MAINTAINING HELLBENDER SALAMANDERS
IN CAPTIVITY

THE EVOLUTION OF OUR KNOWLEDGE

Max A. Nickerson, Head-Vertebrate Division, Milwaukee Public Museum, Milwaukee, Wisconsin 53233; Adjunct Scientist, Max Allen's Zoological Gardens, Eldon, Missouri 65026

For decades the staffs of numerous zoological parks have tried to create natural conditions for their captives, especially those they desired to breed. This information must be gleaned from field studies. Field studies are also important in pinpointing natural populations of sufficient size to be harvested for laboratory research, exhibition and educational purposes.

Often it is impossible to answer questions in the field because of varying conditions, the inability to utilize specialized equipment, lack of sterile conditions, etc. Furthermore, it has been my experience that field work often gives rise to questions which can be taken into the laboratory for answers. Therefore, I should like to use this opportunity to explain how we have coupled field and laboratory research to answer some questions important in maintaining hellbender salamanders, Cryptobranchus alleganiensis in captivity.

Initially after discovering a population of Ozark hellbenders, C. a. bishopi, we undertook tag-recapture studies to determine population size, population structure, biomass, movements, sex ratios, etc. Previously only one specimen had been known from this watershed and we were somewhat surprised to find that instead of being rare, Ozark hellbenders were one of the dominant organisms within this stream system. There were between 341 and 573 tagable sized individuals per km of stream-bed. Riffles studied had densities of one hellbender per 6 to 16 square meters. (Nickerson & Mays, 1973a; Nickerson & Mays, 1973b).

Observations made during the first year's field work caused us to ask several questions which we and/or others answered or tried to answer in subsequent years. These questions related to water quality, (oxygen and carbon dioxide concentration, pH, etc.) flow and depth as it effects hellbenders. Therefore, we made weekly year-round water quality studies within our main Missouri research stream section.

From this we determined that year-round variations, of these important environmental parameters, within what is probably optimal habitat were: oxygen 8.4-13.6 ppm; carbon dioxide near 0-9.8 ppm; pH 7.6-9.0; alkalinity 122-289 ppm, and temperature 9.8-22.5 °C (Nickerson & Mays, 1973b). Furthermore, we noted that at times during the warmest part of the summer, with water temperatures of 21-22.5 °C and essentially saturated with oxygen, hellbenders moved from still water to riffles. We initially thought that this might reflect differences in temperature and oxygen concentrations under the rocks which serve as their daytime retreat. However, subsequent sampling indicated that there were no significant differences in oxygen concentration and temperature between these sites (Nickerson, unpubl. data). This caused us to
consider the complex topic of respiration. Upon hatching hellbenders have gills and lungs. Usually within the first two years of life or by the time they reach approximately 125 mm in length the gills are absorbed and the lungs retained. However, during all of our diurnal investigations only once did we observe a hellbender swim to the surface of a stream. Therefore, we questioned the utilization of the lungs as efficient respiratory surfaces. About this time Guimond (1970), utilizing a special respirometer which separated the head, gill and body regions of the animal, determined that the lungs were responsible for less than 6% of the oxygen uptake required by Cryptobranchus at temperatures up to $25^\circ$ C. Perhaps the lungs are involved in hydrostatic functions. Histological studies have shown that the lateral folds are areas of high vascularization, and also the areas where the skin has the fewest layers of epithelial cells (Noble, 1925; Bernstein, 1953). These folds are therefore suspect as centers of cutaneous respiration. When hellbenders are placed in still water at high temperatures they may undergo a side to side rocking. Recently this has been shown to be stress related (Wilkinson, unpubl. data). It would still seem that the rocking would break up the boundary layer of water, which presumably has a lowered oxygen content, and expose these folds to more water with higher oxygen qualities. Therefore, hellbenders in riffles would presumably expose the lateral folds to more oxygen molecules than those in still waters. There is, however, an intimate relationship between oxygen concentration, temperature, and flow across the folds which relates to the respiratory efficiency of such a cutaneous system. Although hellbenders prefer cooler temperatures and probably require them for effective maintenance and reproduction, their critical thermal maximum which is the temperature above which they are unable to help themselves, is 32.7-36.6$^\circ$ C with 5-25$^\circ$ acclimation temperatures (Hutchison et al., 1973). However, they may be removed from streams at 22$^\circ$ C plunged directly into ice water and maintained at near 0$^\circ$ C for several days (Nickerson & Mays, 1973b). Although hellbenders may consume a wide variety of food ranging from earthworms, aquatic insects and fish to other hellbenders, crayfish serve the bulk of their diet in all sampled populations. However, they feed on carrion and some will even accept hot dogs. They have food in their digestive tracts year-round in Arkansas and Missouri streams but their digestive processes are very slow. Some are able to survive five months without food. They are known to be parasitized by fungi, protozoans, nematodes, trematodes, cestodes, acanthocephalans and annelids (See Nickerson & Mays, 1973b). A new species of leech, which is currently being described, is apparently specific for Ozark hellbenders.

There are few recorded predators of hellbenders. Apparently other hellbenders and fish are the major predators when man is excluded. Certainly very small individuals should not be displayed with large adults as they are readily consumed. Additionally, Cryptobranchus appear territorial and usually only one resides under a single rock.

They are very sensitive to white light and have been characterized as nocturnal although they are more diurnally active in the spring and fall. Additionally, we have laboratory controlled photoperiod data which indicates two peaks of activity. One would approximate sunrise and the other sunset. These data need to be confirmed by field observations (Neeske and Nickerson, unpubl. data). When maintained under red light they are readily active and appear less positively thigmotactic. When maintained under white light, they are prone to spend most of their time under rocks, etc.

Hellbenders are fall breeders and are the only North American salamanders which practice external fertilization. They breed as day length and water temperatures
are decreasing (Nickerson, in manuscript). Typically nests are excavated under rocks and logs. Females deposit about 200-450 eggs which undergo a 68-84 day incubation period before hatching (Bishop, 1941). They remain larval for two years or perhaps three years in some populations (Nickerson & Mays, 1973b). Sexual maturity is reached in about five to six years. Males may be distinguished from females by the presence of enlarged cloacal glands just before, during and sometimes after the breeding season. Additionally, females have been shown to have much higher serum calcium levels than males (Nickerson & Mays, 1973). Cryptobranchids are long-lived and are known to reach 55 years in captivity (Nigrelli, 1954).

In the summation hellbenders should be exhibited under red light within highly oxygenated, alkaline, cool water (20°C or lower) and fed crayfish and fish. A cover rock or tile should be provided for each salamander and very small individuals should not be housed with large adults. If breeding is desired, photoperiod and temperatures should be reduced.
LITERATURE CITED


