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Hematology as Related to Diving Characteristics of
Elaphe obsoleta, Nerodia erythrogaster,
Nerodia fasciata and Nerodia rhombifera

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ABSTRACT

The diving capabilities of Nerodia erythrogaster flavigaster and Nerodia fasciata confluens
were investigated and the results were compared with similar studies on Nerodia rhombifera
rhombifera and Elaphe obsoleta obsoleta (Baeyens et al., 1978). In addition, morphological and
hematological parameters contributing to underwater survival were examined.

The duration of underwater survival for N. erythrogaster and N. fasciata was approximately
one hour with no difference between the species. The lung volumes of the two species were
also similar but were significantly less than lung volumes reported for E. obsoleta. There were
no significant differences in hemoglobin concentration, red blood cell count or hematocrit
between N. rhombifera, N. erythrogaster, N. fasciata, and E. obsoleta. Based on similarities in
underwater tolerance, lung morphology and hematology, Nerodia more closely resembles
the terrestrial E. obsoleta than those reptiles specifically adapted to an underwater existence.

INTRODUCTION

Certain representatives from all the vertebrate classes display pronounced respiratory and cardiovascular changes in response to sub-
mergence. These animals, collectively referred to as the diving ani-
mals, are physiologically and morphologically suited for underwater
survival. Most of the experimentation to date has focused on the diving
mammals and birds, and relatively little is known of the physiology
of diving reptiles.

This study represents a continuation of work reported earlier
(Baeyens et al., 1978) and has two specific purposes. First, to com-
pare the diving abilities of two species of water snakes (Nerodia ery-
throgaster flavigaster, and Nerodia fasciata confluens) with the diving
ability of the terrestrial black rat snake. Second, to explore some of
the hematological and morphological attributes which might contrib-
ute to underwater survival in N. erythrogaster, N. fasciata, N. rhom-
 bifera and E. obsoleta.

MATERIALS AND METHODS

Specimens of N. erythrogaster, N. fasciata and N. rhombifera were
collected at night from various minnow farms in Lonoke County,
Arkansas. E. obsoleta were collected during the day from wooded
areas in Pulaski County, Arkansas. Weights of all the experimental
animals ranged between 450 and 800 g. Most snakes were utilized
within one week of capture. Snakes kept in captivity over two weeks
were fed leopard frogs and minnows (Nerodia) or small mice (Elaphe).
Most experiments were carried out between March and September,
a period during which snakes are most active in Arkansas.

For statistical analysis a Student-Newman-Keuls test was used to
make multiple comparisons among means, and values considered
significantly different have a p value of 0.05 or less (Sokal and Rohlf,
1969).

The duration of underwater survival for N. erythrogaster and N. fasciata was determined by subjecting the snakes to involuntary dives
as previously described (Baeyens et al., 1978). The dive began in the
instant the animal voluntarily submerged its external nares at which
time the cage containing the animal was totally submerged. The
snakes were kept under close observation throughout the dive. Termi-
nation of the dive occurred at the first sign of stress. The outward
indications of stress varied from snake to snake but were usually
associated with a release of air from the lung and a sudden increase in
activity in an attempt to reach the surface. Snakes remained under

close observation after surfacing to insure that they were not seri-
ously impaired as a result of the dive.

Lung volumes were determined for N. erythrogaster and N. fasciata by injecting air into the lung until the point of maximal lung ex-
pansion was reached (Baeyens et al., 1978). The lung capacities are
expressed in terms of ml per kg body weight.

In all four species blood samples were collected from the hepatic portal vein with a 23 gauge needle fitted to a 5 cc syringe containing
EDTA as an anticoagulant. Approximately 4 ml of blood were drawn
from each animal. Hemoglobin concentration was measured as cyano-
methemoglobin using Drabkin’s diluent (Davidsohn and Wells, 1963). For hematocrit determinations, nonheparinized capillary
tubes were filled with blood and one end was sealed with clay. The
tubes were immediately centrifuged at approximately 10,000 RPM
for ten minutes. Red blood cells were counted with a standard
Neubauer counting chamber with Hayem’s solution as the diluent
(Davidsohn and Wells, 1963). Five red blood cell counts were made
for each snake and the average was recorded.

RESULTS

Dive Times - Snakes were closely watched throughout the dive and
at the first sign of stress the dive was terminated. When a snake was
severely stressed as a result of a dive, it would be comatose and
would take several hours to recover. Dive times were recorded only
for those snakes which showed no signs of hypoxic stress upon surfac-
ing.

Members of each species tolerated dive periods exceeding one
hour (Table 1). There were no significant differences in the submer-
gence times of the two species.

Lung Morphology - In both N. erythrogaster and N. fasciata the
left lung has been lost, and the right lung is a simple tubular-shaped
structure. The general lung structure of both species was similar to
that described for N. rhombifera and E. obsoleta (Baeyens et al.,
1978). The vascular portion of the lung comprised 24% of the total
lung length in N. erythrogaster and N. fasciata and there were no
significant differences in total lung volume between the species. The
lung volumes of N. erythrogaster and N. fasciata were similar to
values reported for N. rhombifera but were significantly less than
values reported for E. obsoleta (Table 1).

Hematology - The results of the hematology studies are given in
Table 2. Statistical analysis revealed no significant differences within
or between species in any of the hematological values measured.
Table 1. Dive times and lung volumes for Nerodia and Elaphe.

<table>
<thead>
<tr>
<th>Species</th>
<th>Dive Time (min)</th>
<th>Lung Volume (ml/kg body wt)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean ± S.E (N)</td>
<td>Mean ± S.E (N)</td>
</tr>
<tr>
<td>N. erythrogaster</td>
<td>76.4 ± 12.6 (10)</td>
<td>64.0 ± 12.2 (10)</td>
</tr>
<tr>
<td>N. fasciata</td>
<td>59.3 ± 20.2 (5)</td>
<td>61.4 ± 9.2 (5)</td>
</tr>
<tr>
<td>N. rhombifera</td>
<td>68.3 ± 9.2 (10)</td>
<td>51.7 ± 11.1 (12)</td>
</tr>
<tr>
<td>E. obsoleta</td>
<td>70.5 ± 8.3 (9)</td>
<td>60.2 ± 12.7 (6)*</td>
</tr>
</tbody>
</table>

*Significant difference from Nerodia at the 5% level.

From Baeyens et al. 1978.

Table 2. Hematocrits (PCV), hemoglobin concentrations (Hb) and red blood cell counts (RBC) for Nerodia and Elaphe.

<table>
<thead>
<tr>
<th>Species</th>
<th>Number of Snakes</th>
<th>Hb g/dl</th>
<th>RBC/mm^3 (10^6)</th>
</tr>
</thead>
<tbody>
<tr>
<td>N. erythrogaster</td>
<td>10</td>
<td>26.0 ± 4.5</td>
<td>10.7 ± 1.2 ± 0.71 ± 0.07</td>
</tr>
<tr>
<td>N. fasciata</td>
<td>5</td>
<td>29.0 ± 5.9</td>
<td>9.7 ± 1.5 ± 0.57 ± 0.03</td>
</tr>
<tr>
<td>N. rhombifera</td>
<td>10</td>
<td>32.3 ± 3.5</td>
<td>10.9 ± 2.1 ± 0.67 ± 0.09</td>
</tr>
<tr>
<td>E. obsoleta</td>
<td>7</td>
<td>31.6 ± 3.5</td>
<td>11.5 ± 2.1 ± 0.55 ± 0.04</td>
</tr>
</tbody>
</table>

DISCUSSION

Two areas which may be utilized for oxygen storage during a dive are the lungs and the blood. The lung and air sac volumes of diving mammals and birds are not significantly larger than those of their terrestrial counterparts (Scholander and Irving, 1941). Andersen (1961) found that the lung volume of the alligator, an excellent reptilian diver, ranges from 76 to 102 ml/kg. This is somewhat higher than the values reported for diving mammals, but lower than those reported for diving birds (Eliasen, 1960). The lung of the completely aquatic marine snake Pelamis platura fills the entire coelomic cavity extending from the neck to the vent (Heatwole and Seymour, 1975). The immensity of the lung in this species is also reflected by its large volume (580 ml/kg body weight). In contrast, the lung volumes were much smaller in the two species we studied (Table 1). Since the lung volume of Nerodia is somewhat smaller than the terrestrial Elaphe, it does not appear that the lung of Nerodia is particularly adapted as an important oxygen storage organ for underwater activity.

The role of elevated hemoglobin concentration for oxygen storage has been shown to be of importance in diving mammals and birds (Andersen, 1966). The importance of hemoglobin concentration in diving reptiles has been difficult to ascertain because of the wide variations in reported values (Seymour and Webster, 1975; Dessauer, 1970). The present study indicates a similarity in hemoglobin concentration between Nerodia and Elaphe. These values fall within the range of hemoglobin concentrations found in sea snakes (Seymour and Webster, 1975). Red blood cell counts and hematocrits were also similar in the four species studied. These similarities agree with Hutton's (1958) findings of no consistent differences in either red blood cell counts or hematocrits between aquatic and terrestrial snakes.

Based on the parameters examined, Nerodia appears to be no better adapted for an aquatic existence than is the terrestrial Elaphe. (Baeyens et al., 1978). The survival time of Nerodia when forcibly submerged is no longer than that of Elaphe, and is much shorter than for some turtles and sea snakes which can remain underwater for several hours (Pickwell, 1972; Graham, 1974). The similarities in hemoglobin concentration in Nerodia and Elaphe suggest that the blood does not have a unique oxygen storage capacity to facilitate underwater survival in Nerodia. In the same regard, the lung volume of Nerodia is smaller than that of Elaphe, and a great deal smaller than the lung volume of sea snakes. Based on the similarities in lung structure, hematology and underwater tolerance between Nerodia and Elaphe, it would seem that some of the physiological potential for an aquatic existence is already present in the black rat snake and presumably in other terrestrial species as well.

ACKNOWLEDGEMENTS

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LITERATURE CITED


