constant influence of salinity fluctuations. Sewell (1934) shows that this lowering of salinity at the head of the Bay of Bengal where the Ganges and Brahmaputra open, affects even up to a depth of about fifty fathoms. The great change in the coastal salinity as a consequence of the monsoon in the coasts of Indo-China is also mentioned by Pearse (1932 *a*). The effects of this prolonged acclimatisation of marine animals to frequent changes in salinity would be a gradual change in their physiology from stenohalinism to euryhalinism, and from poikilosmoticity to varying grades of homoiosmotic behaviour, depending upon the species concerned and the exact conditions of the environment. Only those species of marine invertebrates which have thus responded to the influence of the environment by a gradual assumption of independence over the osmotic concentration of the environment have succeeded in colonising brackish-waters. The inorganic materials washed down into the sea by the intense rainfall and the numerous large rivers, support a rich Diatom flora which increases the food resources of the coasts and thereby attract numerous marine animals (Sewell, 1934). From the description of the area on which this study is based, it will be clear that the coastal salinity is not lowered to any appreciable extent, there being no large river in the vicinity of the city of Madras, and the rainfall being comparatively poor. The conditions here would seem to favour the temperature factor more than anything else, since the brackish-water fauna is as representative and predominantly marine as that of the Gangetic Delta or of the Chilka Lake.

Integumental Adaptations.—The changes attendant upon the migration of marine animals into brackish and fresh waters are many, but from the point of view of their morphology, the important among them are the integumental adaptation and the strengthening of the respiratory system by the development of accessory structures to cope with increased oxygen requirements. Most brackish-water animals have well-developed

mucus secreting devices which effectively guard against sudden changes in salinity by preventing the passage in or out of water for a certain period. Paul Bert (1871 and 1885) made the interesting discovery that eels, which were carelessly handled so that the mucus was completely removed, were no longer able to withstand sudden changes from fresh-water to sea-water and *vice versa* (Dakin, 1935). This has been corroborated by the interesting series of experiments of Duval (1925). The power of mucus secretion is widely prevalent amongst aquatic animals ; but it is especially well developed in euryhaline and brackish-water species. Mucus-cells in the body-wall are remarkably developed in the brackish-water Halcampactids of Adyar, but they are comparatively few and insignificant in a related marine species (Panikkar, 1936, 1937 and 1937 *c*). The Polychætes, *Lycastis indica*, *Diopatra variabilis* and certain others occurring here have also got mucous glands on the body-wall which are remarkably developed, while there is not a single Gastropod of Adyar that is not capable of copious mucus secretion. Many species remain enveloped in mucus whenever environmental conditions are adverse, similar to what Duerden (1906) observed in certain corals. The prominence and wide-spread occurrence of such external secretory structures in brackish-water species, and the way they are brought into action when animals are transferred to media of varying salinities, would indicate that they are of great advantage to these animals. In the case of species that are under the constant danger of being left exposed for fairly long periods, the presence of mucus would also undoubtedly prevent desiccation.

Respiration.—Several observers have shown that the oxygen content of shallow brackish-waters and salt marshes is low as the temperature is high in small volumes of water. Unfortunately, we have not made studies on the oxygen content of the water, but having observed the high thermal limits to which the pools of brackish-water get heated up, and the occurrence of decaying matter in the river and backwater, there is reason to believe that the oxygen present in the water is low. This raises another problem of survival of the brackish-water organisms. The predominance of the amphibious element in the Adyar fauna was emphasized in an earlier section ; it was shown that the species inhabiting the marginal zone or the actual water edge are many and varied, and larger in communities than those that inhabit the deep water and rely completely on aquatic respiration. The animals which have developed extensive means of aerial respiration are the crabs and fishes. The proportion of oxygen to the total volume is much higher in air than in water : while the oxygen content of the air is about 20%, water under normal conditions of temperature holds only

5 to 10 c.c. of oxygen per litre. Winterstein (1921) has indicated that air is more favourable for oxygen absorption than water which, in turn, is better suited than air for carbon dioxide liberation (*cf.* Carter, 1931). In general, the respiratory changes that we find in brackish-water animals are caused by the growth of organs of aerial respiration, and not the increased development of gills for aquatic respiration. According to Carter and Beadle (1931) the accessory respiratory organs usually developed in fishes are chiefly organs of oxygen absorption, while the original gills discharge the function of carbon dioxide liberation. These additional structures are internal in those animals since they still live in an aquatic medium, in shallow water or at the water edge. The changes that have taken place in animals which became slowly adapted to respire in air are (1) the development of additional structures like arborescent folds, etc.; (2) devices to maintain the dampness of the epithelium; and (3) devices to prevent evaporation of water from the respiratory surface. Amongst the Adyar fishes, organs for aerial respiration are present in the form of vascularised walls of gill chambers, gill septa, etc., in *Periophthalmus kœlreutri*, *P. pearsei* and *Boleophthalmus boddœrti*. In the last species, the body is covered by numerous minute papillæ which have a respiratory function (Harms, 1929). The Amphipods of Adyar, though amphibious in habits, do not seem to have any special structural modification in their respiratory organs. The Isopod *Ligia exotica*, though depending completely on aerial respiration, is not found far away from the water edge. The thinly chitinized endopodites of pleopods in the aquatic Isopods function as lung in the case of terrestrial species (*cf.* Verhoef, 1919). Bepler (1909) finds that they are provided with glands at their bases, the secretion of which keeps them moist. The air-breathing capacities of several Decapods are well known; among the crabs, we find a series of adaptations intended for this purpose. Structural adaptations are absent in Macrurous species, though some forms, like *Penæopsis monoceros* are capable of remaining outside water in a healthy condition for fairly long periods. The Anomura of Adyar are all amphibious and respire partly in air. The gills are normal in most Decapods except in completely terrestrial genera. The Graspidæ and the Ocypodidæ, which are either amphibious or are completely terrestrial, show a common modification directed to retaining water in the gill chamber (Carter, 1931). The abnormally developed hairs near the opening of the gill chamber in *Sesarma*, *Cardisoma* and *Uca* (*Gelasimus*) (Ortmann, 1901), the spongy structures on the walls of the gill chamber in *Gecarcinus* and *Ocypoda* (Winterstein, 1921), and the peculiar fold at the floor of the gill chamber in *Uca* (Jobert, 1876) are all disigned for this purpose. Enlargement of

the gill chamber is seen in many brackish-water species like *Gecarcinus* (Calman, 1911), *Uca* and *Cardiosoma* and an upper lung chamber and a lower gill chamber are distinct in *Gecarcinus* (Calman, 1911 ; Carter, 1931). Vascularised epithelial folds that function as accessory organs are met with in the gill chambers of *Gelasimus* (*Uca*) (Jobert, 1876), *Cardiosoma* and *Ocypoda* (Zimmer, 1926–27) ; and lastly, special apertures that assist the entrance of air are found in the chambers (usually the posterior part) of *Ocypoda*, many Catametopa, and *Graspus* (Muller, 1863 ; Ortmann, 1901). All these modifications have not much affected the gills proper ; and as a rule, the gill chambers are provided with air in the case of air-breathing forms, and not water. Carter (1931) suggests that the need for adaptations designed to retain water in the gill chamber is probably caused by the necessity to keep the vascular folds damp.

Exposure and Desiccation.—We have found from field observations as well as experiments with several species, that many of the brackish-water Invertebrates of Adyar can survive exposure to air for a longer period than they can remain in freshwater. Exception should, however, be made of the species that have a wide range of regional distribution from the sea to almost freshwater. This fact explains the predominance of the amphibious element in the fauna of the brackish-waters of the type described here. In many terrestrial species life under water is impossible even though these species may be found only in the damp zone just above the water edge. Many of the amphibious forms like *Clibanarius padavensis* and *Clibanarius olivaceous* cannot thrive under water for long periods. The result is that these species have to keep moving to and fro so as to remain at the water edge when changes in level take place by tidal action. It would appear from numerous examples that in brackish-water animals, the tendency to become terrestrial is more marked than that to become freshwater inhabitants. Our observations are in agreement with the suggestion made by Pearse (1929) that the number of animals which have reached the land from the littoral marine and from brackish-water is much higher than the number of species that have become fluviatile.

The brackish-water areas of the Indian coasts are subject to periodical desiccation in the summer ; and the problem of survival during the period of drought is another important factor that the brackish-water animals have to cope with. It is the amphibious and the attached animals which are affected by drought. For the first group, which consists mostly of burrowers, it is difficult to leave their original burrows and migrate downwards ; but this is actually done by several crabs like *Uca annulipes* and *Sesarma quadratum*. Species of *Clibanarius*, *Ocypoda cordimana* and *Scylla*

serrata exhibit what may be called migratory movements in response to seasonal changes. During summer, these species are practically absent from the fringes of the backwater, but congregate in large numbers on the southern bank of the river. Most of the attached forms like *Companularia noliformis, Laomedea spinulosa, Balanus amphitrite, Hydroides norvegica* and *Aiptasiomorpha* sp. perish during the summer; but fresh individuals settle down every year when the bar is open. The periodic inactivity or æstivating habit of the two Grapsoid crabs *Varuna litterata* and *Sesarma tetragonum* has been described by Hora (1933); of these, the former is extremely rare at Adyar during the summer, but *S. tetragonum* which occurs in large numbers in the banks of the backwater and the Cooum, behaves in the same manner as in the Gangetic Delta described by Hora. We may add to this list another species, *Sesarma quadratum* which also retires into the burrows during the summer and remains more or less inactive. It may also be mentioned here that none of the burrowing crabs has been observed to breed during the summer months. The Gastropod *Potamides cingulatus* is capable of surviving exposure to air and sunlight for long periods; and specimens have on several occasions been collected far away from the water in an inactive state but which become active again on removal to water. The anemone *Phytocœtes gangeticus* remains alive in the mud outside water for weeks together; the anemones do not perish so long as the mud remains a little moist (Panikkar, 1937). Many sedentary brackish-water organisms are known to have evolved peculiar methods of asexual reproduction, reminding one of the gemmule formation of the freshwater sponges, whereby the survival of the species is ensured; the well-known instances are Hydroid *Annulella gemmata* (Ritchie, 1915), the sponge *Laxosuberites lacustris* (Annandale, 1915 *a*), and the Polyzoan *Loxosomatoides lævis* (Annandale, 1915 *b* and 1922). None of these species has so far been observed here; and perhaps the only instance of active asexual reproduction is that of a sea anemone *Boloceractis gopalai* where there is a peculiar method of tentacular regeneration (Panikkar, 1937 *a*). This cannot, however, be considered as having any bearing on the habitat as similar features have been noticed also in a related marine genus.

Abbreviation of Life-History.—The disadvantages of the free-swimming ciliated larvae in the brackish and fresh-waters have already been pointed out. The changes in reproductive habits consequent upon marine animals taking to a brackish-water mode of life are interesting as they involve curtailment of life-history in several of the species, especially the invertebrates. This is very well illustrated by the life-histories of certain brackish-water Polychætes. *Marphysa gravelyi* (Aiyar, 1931) and *Diopatra variabilis*

(Krishnan, 1936) have been studied in detail from Adyar; in both the species an abbreviated development has been observed by the above authors. In the first, the eggs are laid in large gelatinous egg cases anchored to the worm-burrows and harbouring thousands of eggs in various stages of development; the jelly serving the three-fold purpose of preventing the larvæ from being washed into the sea, of protecting them from drought when they are exposed during low tide, and of catering nutriment to the large number of rapidly developing nectochæts. The richly yolk-laden gigantic eggs of *Diopatra variabilis** metamorphose into the young worms even in the tube itself, without the intervention of a free-swimming larva. The development of this species is characterised both by precocity and by increased provision of food yolk in the eggs as compared to the other species of the same genus; and the developmental differences of very closely allied species could only be explained on the basis of the differences in environmental conditions. Gigantic eggs are also found in *Lumbriconereis* sp., also a genus in which Fewkes (1883–85) observed an abbreviated development. The collection of eggs in gelatinous egg-masses is a feature common to most of the Gastropods noticed at Adyar and to certain other species of Polychætes like *Scoloplos* sp. Among the Gastropods there is no doubt a free-swimming stage in the life-history, but this phase is often extremely short. Interesting details of an extremely short larval stage and rapid metamorphosis have been observed by Rao in the Nudibranch (Ascoglossa) *Stiliger gopalai*.† Most of the species of fish that breed at Adyar have demersal eggs; and though specimens of Clupeid and other groups of fish are commonly caught in the brackish-water as the list of animals collected by us would show, none of them breed in the brackish-water.‡

High Rate of Reproduction.—Apart from the modifications in development and the asexual reproductive devices, there is another aspect which has not received the proper attention it deserves. This is the high intensity of reproductive activity of many of the species. As in most tropical animals (*cf.* Orton, 1920) many species found at Adyar would appear to be able to breed all through the year, though a well-marked season for breeding is noticeable in many of them in as much as a high rate of reproduction is noticeable during this period. As pointed out before, this season is determined by the optimum environmental conditions for any particular species.

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* Fauvel (1931) considers the species as being synonymous with *Diopatra neapolitana*.

† "Habits, Structure and Early Development of a New Species of *Stiliger*," by K. V. Rao (1937), unpublished.

‡ *Engraulis purava* is a possible exception, *vide* Raj, 1916.

The high rate of sexual propagation accounts for the high intensity of population of animal communities in certain biotopes. The animal communities also often prove the correctness of Thienemann's rule. Most of the species attain sexual maturity at a very small size ; well-developed sex-cells are observed in very small individuals of *Potamides cingulatus*, *Sesarma quadratum*, *Acentrogobius neilli*, *Clibanarius olivaceous*, *Metasesarma rousseaxii* and *Meretrix casta*. Rao (*op. cit.*) finds that in *Stiliger gopalai*, sexual maturity is attained within a very short time after metamorphosis and several generations of these Gastropods are produced with singular rapidity. In the Anemone *Phytocætes gangeticus* where the early development up to the Edwardsia stage is rapid, the post-Edwardsia stages are rather prolonged and the gonads develop even in the larval Edwardsia stages with the incomplete quota of mesenteries. This instance of probable neoteny is further confirmed by the presence of blastula-like stages in the cœlenteron of post-larval individuals. It is probable that the brackish-water habitat may, in some measure, be responsible for this capacity for juvenile reproduction (Panikkar, 1937). Almost every species of invertebrate from Adyar investigated so far, has shown a definite tendency towards early sexual maturity and rapid development ; and other reproductive changes like the assumption of hermaphroditism have been observed in the Polychæte *Lycastis indica* (Aiyar, 1935).

Classification of Faunistic Elements.—A convenient basis of classification of animals living in an environment of variable features as the brackish-water is necessary to estimate the exact ecological characters of the different species. Based on the chlorine content of the water, Redeke (1922 and 1931) suggested a division of the brackish-water species into oligohaline, mesohaline and polyhaline groups ; the first representing the least saline region (salinity 0·2–1·9 per cent.; Cl, 0·1–1·0 gm. per litre) adjoining the freshwater ; the second mesohaline region forming the middle zone (salinity 1·9–18·6 per cent. ; Cl, 1·0–10·0 gm. per litre) ; and the last polyhaline region merging into the sea-water (salinity 18·6–31·8 per cent. ; Cl, 10·0–17·0 gm. per litre). He pointed out that these differences in the chlorine content correspond exactly to the differences in the fauna, irrespective of the type of brackish-water investigated. However much this classification may be satisfactory when applied to large volumes of brackish-water like the Baltic Sea, the Black Sea, the Chilka Lake, etc., this division ceases to have any value for small bodies of water as suggested by Redeke himself, and as conclusively shown by Nicol (1935) for salt marsh pools. At Adyar, the grouping of animals according to Redeke's method is not at all applicable since every sudden outbreak of rain in the locality would, especially

when the bar is closed, result in quick changes from polyhaline to oligohaline or almost lacustrine conditions, and the most interesting feature of the fauna is the singular capacity of several species to thrive in environments liable to profound changes in salinity and temperature. Many of the burrowing invertebrates adjust to salinity changes by vertical migrations (*cf.* Panikkar, 1936). So far as our observations go, we have not found strict demarcation of animal communities exclusively on salinity basis. At Adyar, the distribution of species is controlled by a multiplicity of factors as the substratum, depth, current of water, vegetation, etc.

Fauna of Adyar and of other Regions Compared.—Comparing the fauna of the brackish-waters of Madras with that of the Gangetic Delta and the Chilka Lake, it is clear that though the area is small and without the facilities for admixture of salt and freshwaters on a large scale, the fauna is as representative and almost as rich as in the two other places, especially in regard to true brackish-water species. The main difference lies in the fact that in the Chilka Lake and the Gangetic Delta, there are many species from the sea, which at Madras are exclusively marine in habits and are not found in the brackish-water. The species of *Philyra, Pleurobrachia bengalensis, Membranipora* sp., *Alcyonidium mytili, Thalassema* sp., *Squilla scorpio, Squilla interrupta* and *Lucifer hanseni,* to mention but a few examples, have not so far been observed at Adyar, though they are common in the Madras Coast, and in the brackish-waters of the Chilka Lake and the Gangetic Delta. The reason for this is that owing to the absence of a proper gradation of salinities, the small size of the area involved, and the pollution of water as the backwater is situated in the city, only the more resistant of the euryhaline species seem to have secured a foot-hold in the Madras brackish-waters. Also, we do not find here a relict fauna as found in the Gangetic Delta represented by recent marine forms that no longer occur in stenohaline or euryhaline conditions, but only in fresh or slightly brackish-water. The general features of the fauna described here are in agreement with those of the fauna of the Gangetic Delta and the Chilka Lake, but the constituent elements of the fauna present distinctive features in the occurrence of several characteristic species amongst the invertebrates, especially the Anemones and the Polychætes. The proper evaluation of the fauna would, however, be possible only after exhaustive studies have been made of the fauna of the numerous other brackish-water tracts of India.

Summary.

The fauna of the brackish-waters of the city of Madras has been studied in detail with special reference to its relation with the habitat.

The environmental conditions are described in detail. About ninety-two species of Invertebrates and fifty-six species of Vertebrates have been observed in the brackish-water. The fauna is predominantly marine and includes representatives of all major marine Invertebrate phyla except the Echinodermata. The freshwater species include a few Crustaceans, Molluscs and fish. The amphibious element in the fauna is well marked, and a number of mud-burrowing species are noted. Vertical and regional distribution of the organisms is described and the groups into which they may be classified according to their habits are indicated. An account of the breeding in brackish-water species is given. The general problems concerning the biology of animal life in the brackish-water are discussed in detail with special reference to the fauna described.

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EXPLANATION OF FIGURES.

Plate XVIII.

Photographs of the Adyar backwater and the river, taken during March 1935. The first is a portion of the backwater between the Adyar cemetery and the sand bank, showing the marginal and middle zones. The second photograph shows the Adyar river after the Elphinstone Bridge. Much of the river-bed is exposed owing to drought.

Plate XIX.

(1) Northern bank of the river above the Elphinstone Bridge.

(2) Inner reaches of the river showing pools of fresh or slightly brackish-water.

Plate XX.

(1) The river after Elphinstone Bridge to show the deep channel on the southern side.

(2) Part of the Adyar backwater near the small bridge close to the cemetery.

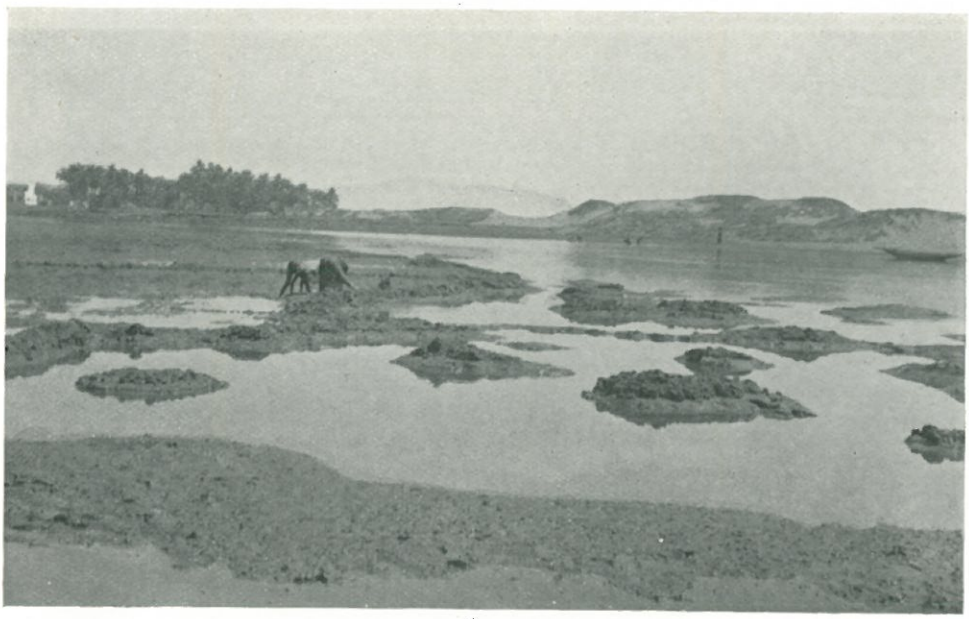
TEXT-FIG. 1.

Map of the Adyar river and backwater to illustrate the different regions surveyed in this study.

TEXT-FIG. 2.

Imaginary section through a mud-flat on the side of the backwater, to show the approximate zonation of animals, especially the burrowing species. Numbers 1–26 represent the following species:—

1. *Pontodrilus bermudensis.*
2. *Ocypoda cordimana.*
3. *Ocypoda macrocera.*
4. *Sesarma tetragonum.*
5. *Varuna litterata.*
6. *Metaplax distincta.*
7. *Uca annulipes.*
8. Zone of *Lycastis indica.*
9. *Lumbriconereis* sp.
10. *Phytocætes gangeticus.*
11. *Sesarma quadratum.*
12. *Boleophthalmus boddærti.*
13. *Periophthalmus pearsei* and *P. kœlreutri.*
14. *Clibanarius olivaceous.*
15. *Potamides cingulatus.*
16. *Phytocœteopsis ramunnii.*
17. *Pygmæonassa orissœnsis.*
18. *Clibanarius padavensis.*
19. *Scylla serrata.*
20. *Stephensonactis ornata.*
21. *Pelocœtes exul.*
22. *Meretrix casta.*
23. *Neptunus pelagicus.*
24. *Neptunus sanguinolentus.*
25. *Marphysa gravelyi.*
26. *Diopatra variabilis.*



1

2

1

2


The
BANGALORE
PRESS
LAKE VIEW
MYSORE ROAD
BANGALORE
CITY