

VII. THE EXTENT OF GILL-SURFACE AVAILABLE FOR GASEOUS EXCHANGE IN CERTAIN INDIAN TELEOSTS

The air-breathing fishes are known to come periodically to the top of the water to breathe atmospheric air and if they are prevented from doing so, sooner or later they get asphyxiated, denoting that aerial respiration is essential for these fishes. This knowledge comes from the labour of many investigators who have conducted asphyxiation experiments on a number of air-breathing fishes. Notable among the investigators are Das (1927), Carter & Beadle (1931), Ghosh (1933-34), Hora (1933, 1935 and 1939) and Schlaifer Arthur (1941). Das was among the first to conduct asphyxiation experiments with Indian fishes for e.g. Anabas scandans, Clarias batrachus, Heteropneusteus fossilis, Amphipnous cuchia etc. He observed that, when the air-breathing fishes are introduced in an aquarium below a diaphragm and thus prevented from breathing atmospheric air, in due course of time, these fishes become exhausted and ultimately get asphyxiated. Fishes kept by him under similar conditions but without the diaphragm as control were all hale and hearty even after a number of days. The asphyxiation experiments conducted by Carter & Beadle on certain tropical fishes including Hoplosternum littorale and Callichthys sp. also revealed that even when the water is well oxygenated,

if the fishes are prevented from breathing atmospheric air, they die of asphyxiation. Hora (1939) who also conducted similar experiments stated that "Under normal conditions a combination of these two (i.e. the aquatic and aerial respiration) seems to be essential." In one of his previous papers (1935) he stated that "Fishes with complicated respiratory organs, even when kept in oxygenated water, always come to the surface to breathe air." Schlaifer Arthur (1941) conducted experiments on tarpon. His findings were that "The tarpon when prevented from coming to the surface to breathe air succumbed in 7 to 128 hours even in highly oxygenated running sea water." I had also conducted similar experiments on certain Indian air-breathing fishes including Anabas scandens (Dald.), Heteropneustus (Saccobranthus) fossilis (Bloch) and Macropodus cupanus (Cuv. & Val.). My results indicate that under the normal conditions, if these fishes are prevented from coming to the top and breathe atmospheric air, they die sooner or later of asphyxiation. From the observations made by the various investigators, one fact is clear that the air-breathing fishes under the normal conditions get asphyxiated if they are prevented from getting a free access to the atmospheric air. It means that the aquatic respiratory organs of the air-breathing fishes are unable to draw all their oxygen requirements and that the aerial respiratory organs obviously supplement the gills.

The fact that the aerial respiratory organs are essential to supplement the gills, shows that they are unable to absorb the full complement of oxygen required for their metabolic activities. It means that gills must be in some way deficient. That the gills are reduced in a lung fish (Dipnoi) Protopterus has been mentioned by Smith (1930). Schöotle (1931) found that the gill-surface in terrestrial gobiiform fishes is less than that of the strictly aquatic fishes. Hora (1935) and Das (1940) giving an account of the gills of Amphipnous cuchia, observed that their gills are very much reduced, and that in adults, they are represented only by finger-like isolated filaments on the second gill-arch, but no quantitative assessment of the gill size was made.

While the investigations of Schöotle show that in the case of terrestrial gobiids, the gills have a lesser gill surface and that in case of Amphipnous cuchia the gills are so under-sized as to be clearly noticed, it is not known what exactly is the nature of the gills as to the surface area in other air-breathing fishes. The possibility that the gills might be degenerated, in other air breathing fishes also has been anticipated and a comparative study of the extent of gill-surface in a number of Indian fishes, comprising both water- and air-breathers, has been made to find out whether the deficiency of the gill-surface is of general occurrence among the air breathing teleosts.

The extent of the gill-surface in a fish may be studied either in relation to its weight or volume. Schöötle (1931), Carter (1931) and recently, Gray (1954) have estimated the gill-surface in relation to the weight of the body. Some investigators including Putter (1909) have estimated it in relation to its body surface. In the present investigations the extent of gill-surface has been determined per unit volume of the fish as it was thought that the weight of the food contents might unduly viciate the results. In either case it is not possible to determine the gill-surface per unit volume or weight with mathematical exactness and the ratios obtained here have to be treated as rough estimations rather than absolute values.

Method of study

A. Area of the gill-surface

The total area of the gill-surface of a fish was ascertained by summing up the areas of all the gill-filaments together. The area of a gill-filament was calculated on the basis of its length and breadth; the thickness being negligible was ignored. Fresh gills were used for taking measurements. The results so obtained were compared with those taken from stained preparations of filaments with eosin and it was found that they tallied. It may be mentioned here that the stained filaments were better for the purpose

of measuring the length and the breadth, as the boundaries became clearer as a result of this process.

It was found that the filaments of a gill were not necessarily of uniform dimensions. They were therefore first assorted into one or more groups. The average measurements of each set were first ascertained separately and from this the total area was obtained.

B. Volume

The volume of the fish was ascertained by the method of displacement by immersing the fish in water.

The names of the fishes examined, arranged according to the classification adopted by Day

A. Water-breathing fishes

Order : PHYSOSTOMI

Family : Siluridae

1. Callichrous malabaricus (Cuv.)
2. Callichrous pabda (maculatus) (Ham.)
3. Arius dussumieri (Cuv. & Val.)

Family : Cyprinidae

4. Barbus vittatus (Day)
5. Barbus dobsoni (Day)
6. Barilius evazardi (Day)

7. Rasbora daniconius (Ham.)
8. Cirrhina fulungee (Sykes)
9. Aspidoparia morar (Ham.)
10. Rohtee ogilbii (Sykes)

Family : Clupidae

11. Coilea dussumieri (Cuv. & Val.)
12. Clupea sindensis (Day)
13. Clupea fimbriata (Cuv. & Val.)
14. Engraulis mystax (Bl. & Schn.)

Family : Scopelidae

15. Saurida nedulosa (Cuv. & Val.)

Family : Cyprinodontidae

16. Gambusia affinis (Girrard)

Family : Scomrescoidea

17. Belone cancila (Cuv. & Val.)

Order : ACANTHOPTERYGII

Family : Percidae

18. Serranus fasciatus (Day)
19. Lutjanus caeruleolineatus (Day)
20. Therapon jarbua (Forsk.)

Family : Sciaeniformis

21. Sciaena miles (Cuv. & Val.)
22. Sciaena ossea (Day)

Family : Carangidae

23. Ecuula blochii (Cuv. & Val.)

24. Ecuula daura (Cuv.)

Family : Scombridae

25. Cybium guttatum (Bl. & Schn.)

Family : Stromateidae

26. Stromateus cinerius (Bloch)

27. Stromateus niger (Bloch)

Family : Trachiuridae

28. Sillago sihama (Gunther)

Family : Mugilidae

29. Mugil borneensis (Bleeker)

30. Mugil amarulus (Cuv. & Val.)

31. Mugil kelaarti (Green)

Family : Chromides

32. Etroplus maculatus (Day)

Order : ANACANTHINI

Family : Gadidae

33. Bregmaceros maclellandi (Thomsen)

Family : Pleuronectidae

34. Plagusia bilineata (Bloch)

Order : PLECTOGNATHI

Family : Sclerodermi

35. Triacanthus brevirostris (Temm. & Schleg.)

Family : Gymnedontis

36. Tetrodon fluviatilis (Ham.)
37. Tetrodon patoca (Ham.)

B. Air-breathing fishes

I. Occasional air-breathers

Order : PHYSOSTOMI

Family : Siluridae

1. Macrones gulio (Ham.)

Family : Notopteridae

2. Notopterus kapirot (Lacep)

Family : Clupidae

3. Megalops cyprinoides (Brau.)

II. Habitual air-breathers

Order : PHYSOSTOMI

Family : Muraenidae

4. Anguilla bengalensis (Day)
5. Ophichthys (Pisoodonophis) boro (Ham.)

Family : Siluridae

6. Heteropneusteus (Saccobranchus) fossilis
(Bloch)

Family : Cyprinodontidae

7. Haplochilus lineatus (Cuv. & Val.)

Order : ACANTHOPTERYGII

Family : Ophiocephalidae

8. Ophiocephalus striatus (Bloch)
9. Ophiocephalus punctatus (Bloch)

Family : Labyrinthici

10. Anabas scandens (Dald.)
11. Osphronemus gourami (Lacep)
12. Macropodus cupanus (Cuv. & Val.)

Family : Gobiidae

13. Boleophthalmus dussumieri (Cuv. & Val.)

Family : Symbranchidae (Mastecembalidae)

14. Mastecembalus armatus (Lacep)

Results

The following tabulated statements show the habitats, volumes and the gill surface per unit volume of the fishes examined :-

WATER-BREATHERS

Sr. No.	Name of the fish	Habitat	Vol. in cc.	Gill-surface per unit vol. in sq. mm.
1.	<u>Callichrous malabaricus</u>	Fresh-water	6.5	152.80
2.	<u>Callichrous pabda</u>	- Do -	68.3	148.00
3.	<u>Arius dussumieri</u>	Marine	7.0	165.90
4.	<u>Barbus vittatus</u>	Fresh-water	1.0	153.60
5.	<u>Barbus dobsoni</u>	- Do -	54.6	137.19
6.	<u>Barilius evazardi</u>	- Do -	4.5	153.30
7.	<u>Rasbora daniconius</u>	- Do -	9.5	140.30
8.	<u>Cirrhina fulungee</u>	- Do -	13.5	163.80
9.	<u>Aspidoparia morar</u>	- Do -	6.0	144.98
10.	<u>Rohtee ogilbii</u>	- Do -	28.0	139.80
11.	<u>Coilea dussumieri</u>	Marine	8.5	153.20
12.	<u>Clupea sindensis</u>	- Do -	14.0	144.00
13.	<u>Clupea fimbriata</u>	- Do -	49.0	150.50
14.	<u>Engraulis mystax</u>	- Do -	37.0	147.60
15.	<u>Saurida nedulosa</u>	- Do -	61.0	148.30
16.	<u>Gambusia affinis</u>	Fresh-water	1.0	148.80
17.	<u>Belone cancila</u>	- Do -	17.5	140.90
18.	<u>Serranus fasciatus</u>	Marine	6.5	165.80
19.	<u>Lutjanus caeruleo-</u> <u>-lineatus</u>	- Do -	40.5	150.40
20.	<u>Therapon iarbua</u>	- Do -	3.8	161.00
21.	<u>Sciaena miles</u>	- Do -	25.0	152.30

Sr. No.	Name of the fish	Habitat	Vol. in cc.	Gill-surface per unit vol. in sq. mm.
22.	<u>Sciaena ossea</u>	Marine	60.0	135.90
23.	<u>Equula blochii</u>	- Do -	6.0	155.60
24.	<u>Equula daura</u>	- Do -	5.5	152.30
25.	<u>Cybium guttatum</u>	- Do -	91.0	153.50
26.	<u>Stromateus cinerius</u>	- Do -	147.0	150.00
27.	<u>Stromateus niger</u>	- Do -	32.0	161.00
28.	<u>Sillago sihama</u>	- Do -	13.0	152.30
29.	<u>Mugil borneensis</u>	- Do -	26.0	143.20
30.	<u>Mugil amarulus</u>	- Do -	3.0	165.48
31.	<u>Mugil kelaarti</u>	- Do -	3.0	148.00
32.	<u>Etroplus maculatus</u>	- Do -	6.0	145.50
33.	<u>Bregmaceros maclellandi</u>	- Do -	1.1	146.00
34.	<u>Plagusia bilineata</u>	- Do -	8.5	163.70
35.	<u>Triacanthus brevirostris</u>	- Do -	6.0	155.60
36.	<u>Tetrodon fluviatilis</u>	- Do -	16.0	162.50
37.	<u>Tetrodon patoca</u>	- Do -	273.0	132.70

AIR-BREATHERS

A. Occasional

1.	<u>Macrones gulio</u>	Marine	37.0	148.68
2.	<u>Notopterus kaporat</u>	Fresh-water	11.0	153.20
3.	<u>Mogalops cyprinoides</u>	Marine	27.5	163.90

Sr. No.	Name of the fish	Habitat	Vol. in cc.	Gill-surface per unit vol. in sq. mm.
B. Habitual				
4.	<u>Anguilla bengalensis</u>	Fresh-water	30.0	91.70
5.	<u>Ophichthys boro</u>	Marine	34.0	86.70
6.	<u>Heteropneustus fossilis</u>	Fresh-water	8.5	70.30
7.	<u>Haplochilus lineatus</u>	- Do -	1.1	98.10
8.	<u>Ophiocephalus striatus</u>	- Do -	15.0	92.10
9.	<u>Ophiocephalus punctatus</u>	- Do -	40.0	95.25
10.	<u>Anabas scandens</u>	- Do -	3.0	60.66
11.	<u>Osphronemus gourami</u>	- Do -	161.0	56.80
12.	<u>Macropodus cupanus</u>	- Do -	1.3	78.70
13.	<u>Boleophthalmus dussumieri</u>	Marine	13.0	61.35
14.	<u>Mastecembalus armatus</u>	Fresh-water	55.0	72.41

DISCUSSION

From the results obtained it is observed that the extent of gill-surface varies from a minimum of 132.7 sq.mm. in Tetrodon to a maximum of 165.9 sq.mm. in Arius dussumieri. The extent of the gill-surface in the three occasional air-breathers varies from a minimum of 148.68 sq.mm. in Macrones to a maximum of 163.9 sq.mm. in Megalops cyprinoides. The corresponding figures for the habitual air-breathers

vary from a minimum of 56.8 sq.mm. in Osphronemus to a maximum of 98.1 sq.mm. in Haplochilus.

It may be mentioned here that two papers pertaining to the extent of gill-surface published by me one in 1941 in conjunction with Professor C.J.George and another in 1951 have been recently reviewed by Carter and Fry respectively in "The Physiology of Fishes - Vol.1" published in 1957 by Academic Press Inc., New York.

CONCLUSION

The finding from this piece of investigation is that the extent of gill-surface available for aquatic respiration in the habitual air-breathing fishes is much less than that met with in the occasional air-breathers and water-breathers.