IV. THE OXYGEN CONTENT OF THE MEDIA INHABITED BY AIR-BREATHING FISHES

New characters acquired by the organisms during the course of evolution may become genetically fixed by selection. One of the major factors which influences the selection of a new character is the favourable nature of the environment. The environment may be such, that it offers opportunities for living in different ways in the same habitat. Under these circumstances, it is not unusual to find different organisms having different habits living in the same habitat. If however, the environmental conditions change, and the old characters are unable to cope up with the new requirements demanded by the changing circumstances, the organisms possessing such characters face the danger of extinction, unless they acquire genetically or otherwise new characters which have a survival value. In due course of time, the suitable and genetically acquired characters as stated earlier, may get fixed by selection.

It is stated and often stressed that the deficiency of oxygen in the waters inhabited by the ancestors of the air-breathing teleosts has been the prime factor in the evolution of the air-breathing habit. If such is the case, one can visualise the conditions of these habitats, before, during as well as after the period of the acquisition of this habit. Before the origin of this habit, there was sufficient oxygen available in the media enabling the fishes to draw all their oxygen requirements with the help of normal-sized gills alone. Later some of these habitats however, due to changed circumstances, were being converted into shallow and stagnant pools, resulting in the paucity of oxygen in their waters. The fishes with normal-sized gills living in these habitats, being unable to secure their normal requirements of oxygen faced the danger of extinction, and only those fishes which adapted to the changed conditions could tide over the crisis. One of the ways to tide over the crisis was to develop extra-sized gills. Among those fishes which could tide over the crisis were also those, which developed during that period, air-breathing organs, to supplement the gills. If the development of the air-breathing organs among fishes was due to the paucity of the oxygen in which the progenitors of these fishes lived, as the progenitors with their normal-sized gills were unable to absorb the normal quantity of oxygen from the media, it is reasonable to expect such water-holds were passable ultimately by only those fishes which were adapted to the changed circumstances: Gradually the population of air-breathing fishes, as well as those with larger sized gills should have increased replacing those having average sized gills. One should not normally expect, therefore, the fishes with average-sized gills i.e.

normal water-breathing ones to live there. A study of the oxygen content in different waters inhabited by the air-breathing fishes has, therefore, been conducted and a survey of the teleostean habitats of these fauna made to find out how far this view can be supported by the facts presently available.

Estimation of the amount of oxygen dissolved in the waters of the habitats investigated

Method

The amount of oxygen dissolved has been determined by the Rideal-Steward modification of the Winkler's method.

To avoid the atmospheric oxygen being absorbed in the waters collected, the samples of water were collected in the way outlined by "The American Public Health Association" - 1923.

The apparatus used was set up as in Fig.65.

A narrow necked glass-stopped bottle (A) of 250.0 cc. capacity was used as the sample bottle. This bottle was connected by a glass tube to a large bottle (B) of 2.0 litre capacity. When fitted up, both the bottles were provided with a two hole rubber-stopper and glass tubes. One of the glass tubes (t_2) connected introduced in one of the holes of the bottle (A) was small, while the other tube (t_1) was large enough almost to touch the base of the bottle. The tube (t_1) was connected with rubber tubing to serve as

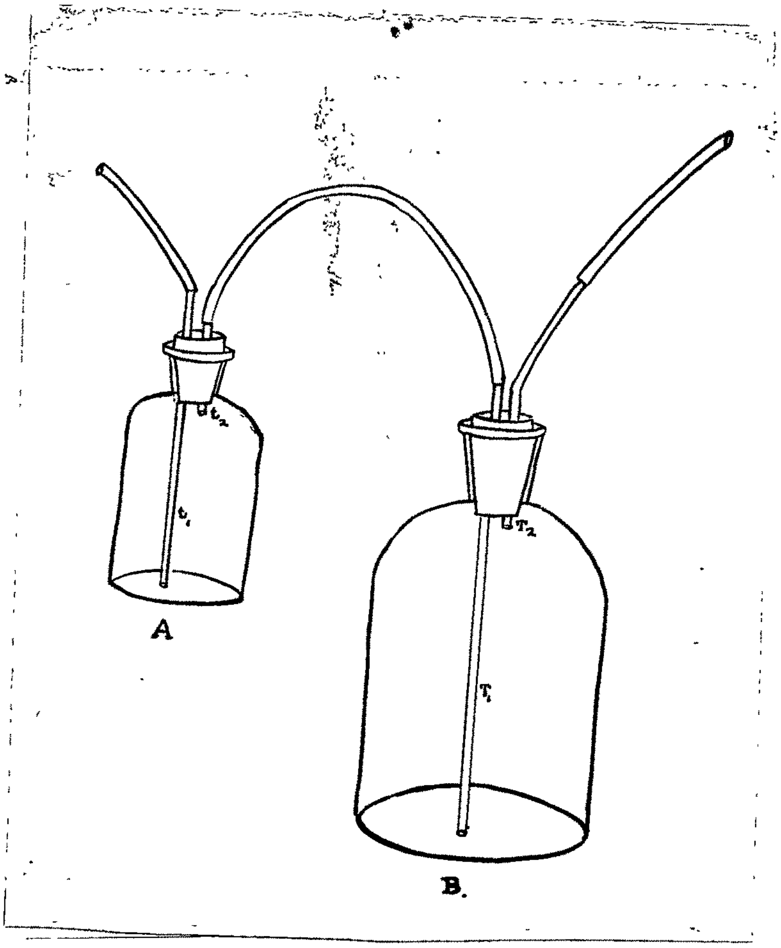

Fig.65. Apparatus used to collect the sample of water for the estimation of dissolved oxygen

inlet for the sample of water to be collected. The shorter glass tube (t_2) of the bottle (A) was then connected with the longer tube (T_1) of the bottle (B) by means of rubber tubing. The shorter tube (T_2) of bottle (B) served as an out-let. During the collection of the sample-water, both the bottles were immersed in water, keeping the sample water at a higher level. The air was sucked from the bottle (A) through the outlet of (B). Precautions were taken to maintain the outlet of the larger bottle (B) at a higher level than the inlet tube of the sample bottle (A).

The water collected into the sample bottle was first allowed to flow into the larger one. When the latter was filled with more than half of its volume, the perforated stopper of the sample bottle was replaced by the glass-stopper, first making sure that there was no trace of air in this bottle.

The following reagents were prepared :-

1. Potassium permanganate solution by dissolving 6.32 gm. of the salt to distilled water and diluting to one litre.
2. Potassium oxalate solution by dissolving 2 gm. of the salt in distilled water and diluted to 100 cc.
3. Manganous sulphate solution by dissolving 12 gm. in distilled water and diluting to 25.0 cc.
4. Alkaline Potassium Iodide by dissolving 35 gm. of Potassium hydroxide and 7.5 gm. of Potassium iodide in distilled water and diluting to 50.0 cc.
5. Sodium thiosulphate solution (0.25 N) prepared by dissolving 0.6025 gm. of chemically pure salt in

freshly boiled and cooled distilled water and diluted to 100.0 cc.

The starch solution which was used as an indicator was prepared by first mixing a small amount of clean starch with cold water to form a thick paste and then stirring the mixture into 150-200 times its weight of boiling water. It was later boiled again for few minutes. A fresh solution was prepared every time.

The necessary tests were performed partly in the field and partly in the laboratory according to the instructions given for the modifications of the Winkler's method. The instructions are as follows :-

"Remove the stopper from the bottle and add first 0.7 cc. of the concentrated Sulphuric acid and then 1.0 cc. of Potassium permanganate solution. These and all other reagents should be introduced by the pipette under the surface of water. Insert the stopper and mix by inverting the bottle several times. If a noticeable excess of Potassium permanganate is not present after 20 minutes, again add 1.0 cc. of permanganate solution. After 20 minutes have elapsed destroy the excess of permanganate by adding 1.0 cc. of the potassium oxalate solution, restopper the bottle at once and mix its contents. Add 1.0 cc. of Manganous sulphate solution and 3.0 cc. of alkaline Potassium iodide solution.

Allow the precipitate to settle. Add 1.0 cc. of the concentrated Sulphuric acid and mix by shaking."

"The procedure to this point must be carried in the field, but after the acid has been added and the stopper replaced, there is no further change and the rest of the test may be performed within a few hours as convenient. Transfer 200 cc. of the contents of the bottle to a flask and titrate it with 0.025 cc. N.Sodium thiosulphate solution as indicator towards the end of the titration. Do not add the starch solution until the colour has become faint yellow. Titrate until the blue colour disappears."

"If 200 cc. of the sample is taken the number of cubic centimeters of 0.025 N.Sodium thiosulphate is equal to parts per million of oxygen by weight. To obtain the results in cc. per litre multiply the number of cc. of Sodium thiosulphate solution used by 0.698."

<u>Habitats investigated</u>

The following categories of habitats inhabited by the Indian air-breathing teleosts were examined for their oxygen content :-

1. A small Laboratory Aquarium
2. A puddle at Ahmedabad

3. A river (Sabarmati) at Ahmedabad
4. A tank at Bandra, Bombay and
5. A brackish-water creek at (Mahim), Bombay.

By way of comparison with regions with sufficient oxygen, the shore waters of Chowpatty, Bombay, were tested for their oxygen content.

<u>The nature of teleostean fauna in the habitats investigated</u>

1. <u>The Laboratory Aquarium</u>

The dimensions of the aquarium used measured 3' x 1½' x 28". It was always kept clean during the period of the experiment and was planted with <u>Vallisneria</u> and <u>Hydrilla</u>. Both air-breathing fishes namely <u>Anabas scandens</u> (Dald.), <u>Haplochilus lineatus</u>, (Cuv. & Val.) and <u>Ophiocephalus punctatus</u> (Bloch) and a water breathing one <u>Barbus vittatus</u> (Day) were introduced in the aquarium.

2. <u>The puddle at Ahmedabad</u>

This puddle located by the side of the Sabarmati river in Ahmedabad is one which dries up in summer. Its water which is by no means clean was 5' to 6' deep at the time of investigations. Its teleostean inhabitants included the air-breathing <u>Ophiocephalus punctatus</u> (Bloch) and the water-breathing <u>Rasbora daniconius</u> (Ham.).

3. <u>The Sabarmati river at Ahmedabad</u>

This river flows through the middle of the city. The water is scanty except during the monsoon when the river may be in high floods. It usually appears as a clean small stream of slow running water along one side of the bank. The vegetation is very poor and consists of Potamegeton, Hydrilla, Vallisneria etc., practically in a submerged state. The spot from where the water was collected for the estimation of the oxygen content was below one of the bridges where water depth was about 5 ft. This spot was chosen because fishermen also fish there. The Ophiocephalus and Mastecembalus are available in abundance there. Other teleostean fauna inhabiting the spot include occasional air-breathing Notopterus notopterus (Pallas), habitual air-breathing Heteropneusteus (Saccobranchus) fossilis and the water--breathing Callichrous bimaculatus (Cuv. & Val.) and Barbus vittatus (Day).

4. <u>The fresh-water tank at Bandra</u>

This tank which was formerly a neglected tank open to the public, is now taken possession of by the fisheries department and used for the breeding and storing of the fishes. It has a surface area of more than one square furlong and has an abundant growth of vegetation especially during and immediately after the rainy season. Fishes such as Osphronemus gourami (Lacep), Cirrhina mrigala (Ham.), Catla catla, Labeo rohita (Ham.) and others have been introduced by the fisheries department for breeding and stocking purposes. The natural members of the fauna include air-breathing Ophiocephalus sp. Haplochilus lineatus (Cuv. & Val.) and water-breathing Barbus sp., Rasbora sp. and others.

5. The brackish-water creek at Mahim, Bombay

During the low tide a vast area of this creek is exposed to the atmosphere and during the high tide water is seen to flow rapidly into the creek. It is full of vegetation comprising Avicinia, possessing air-breathing roots. Other vegetation of this creek includes Acanthus, Rhizophora etc. The spot from where the water was collected was below the bridge which connects the Bombay and Salsette islands. The occasional air-breathing Macrones gulio (Ham.), the habitual air-breathing mudskippers, Periopthalmus sp. and Boleopthalmus, the eel Ophichthys (Pisoodonophis) boro (Ham.) and water-breathing Sillago sihama (Gunther) and Therapon jarbua (Forsk.) are some of the fishes found to inhabit this creek.

The Sea-shores of Chowpatty, Bombay

No air-breathing fishes are found to inhabit this sea-shore. Similar places elsewhere however are found to be inhabited by air-breathing mudskippers and certain eels.

The sea is shallow here and a vast area is exposed to the atmosphere during low tides.

RESULTS

The results obtained are as follows :-

Sr. No.	The place of collection	Mean temp. of water	The mean amount of oxygen dissolved	
			In parts per million by weight	In cc. per litre of water
1	The aquarium	24° C	12.95	9.03
2	The puddle	27° C	5.92	4.13
3	The river	26° C	9.80	6.84
4	The tank	23° C	8.10	5.65
5	The brackish-water creek	24° C	11.80	8.24
6	The sea-shore	23° C	12.90	9.00

i. All samples of waters were collected in the mornings during the month of March between 8-0 a.m. and 10-0 a.m.

ii. The oxygen content of waters depends upon several factors such as the time of the day, the temperature, the season, salinity, the flora and fauna inhabiting the place, the area exposed to the atmosphere, the flow of water etc.

Reduction of temperature, a rapid flow of water and the photosynthesis carried out by the plants, are some of the factors which bring about an increase in the oxygen content. The rise of temperature, the presence of salts, the pollution of the water etc. are some of the factors which tend to reduce the oxygen content. Under the circumstances the estimation of oxygen have to be treated as rough estimations rather than absolute values.

DISCUSSION

The importance of oxygen to the organism need not be emphasized here as it is too well known. The amount of this gas present in the water holds should obviously influence the density of the animal population. Consequently the waters with depleted oxygen are thinly populated.

The minimum oxygen tension essential for the survival of animals differs with different groups. It has been estimated by Pruthi (1927) that the minimum oxygen-tension required for the stickle-backs varies from 0.25 to 0.50 cc. per litre (i.e. 0.36 to 0.72 parts per million by weight). The corresponding figures estimated for a number of fishes estimated by Powers (1927), is about 1.7 cc. per litre (i.e. 2.43 parts per million by weight). Rounsefell & Everhart (1953) who have recently surveyed the literature available on this subject state that, the fish have been found to live in a healthy condition at extremely low concentrations of oxygen. The minimum oxygen-tension value for a number of fishes investigated by Moore (1943), Jahoda (1947), King & Smith (1947), Lindroth (1949) and Copper & Washburn (1949) varies from 0.14 cc. (i.e. 0.2 parts per million by weight) to 1.89 cc. per litre (i.e. 2.3 parts per million by weight). For most of the fishes the value is less than 0.35 cc. per litre (i.e. 0.5 parts per million by weight).

It is quite likely that under certain environmental conditions, the air-breathing habit has an advantage over the water-breathing one in waters having a very low concentration of oxygen. It is also observed that uptake of oxygen of some organisms including fishes decreases with the fall of oxygen content (Tang-1933 & Fry-1957). But does this mean that the water-breathers inhabiting these habitats are in troubled waters? If so, how far has this influenced the development of the aerial respiratory organs? In order to provide answers to such questions it becomes incumbent on one to examine carefully the various habitats in order to see how far the facts of fish life there lend support to the theory of the depletion of oxygen as a factor which induced the origin of the air-breathing habit.

The solubility of oxygen in fresh-water at 25° C (which can be considered as the average temperature of the habitats under consideration), when exposed to an atmospheric pressure containing 20.9 % of oxygen under a pressure of 760 mm. is 5.86 cc. per litre (i.e. 8.36 parts per million by weight), according to the figures given by American Public Health Association (1923). On this assumption, the habitats based on the relative abundance of oxygen in which the air-breathing teleostean fauna lives, can be divided into two main categories : (i) the habitats with less amount of oxygen in their waters e.g. tanks, pools, puddles, marshes, swamps, etc. and (ii) the habitats with a higher amount of oxygen found in water holds such as the rivers including the hill-streams, sea-shores, brackish-water creeks, estuaries and others.

1. THE HABITATS WITH A LESSER AMOUNT OF OXYGEN

The swamps of Paraguayan Chaco investigated by Carter & Beadle (1930 & 1931), the puddle at Ahmedabad and the tank at Bandra, belong to this category. The swamps of Paraguayan Chaco contain very little oxygen, usually less than 0.5 cc. per litre (i.e. 0.71 parts per million) in its waters, of the surface layer among the weeds. The pools in the vicinity of these plants however contained a minimum of 2.3 cc. of oxygen per litre (i.e. 3.4 parts per million by weight). Hardly there was a place the oxygen contents of which approached the conditions of satu[r]ation.

It can therefore be safely assumed according to the statements made by these authors, that the waterholds were very deficient in oxygen. A study of the teleostean fauna investigated by them revealed that about 20 species inhabitated these waters. Only 8 of them including a dipnoan were found to be air-breathers and all the rest were water-breathers. Hora's (1935) collection of fishes in the paddy fields at Utterbhag, lower Bengal, the water of which had a salinity of 4.3 per mille, likewise included water breathers such as Barbus licto and B.sophore, and air breathers such as Ophiocephalus, Mastecembalus, Pseudopocryptes lanceolatus and others. The puddle at Ahmedabad, the water of which was examined during the investigations, contained 4.23 cc. per litre of oxygen (i.e. 5.92 parts per million by weight). Similarly the Bandra tank contained 5.65 cc. per litre (i.e. 8.1 parts per million by weight). Both the above mentioned habitats as stated earlier contained in their waters both water-breathing as well as air-breathing teleosts.

2. THE HABITATS WITH A HIGHER AMOUNT OF OXYGEN

These habitats can be further divided into two groups viz. (A) the fresh-water and (B) marine habitats.

A. Thefresh-water habitats

The fresh-water habitats which are known for high oxygen content in their waters include rivers, especially the hill-streams. These waterholds on account of a flow of their water and their water dashing against the banks, stones etc., expose more and more surface area of their water to the atmosphere; consequently the rate of diffusion is accelerated and the water often gets super-saturated.

The water of the Sabarmati river, the flow of which is slow except during the monsoon, contained 6.8 cc. of oxygen per litre (i.e. 9.8 parts per million by weight). It may be presumed that the similar waters of Mutha river of Poona likewise contains a high amount of oxygen. The occasional air-breather Notopterus, the habitual air-breathers Ophiocephalus striatus, Anguilla bengalensis and the water-breathing Aspidoparia morar and Cirrhina fulungee are some of the teleostean fauna inhabiting this river.

The hill-streams contain a high amount of oxygen in their waters (Hora-1921, 1935 etc.). Both water-breathers and air-breathers are observed to inhabit these habitats. The water-breathing fishes collected by Hora (1921) in hill-streams included Barilius barila, Garra sp. and Nemachilus zonalternans. The air-breathing teleostean fauna collected by the same investigator (1922 & 1935) included Lepidocephalichthys, Acanthopthalmus and Amblyceps.

Beadle, while referring to air-breathing habit among fishes made a mention of fishes living in well-oxygenated waters of Central Africa (1932). Those fishes obviously belong to this category. He has however neither given an account of the nature of the habitats nor the fishes inhabiting there.

B. The marine habitats

These habitats comprise brackish-water creeks, estuaries, sea-shores and others. The brackish-water creek at Mahim can be cited as a typical example of this group. The amount of oxygen dissolved in its waters was 8.24 cc. per litre (i.e. 11.8 parts per million by weight). As stated previously both water- and air-breathing teleosts are found to live there. Air-breathing fishes living in similar waters also include Taenoides (Hora-1933 & Nayar-1951), and Trypauchen vagina (Nayar-1951).

The waters of the sea-shores are also highly oxygenated as they are always under the tidal influence and the breaking of the waves. The waters of the sea-shore of Chowpatty for instance, contain as high concentration of oxygen as 9.0 cc. per litre (i.e. 12.9 parts per million by weight). Some of the air-breathing teleosts living in habitats similar to that of Chowpatty, are the mudskippers Periopthalmus and Boleopthalmus. The last named is a common Mudskipper of Bombay found inhabiting the sea-shores of Worli and elsewhere.

Other air-breathing fishes living in the waters of the sea-shores are certain blenniid fishes including Andamia and Petroscrites (Hora-1935). Sole fish of the genus Achirus (Breder-1941) and the tarpon, Megalops (Breder-1941 & Kulkarni & Jaggi-1954) are some of the marine fishes which are adapted to air-breathing.

CONCLUSION

Based on the investigations conducted here and by others, it can be stated that fishes - both water-breathing and air-breathing ones - live in habitats having an oxygen-tension varying from 0.5 cc. per litre to 9.0 cc. per litre. It is also observed that all those habitats including the ones that have a very low concentration of oxygen, where air-breathers are found to inhabit, are inhabited by water-breathers also.