THE HELLBENDER, *CRYPTOBRANCHUS ALLEGANIENSIS*, IN INDIANA

A Master's Thesis

Presented to

The School of Graduate Studies

Indiana State University

Terre Haute, Indiana

In Partial Fulfillment

of the Requirements for the

Master of Arts Degree

LIFS

by

William H. Kern, Jr.

May 1984

APPROVAL SHEET

The thesis of William H. Kern, Jr., Contribution to the School of Graduate Studies, Indiana State University, Series I, Number 1462, under the title The Hellbender, Cryptobranchus alleganiensis, in Indiana is approved as counting toward the completion of the Master of Arts Degree in the amount of six semester hours of graduate credit.

10 May 1984
Date

John O. Whitaker Jr.
Committee Chairperson

William B. Hoffs
Committee Member

Jack R. Munace
Committee Member

1 June 1984
Date

Stephen T. Connelly
For the School of Graduate Studies

ABSTRACT

Very little was previously known about the Hellbender, *Cryptobranchus alleganiensis alleganiensis*, in Indiana. The purpose of this study was to determine its current range and status in Indiana and collect life history information.

The hellbenders were captured by hand from under rocks and with hoopnets baited with cut fish. They were tagged, measured, weighed, examined for large external parasites, wounds, and reproductive condition. Stomach contents were taken with a non-lethal, stomach-flushing technique. The animals were then released at the site of capture.

Although they were originally found in the Ohio River, Whitewater River, Fourteen-mile Creek, Silver Creek, Blue River, and the lower Wabash River, they currently are found only in the Blue River Watershed in Harrison, Crawford, and Washington Counties in Indiana.

Crayfish were the dominant food with fish, carrion, and other animal material being taken when available. Man is the only predator known to take adult hellbenders, although it is likely that large catfish prey on them.

Most of the hellbenders captured were between 425 and 525 mm in length and 400 to 1000 g in weight. No larvae and only 2 immatures were found. Breeding occurs from mid September through early October. A nest containing 153 eggs was found on September 27.

The vast majority of hellbenders was taken from under large limestone slabs in shallow water with a moderate to strong flow. The density of hellbenders was dependent on the type of streambed material

and the number of large flat rocks to provide sheltered daytime retreats and nests.

In the Blue River the population of hellbenders appears to be sustaining itself and should not be in any danger of extinction unless there are major changes in the watershed. It is proposed that this species be placed on the Indiana endangered species list, due to the reduction of its range in the last fifty years.

ACKNOWLEDGMENTS

I thank Dr. John O. Whitaker, Jr. for his help, advice, and aid in editing. I am very grateful to Dr. Sherman A. Minton, Jr. for all his helpful information; Anthony Brentlinger for the photographs that appear in this work; Pete Thorne, Property Manager of Wyandotte Woods State Recreation Area for providing me with free camping during my field work in southern Indiana and much useful information; Barbara Brown and William Santee for their help with the computer processing of data. I offer special thanks to my wife, Valerie, and father, William, for their help with the field collection of data and my mother, Florence, for her typing of the numerous drafts of this work.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1

INTRODUCTION

Cryptobranchus alleganiensis alleganiensis (Daudin) is a thoroughly aquatic salamander recognized by its large size, broad flat head, lack of external gills in the adults, and the presence of loose folds of skin on the lateral margins of the trunk. The common name of *Cryptobranchus* is "hellbender," but many southern Indiana residents call it "waterdog," which sometimes causes it to be confused with the mudpuppy, *Necturus maculosus*.

The hellbender ranges from southern New York and eastern Pennsylvania in the Susquehanna River watershed and from southwest New York and western Pennsylvania in the Allegheny River and through much of the Ohio River watershed to western Tennessee and Kentucky, south to northern Alabama and Georgia, and east to the mountainous regions of South Carolina, North Carolina, and Virginia. Two isolated populations, one of the hellbender and another, the Ozark hellbender, occur in Missouri and northern Arkansas (Figure 1). Its occurrence in Indiana is marginal, having been found in the few larger streams that empty directly into the Ohio River and the lower sections of the Wabash River. Based on the range information given by Minton (1972), it was apparent that the range of the hellbender in Indiana is shrinking.

Studies of hellbenders have primarily been conducted in the east and Missouri. The breeding season of hellbenders was found to be from late August to early September in the east (Bishop, 1941; Huheey and

Stupke, 1967; King, 1939; Smith, 1907; Swanson, 1948) and from early September to early November in Missouri (Dundee and Dundee, 1965; Nickerson and Mays, 1973). Crayfish were found to be the dominant food throughout the species range (Green, 1935; Nickerson and Selby, 1969; Smith, 1907; Swanson, 1948). Hellbenders normally hide under large flat rocks during the day, and that these shelters are important to the density of the population was shown by Hillis and Bellis (1971), Nickerson and Mays (1972), and Swanson (1948). Smith (1907) determined size classes for immatures up to four years of age by examining series of immatures he collected. Animals over four years of age could not be divided into size classes due to extensive overlap.

Minton's limited treatment of hellbenders in Indiana in his 1972 publication was the only source of range, habitat, or habits information from Indiana. As he stated, virtually nothing was known of reproduction or growth of *Cryptobranchus* in Indiana.

The objectives of this study were to determine the current range and status of the hellbender in Indiana and to collect life history information, including: food habits, reproduction, causes of mortality, and population density of a midwestern population at the periphery of this species' range. This comprehensive population analysis could then be used to formulate a management plan to preserve this unique element of Indiana's fauna.

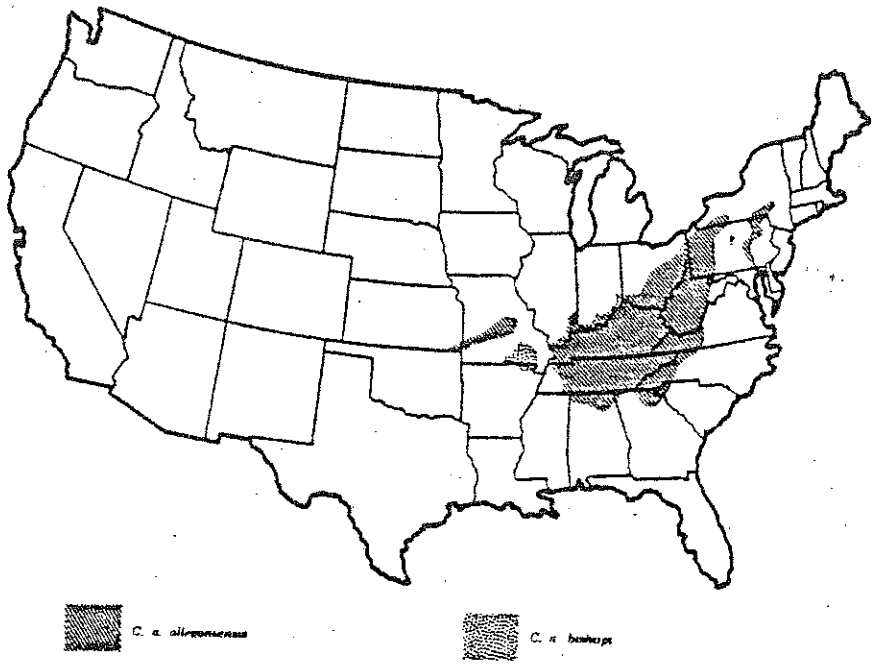


Figure 1. The range of the hellbender, Cryptobranchus alleganiensis, in the United States (by R. Conant from Nickerson and Mays,1973).

CHAPTER 2

METHODS AND MATERIALS

RANGE

The recent range of the hellbender in Indiana was determined from accounts in the literature. Additional recent information was received from conversations with Dr. Sherman Minton, Jr., local fishermen and Conservation officers of southern Indiana.

After the historical range was determined, I sampled those streams within Indiana that have supported hellbender populations. Also, other large streams located near known hellbender sites were examined. If favorable habitat was found, then these streams were also sampled.

I did not sample the Wabash or Ohio Rivers due to the difficulty involved in sampling these large rivers. The north shore of the Ohio River forms the south boundary of Indiana; thus technically it is not within the boundaries of the State. Due to extensive manipulation by man, much of the previous habitat has been destroyed and I doubt if hellbenders still exist there. More data are needed to be sure. The Wabash River supports an extensive commercial and sports fishery. I believe that if hellbenders currently existed in the Wabash River, they would occasionally be taken by fishermen. However, no specimens have been taken since the late 1940's, but more data are needed.

Two sampling techniques were used to determine the presence of hellbenders in a watershed: physical search and baited hoop nets. Physical search involved wading or canoeing sections of each stream

looking for suitable habitat, large flat rocks over a gravel bottom. When this habitat or other suitable cover was found, the sheltering material was overturned. If the stream was cloudy, search was by touch for any hellbenders that might have been under the rock. If the stream was clear enough to plainly see the bottom, I waited for the current to clear the stirred up sediment. When a hellbender was detected, I would grab it behind the head or in front of the pelvic girdle and transfer it immediately to a dip net or bucket to prevent its escape. Hoop nets were used when water depth or temperature made physical search impractical. Five hoop nets were used, each consisting of seven hoops. The first hoop was D-shaped and measured 46 inches across the bottom and 30 inches high. The remaining six hoops were circular and measured 30 inches in diameter. All hoops were made of 1/4 inch galvanized steel. Between the first and second hoops, the netting was 1 1/2 inch square mesh, knotless nylon. From the second hoop to the back, 1 inch square mesh, knotless mylon netting was used. Two 8 lb. iron weights were attached to the drawstring of each hoop net. A plastic buoy was attached to the first hoop by a 12 foot length of 1/4 inch braided nylon rope. The open end of the hoop net faced downstream. The nets were set so their openings were immediately upstream from areas of promising habitat. The hoop nets were baited with cut suckers which were tied to the inside of the rear compartment.

Determination of the current range was based on the capture of hellbenders. Failure to collect any hellbenders, at all sites of favorable habitat on a particular stream, indicates that any previously existing population are now extinct or at most existing in very low numbers. Since hellbenders are strongly habitat dependent, then failure

to find them where all suitable habitats were examined would make it unlikely they would occur in that stream.

FOOD HABITS

Due to the protective status given to hellbenders as an endangered species in Indiana, it was necessary to devise a non-lethal method to collect stomach contents. The large esophagus of the hellbender, and its habit of regurgitating when disturbed, made stomach flushing seem feasible. A portable douche bag with a 130 mm plastic nozzle was used. The nozzle was removed and the rubber bag filled with river water. The nozzle was then screwed back into the plastic ring at the top of the bag. The jaws of the hellbender were pried far enough apart to allow the tip of the nozzle into the mouth cavity. The hellbender was then supported vertically, head up, and the nozzle was slowly eased down the esophagus. The water from the bag passed through the nozzle to fill the stomach. Once the stomach was full, any excess water would pass around the nozzle and up the esophagus. This prevented any internal injury to the hellbender due to excess pressure. Once the stomach was full, the hellbender was placed in a large, clear plastic bag, with the nozzle still down its esophagus. While trying to disgorge the nozzle, it would also regurgitate the water and stomach contents. Often large food items were felt by palpating the ventral abdominal surface of the hellbender. If no material was recovered by flushing but was detected by palpation, then the flushing technique was used again until the material was recovered. If no material was recovered by flushing and nothing was detected by palpation, then the stomach was considered empty. The stomach flushing technique only recovers material from the stomach and

does not affect the intestinal contents. These data, therefore, represent only recent feeding activity.

The material recovered from the stomachs of hellbenders captured in hoop nets was analyzed separately from those data obtained from hand caught specimens. This was because the hellbenders caught in nets had obviously been feeding on the fish caught in the same traps. The % frequency, % volume, and % of total number of organisms was determined for both sets of data. The % frequency is the number of stomachs with a particular food item, divided by the total number of stomachs with food, multiplied by 100. The % volume is the summation of the % volume of a food item from each stomach with food, divided by the total number of stomachs with food.

Seasonal variation in feeding activity was determined by comparing the percentage of hellbenders with stomach content on a monthly basis.

REPRODUCTION

The reproductive season for hellbenders was initially approximated from reports in the literature. In 1982 and 1983, during the months of August, September, and October, a concentrated effort was undertaken to more accurately identify the mating season of hellbenders in southern Indiana.

Observations were made during these months to detect external physical changes in a specific population in the Blue River. These observations included condition of the cloacal gland and release of milt in the males and whether the females were gravid or spent. Also, during these three-month periods, considerable effort was devoted to finding hellbender nests with eggs, the best evidence of reproduction.

POPULATION AND MEASUREMENTS

All hellbenders, whether taken by hand or hoop-net trap, were tagged with an aluminum, size 3, type 898 wing band, around the median portion of the mandible. This was a permanent marking method that allowed identification of recaptured animals even over a year after their initial capture. The date, location, and description of the capture were recorded. The following measurements were taken: total length, tail length from vent to tip of tail, head width at the widest part of the skull, and weight to nearest 10 grams. The total length and tail length were taken as the hellbender was resting in a fold of a 20x20 inch piece of 1/2 inch mesh hardware cloth. This caused the hellbender to lay straight, for more accurate measurement. Weight was determined by placing the animal in a dry plastic bag and weighing it with a dial type, spring scale with a 2000g capacity in 10g graduations. During the reproductive season, July through October, sex was determined. These data were used to determine sex ratios, size classes based on total length and weight, and statistics (maximum, minimum, mean, median, standard deviation) of the population as a whole for all measurements.

A sample of the population density in the Blue River was conducted at Site 4 in Washington County. This site was chosen due to the good population found there and ease of sampling because of shallow water levels. A concentrated recapture study was conducted in this 100 meter stretch of river. Adjacent areas, Sites 9, 11, 12 (Table 1) were also sampled to locate animals moving from Site 4. The site boundaries are often arbitrary, with no barriers to hellbender movement present. The formulas to estimate the size of the marked population were from Jolly (1965), as follow:

$$M_i = \frac{S_i Z_i}{R_i} + m_i$$

M_i = marked population size at time i

m_i = marked animals actually caught at time i

S_i = total animals released at time i

Z_i = number of individuals marked before time i, not caught in the ith sample but caught in a sample after time i

R_i = number of the S_i individuals released at time i that are caught in a later sample

Once the marked population size was known for each sample, it was possible to calculate an estimate of the total population size.

$$TPS_i = \frac{M_i}{\frac{m_i}{C_i}} = \frac{M_i C_i}{m_i}$$

TPS_i = total population size at time i

M_i = marked population size at time i

m_i = marked animals actually caught at time i

C_i = total animals captured at time i

With a multiple recapture study it is possible to determine changes in population as well as the population size.

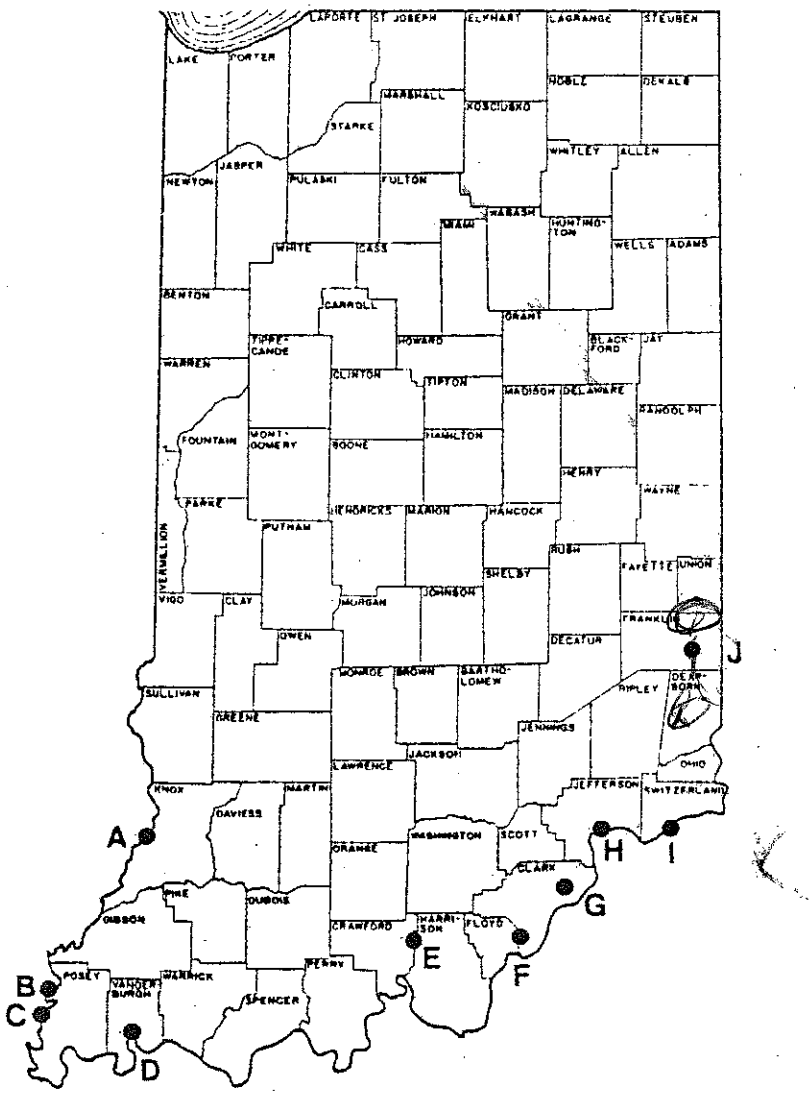
CHAPTER 3

RESULTS AND DISCUSSION

RANGE IN INDIANA

The recent range of the hellbender in Indiana, based on the literature, is as follows: The Ohio River at Evansville (USNM 9204), Vevay, and Madison (MCZ 14846) (Hay, 1892), the Whitewater River to Brookville (Hay, 1892), Fourteen-mile Creek to the Tunnel Mill Boy Scout Camp in Clark County (Minton, personal correspondence, 1981), Silver Creek at New Albany (Minton, 1972), the Blue River to Milltown in Harrison and Crawford Counties (Minton, 1972), and the Wabash River at Terre Haute (Allyn and Shockley, 1939), Vincennes (Gaines, 1895; Minton, 1972), New Harmony (MCZ247) (Wied, 1839), and Maunie, Illinois in White County (Stein and Smith, 1959) (Figure 2).

The Terre Haute record is suspect, since Allyn and Shockley did not see any specimens. They stated that Glenn Cowgill, Vigo County Game Warden, reported that the hellbender was rather common in the Wabash River south of Terre Haute. This was their only evidence of hellbenders in Vigo County. Blatchley (1891) reported that "Necturus maculatus" was common in the Wabash River, but said that specimens of two feet in length (61 cm) and over were often taken in spring and fall. Nickerson and Mays (1973) believed that these reports were Cryptobranchus rather than Necturus, based on size. However, the exaggerated sizes could have been based on secondhand reports from local fishermen. Blatchley probably correctly identified the animals as Necturus maculosus.



A Vincennes-late 1940's and Gaines (1895)
B New Harmony-Wied (1839)
C Maunie,Ill.-1947
D Evansville-Hay (1892)
E Blue River at Milltown-1966
F Silver Creek at New Albany-1930's
G Fourteen-Mile Creek-1955
H Madison-Hay (1892)
I Vevay-Hay (1892)
J Whitewater River at Brookville-Hay (1892)

Figure 2. Hellbender site locations from the literature with the year of sighting or report publication.

Hellbenders did occur in the lower Wabash River, since at least four specimens have been taken. Specimen (MCZ247) came from New Harmony between 1832 and 1834 (Wied, 1839). A specimen caught by a commercial fisherman with a baited hook in 1947 near Maunie, IL. is now in the biology lab at Carmi Township High School in Carmi, IL. A seventeen inch (43 cm) specimen was captured near Vincennes sometime prior to 1895 (Gaines 1895). Gaines also stated that the hellbender was "probably rare in this locality." A hellbender was "collected in the late 1940's near Vincennes and kept alive for several years at the Riverside Fish Hatchery in Indianapolis" (Minton, 1972). Since no hellbenders have been reported from the Wabash River since the late 1940's, and this river has an extensive sport and commercial fishery that uses methods proven to take hellbenders, it seems likely that the hellbender is now absent from the Wabash River. However, it is possible that hellbenders could still occur in low numbers in sections of the Wabash River not greatly exploited by fishermen. The Wabash River watershed covers most of Indiana's row crop farming areas, and during the 1950's and 1960's there was a major increase in topsoil erosion and the use of agricultural chemicals, especially pesticides. This causes serious silting and pollution of the river. Based on the low number of specimens taken from the Wabash River, I doubt if the hellbender ever occurred in large numbers there.

The three sites on the Ohio River were reported by O. P. Hay in 1892, and no confirmed sightings have been made recently. The extensive channelization and manipulation of the Ohio River probably destroyed most of the Hellbender habitat there, although hellbenders may still exist in the Ohio River where suitable habitat can be found. More field work is needed to determine this. I examined a one-mile stretch

of the north shore of the Ohio River, east of the mouth of the Blue River, in Harrison County, and found no habitat suitable for hellbenders. One fisherman I talked to, on the Blue River, reported that he had caught a hellbender in the Ohio River near one of the old locks several years before.

In 1892 O. P. Hay reported that the hellbender occurred in the Whitewater River upstream to Brookville in Franklin County. Rob Vickroy, the Conservation Officer for Franklin County, was contacted on August 3, 1982 and reported that he had not heard of anyone catching hellbenders in the Whitewater River in many years. A fisherman in Cedar Grove in Franklin County said he used to catch "waterdogs" in the Whitewater River, but had not heard of anyone catching any in almost 20 years. He identified the waterdog as a hellbender rather than Necturus from photographs. I examined the East Fork of the Whitewater River from the main fork to the spillway of Brookville Lake and the West Fork from Morgan's Brookville Canoe Livery to below the island at the fork of the river. No hellbenders were found. I have no explanation for the absence of hellbenders in this stream. Perhaps there was some unseen cause, such as pollution, or past event, such as the construction of the Brookville Lake Dam, for their decline. For that matter, the Whitewater River may still contain some hellbenders, since much of the habitat required by hellbenders is still present and crayfish, their primary food, are very abundant.

Dr. Sherman Minton told me that Fourteen-mile Creek in Clark County had hellbenders up to about 1955. In October 1981, I examined several sections of this stream from the Tunnel Mill Boy Scout camp to the Indiana Arsenal Reservation, the area where Minton had originally

found hellbenders. No hellbenders were found. I doubt that a population exists there, since an exhaustive search was conducted. The lower sections of Fourteen-mile Creek had a gravel or mud bottom with little cover in the way of large flat rocks. Upstream, near the Boy Scout camp, the habitat was much better. There were numerous large, flat, limestone slabs over a gravel bottom, but the water level was very low. This caused the stream to be broken into a series of separate, shallow pools. Necturus maculosus was very common here, being found under most of the larger slabs. The cause of the low water level appeared to be a new dam built at the Boy Scout Camp. This dam created a lake upstream and drastically decreased the downstream flow during dry periods. Both of these situations are detrimental to hellbenders.

Minton reported that "up to the early 1930's, hellbenders were common in Silver Creek near New Albany," but "they apparently are extinct in that stream today" (Minton, 1972). On August 10, 1981, John Whitaker and I examined a three-kilometer stretch of Silver Creek from Blackiston Mill downstream. No hellbenders were found. However, we did see considerable evidence of urban pollution, including oil films on the surface and refuse cluttering the bottom. I agree that hellbenders are probably extinct in Silver Creek.

Minton (1972) reported that in Indiana the hellbender persisted in fairly good numbers only in the Blue River, where they occurred upstream at least to Milltown, in Crawford and Harrison Counties. Nickerson and Mays (1972) stated that as late as "1966 fishermen were still taking them regularly in the Blue River near Milltown, Crawford County." All of the hellbenders captured during this study, a total of 130, were from the Blue River watershed, with 126 being tagged and

released at the site of capture. Those found dead were preserved. Table 1 indicates the site locations and number of hellbenders taken per site.

Prior to this study, Whitaker and several of his students captured four hellbenders at site 2, Blue River Chapel, and fourteen at Site 1, Horseshoe Bend. It is evident that hellbenders are strongly habitat dependent. They were found in areas of good habitat from near the mouth of the Blue River to near the town of Beck's Mill in Washington County. They were also found in the South Fork of the Blue River to a point 4.5 kilometers from the fork in the river (Table 1 and Figure 3). I examined most of the major tributaries of the Blue River, beyond the range described above, and found no hellbenders. It would not be surprising, however, to find them in any of the larger tributaries, considering the numbers of hellbenders I found in the main body of the Blue River.

Sherman Minton said that several years ago a Southern Indiana resident told him that hellbenders were in some of the large Harrison County streams other than the Blue River.

I examined three streams near the Blue River which had not been cited in the literature as containing hellbenders: the Little Blue River in Crawford County and Indian Creek and Buck Creek in Harrison County. No hellbenders were found. Buck Creek seemed too small and lacked the proper habitat requirements for hellbenders.

While examining Indian Creek, I talked to a fisherman who claimed to have caught a hellbender while fishing at night about thirty years ago. He said that he knew it was a hellbender because he had caught them before in the Blue River. Indian Creek contained large areas

Table 1. Hellbender Site Locations on the Blue River.

Site #	Location	County	Number Captured	No. Tagged & Released	Number Found Dead
1	SE 1/4 SW 1/4, Sect 23, T1S R2E	Crawford/ Harrison	9	9	0
2	SE 1/4 NW 1/4, Sect 25, T3S R2E	Harrison	6	5	0
3	S of US460 Sect 9, T3S R3E	Harrison	2	2	0
4	N 1/2 SW 1/4, Sect 2, T1S R3E	Washington	68	65	1
5	at bridge Sect 14, T1S R3E	Washington	3	3	1
6	NE 1/4 NE 1/4, Sect 14, T1N R3E	Washington	1	1	0
7	SW 1/4 NW 1/4, Sect 36, T1S R2E	Crawford/ Harrison	1	1	0
8	N of bridge NE 1/4, Sect 2, T1S R3E	Washington	16	16	0
9	N 1/2 SW 1/4, Sect 2, T1S R3E	Washington	10	10	0
10	SE 1/4 SE 1/4, Sect 34, T1N R3E	Washington	5	5	0
11	N 1/2 SW 1/4, Sect 2, T1S R3E	Washington	5	5	0
12	N 1/2 SW 1/4, Sect 2, T1S R3E	Washington	4	4	0

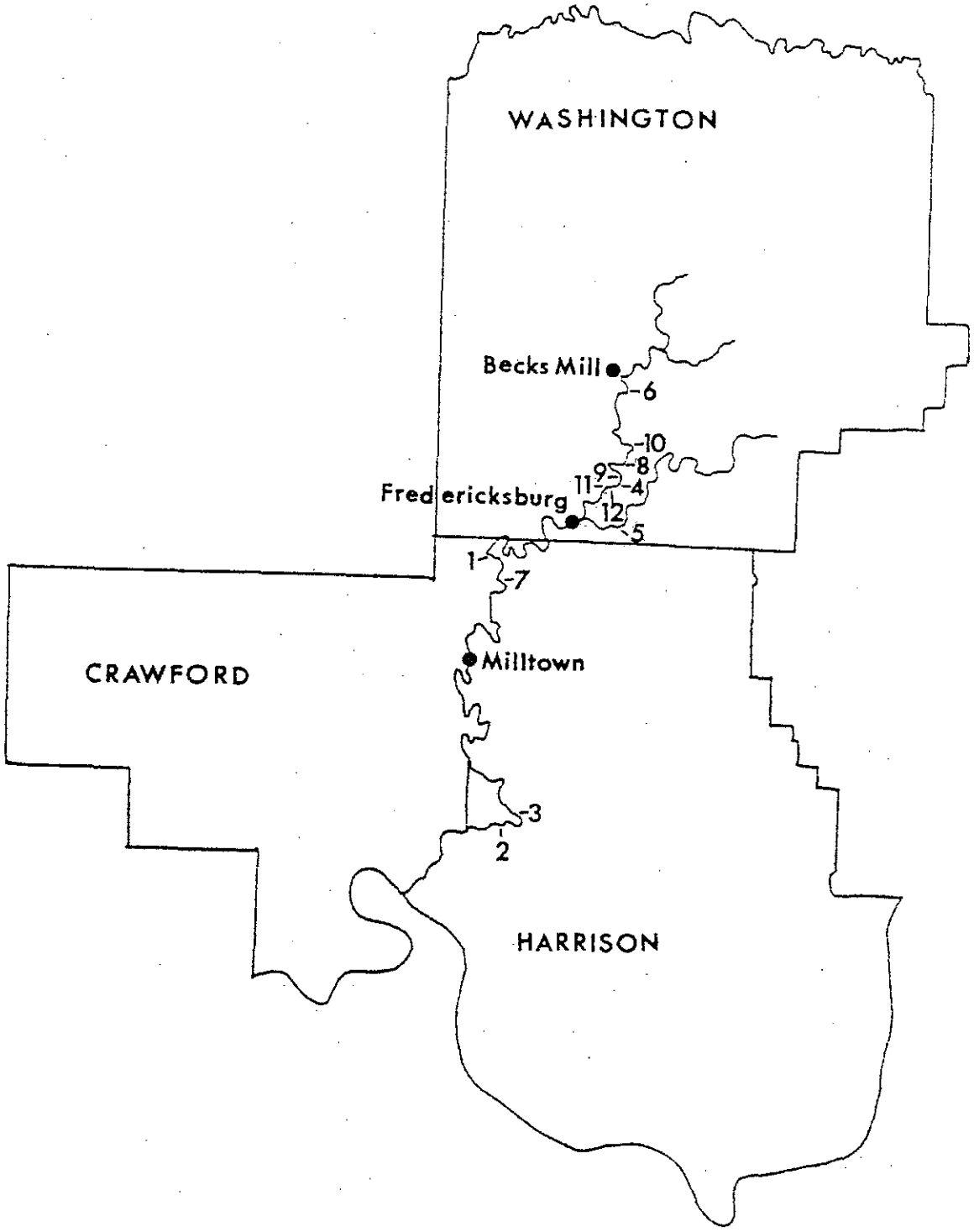


Figure 3. Hellbender site locations in the Blue River watershed.

of excellent habitat, large limestone slabs over gravel. In summer, however, the water level gets very low and the stream breaks up into a series of separate pools. The temperature in some of these pools in August reached 30.5°C (87°F), which would be too warm for hellbenders. The cause for these low levels in summer is a series of three or four dams located on Indian Creek in and above the town of Corydon. It is probable that there once were hellbenders in Indian Creek and some may be found in this stream above Corydon, although the habitat appeared less favorable than areas downstream.

Several sites on the Little Blue River in Crawford County were examined. The lower 10 kilometers of this stream were flooded by the construction of the Channelton Lock and Dam and exhibit little flow except during periods of heavy rain. This area is bordered by limestone cliffs, and large flat slabs of limestone are found on the gravel bottom. Above section 16, T4S R1E the stream bottom is mostly gravel with few large stone slabs. Although no hellbenders were captured, they may have occurred in this stream in the past. An old fisherman who lived next to the bridge in Sect. 27, T4S R1E said that they used to catch "two kinds of waterdogs" under that bridge. The smaller "blue waterdog" was identified as Necturus maculosus from a specimen I captured at this site. The larger "yellow waterdog" was a much different animal, as long as a man's hand and forearm, according to this fisherman's description. I believe that he was describing Cryptobranchus. The water depth in this section of the Little Blue River varied from 10 to 14 feet, making sampling very difficult. Hellbenders may be present in this stream, and my failure to find any may simply be due to the limited sampling I was able to accomplish.

One additional stream I did not sample, that may yield hellbenders, is Laughery Creek in Ohio, Dearborn, and Ripley Counties. It flows into the Ohio River about 10 miles downstream from the mouth of the Whitewater River, a site earlier harboring hellbenders.

FOOD HABITS

Swanson (1948) described the stomach contents of 51 hellbenders taken in northwest Pennsylvania, and I derived the frequencies to be: crayfish 94.1%, fish 23.5%, and hellgramites 1.9%. From this same area of Pennsylvania, Smith (1907) examined 12 stomachs and found that nine contained crayfish (75%) and three contained fish (25%). From West Virginia, Green (1935) examined the stomachs of 34 hellbenders and these data were used to determine the frequencies of the 33 stomachs with contents as crayfish 60.6%, fish 36.4%, and insects, worms, and tadpoles 21.2%. Nickerson and Selby (1969) reported that the % frequency of stomach contents from 40 *Cryptobranchus alleganiensis bishopi* from Missouri were crayfish 87.5%, snails 52.5%, Mayfly nymphs 12.5%, and unidentified animal material 10.0%.

Minton (1972) examined the stomachs of five Indiana specimens, and they contained only crayfish.

The stomachs of 95 hand-captured and 11 net-captured hellbenders were examined by flushing and palpation. Seventy-four stomachs from hand-captured hellbenders and three from net-captured hellbenders were empty. Information from the contents of the stomachs of twenty-one hand-caught hellbenders and eight net-caught hellbenders is summarized in Table 2.

Table 2. Food Analysis of Indiana Hellbenders.

FOOD ANALYSIS OF 21 HAND-CAUGHT HELLBENDERS

Food	% Frequency	Number of Organisms	% of Total Number of Organisms	% Volume
Crayfish (*Orconectes* sp.)	81.0	32	78.0	73.81
Insect larvae	14.3	3	7.3	9.05
Ephemeroptera	(9.5)	(2)	(4.9)	(7.14)
Neuroptera	(4.8)	(1)	(2.4)	(1.91)
Shed skin	9.5	2	4.9	9.52
Fish (Unidentified)	4.8	1	2.4	3.76
Frog (*Rana* sp.)	4.8	1	2.4	2.38
Earthworm	4.8	1	2.4	.24
Nematomorpha	4.8	1	2.4	.24

FOOD ANALYSIS OF 8 NET-CAUGHT HELLBENDERS

Food	% Frequency	Number of Organisms	% of Total Number of Organisms	% Volume
Crayfish	87.5	13	61.9	28.12
Fish	87.5	8	38.1	71.88

It is apparent that crayfish are the staple food of the hellbender. The high % frequency for both hand-caught (81.0%) and net-caught hellbenders (87.5%) demonstrated this. The % volume of crayfish from hand-caught hellbenders was 73.8%, indicating that crayfish provide the majority of the food eaten by hellbenders occurring in natural situations. The net-caught hellbenders were confined with an abnormal concentration of trapped fish prior to having their stomachs flushed. The high % volume of fish (71.88%) and correspondingly low volume of crayfish from the net-caught hellbenders (28.12%) is due to the glut of fish available to the hellbenders after they were caught in the hoop-nets. Of the 21 stomachs from hand-caught hellbenders that contained food, 14 or 66.6% contained only crayfish. On two separate occasions, crayfish recovered from hand-caught hellbenders were still alive, indicating that they had probably been eaten within the hour, during daylight. One small crayfish was recovered from the only immature hellbender taken during this study that had any stomach contents.

Consumption of fish seemed to be strongly related to availability, based on the conflicting results of food analysis from hand- and net-captured hellbenders. The one fish recovered from a hand-caught hellbender was in an advanced state of decomposition and probably had been found dead. The fish recovered from net-caught hellbenders included two Common Shiners (*Notropis chrysocephalus*), two White Suckers (*Catostomus commersoni*), three Redhorse Suckers (*Moxostoma* sp.), and one fish that was not identifiable due to its advanced state of decomposition. All the fish recovered from net-caught hellbenders were considered together, since the fish recovered from the stomachs were always the same species found in the traps with the hellbenders. One

hellbender, measuring 610mm in length, regurgitated two Moxostoma measuring 9 inches and 10 inches, one whole large crayfish, and parts of a second. Its weight at capture was 1840g. I recovered 420g of material from its stomach, or 23% of its capture weight.

The aquatic larvae or nymphs of insects seem to be a minor food item of the adult hellbender. The three immature insects recovered were a hellgrammite (NEUROPTERA, CORYDALIDAE, Corydalus cornutus), a mayfly nymph (EPHEMEROPTERA, EPHEMERIDAE) and a mayfly nymph (EPHEMEROPTERA) that could not be identified to family. Based on size alone, it is likely that immature insects and other small aquatic invertebrates, such as snails and isopods, are more important as food for the larvae and immature hellbenders than for the adults.

Two hellbenders caught in October had only shed skin in their stomachs. In terms of % volume this is the second most important food item of hand-caught animals, at 9.52%. Eating their own shed skin is an important method of recycling nutrients that might otherwise be lost. This is a common practice with many amphibians.

The frog, earthworm, and Nematomorpha, as well as the parts of three crayfish, all came from the stomach of one hellbender captured on January 25, 1981. The frog may have been found dead and then eaten, because another small frog was found dead on the bottom near where this hellbender was captured.

Hellbenders are opportunistic. Based on my findings, reports in the literature, and reports from fishermen, hellbenders will eat whatever type of animal material they can catch or scavenge. Fishermen using trotlines or other bottom fishing methods reported catching hellbenders with nightcrawlers, crayfish, chicken livers, pieces of

fatty meat, cut or whole fish, and prepared catfish bait.

Seasonal variation in feeding activity was detected (Table 3 and Figure 4). From January through April the percentage of stomachs containing food was high: 87.5% for January/February and 78.6% for March/April. Mr. and Mrs. W. B. Janes reported that hellbenders are taken on baited hooks in the Blue River near White Cloud (Site 3) in greatest numbers from early March to late May (Minton, 1972). Minton (1972) stated that "a large male taken March 29 ceased feeding in early June, and the rugae about the vent became somewhat swollen." From at least July through October there was a definite decrease in feeding activity, corresponding with increased reproductive development. Only 14.3% of stomachs examined in July/August contained food. The Blue River population breeds in September and October, which corresponds to the period of minimum feeding activity. Two adults caught in October had only shed skin in their stomachs. Both immature hellbenders were caught in September, but they were not affected by reproductive behavior and one of them had eaten a crayfish. Only 8.2% of the 61 adults examined during September and October had been actively feeding on other organisms. It is apparent that hellbenders actively feed from January through May and then essentially fast from June through October, or during the reproductive season. More work is needed in studying the transitional period of May/June and November/December.

PREDATORS AND PARASITES

I have no evidence of predation on the young or eggs of the hellbenders, although these are likely the stages most often preyed upon, since they are a more manageable size for most predators. Bishop (1941)

Table 3. Monthly Incidence of Hellbenders with Food in Their Stomachs.

Month	Number of stomachs with food	Number of stomachs empty	% of stomachs with food
January	5	0	87.5
February	2	1	
March	6	1	78.6
April	5	2	
May	-	-	No Data
June	-	-	No Data
July	1	4	14.3
August	2	14	
September	3	30	12.7
October	5	25	
November	-	-	No Data
December	-	-	No Data

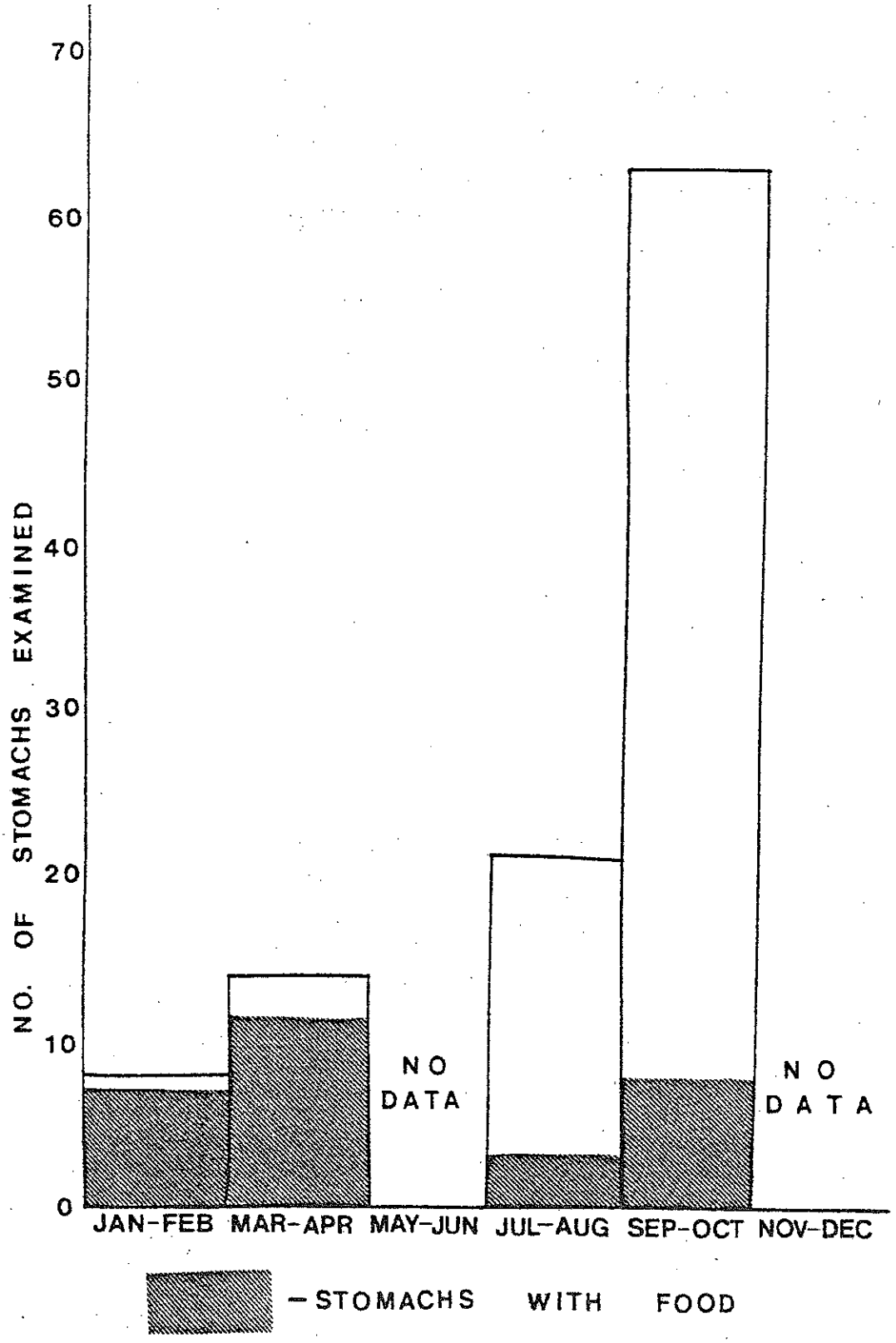


Figure 4 . Seasonal variation in hellbender feeding activity.

and Smith (1907) reported that the hellbender "sometimes eats its own eggs and young."

Mr. W. B. Janes told Minton (1972) that he had found both hellbenders and Necturus in the stomachs of catfish. Near White Cloud (Site 3), I caught a hellbender in the Blue River that had a large rectangular wound in its side between the fore and hind legs. The shape of the wound led me to believe it may have been caused by a large catfish. The most important predators of adult hellbenders in the Blue River are fishermen using natural baits. Many fishermen release hellbenders, because they realize they are protected, and some fishermen believe they are poisonous. However, many fishermen consider them pests to be destroyed. I found one hellbender at Site 5, the south fork of Blue River, lying on the bank with its head crushed. A hellbender caught at Site 1, Horseshoe Bend, had a wound in its upper jaw where a fishhook had been ripped through the maxillary bone. The best protection for the hellbender is the education of the fishing public. Although the fear that hellbenders are poisonous has saved some animals, because fishermen would cut their lines rather than risking contact with these creatures, many have been killed by sportsmen who thought they were destroying a dangerous pest.

Minton (1972) reported that many Indiana Cryptobranchus are parasitized by dracunculoid worms, that may be seen embedded just under the skin. A worm similar to that described by Minton was recovered from a Necturus maculosus from Fourteen-mile Creek. Nickerson and Mays (1972) reported that "leeches (Hirudinea: Glossiphoniidae: apparently an undescribed species) were found on most Ozark hellbenders in the North Fork of the White River, Ozark County, Missouri. These are presumably

the same or closely related to those mentioned by Dundee and Dundee (1965) from Spring River in Arkansas." Evidently these hellbender leeches are not found in the waters of the Blue River. Of the 130 hellbenders I captured and examined from the Blue River, none were found with any large external parasites. No attempt was made to find smaller external parasites and no internal examinations were conducted.

One hellbender kept in captivity developed and eventually died from an infection of the water-mold, Saprolegnia.

MEASUREMENTS

Measurements of the Blue River hellbenders are listed in Table 4. The maximum and minimum values are the measurements of the largest and smallest hellbenders taken. The smallest animal was an immature, estimated to be three years old, based on the age classes determined by Smith (1907) from numerous samples of immatures. Figures 5 and 6 show the size class distribution by total length and weight. Most Indiana hellbenders were 425 to 525 mm long and weighed between 400 and 1000 g. A distribution pattern of few small and many large animals generally leads to population decline in vertebrate species. However, this type of size distribution pattern appears to be common with hellbenders. Swanson (1948) reported that of 750 hellbenders captured from northwest Pennsylvania, no individuals less than a foot long were found. Nickerson and Mays (1973) found that about 90% of the Ozark hellbenders examined were between 250 and 500 mm. Cryptobranchus alleganiensis bishop (with a mean weight = 365 g, n = 435) tends to be smaller than C. a. alleganiensis (mean weight of Indiana population = 685.9 g, n = 126), but the trend of larger-sized animals being most plentiful was still apparent.

Table 4. Hellbender Measurement Statistics for the Blue River Population

	Maximum	Minimum	Mean	Standard Deviation	N
Total Length in mm	610.0	260.0	481.8	47.6	113
Body Length in mm	410.0	175.0	320.0	33.1	112
Tail Length in mm	200.0	85.0	161.1	19.2	112
Head Width in mm	85.0	28.0	69.6	9.3	112
Weight in g	1840.0	79.6	685.9	216.3	126

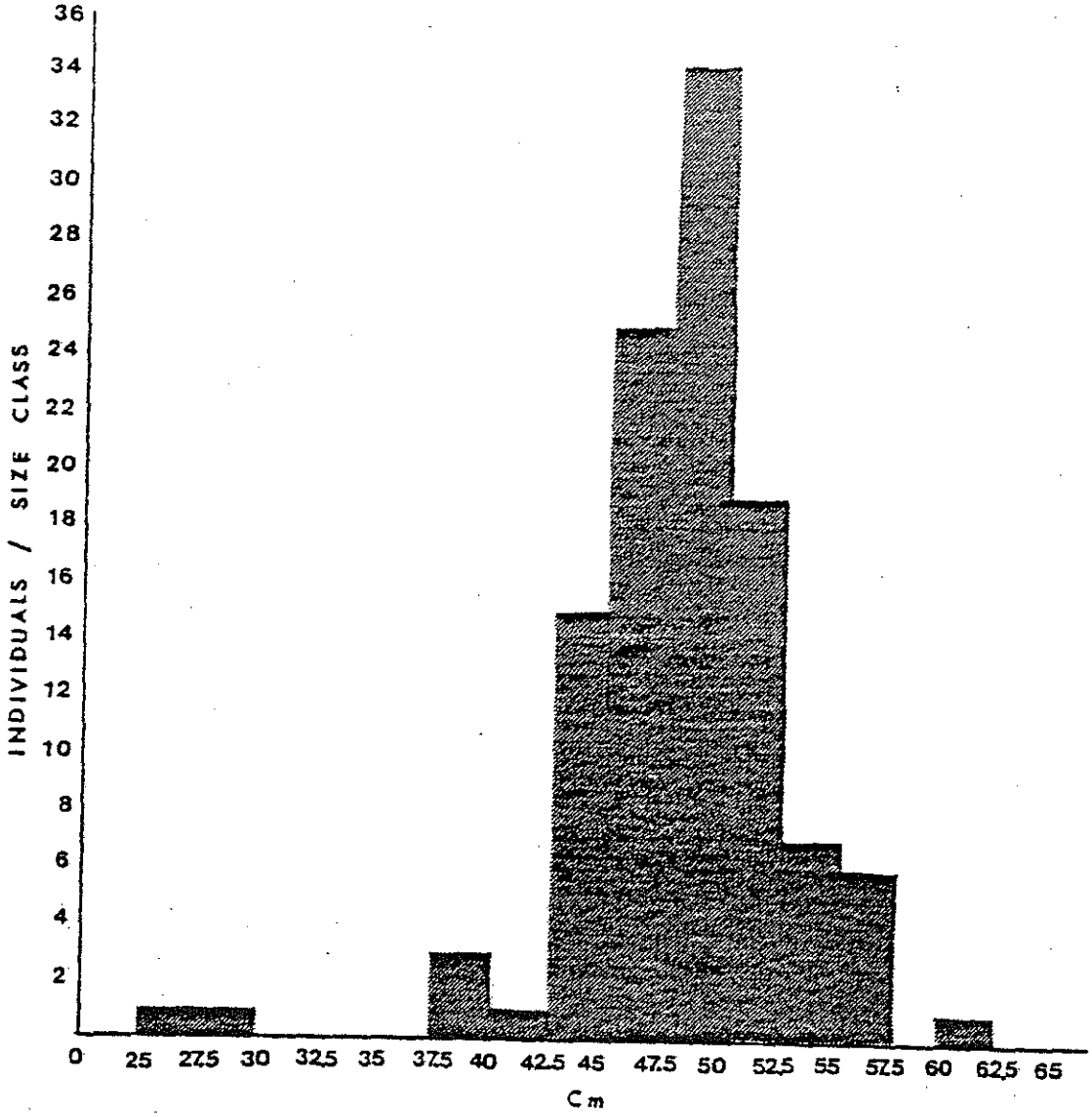


Figure 5. Size class distribution of Indiana hellbenders by total length.

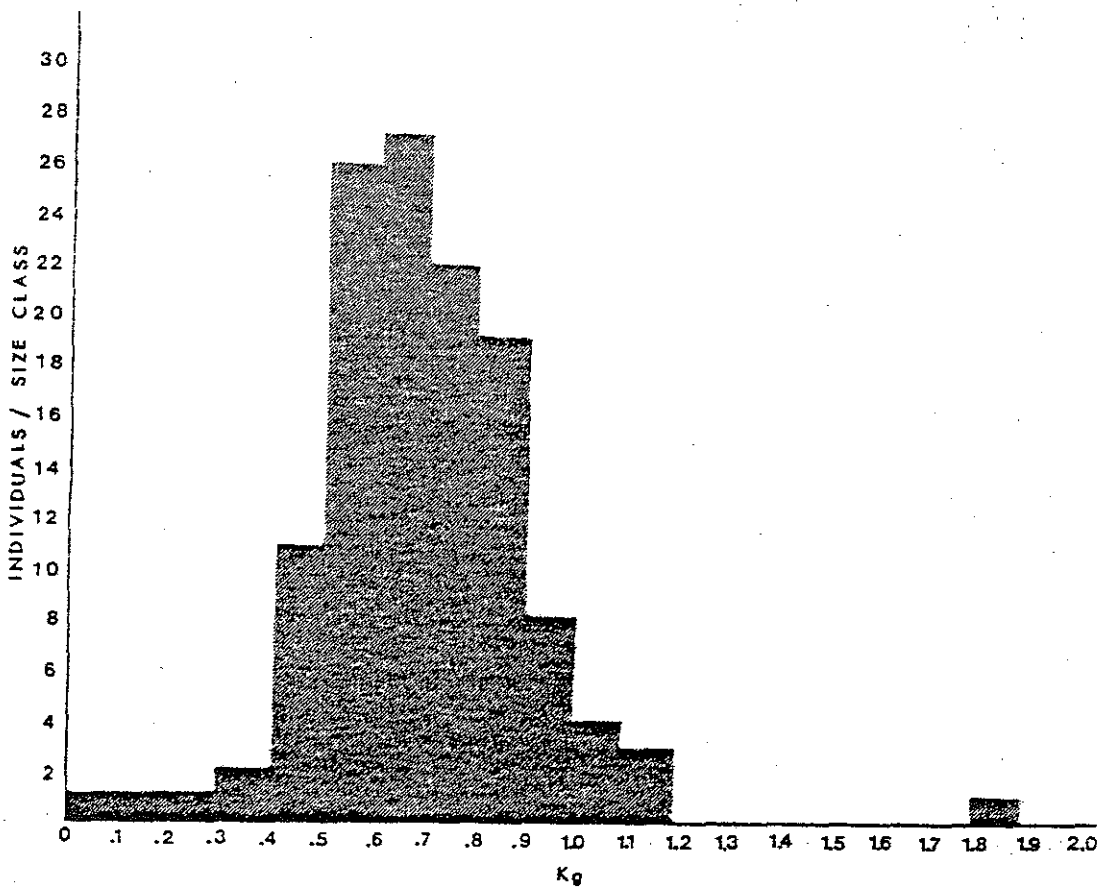


Figure 6. Size class distribution of Indiana hellbenders by weight.

Apparently this size class distribution relates to the long lives of the animals, up to 55 years in captivity (Nigrelli, 1954), coupled with a very low replacement rate. Smith (1912) found that an average-sized female deposits about 450 mature eggs each season, and females become sexually mature at a length of about 350 mm. Bishop (1941) believed that females reached sexual maturity in five to six years. The number of eggs produced increases with the size of the female.

If we assume a population size of 100 hellbenders with an average life span for adults of 30 years, we would expect 3.3% annual mortality. If we also assume that sexual maturity is reached after 5 years, then a female would have 25 years to produce enough offspring so that two will reach maturity. An average of only 3.3 young born each year need to eventually reach maturity for the population to remain stable. Reproductive success and survival of immatures varies widely from year to year, depending on river conditions. This probably causes the number of immatures in some size classes to be low, while the number in other classes are larger than expected. The low number of immatures needed to maintain the population and their small size (individuals of year classes I through III are so small as to be unlikely to be taken by my sampling methods) causes a sampling bias that greatly favors the taking of larger adults.

Most of the eggs and young do not survive, but the young that do survive grow relatively rapidly, more than doubling their length in the first year, increasing in length by 64% in the second year, and 72% in the third year to an average length of 196 mm (Smith, 1907; Bishop, 1941). Nickerson and Mays (1972) found that Ozark hellbenders between

300 and 400 mm only increase in length an average of 8.5mm/yr., or less than 2.8%; those animals between 400 and 500 mm increase an average of 3.8 mm/yr., or less than 0.95%; and one that measured 505 mm did not increase in length in two years. This slowing of the growth rate seems to correspond with sexual maturity and causes a concentration of animals in the larger size classes, between 425 and 575 mm in the Indiana population. Once an animal reaches adult size, it has few natural enemies. Although the mortality of eggs and young is high, and thus replacement rates are low, the long life span of adult hellbenders allows them to maintain their population levels.

REPRODUCTION

Swanson (1948), Smith (1907), and Bishop (1941) reported that hellbenders bred from the last week in August through the first half of September in northwest Pennsylvania and southwest New York, with most of the nests being found in the first week of September. King (1939) and Huheey and Stupka (1967) found evidence of hellbender breeding from August 26 through September 23 in the Great Smoky Mountains National Park. A pair were observed mating in the West Prong of the Little Pigeon River on September 15 by Park Forester Manley (Huheey and Stupka, 1967). Nickerson and Mays (1973) stated that Cryptobranchus alleganiensis alleganiensis in Missouri appeared to have a longer breeding season than the eastern populations. The earliest nests were found on September 3 in Niangua River (Dundee and Dundee, 1965), and September 13 and October 6 in the North Fork of the White River (Nickerson and Mays, 1973). "Ripe" females have been taken as late as November 14 from the Niangua River, and on November 3, 1971 males were releasing milt, while most females appeared spent (Nickerson and Mays, 1973).

In Indiana, the breeding season appears to be somewhat intermediate between that of eastern and western populations. The 51 adult hellbenders captured from January through April showed no obvious external sexual differentiation. Minton (1972) reported that a large male taken March 29 ceased feeding in early June and the rugae about the vent became somewhat swollen. My observations of the external characteristics of hellbenders captured from July through October are summarized in Table 5. During this period the cloacal gland of the male swells and becomes turgid. It appears as a swollen ring around the cloacal openings (Figure 7). Females never show this type of swelling (see Figure 7). A fully gravid, or ripe, female appears bloated with the abdominal skin pulled taut. The lower abdomen of a ripe female perceptibly sags when she is held vertically. This is due to the accumulation of mature eggs in the oviducts.

It appears that the Blue River population bred between September 7 and October 11, with the peak breeding activity between September 15 and October 4, during the fall seasons of 1982 and 1983.

A hellbender nest, containing 153 eggs, was found on September 27, 1983. The eggs were very recently laid, since they were not dulled by silt on their surfaces. The nest was located at SW 1/2 NE 1/4 SW 1/4, Sect 2, T1S R3E in site 4 on the Blue River in Washington County. It was found under a large limestone slab that measured 90 x 76 cm and varied from 6 to 10 cm thick. The edges of the slab were buried on three sides. The entrance was located on the downstream side with evidence of excavation apparent around the opening. The nest was in about 12 inches (30.5cm) of water, sheltered by a projection from a rock ledge, and out of the main flow of the stream. The water temperature in

Table 5. Summary of Observations of External Reproductive Characteristics from 1982-1983.

Date	Male			Female		
	Cloacal Gland Swollen but Flaccid	Cloacal Gland Turgid	Cloacal Gland Swollen & Milt Released When Handled	Not Fully Gravid	Fully Gravid (Ripe)	Spent
11 July	2	2		2		
10-11 August		4			9	
18 August		1				
26 August		3			2	
7 September		3			5	
15 September		5	1	1	2	
20 September		1	4	1	4	
25-27 September		8	5	2	5	5
4 October		7			3	4
11 October	5	4				4

Cloacal region of male.

Cloacal region of female.

Figure 7. Sexual differentiation of hellbenders during the breeding season (July-October).

the immediate nest area was 16°C. The attending adult escaped, but on October 4 a very aggressive male was captured under this same rock. I can not be sure that this male was the escaped attending adult. The cavity under the rock where the attending adult was located varied from 5 to 10cm high. The egg mass was located toward the rear of the nest cavity in a bowl-shaped depression, 8cm deeper than the surrounding cavity floor.

Two immature hellbenders, measuring 260 mm and 282 mm total length, were both caught at site 4 in September 1983. Based on size class information from Smith (1907) and Bishop (1941), these subadults were probably three years old, from the time of fertilization. No larva have been found in Indiana. Minton (1972) examined two juveniles from Indiana, the smallest being 260mm in length.

The smallest sexually mature hellbender found during this study was a male captured August 21, that weighed 250g and measured 385mm total length.

In the Blue River, at least, the hellbender is still successfully reproducing young, although the replacement rate appears fairly slow.

POPULATION DENSITY AND ANALYSIS

The population density of hellbenders appears to be directly associated with the occurrence of shelter. In areas where shelter is plentiful, the density of hellbenders can be quite high. Swanson (1948) collected about 650 hellbenders from a three-mile (4.8 km) stretch of Big Sand Creek in Venango County, Pennsylvania, and originally, hellbenders could be found under almost every suitable rock.

Hillis and Bellis (1971) captured and marked 152 hellbenders in a 220m x 70m study area in northwestern Pennsylvania and their distribution was largely correlated with the distribution of large, flat rocks. Nickerson and Mays (1972) conducted a mark-recapture study on a 4.6Km section of the North Fork of the White River in Missouri and found 428 "taggable sized" Ozark hellbenders/Km of stream bed, with 95% confidence limits of 341-575 hellbenders/Km. In the 26Km section of the river examined by Nickerson and Mays, density appeared to be related directly to the number of large rocks suitable for shelter.

Prior to this study, John O. Whitaker Jr. and several of his students from Indiana State University captured 18 hellbenders in the Blue River. One was captured under a submerged log, and the remaining 17 were found under large flat limestone slabs. Of 136 captures or recaptures during the present study, 29 were taken with hoop nets, 105 were captured from under large flat rocks, one was taken from inside a sunken auto tire, and one was taken from under a sheet of aluminum siding that was partially buried by sediment. Only one hellbender was seen away from cover during the day. It was about 6 inches from shore on an overcast, rainy day, but escaped into deep water when an attempt was made to capture it. I surmised that it was looking for food washed into the water by rain. No hellbenders were found in areas with solid bedrock or pure gravel bottoms.

Hellbenders appear to prefer shallow, well-oxygenated water. Hillis and Bellis (1971) reported that a characteristic of most capture sites of hellbenders was swift, shallow water: "more than 72.4% of the hellbenders were captured in water 12 to 36 cm deep and 92.8% in water

from 12 to 46 cm deep." The maximum depth in their study area was 180 cm at low water levels.

Of 136 captures during my study, 29 were taken with hoop nets from water 75 cm to 200 cm deep and 107 were taken by hand in water from 15 cm to 80 cm deep. It was possible that the greater success in shallow water was due to greater efficiency of the hand capture method over the trap method or the fact that nets were used much less than hand capture. It was possible that hellbenders are more often found in shallow water, because it tends to have a stronger flow than deep water, and only 2.2% of all the hellbenders taken came from slowly flowing pools, while the majority, 97.8%, came from areas of moderate to strong flow, often near riffles. In cool, well-oxygenated, flowing water, hellbenders can get all the oxygen they require by cutaneous respiration. In still water, I observed that hellbenders come to the surface to gulp air for buccopharyngeal or lung respiration. This behavior was also reported by Bishop (1941) and Smith (1907). Therefore, by locating themselves in areas of well-oxygenated water, hellbenders are able to remain under cover and not expend energy or expose themselves to predators by coming to the surface as would be necessary in poorly oxygenated waters.

A population density mark-recapture study was carried out in Site 4 (Table 6) from August 10, 1982 to October 11, 1983. During this period, 15 samples were taken. Site 4 had a gravel bottom with numerous large, limestone rocks. This site was 100 m long and varied in width from 4 to 10 m. Water depth varied from 30 to 60 cm at low water levels, but was over 1 m deep during normal spring flow. The southwest bank of Site 4 was a limestone ledge and outcropping at the base of a

Table 6. Estimates of Hellbender Population Size at Site 4 on the Blue River in Washington Co., Indiana.

Date	Sample #	m_i	S_i	Z_i	R_i	M_i	Total Population Size	Standard Error
Aug. 10	1	0	9	-	3	*	*	
Sep. 26	2	0	1	3	1	4	*	
Jan. 20	3	0	1	4	0	*	*	
Feb. 22	4	0	3	4	2	6	*	
Mar. 15	5	1	2	6	0	*	*	
Mar. 28	6	0	5	6	3	10	*	
Mar. 31	7	0	12	9	0	*	*	
Apr. 6	8	0	8	9	0	*	*	
Apr. 28	9	1	4	8	0	*	*	
Sep. 7	10	0	6	8	3	16	*	
Sep. 15	11	5	6	5	4	12.5	15	2.74
Sep. 20	12	6	7	3	5	10.2	11.9	1.84
Sep. 27	13	3	12	5	5	15	60	30
Oct. 4	14	9	14	3	3	23	35.8	7.13
Oct. 11	15	11	12	-	-	-	-	

M_i = marked population size at time i

m_i = marked animals actually caught at time i

S_i = total animals released at time i

Z_i = number of individuals marked before time i, not caught in the ith sample but caught in a sample after time i

R_i = number of the S_i individuals released at time i that are caught in a later sample

Table 6 - continued

$$M_i = \frac{S_i Z_i}{R_i} + m_i$$

$$\text{Total Population Size} = \frac{\text{Marked population size}}{\text{proportion of animals marked}}$$

110 ft high ridge. The northeast bank was composed of gravel and sand, eroding in places to form gravel bars.

The data from this mark recapture study can be seen in Figure 8. Of the 68 hellbenders captured in Site 4, 42 of those tagged and released were only captured once; 3 were removed from the population after being captured once; 15 were captured twice; 4 were captured three times; 3 were captured four times; and one individual was captured five times. No movement into or out of Site 4 was shown by samples taken in adjacent areas. Ten hellbenders were captured and tagged immediately upstream from Site 4 and 8 more downstream; none of these 18 animals had previously been captured or were ever recaptured in Site 4. During sampling periods 7 through 9, a total of 24 hellbenders was captured, tagged and released, but never recaptured. These samples were taken with 2 baited hoopnets located in the middle of and at the downstream boundary of Site 4. I believe that these baited traps attracted hellbenders from the slightly deeper waters immediately downstream from Site 4, and they returned there after their release. This was supported by the fact that the animals from sample 6 were all caught in a hoopnet at the upstream boundary of Site 4, and 3 of these 5 animals were recaptured a combined total of seven times. This trap, set at the upstream boundary, was drawing animals from Site 4, and they remained there when released.

Table 6 indicates how the marked population and total population size are determined. Animals not recaptured were discounted as marginal or transient by causing the denominator of the formula to be "0" and the population size to become "undefined," which means unknown. The total population size can only be estimated if the marked population size

Time of last capture	Time of capture of marked animals														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Au 10 = 1	(9)	-	-	-	-	-	-	-	1	-	1	-	-	1	1
Se 26 = 2		(1)	-	-	-	-	-	-	-	-	1	-	-	1	-
Ja 20 = 3			(1)	-	-	-	-	-	-	-	-	-	-	-	-
Fe 22 = 4				(3)	1	-	-	-	-	-	-	1	-	-	-
Mr 15 = 5					(2)	-	-	-	-	-	-	-	-	-	-
Mr 28 = 6						(5)	-	-	-	-	2	3	1	-	1
Mr 31 = 7							(12)	-	-	-	-	-	-	-	-
Ap 6 = 8								(8)	-	-	-	-	-	-	-
Ap 28 = 9									(4)	-	-	-	-	-	-
Se 7 = 10										(6)	1	2	2	1	2
Se 15 = 11											(6)	-	-	1	-
Se 20 = 12												(8)	-	1	-
Se 27 = 13													(13)	4	3
Oc 4 = 14														(14)	4
Oc 11 = 15															(12)

( ) = total number of animals caught at time i.

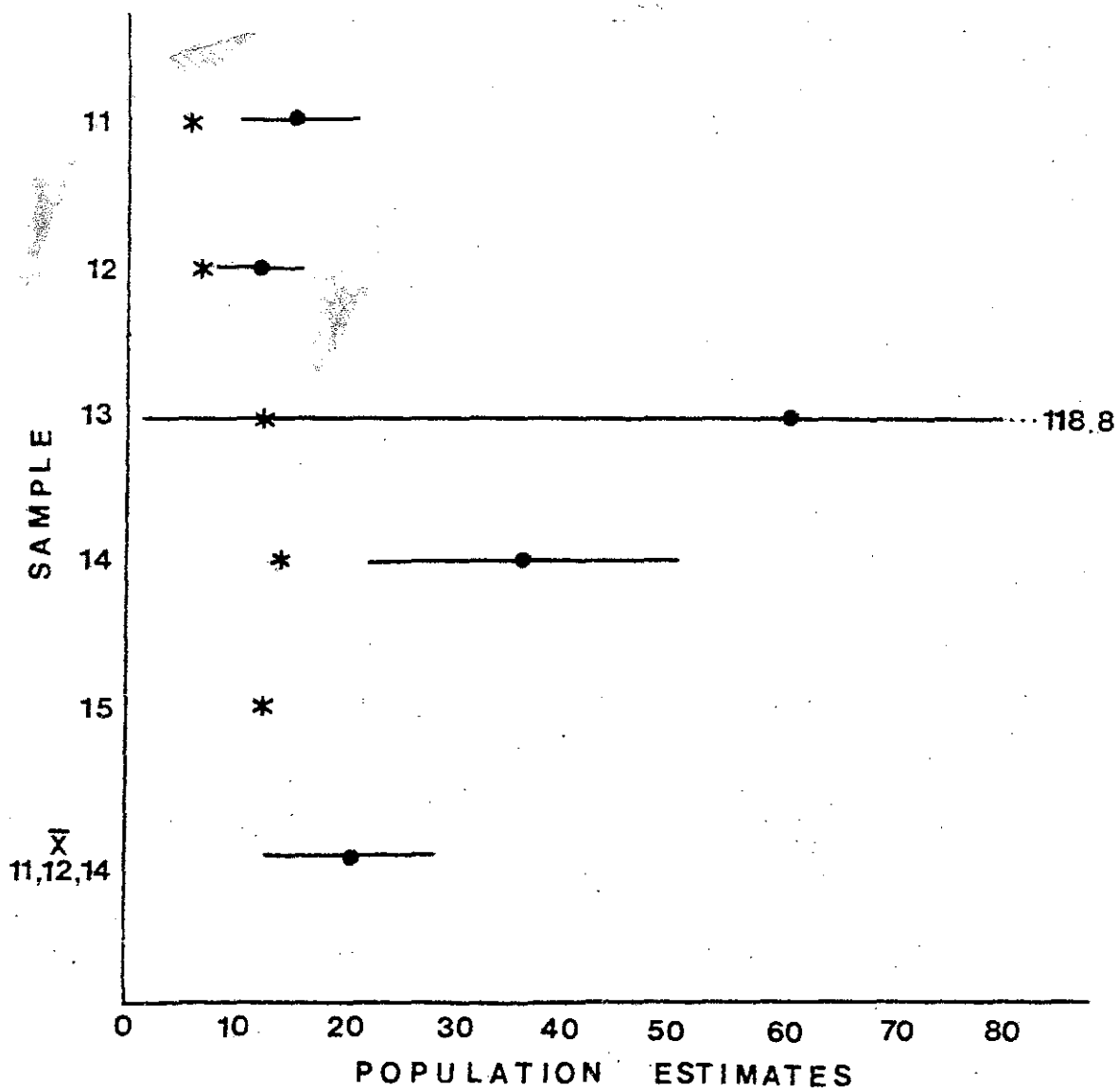
rows = indicate when animals tagged at time i were recaptured.

columns = indicate when recaptured animals caught at time i were tagged.

Figure 8. Recapture data from Site 4, Washington County (August 1982 - October 1983).

is a real number and there are recaptures; therefore, the total population estimates were calculated only for Samples 11 through 14 (Figure 9). The population estimate of 60 from sample 13 was obviously unreliable due to its Standard Error of 30 and 95% confidence limits of 60 $\pm$ 58.8. By using the mean values for m_i, S_i, Z_i, and R_i from samples 11, 12, and 14 (Table 6), we can estimate the mean marked population size (M_i) as 15.03 and the total population size for Site 4 as 20.2 $\pm$ 7.7 hellbenders/100 m of stream bed. We know that this 100 m section of stream will accommodate a minimum of 14 animals, since that number was taken in a single sample. It was a minimum value since it was not possible to turn over all rocks that could harbor hellbenders. While it is apparent that there was considerable turnover in the population at Site 4 on the Blue River, there was some consistency demonstrated by the presence of two animals more than one year after their initial capture (Figure 8).

Based on data from July through October, the sex ratio of hellbenders in the Blue River was 1.03 males to one female with n = 75. However, in a sample from Site 4 in Washington County, a known nesting location, the sex ratio was 0.74 males to one female with n = 33. This may be due to the fact that the larger males should be defending the best nests under the largest rocks and therefore are inaccessible. These ratios were substantially different from what other researchers have found. Smith (1912) reported a sex ratio of 3 males/1 female with a 1:1 ratio in the breeding areas. Hillis and Bellis (1971) found a sex ratio of 1.58 males: 1 female.



* - Actual sample size.

Figure 9. Total population size estimates for a 100m section of the Blue River in Washington County with 95% confidence limits.

MANAGEMENT RECOMMENDATION

The most important steps needed to insure the survival of the hellbender in Indiana are the protection of the Blue River as a natural river and the education of the fishing public that hellbenders are endangered and therefore protected. I do not believe that hellbenders would become extinct in the Blue River unless there was a drastic change in the watershed or commercial collecting for this species took place. The evidence for this belief was the large number of hellbenders found and the fact that reproduction was taking place.

It would also be valuable for this species to be reintroduced into areas where they were previously found and the habitat is still favorable. The only stream that seems to meet these requirements is the Whitewater River. The East Fork of the Whitewater River is an ideal location for reintroduction of the hellbender. The water quality is very good because the Brookville Lake acts as a giant silting pond, and the water remains cool due to the deep water outlet. The good water quality is also demonstrated by the presence of stocked trout living in this stream. Hellbenders have never been shown to take trout and would not be likely to take healthy fish, so they should not compete with fishermen after trout or bass. Both cover and crayfish are plentiful, so the introduced animals would not have to compete with each other for food or shelter. The biggest difficulty in restocking hellbenders would be the need to introduce a large initial stocking population to compensate for the low reproductive replacement rates of this species. It is difficult to raise hellbender larva according to Smith (1907), but easy to get the eggs to hatch, so it may be possible to release large

numbers of newly hatched larvae from a small captive breeding population and hope for enough survival to produce a breeding population in five to seven years. This would be a long term venture, requiring additional stockings of larvae for several years if it is to be successful.

BIBLIOGRAPHY

Allyn, W. P. and C. H. Shockley. 1939. A preliminary survey of the surviving species of Caudata of Vigo County and vicinity. Proc. Indiana Acad. Sci., 48: 238-243.

Bishop, S. C. 1941. The salamanders of New York. New York State Mus. Bull. No. 324. 354 pp.

Blatchley, W. S. 1891. Notes on the batrachians and reptiles of Vigo County, Indiana. J. Cincinnati Soc. Nat. Hist. 14: 22-35.

Dundee, H. A. and D. S. Dundee. 1965. Observations on the systematics and ecology of Cryptobranchus from the Ozark Plateaus of Missouri and Arkansas. Copeia 1965 (3): 369-370.

Gaines, A. 1895. Batrachia of Vincennes, Indiana. Amer. Nat., 29: 53-56.

Green, N. B. 1935. Further notes on the food habits of the waterdog, Cryptobranchus alleganiensis Daudin. Proc. West Virginia Acad. Sci. 9: 36.

Hay, O. P. 1892. The batrachians and the reptiles of Indiana. Indiana Dept. of Geology and Natural Resources 17th Annual Report (1891). Indianapolis, pp. 409-602.

Hillis, R. E. and E. D. Bellis. 1971. Some aspects of the ecology of the hellbender, Cryptobranchus alleganiensis alleganiensis, in a Pennsylvania stream. J. Herpetol. 5 (3-4): 121-126.

Huheey, J. E. and A. Stupka. 1967. Amphibians and reptiles of Great Smoky Mountains National Park. Univ. of Tenn. Press. Knoxville. ix + 98 pp.

Jolly, G. M. 1965. Explicit estimates from capture - recapture data with both death and immigration - stochastic model. Biometrika 52 (1 and 2): 225-247.

King, W. 1939. A survey of the herpetology of Great Smoky Mountain National Park. Amer. Midland Nat. 21 (3): 531-582.

Minton, S. 1972. Amphibians and reptiles of Indiana. Indiana Acad. of Sci. Monograph No. 3, v + 346 pp.

Nickerson, M. A. and C. E. Mays. 1973. The Hellbenders: North American "Giant Salamanders". Milwaukee Public Museum. Publications in Biology and Geology No. 1, 1973. viii + 106.

Nickerson, M. A. and M. Selby. 1969. Unpublished data.

Nigrelli, R. F. 1954. Some longevity records of vertebrates. Trans. New York Acad. Sci. Ser. II, 16 (6): 296-299.

Smith, B. G. 1907. The life history and habits of Cryptobranchus allegheniensis. Biol. Bull. 13 (1): 5-39.

Smith, B. G. 1912. The embryology of Cryptobranchus alleghenienses, including comparisons with some other vertebrates. J. Morphol. 23 (1): 61-157.

Stein, H. A. and P. W. Smith. 1959. The hellbender, Cryptobranchus alleganiensis, in Illinois. Copeia 1951 (2): 178-179.

Swanson, P. L. 1948. Notes on the amphibians of Venango County, Pennsylvania. Amer. Midland Nat. 40 (2): 362-371.

Wied, M. 1839. Reise in das innere Nord-Amerika in den Jahren 1832 bis 1834. J. Hoelscher, Coblenz, Vol. 1, xvi + 653 pp.