MASTER

INTEGRATIVE STUDIES OF THERMOREGULATION IN ECTOTHERMIC
VERTEBRATES IN AQUATIC HABITATS

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for Period

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ABSTRACT

Field experiments are underway to determine the behavioral mechanisms by which largemouth bass, Micropterus salmoides, respond to rapid temperature changes in their natural environment. Laboratory experiments are clarifying the relationship between basking behavior of the turtle, Pseudemys scripta and its nutritional state. Important progress has been made in the development and miniaturization of a multichannel, temperature sensing, radio transmitter for fish. Theoretical analysis and mathematical modeling have defined the realized and fundamental climate space of P. scripta and allows us to predict the behavior of this turtle.

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INTRODUCTION

The purpose of this research has been to determine quantitatively the mechanisms by which behavior, physiology and the physical environment place constraints on the ability of aquatic ectotherms to thermoregulate in their natural environment. During the 1980-81 project year significant progress has been made in all areas of our research and we have accomplished all of our objectives for the year. Particularly important contributions have included progress on development and miniaturization of the multichannel, temperature sensing, radio transmitter for fish, completion of the first set of field experiments on the reaction of largemouth bass (Micropterus salmoides) to thermal effluents in Pond C on the Savannah River Plant, the initiation of laboratory experiments to determine the relationship between basking behavior of the turtle, Pseudemys scripta, and its physiology and continued progress in integrating theoretical analysis with field data on the fundamental and realized climate space of the turtle, P. scripta. Edward Standora continued to provide strength to our theoretical and technical efforts and has been particularly active in directing day-to-day laboratory activities. Kimberly Hammond and Teresa Tuel have made very good progress on the turtle and fish experiments. Since joining the laboratory last fall they have greatly improved their analytical and technical skills and have begun to make important contributions to this project.

Overall objectives for this renewal period (October 1980 to October 1983) are to: 1.) Determine the role of heat transfer properties of tissues of largemouth bass, Micropterus salmoides, in the thermoregulatory behavior of this fish in its natural environment, 2.) Quantify the role of behavior in the ability of bass to survive in a hostile thermal environment, Pond C on the Savannah River Plant, Aiken, South Carolina, 3.) Determine the relationship between behavior,

physiology and the preferred body temperature of the turtle Pseudemys scripta, and 4.) Continue theoretical analysis (mathematical modeling) of the interaction between biophysical and behavioral aspects of the thermoregulation of these animals in response to multiple stresses in their environments.

Specific objectives to be accomplished in this project year (October 1980 to October 1981) were to: 1.) Complete development, miniaturization and testing of the multichannel temperature sensing, radio transmitter for use in the heat transfer study of largemouth bass, 2.) Begin a field study on the reaction of bass to the entry of thermal effluent into Pond C and the movements, home ranges and site specificities of bass in that reservoir, 3.) Continue observations to document the behavior of bass while they are confined to refuge areas in Pond C, 4.) Begin laboratory experiments to measure the relationship between basking behavior, nutritional status, physiology and temperature preferenda-optima of the turtle Pseudemys scripta, and 5.) Continue theoretical analysis, data reduction and manuscript preparation based on data currently being acquired. All of these objectives will have been met by September 30, 1981. Details are given below.

MULTICHANNEL TEMPERATURE TRANSMITTER FOR LARGEMOUTH BASS

By September 30, 1981 we will have completed development and testing of a miniature, multichannel, temperature transmitter for use in heat transfer experiments on largemouth bass. Standora has already solved the leakage problem that plagued our early multichannel transmitters. A combination of epoxy casting resin and plastic sealants positively seals the transmitter and has been shown to be effective for up to six weeks in the field. New hybrid integrated circuit chips replace conventional integrated circuits and allow us to reduce transmitter

size by 1/2. This summer Standora will implant transmitters in bass and place the fish in large holding tanks at the Savannah River Ecology Laboratory. We will observe them for extended periods of time to determine their reaction to the transmitter and sensor implants, their rate of healing and the reliability of the transmitter itself.

ROLE OF BEHAVIOR IN THE ABILITY OF BASS TO SURVIVE IN A HOSTILE THERMAL ENVIRONMENT

This experiment is well underway. A pilot experiment was conducted in March. We implanted single channel, temperature sensing, radio transmitters into two largemouth bass and followed them for several days during a reactor up cycle. These fish avoided the hot effluent and acted in a manner that appeared to be partly "predictive" and partly "reactive" (Neill, 1979). After reactor shut down in late April one of these fish moved out of Sanctuary cove and moved to the Hot Dam (Fig. 1). From this data and that of Ross (1980) it appears that bass in Pond C may include the entire 67 ha of this reservoir in their home range. If that is the case, then the "predictive" mode of behavior may be of great importance to these fish. They have the opportunity to "learn" the thermal and spatial topography of the reservoir and thus could act in a "predictive" way when heated water enters Pond C at the beginning of a reactor up cycle.

Teresa Tuel will conduct two telemetry experiments this year. One will take place in July and the second in September. Five bass will be followed during each experiment. Two more experiments will be conducted in November 1981 and February 1982. Tuel has completed all of her transmitters and successfully field tested two of them during the March experiment.

The mark recapture experiment will begin in July, 1981. After bass are

restricted to the refuges we will capture them with a trap net and mark them with color coded Floy tags (FD 68 B). We will then recapture them during each of the next three reactor cycles to trace their movement and determine site specificity. Experiments with naive bass are being planned and will be detailed in the renewal proposal.

BEHAVIOR OF BASS IN REFUGE AREAS OF POND C

A second observation tower has been erected along Sanctuary cove at Pond C. We continue to observe bass behavior and record interactions. Intensive periods of observation are planned for the July and September reactor up cycles of 1981. Specific behavior categories are being established which are consistent with prior studies (Miller, 1975; Heidinger, 1975). In Years II and III we will score individual bass as to the amount of time they spend engaged in each of these behaviors.

PHYSIOLOGY AND BASKING BEHAVIOR OF TURTLES

By September 30, 1981 the laboratory experiments to determine the interactive effects of acclimation temperature and nutritional status on the basking behavior of P. scripta will be well underway. Kimberly Hammond has modified the climate space simulation chamber of Terpin, et al. (1979) to provide two test areas for simultaneous experiments on fed and non-fed turtles. Each area has a pool (30 cm deep) and an adjacent basking platform. The basking platform is illuminated by a 400 watt sodium vapor lamp and two photoflood lamps. The remainder of the test area is lighted by the overhead fluorescent lights of the environmental chamber shining through a plexiglass partition. A 12 hour

light/12 hour dark photoperiod is maintained. Temperatures are controlled to $\pm 1^{\circ}\text{C}$.

Duplicate test areas allow us to study fed and non-fed turtles simultaneously. Four animals will be chosen for each experimental group. They will be weighed, measured and placed into the test area. Each turtle carries a single channel radio transmitter or implanted thermocouple to record body temperature. After a five day adjustment period we begin to record basking behavior and body temperatures. Behavior is filmed at four frames/minute with an 8 mm movie camera. Body temperature is recorded once each 15 minutes. Each experiment lasts two weeks.

The following experimental conditions are being tested: temperatures of 10, 20, 30 and 35°C with turtles being either fed or non-fed. Two replications will be conducted for each condition. Results are analyzed using the SAS (Barr, et al., 1976) statistical package on our IBM 370/168 computer.

Metabolism experiments are being planned and will be detailed in the renewal proposal.

THEORETICAL ANALYSIS AND MATHEMATICAL MODELING

Theoretical analysis and mathematical modeling have further clarified the realized climate space of the turtle P. scripta. On cold days (Figs. 2 and 3) turtles operate at body temperatures that are within the range provided by available water temperatures. They seldom bask and thus use only a small portion of their climate space. On hot days, they do bask and thus often operate at temperatures above the range provided by the aquatic portion of their environment (Figs. 4 and 5). Thus, on a hot, clear day they tend to operate near the full sun line of their climate space (Fig. 6). On a hot, cloudy day, available

microclimates are greatly restricted and turtles have a reduced opportunity to raise their body temperatures by basking (Fig. 7). On cold days (Figs. 8 and 9) the realized portions of a turtles climate space are much reduced and represent very cold conditions. Since venturing into the atmospheric part of their microclimate would result in a cold body temperature, turtles generally stay in the water. There they operate along the blackbody line of the climate space and can maintain a higher body temperature than they could on land. We conclude that the realized climate space of P. scripta is only a limited part of the fundamental climate space. The realized portion changes with the seasons and puts constraints on the behavior and physiology of this turtle. Completion of this analysis will allow us to predict the effect of thermal stresses on the behavior of this turtle.

CONCLUDING COMMENTS

During this year we have published two articles (Davis, et al., 1980, Spotila, et al., 1981) and one note (Schubauer, 1981), have four papers in review or in preparation and three students finished their masters theses (Crawford, 1980, Weinheimer, 1980, and Schubauer, 1981). This summer we will be presenting two papers at the joint meeting of the Herpetologists League and the Society for the Study of Amphibians and Reptiles.

Cooperation with the Savannah River Ecology Laboratory (SREL) continues to be an important factor in our field research. This year we have worked with Dr. I.L. Brisbin and members of his laboratory. We continue to maintain close contacts with Drs. Michael Smith and J.W. Gibbons. By maintaining this cooperative effort we have increased the effectiveness of our research effort and contributed to the research goals of SREL.

The project director, James R. Spotila, spent 100% of his time on this project for 1 1/2 months (June 1 - July 15, 1981). He spent 33% of his time on this project during the 1980-81 academic year.

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Figure 1a. Movement of a bass carrying a temperature sensitive radio transmitter in Pond C, a nuclear reactor cooling reservoir, located on the Savannah River Plant, Aiken, South Carolina. Reactor becoming operational March 24, 1981. Bass restricted to cool arm. * marks locations of bass at times indicated in brackets. Dashed line indicates estimated travel path of bass. Underlined temperatures were telemetered from the fish. Surface water temperatures are in parentheses. Shaded areas indicate thermal refuge areas which are fed by cool springs or streams.

Figure 1b. Reactor operational March 25. Bass restricted to refuge area. Dashed line indicates movement of bass from 17:00 March 24 to 11:30 March 25. See 1a for explanation of numbers and symbols.

Figure 1c. Reactor shut off May 2. Bass moves throughout entire pond. Dashed line indicates shortest possible route of bass from Sanctuary Cove to Hot Dam.

Figures 2-5. Graphs of water temperatures available during contrasting climatic conditions. Stippled area indicates range of water temperatures present throughout a typical day. Solid and dashed lines represent environmental temperatures telemetered from free-ranging P. scripta. If these lines exceed stippled values, the turtle is no longer in the water.

Figure 2.

Figure 3.

Figure 4.

Figure 5.

Figures 6-9. Climate space diagrams for *P. scripta*. Shaded area represents range of air temperatures and radiation levels which were available to the animal. Dots indicate conditions during which basking occurred. The dark band on the black body line shows the range of available water temperatures. The numbers 10, 100, and 400 indicate wind speed limits in cm sec^{-1} . a is absorptance to solar radiation.

Figure 6.

Figure 7.

Figure 8.

Figure 9.

APPENDIX I

Scientific PresentationsArticles

- Davis, J.E., J.R. Spotila, and W.C. Scheffler. 1980. Evaporative water loss from the American alligator, Alligator mississippiensis: the relative importance of respiratory and cutaneous components and the regulatory role of the skin. *Comp. Biochem. Physiol.* 67A: 439-446.
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Master's Theses

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