

# EFFECTS OF TEMPERATURE AND LIGHT ON AERIAL BREATHING OF THE LONGNOSE GAR, *LEPISOSTEUS OSSEUS*<sup>1</sup>

VISHNU P. SAKSENA<sup>2</sup>

*Department of Zoology, University of Oklahoma, Norman, Oklahoma*

SAKSENA, VISHNU P. Effects of temperature and Light on Aerial Breathing of the Longnose Gar, *Lepisosteus osseus*. Ohio J. Sci. 72(1): 58, 1975.

The effects of temperature and light on the rate of aerial breathing of longnose gar (*Lepisosteus osseus*) were studied under laboratory conditions by using a 3-channel E & M Physiograph. The method to record the aerial breathing of longnose gar is described in detail and perhaps can be easily adapted to monitor many activities of various aquatic organisms. The aerial breathing rates were recorded at various temperatures ranging from 38° to 96° F. In general, the aerial breathing rate increased as the temperature increased. The  $Q_{10}$  (temperature coefficient) values for the temperature range of 40° to 90° F varied between 4.04 to 1.05. At temperatures below 54° F the longnose gar had a higher aerial breathing rate during the day but at temperatures above 54° F they breathed more during the night. A natural diurnal rhythm of aerial breathing was not evident in the longnose gar. In two complementary experiments at 72° F the rate of aerial breathing was higher during darkness than during equal periods of light regardless of whether the darkness occurred in natural day or night. The difference in aerial breathing rates in day and night (or light and darkness) may be related to activity since all experimental fish were more active during periods of higher breathing.

Aerial breathing of fishes has aroused the curiosity of biologists for more than 100 years. The common air-breathing fishes in North America are species of gar (*Lepisosteus*) and bowfin (*Amia calva*). Gars inhale by approaching the surface and thrusting the jaws out of the water and exhale through the opercular openings. Biologists who first described this behavior in *Lepisosteus* were not certain of its purpose, although they suspected it to be concerned with aerial breathing (Wilder, 1876; Mark, 1890; Potter, 1926). The first experimental evidence that gars actually are air-breathers was provided

by Potter (1927). More recently, Winston (1967), and de Roth (1973) have described the effects of temperature and light on the aerial breathing of the alligator gar (*L. spatula*) and the spotted gar (*L. oculatus*) respectively. A similar study on the bowfin (*Amia calva*) has been reported by Horn and Riggs (1973). Additional studies related to behavior and physiology of respiration among gars have been done by McCormack (1967, 1970) and by Rhan *et al* (1971).

Objectives of the present study were to evaluate effects of temperature and light on the rate of aerial breathing of the longnose gar (*L. osseus*) and to describe a method for recording the aerial breathing rate of gars. The recording technique may be adaptable for the study of activity of other kinds of aquatic organisms.

## MATERIALS AND METHODS

Three longnose gar (*L. osseus*), designated as A, B, C, and ranging from 348 to 436 mm total length, were collected in the summer of 1962 from Lake Texoma, an impoundment of the Red and Washita rivers, Oklahoma and Texas. The fish were brought to the University of Oklahoma campus where the study was conducted in a controlled temperature room, illuminated by two 60-watt 48T12, fluorescent, cool-white tubes, connected to an automatic time switch. Each fish was kept in 50-gallon aquarium filled with laboratory tap water. Aquaria covers made of rubber mesh prevented fish from jumping out and also allowed ventilation, and light entered from the top and sides of each aquarium.

A 3-channel E & M Physiograph provided continuous recording of aerial breathing of the three fish simultaneously in both light and darkness (fig. 1). Each recording channel consisted of a transducer, an A.C. coupler to filter out 60-cycle disturbances, an amplifier, and a pen recorder. A ping-pong ball was hooked to the transducer shutter by a taut nylon thread which allowed it to float on the water. The disturbance of the water surface caused by air breathing moved the ping-pong ball and produced a chronologic marking on the recording paper. This marking of aerial breaths could be easily distinguished

<sup>1</sup>Manuscript received May 8, 1974 (#74-13).

<sup>2</sup>Present address: Department of Biology, Muskingum College, New Concord, Ohio 43762.

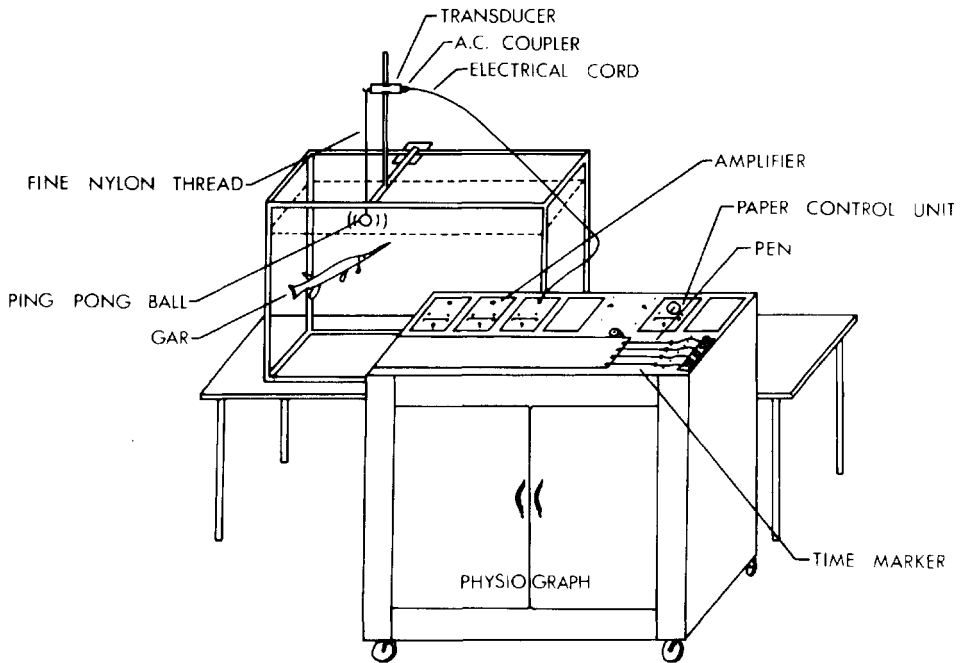


FIGURE 1. Diagrammatic sketch of the experimental apparatus including the Physiograph for recording the aerial breathing of longnose gar (*Lepisosteus osseus*).

from any other disturbance or fish activity based on observations made throughout the study. The automatic time-marker on the Physiograph provided the exact time of each breath and thus intervals between breaths were easily determined.

**Experimental Procedure.** Aerial breathing rates of 3 longnose gars (A, B, C) were determined at 38°, 42°, 46°, 50°, 54°, 60°, 66°, 72°, 86°, and 96° F. The temperature was changed in a stepwise fashion allowing sufficient time (at least 3 days) for acclimation. The experimental fish were fed live mosquitofish (*Gambusia affinis*) during acclimation time. At each temperature, aerial breathing was recorded continuously for six days (144 hrs.). Lights were automatically turned on from 6 AM to 6 PM and off from 6 PM to 6 AM. The dissolved oxygen in the aquaria was monitored by the Winkler Method and ranged from 4.9 ppm (at 38° F) to 2.1 ppm (at 96° F). Gar A died after 66° F, B after 86° F, and C after 96° F.

Since the temperature experiments were conducted with equal periods of light and darkness, the data provided information on the effect of light on the rate of aerial breathing. To determine whether the aerial breathing rate is affected strictly by the presence or absence of light rather than the natural diurnal cycle, two additional experiments, each of 72-hour duration, were conducted at 72° F. During the first experiment the light was off during the day (6 AM to 6 PM) and on during the night (6 PM to 6 AM), and during the second experi-

ment the light was alternately on two hours and off two hours for the entire recording period.

## RESULTS

**Effects of Temperature.** In general, the rate of aerial breathing of longnose gar increased as temperature increased. At lower temperatures (38° to 46° F), fish ate very little and remained mostly inactive on the aquarium bottom except for infrequent trips to the surface for aerial breathing. At higher temperatures (above 54° F), fish were more active and their appetite increased accordingly.

The data were fitted by linear regression plotting average breaths/hour against temperatures on a log scale (fig. 2). The breaths/hour value at 96° F was not included in the regression analysis because the fish obviously was under stress at that high temperature, and died shortly thereafter. The equation for the longnose gar is  $\log \bar{Y} = -3.69966 + 0.06030X$  where  $\bar{Y}$  is breaths/hour and  $X$  is temperature. The  $Q_{10}$  (temperature coefficient) values for the temperature ranges of 40° to 50° F, 50°

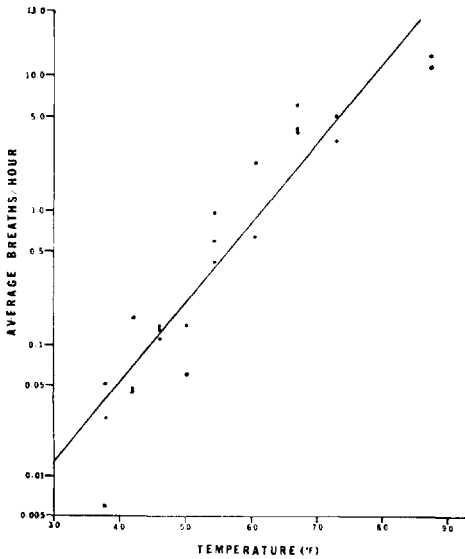


FIGURE 2. Relationship of aerial breathing of three longnose gar (*Lepisosteus osseus*) to temperature.

to 60° F, 60° to 70° F, 70° to 80° F, and 80° to 90° F, were 4.04, 4.2, 4.09, 3.05, and 1.45 respectively.

**Effects of Light.** Data for longnose gar (table 1) clearly indicate that at lower temperatures (38° to 54° F) the rate of aerial breathing was slightly higher during the day than at night but that at higher temperatures (above 54° F) they breathed more during night than day. When data for high and low temperature ranges were analyzed using a 2×2 contingency test, a statistically significant difference (A and B: .001 > P > .0005; C: .025 > P > .01) was evident between day versus night aerial breathing rates of the longnose gar.

When the longnose gar was exposed to 12-hour alternate periods of light and darkness at 72° F, under reversed natural diurnal cycle, breathing rates were greater in dark than in light, although this difference was statistically significant (P > .001) only for gar B. In the experiment at 72° F light was turned on and off at 2-hour intervals, and the longnose gar again showed a tendency for more breathing in darkness than in light. This difference was statistically significant (P < .001) only for gar B.

#### DISCUSSION AND CONCLUSIONS

In general, the rate of aerial breathing of longnose gar (*L. osseus*) increased as temperature increased. Similar results were reported for the alligator gar (*L. spatula*) by Winston (1967), for the spotted gar (*L. oculatus*) by de Roth (1973), and the bowfin (*Amia calva*) by Horn and Riggs (1973).

The relationship between aerial breathing in light and dark conditions seems to differ among air-breathing fishes. The longnose gar showed higher aerial breathing rates during the day at lower temperatures (38° to 54° F) but Winston (1967) found the reverse to be true for the alligator gar (below 60° F). At higher temperatures (above 54° F), longnose gar had a higher breathing rate during the night whereas Winston (1967) showed that alligator gar (above 75° F) breathe more during the day. At all experimental temperatures (55° to 80° F), the spotted gar had a significantly higher aerial breathing rate during darkness than during the daylight hours (de Roth, 1973). Results similar to those for the spotted gar were reported for the bowfin by Horn and Riggs (1973) although, in a relatively few trials at lower temperatures (below 55° F), they found the fish had a higher aerial breathing rate during the day than the night.

The data from the light experiments at 72° F to determine if the aerial breathing rate was affected by the presence or absence of light indicated that longnose gar have a higher aerial breathing rate during darkness than in light regardless of whether darkness occurs in natural day or night. Similar results are reported for the alligator gar (Winston, 1967), and the bowfin (Horn and Riggs, 1973).

The higher aerial breathing rate of longnose gar during darkness may be related to activity in addition to temperature. I observed the longnose gar to be more active and nearer the water surface in the laboratory during darkness as well as in Lake Texoma at night. Perhaps, this higher breathing activity at night is related to feeding in their natural habitat. Similar conclusions were reached for alligator gar (Winston, 1967), spotted gar (de Roth, 1973), Florida gar, *L. platyrhincus* (Hunt, 1960), and bowfin (Horn

TABLE I

Average number of daily aerial breaths per hour and during successive periods of day (6:00 A.M. to 6:00 P.M.) and night (6:00 P.M. to 6:00 A.M.) of three longnose gars.

AVERAGE BREATHS PER HOUR			
Temp. F°	24-Hour Period	Day	Night
Longnose Gar A			
38	0.029±0.010*	0.034±0.011*	0.023±0.013*
42	0.048±0.010	0.068±0.024	0.027±0.016
46	0.141±0.031	0.180±0.013	0.104±0.010
54	0.991±0.298	0.588±0.067	1.396±0.136
66	4.128±0.509	2.818±0.124	5.449±0.143
Longnose Gar B			
38	0.053±0.016	0.064±0.010	0.042±0.012
42	0.166±0.036	0.216±0.021	0.116±0.018
46	0.133±0.086	0.196±0.063	0.078±0.059
50	0.145±0.019	0.168±0.029	0.124±0.042
54	0.618±0.122	1.208±0.109	0.230±0.098
60	0.673±0.048	0.282±0.086	1.055±0.144
66	3.785±0.115	2.875±0.169	4.696±0.283
72	3.430±0.779	2.338±0.234	4.524±0.564
86	10.437±0.687	9.854±0.289	11.025±0.405
Longnose Gar C			
38	0.006±0.005	0.008±0.003	0.004±0.001
42	0.048±0.015	0.058±0.024	0.038±0.016
46	0.111±0.041	0.143±0.046	0.089±0.023
50	0.062±0.007	0.078±0.017	0.054±0.013
54	0.431±0.111	0.602±0.198	0.268±0.085
60	2.327±0.121	1.982±0.133	2.674±0.245
66	6.277±0.708	4.574±0.289	7.983±0.643
72	5.124±0.626	3.643±0.183	6.612±0.459
86	11.041±0.609	10.112±0.433	11.948±0.501
96	7.416±0.282	6.745±0.296	7.992±0.167

\*Mean ± standard error of the mean.

and Riggs, 1973). Grigg (1965) correlated greater frequency of air breathing in nature by Queensland lungfish (*Neoceratodus forsteri*) with increased nocturnal activity.

The highly vascularized swim-bladder in *Lepisosteus* is supplied with oxygenated blood by branches of the dorsal aorta (Jollie, 1962). Possibly, the higher oxygen demand created during increased activity cannot be adequately met by gill respiration alone. Aerial respiration may serve to supplement gill respiration in meeting this increased oxygen demand. Similar conclusions were drawn by Grigg (1956), who reported that seasonal stagnancy and dextoxygenation were unlikely factors accounting for the air-breathing habit in Queensland lungfish, but the lung acts as an accessory respiratory organ during active periods.

*Acknowledgments.* I am grateful for the aid of Dr. Carl D. Riggs for guidance in research; Dr. Arthur Ghent for help in the data analysis; Dr. Edward D. Houde for assistance in the analysis of data and for his critical review of the manuscript.

Part of a doctoral dissertation submitted in 1963 to the University of Oklahoma, Norman, Oklahoma.

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