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Some Aspects of the Ecology of the Hellbender, *Cryptobranchus Alleganiensis Alleganiensis,* in a Pennsylvania Stream[1]

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ABSTRACT — Ecology of hellbenders (*Cryptobranchus alleganiensis*) was studied in French Creek of northwestern Pennsylvania. The 220 m x 70 m study area formed a grid with markers at 10 m intervals. Hellbenders were individually marked; 152 individuals were captured and 81 recaptured at least once. Hellbenders were most abundant in relatively shallow rapids areas and utilized large rocks for cover. The mean distance between successive captures was small, 54.8 per cent showing inter-capture distances of 10 m or less; maximum distance was 160 m. Males did not differ significantly from females in the median distance between successive captures. The average mean activity radius was 10.5 m and most home ranges were small. Hellbenders showed a tendency to home upstream or downstream after displacement. They defended the area under a cover rock. The sex ratio was 1.58 males to one female. Most captured were sexually mature.

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INTRODUCTION

The largest of North American salamanders, the hellbender (*Cryptobranchus alleganiensis* Daudin) is widely distributed in rivers and large creeks over much of eastern United States. Although it has been collected extensively and reports on its natural history have been published (Bishop, 1941), as yet no comprehensive ecological studies have been done. During the summer of 1968 we made a study of the ecology of *Cryptobranchus* in French Creek, a tributary of the Allegheny River, in northwestern Pennsylvania. Major emphasis was placed on the following and their interactions: habitat preference, effects of physical environmental factors within the stream, home range and movements, homing ability, territoriality, population size and structure, and general behavior of hellbenders.

THE STUDY SITE

At the study site, between the towns of Meadville and Saegertown, the stream flows southward and is about 70 m wide. Deciduous trees border the stream and add much allochthonous material through leaf fall. Herbaceous annuals provide thick growth along the bank.

The stream bottom is primarily a sandy gravel, especially in the main channel. Near the east bank the bottom is partly covered by a thick (6-60 cm) deposit of silt and clayey ooze. A sandy shale bedrock underlies the sandy gravel and outcrops in the stream channel. Large slabs have broken away from the bedrock and they litter the stream bottom. These slabs provide abundant cover for hellbenders, other salamanders, crayfish and some fish. The dorsal color of captured hellbenders, which varied from gray to brown, was usually closely matched to these rocks.

Water depth varied greatly throughout the study section. Also, it fluctuated drastically during the period of study as French Creek has an extensive watershed and flooding was common. Rains often caused cessation of field work for two or three successive days. Water depths, determined when the stream was at a low level in mid-August, are shown in Fig. 1 along with other stream characteristics. The maximum depth at low water levels was 180 cm.

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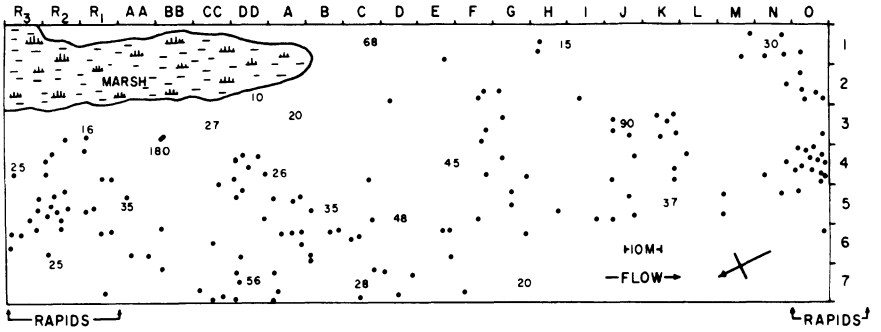

FIGURE 1. The French Creek study area showing water depth (cm), the grid system for locating marked hellbenders, and first capture sites for all hellbenders marked during the study (dots). Section DD-4 is release site for homing studies.

Rapids occurred at the upstream and downstream ends of the study section; water depth here was less than in most of the intervening areas. On average days in mid-August, the current velocity of both upstream and downstream rapids was about 1.0 m/sec and 0.5 m/sec in the main channel.

METHODS

The entire study section was laid out as a grid with painted, numbered stakes on the bank and plastic jugs in the stream. Jugs were anchored with railroad spikes attached with wire. Markers were set at 10 m intervals, the grid being made up of 144 squares, each 10 m on a side. Identifying letters and numbers were painted on each marker (Fig. 1).

A long-handled, four-prong potato hook was used for turning rocks. If a hellbender was uncovered, the hook was dropped to indicate the capture site and the animal was pursued. The best capture technique was lifting the cover rock on edge or shifting it from side to side, the rock being shifted or lifted by the upstream edge. This caused the hellbender to slowly move upstream and away from the silt-clouded water downstream resulting from lifting the rock. Hellbenders were approached rapidly and netted or grabbed behind the head.

Hellbenders were individually marked by the toe-clipping technique of Martof (1953); modifications were used to avoid misidentification of individuals due to accidental loss of toes. To retard regeneration, toes were clipped as close to the foot as possible with scissors. Regeneration was not a problem while the study was in progress but, as determined in the laboratory, regeneration will cause misidentification over the period of a year.

Data on sex and individual markings, water depth of the capture site, and the greatest diameter of the cover rock were recorded. Salamanders were measured in a 60 cm (O.D. 7 cm) clear polyethylene tube, graduated in centimeters. A round, plastic cap with a hole in the center (for removal of water and positioning of the hellbender) was cemented to one end. The animal was placed head-first into the other end. This measuring technique worked well, for salamanders extended to their full length and only one had too much girth to fit into the tube.

In homing studies, some hellbenders were transported in a plastic bag to other parts of the stream. Most were released where they were first seen.

Water temperatures, one in the shallow waters of the east bank where hellbenders were captured, and one in the main stream channel, were taken at about 1:00 pm on days that salamanders were captured.

A complete survey of the study area required 3 to 4 days. Three complete surveys involving capturing and marking of individuals were made between 11 June and 3 August. Six additional surveys, primarily involving recapture and release of marked individuals, were made between 5 August and 21 September. Few unmarked salamanders were found during this period.

DISPERSION AND COVER

A total of 152 individuals was captured at least once; 71 were captured once, 39 twice, 29 three times, 8 four times and 5 five times.

The distribution of initial capture sites for all hellbenders is in Fig. 1. The dispersion pattern was largely correlated with the distribution of large, flat rocks. Rounded boulders were not chosen as shelter probably because they were too deeply embedded in the bottom and contained little surface for concealment. Another characteristic of most capture sites was swift, shallow water; more than 72.4 per cent of the hellbenders were captured in water from 12 to 36 cm deep and 92.8 per cent in water from 12 to 46 cm deep. The lack of captures from very deep water was partly due to difficulties of maneuverability and visibility of the investigator, but nevertheless most animals appeared to be in shallow water. Preference for swift, shallow water is shown by the captures from the rapids areas at the north and south ends of the study section, 22 individuals being captured at least once in the section 0 quadrangles at the south end. Bishop (1941) noted that hellbenders are in greatest abundance where the water is one to two feet deep and the current is swift and that large slabs of rocks, sunken logs or boards are required by them.

The scarcity of hellbenders in sections A through G along the east edge is probably due to a thick layer of silt surrounding the rocks.

The distribution of two size groups of hellbenders (those from 22 to 46 cm total length and those from 47 to 56 cm total length) in relation to water depth of the capture site is shown in Fig. 2.

The greatest horizontal diameters of all rocks that hellbenders used as cover were determined. These ranged from 38 to 137 cm. Only four salamanders were initially found under rocks 55 cm or less in greatest diameter. Rocks from 56 cm to 109 cm provided shelter for 102 (67.1 per cent) of the individuals (Fig. 3). There is no apparent relationship between salamander size and diameter of the cover rock: some of the largest salamanders utilized relatively small rocks and several small salamanders utilized large rocks for cover.

While water temperature probably plays a role in dispersion, its effects were not evident in our study. The mean temperature differential between the east bank (28.0 C) and the main channel (26.7 C) was only 1.3 C.

HOME RANGE AND MOVEMENT

Although we displaced some hellbenders in studies of homing ability, 73 of the 81 recaptured at least once were not displaced between the first and second captures. Movement of these was analyzed by plotting capture sites on a grid and determining the distance between the first and second capture sites to the nearest meter. In all cases at least one week elapsed between the first and second captures.

Forty of the 73 hellbenders (54.8 per cent) were recaptured 10 m or less away from the initial capture site; six of these were recaptured under the rock where their first capture was made. A few inter-capture distances were large; the maximum was 160 m.

Forty-four of the 73 hellbenders were males and their mean inter-capture distance was 18.8 m, the mode was 5.0 m, and the median 10.7 m. For 29 females, the mean was 18.7 m, the mode 5.0 m, and the median 8.1 m. As the mean distance between captures is strongly influenced by a few large values, we used the median as a measure of central tendency in comparing inter-capture distances between sexes and size groups. The median of females (8.1 m) was applied to the distribution for the 44 males and the number of males on either side of 8.1 was determined. The ratio (18:26) was compared by a chi-square test with an even ratio of males (22:22). No significant difference was found ($X^2 = 1.454$; $p > .10$).

In addition to the study of distances between successive capture sites, home range was analyzed by determining the mean activity radius (MAR) as used by Hayne (1949) and Currie and Bellis (1969). This technique involves determining the geometric center of all capture sites of an individual (center of activity) and determining the mean distance from this center to each capture site. This mean activity radius is an index of home range size. Data from the same 73

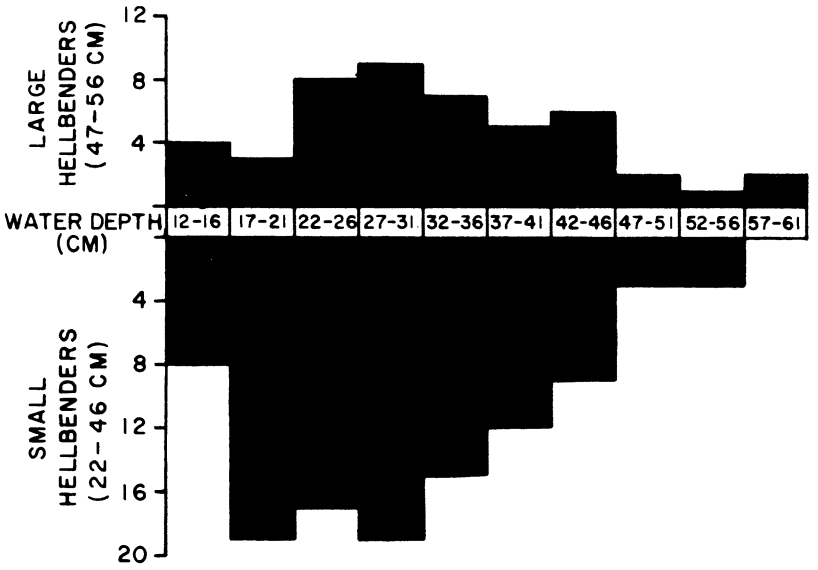

FIGURE 2. Home site water depths of two size groups (total length) of *Cryptobranchus alleganiensis.*

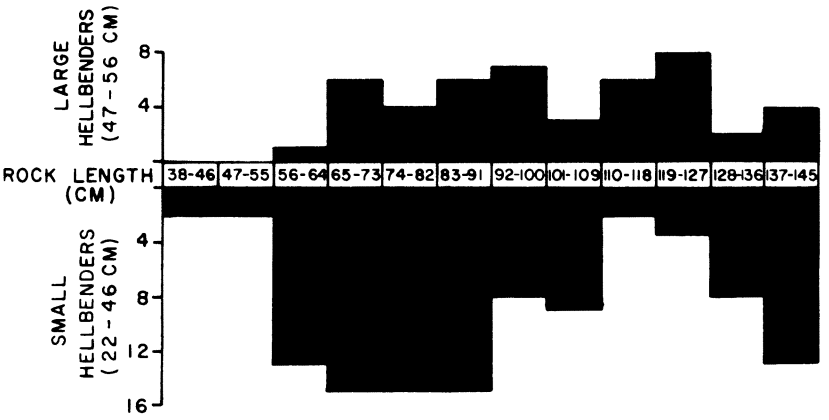

FIGURE 3. Home site rock length of two size groups (total length) of *Cryptobranchus alleganiensis.*

animals used in analyzing the first to second capture site distances were used in the MAR studies. Third, fourth, and fifth capture sites were also included.

The average MAR for all hellbenders was 10.5 m, the mode 2 m, and the median 6.0 m. Comparisons of the median MAR between sexes and between size groups revealed no significant differences but the length of the MAR varied greatly within groups. The longest MAR was 74 m and the smallest 1 m. However, as most individuals were captured only a few times one must regard these extreme values with caution; excessively long or excessively short changes in position can make the method invalid if only a few captures are made. However, the average of the entire group probably gives a good index of home range size. If the average MAR (10.5 m) is used as the radius of a circular home range, the average home range size is 346.4 m^2 and the median 113.1 m^2. By the same calculations, 34 of the 73 hellbenders would have home ranges smaller than 100 m^2 and 9 between 100 m^2 and 200 m^2.

HOMING

After at least two capture sites were established for each, 28 hellbenders were transported to quadrangle DD-4 and released to test their homing ability. Ten were taken from sites upstream from DD-4 and 18 from sites downstream from DD-4. They were individually released at the displacement site soon after capture.

Nineteen of the 28 displaced were captured at least once after they were displaced. At least one week elapsed between the date of displacement to DD-4 and the first recapture of any one.

Of the 10 displaced downstream, six were recaptured upstream from DD-4 and four of these were recaptured at least once within one mean activity radius of the previously established center of activity. Only one was recaptured downstream from DD-4. Three were not recaptured.

Of the 18 displaced upstream, 11 were recaptured downstream from DD-4 and 9 of these were recaptured at least once within one mean activity radius of the center of activity. Only one was captured upstream from DD-4. Six were not recaptured.

Although more data on homing are needed, the foregoing results strongly suggest homing ability from both upstream and downstream directions in hellbenders. We are in no position to suggest the sensory basis of homing from these limited experiments but as hellbenders home from upstream locations we believe that olfaction is not the principal mechanism.

An attempt at following the movement of hellbenders was made by attaching fishing bobbers to their tails with monofilament line, but the bobbers disappeared within 48 hours, before observations could be made.

BEHAVIOR

After hellbenders were released at the capture site they crawled or swam upstream or downstream 10 to 20 m and immediately sought cover. If they did not find a suitable cover rock immediately after release, they often coiled themselves about a rounded boulder for a short period and then continued searching for cover, sometimes temporarily investigating small, flat rocks obviously inadequate for their needs.

None were seen during the study except when a cover rock was removed; they did not move about during the day. Swanson (1948) found that they are active at night, crawling about the bed of the stream; they are easy to catch at this time. Smith (1907) remarks on their avoidance of light and their habit of lying under a rock with only the fore-part of the head exposed during the daylight hours.

Hellbenders appear to be very opportunistic in utilizing cover rocks and on several occasions they were observed to occupy home sites recently vacated by other hellbenders. Only once during our study were two hellbenders found under the same rock. Frequently, when one was released or chased by the investigator, it would crawl under a nearby rock, then clouds of silt would emerge from under the rock, followed by the emergence of the salamander that had crawled under. Subsequent lifting of the same rock would always reveal another hellbender. Smith (1907) also noted that seldom does more than one individual lie under a rock.

Further evidence of territoriality is seen in the protection of the eggs, which are laid in excavations under flat rocks and appear to be aerated by the male (Bishop, 1941). Smith (1907) observed active defense of the eggs by the male, intruding hellbenders being seized and chased away. Apparently females do not share in nest defense. Males, however, feed on their own eggs and defense of them may merely mean protection of his own food supply (Smith, 1907).

Rocks used for cover by hellbenders also serve as cover for prey, especially crayfish which appear to be the principal food source (Swanson, 1948). Other food consists of fish (including suckers), molluscs, worms, insects and animal refuse (Bishop, 1941).

Mating and egg development occur in very late summer and fall; thus we had little opportunity to observe them. According to Bishop (1941) mating begins in late August and continues for 10 days to two weeks. At this time males appear to outnumber females. Hatching takes place in November.

POPULATION STRUCTURE

Sexes were differentiated by the swollen cloacal lips of the male. The sex ratio was 1.58 males to one female. Smith (1907) also reported a high sex ratio in this species; he observed 8 males per female in studies in a western Pennsylvania stream in August and September.

Although breeding takes place in the stream occupied by the adults no larvae were collected in the study; only adults and sub-adults were captured. Snout-vent lengths of males and of females were normally distributed; the mean snout-vent length for males was 28.1 cm and 29.1 cm for females. Snout-vent lengths of hellbenders captured in Missouri by Dundee and Dundee (1965) fell into three size groups, however, and they were able to estimate age groups. Both Bishop (1941) and Dundee and Dundee (1965) suggest that sexual maturity is reached during the fifth or sixth year. According to their criteria, most of our animals were sexually mature.

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