Aerial Respiration in the Florida Spotted Gar

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MANY physotomous fishes use their gas bladder as a temporary or supplementary organ of respiration. Among these are included the Osteoglossidae, Mormyridae, Characidae, and Holostei (Bertin, 1957). Among the holostean fishes, the gars (*Lepisosteus*) occur naturally in fresh and brackish waters, generally in ponds, lakes, canals, and estuaries. They are very common in the Mississippi Valley and Florida. *L. platyrhincus* De Kay is quite common in the Everglades, where it feeds on *Gambusia affinis, Fundulus chrysotus, Jordanella floridae,* and the young of many other fishes. It is itself an important prey of the alligator (*Alligator mississippiensis*). Its chief method of catching food is to float motionless in mid-water and dart into a school of smaller fish, seizing one of them in its long jaws armed with needlelike teeth.

It has long been known that gars may survive in waters of low oxygen concentration, such as often occur during dry periods in the Everglades, when numerous fish crowd into the larger ponds. The gars have often been seen to gulp air at the surface by rising parallel to the surface and, when their backs touch it, they thrust their snout out of the water and gulp some air. I have noticed in the tank that the fish almost invariably, after this, let out a few bubbles of air through their gill openings. This "exhalation" can occur at other times as well, however, such as just before they gulp air, or even while they are merely swimming or resting on the bottom.

For a long time there was uncertainty as to whether or not the gas bladder was really the organ whereby the garfish utilized oxygen from the air. It was not until Potter (1927) analyzed samples of gas drawn from the bladders of long-nosed gars (*Lepisosteus osseus*) and showed that a gaseous exchange of oxygen and carbon dioxide indeed takes place in the gas bladder. The oxygen concentration was highest immediately after the fish gulped air and then gradually decreased, while the concentration of carbon dioxide increased correspondingly. The gas bladder is thus definitely the organ of aerial respiration in the garfish. Potter further estimated that 50 per cent of the oxygen in the air was absorbed by the gas bladder. When a screen prevented the fish from going to the surface to gulp air, the fish would die in five to six hours in water of low oxygen concentration. It is this second set of experiments that I have tried to repeat and expand, using *L. playtyrhincus* as the subject. In this way one can compare how a different species of gar reacts to the same conditions. Temperature considerations were introduced here, which Potter had almost entirely ignored, so that the correlation between the two species can only be approximtae.

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Materials and Methods

The fish used in the experiments were collected at "40 Mile Bend" on the Loop Road (U. S. 94) off the Tamiami Trail. They varied from 11-14 inches in total length. Before the experiments they were kept for several weeks in an unaerated 35 gallon tank and fed live *Gambusia*. At the time of the experiments all the fish were transferred to another tank and then were tested one by one in their original tank. Some fish were tested in another tank in which the water temperature was lower. Oxygen concentration was controlled by means of an air pump. Without a heat control system, however, the temperature could not be regulated.

The experiments consisted essentially in placing a fish in the tank, waiting for an hour or so until it got adjusted to its new environment, which could be inferred when it began to swim normally and gulp air. A flexible plastic screen was placed on top of the tank below the surface and wedged in with wooden supports. In this manner a free exchange of oxygen from air to water could be maintained, so that the oxygen content of the water would remain constant. Measurements of temperature and oxygen concentration in the water were made during the course of the experiments by a YSI Model 51 Oxygen Meter.

The first three experiments show that *Lepisosteus platyrhincus* cannot survive without breathing air at temperatures of 20-21 C and 2-3 parts per million of oxygen. When access to air was permitted under the same conditions the fish survived for over a month. *L. osseus* survived for 5-6 hours in what were probably the same conditions (Potter, 1927), while *L. platyrhincus* died in about an hour. We may thus have here a significant species variation.

At 21-22 C, and much higher oxygen concentration, as shown by fish no. 5, *L. platyrhincus* can survive indefinitely without aerial respiration. Fish no. 6 shows that this is also true for temperatures lower than 21 C. This is qualitatively true for many other air-breathing fishes (Willmer, 1934; Horn and Riggs, MS). What is interesting to note here, however, is that fishes nos. 5 and 6

TABLE 1

Effect of oxygen concentration and temperature on survival of garfish not given access to surface

Fish No.	Time	0_2 ppm	Temp° C	Total time
1	1230-1345	2.0	20.0	1 hr 15 min
		2.5	20.4	
2	1600-1650	2.5	21.0	50 min
		2.5	21.0	
3	1400-1500	2.3	20.4	1 hr
		2.5	20.4	
4	1330-1830	6.5	24.0	5 hr
		6.5	24.0	
5	1800-2300	5.5	21.5	5 hr*
		6.0	22.0	
6	1330-0930	6.5	14.5	21 hr*
		6.5	15.0	

*Fish removed alive.

actually tried to gulp air, even though the experiments showed that they did not need it. Other fish in conditions identical to experiment 6, but without the screen, were observed to gulp air once every 10-15 minutes. This implies that aerial breathing behavior may be partially independent of temperature and oxygen concentration influences. Fishes nos. 1-3 were observed to gulp air every 2-5 minutes. Thus the rate of aerial gulping does depend somewhat on oxygen concentration, but the behavior is shown independent of oxygen values as well.

Fishes nos. 4 and 6 show that, as expected, at higher termperatures the fish need greater amounts of oxygen. Much more work needs to be done on this with adequate temperature controls.

The characid, *Erythrinus unitaenatus*, does not use its gills at low concentrations of oxygen (Willmer, 1934). The same was noted in the experiments on *Lepisosteus*; at oxygen concentrations of 2.0-2.5 ppm the opercles are shut tight. At such low concentrations of oxygen the fish's blood may contain more oxygen than the medium; to expose its gills to the water at such a time would result only in the loss of more oxygen. Thus the fish conserves oxygen by not using its gills.

L. platyrhincus, however, shows opercular activity under these conditions. Just before the fish gulped air at the surface its opercules expanded and contracted several times, although the gill membranes remained shut. This may be the way the fish draws out stale air from its bladder preparatory to gulping new air. Another series of opercular puffings was seen after the fish had gulped air and exhaled through its gill openings. Perhaps the fish now was forcing the new air into its bladder.

At higher concentrations of oxygen *L. platyrhincus* clearly uses its gills for respiration. Fish no. 4, for example, had a respiratory rate of 20 opercular pumpings per minute when it was also allowed to gulp air. Once the screen was put on this rate rapidly climbed to 40 pumpings per minute.

Summary and Conclusions

L. platyrhincus has both aquatic and aerial respiration and can exhibit both at the same time or either one alone, depending on the conditions. At low temperatures and high oxygen concentrations the fish can survive indefinitely without aerial respiration. The gills are adequate, but the fish still tries to gulp air, perhaps to ease the work load of the gills. At very low oxygen concentrations, the fish closes the gill covers and may live indefinitely on aerial respiration alone. At intermediate levels of oxygen and temperature the fish exhibits both aerial and aquatic respiration.

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