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Analysis and Comparison of Three Capture Methods for the Eastern Hellbender (*Cryptobranchus alleganiensis alleganiensis*)

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The Hellbender (*Cryptobranchus alleganiensis* Daudin) is North America's only member of the Cryptobranchidae, and one of the world's largest salamanders. Hellbenders are elusive animals; they are nocturnal, cryptically-colored, and spend most of their time beneath large rocks on the bottoms of swift-flowing streams. These characteristics make them difficult to locate and capture. A variety of capture methods have been tested and evaluated, but even the most widely accepted of these are still questionable in terms of their impact on breeding habitat and reproductive behavior. In addition, no effective technique has been reported to consistently locate and capture larvae or juveniles.

A common method of searching for Hellbenders involves lifting the upstream ends of rocks greater than 30 cm diameter, and capturing any Hellbender below it by hand or net with or without the aid of a mask and snorkel. Whereas this method is inexpensive and relatively quick (Nickerson and Krysko 2003), turning rocks during the breeding season may disrupt nest sites and result in mortality of eggs or larvae (Williams et al. 1981). Although appropriate for locating large adults, it may be ineffective for locating smaller size classes, especially larvae and juveniles less than 20 cm total length (Peterson et al. 1983). Nickerson and Krysko (2003) speculated that turning small rocks and other objects in shallow water might yield more larval Hellbenders. Additional disadvantages to rock turning include injury to the researcher due to heavy lifting, difficulty seeing Hellbenders because of stream surface glare, possibility of Hellbenders escaping unnoticed by researchers, inability to locate Hellbenders in deep water, and time required for silt to clear after a rock is lifted (Nickerson and Krysko 2003; Pauley et al. 2003).

Electroshocking has been used extensively with high capture success reported (Williams et al. 1981). Bothner and Gottlieb (1991) reported that Hellbenders were completely unaffected by the electrode unless directly touched with it, and even then appeared only mildly disturbed. Regardless of capture success, electroshocking equipment is heavy and expensive, and risk to researchers and Hellbenders, especially eggs and larvae, is potentially significant (Nickerson et al. 2002; Nickerson and Krysko 2003).

Searching the stream bottom at night using spotlights is another technique that has been used to locate Hellbenders (Humphries and Pauley 2000). Hellbenders observed in the open are captured by hand or net, and rocks are lifted when Hellbender heads are observed protruding out from underneath. Nighttime searches may be useful for determining the presence/absence of Hellbenders during periods of peak nocturnal activity (Humphries and Pauley 2000). Humphries (2007) reported on an apparently unique population in North Carolina that seasonally exhibits a high degree of diurnal activity which made daytime visual searches very productive.

Several attempts have been made to capture Hellbenders using baited traps. Hellbenders are believed to forage at least partially by chemoreception, and have been documented responding to dead bait from a considerable distance (Nickerson and Mays 1973). Wire mesh traps baited with chicken liver proved unsuccessful (Soule and Lindberg 1994), but hoop traps baited with sucker fish did successfully capture Hellbenders (Kern 1984). Despite the mixed success with which traps have been used, they allow researchers to investigate deeper areas, and are not affected by turbidity.

Nickerson et al. (2003) effectively used snorkeling and SCUBA to capture Hellbenders, including larvae, in deep water areas. In their study more than 20 Hellbenders under 20 cm total length were located and 16 of these were gilled larvae. Most were located under small rocks, or in the interstices of small accumulations of gravel or gravel mixed with twigs near the stream banks, but some were located under large rocks in deeper water, or in deep gravel beds. Petokas (pers. comm.) has captured Hellbenders in water as deep as 6 m in the Susquehanna River in Pennsylvania using SCUBA techniques.

The objective of this study was to examine three methods of searching for Hellbenders in terms of efficiency and effectiveness: turning rocks, trapping, and searching along stream banks. Advantages, disadvantages, and limitations also were assessed in order to recommend a capture protocol for Hellbender population studies that will minimize disturbance and increase the likelihood of locating individuals of a variety of size classes.

Materials and Methods

Study Sites

This study was conducted at eight sites in three streams of the Allegheny River drainage in Cattaraugus County, New York, USA. Extant populations of Hellbenders were documented in these sites by a previous study (Bothner and Gottleib 1991). Substrate composition and embeddedness were visually estimated along transects at each site. Percent composition was visually estimated across the entire transect. Embeddedness was estimated at each bank, and at $^1/_4$, $^1/_2$, and $^3/_4$ of the stream width. Three independent estimations were averaged for each transect.

Capture Methods

Rock Turning.—As part of a mark-recapture study, rock turning searches were conducted between late August and October of 2004 and 2005, and generally involved two to four active searchers. Hellbenders were located by slowly lifting the upstream ends of suitable rocks in each study site. A peavey or cant hook was used to provide leverage when needed. Suitable rocks were defined as those measuring at least 30 cm in diameter that did not require the use of multiple leverage devices for lifting. Before lifting a rock, a net was placed against the downstream edge to catch Hellbenders escaping with the silt plume. Hellbenders remaining in place or moving upstream were captured by grasping them behind the head and maneuvering them into a trout net. Rocks deemed likely to be nest sites were not turned in 2005. This is because during the 2004 survey, several nests were discovered and later found to be destroyed, possibly as a result of being disturbed.

Bank Searches.—Bank searches were conducted at all sites during the summer of 2005, between late May and late August, in an effort to locate smaller size classes. This technique was performed by two searchers. Habitable stretches of bank area, defined as having substrate larger than 7 cm in diameter, within the study site were divided into sections 1 m wide and extending 4 m into the stream. Five percent of these sections were randomly selected for search in each site (see Foster 2006 for site descriptions). Searching involved turning or agitating all substrate particles in the section. Aquarium nets with flat bottoms were held downstream to capture any juvenile hellbenders that were observed. Hellbenders were located by feel and captured by hand when visibility was poor.

Trapping.—The traps were a rectangular box design made of 1.3 cm plastic-coated hardware cloth. The traps measured 61 × 46 × 23 cm with a funnel on one end 7.5 cm high and 10 cm wide. A hinged door on the end opposite the funnel, held closed with a bungee cord, could be opened to add bait or remove any captured animals (Fig. 1). During the summer of 2004 we conducted a preliminary trapping test at Site No. 5 to aid in protocol development. We informally tested two baits: previously frozen venison (*Odocoileus virginianus*) and White Sucker (*Catostomus commersonii*). Both baits were selected for their availability, and

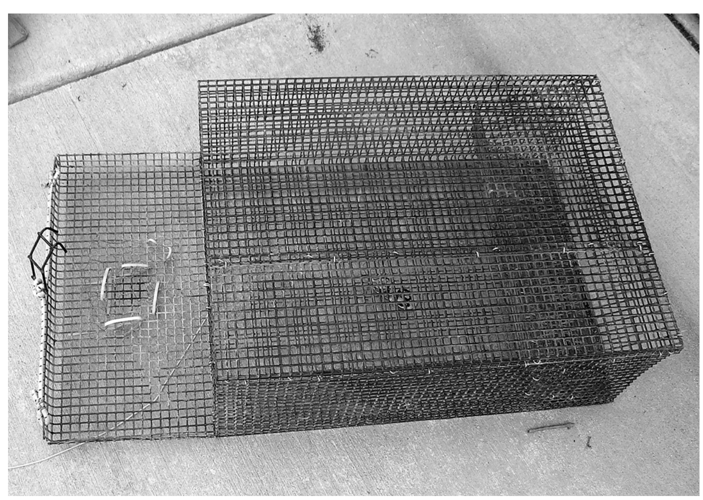

Fig. 1. Trap used to capture Hellbenders in Allegheny River drainage during the summers of 2004 and 2005. Bait (White Sucker) was attached to the inside of the hinged door in a wire mesh cage (later the cage was removed and replaced with plastic zip ties, see text).

sucker fish has been used successfully to capture Hellbenders in hoop traps (Kern 1984). Based on the preliminary data generated, we selected White Sucker as the bait for our future trapping efforts.

Trapping was conducted in all sites during the summer of 2005, between late May and late July. Trapping was performed at one site in May, two sites in June, and five sites in July. We performed four consecutive nights of trapping in each site. The number of traps used varied with site size. Traps were set approximately 20 m apart in potentially habitable areas with sufficient water depth to cover the entire trap (0.25 m minimum). These areas included sections of stream bed covered with large rocks, wood, or decaying vegetation, and areas with rock ledges at the banks. Traps also were set in areas that lacked large cover rocks, but were adjacent to habitable areas. In areas that contained habitat not accessible by turning rocks, such as rock ledges or large, unliftable rocks, and in areas too deep to be searched by hand, traps were set more densely (up to every 5 m). Traps were baited with pieces of White Sucker placed in a wire mesh cage on the trap door (Fig. 1) and set with the entrance facing downstream. In shallow water, traps were set flat against the stream bottom. In deep water, this often was not possible to ensure. Traps were tied to sturdy vegetation and weighted down with rocks. They were checked and bait was changed daily, except for site No. 8, at which bait was only changed every other day. Baiting and setting traps was completed by 1500 h each day, and traps were checked the following morning.

Evaluation of Capture Methods

Efficiency.—Capture efficiency was calculated for each method as the number of Hellbender captures per unit of effort. For the two manual search methods, effort was measured in person hours. Person hours included all time spent actively searching for and processing Hellbenders. Hellbenders were processed as they were found and processing time averaged 8 min/Hellbender. For the trapping method, effort was measured in trap nights. Trap nights were calculated by multiplying the number of traps set by the number of nights deployed. One trap night required 0.5 person hours

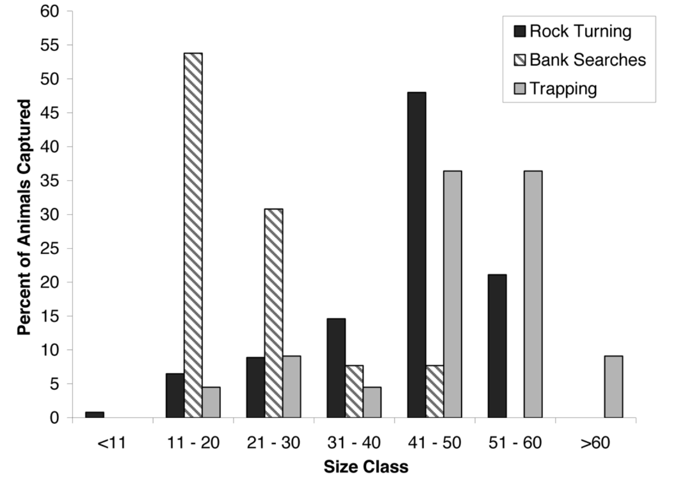

FIG. 2. Relative success of three capture methods in locating various size classes of Hellbenders (Rock Turning, N = 123; Bank Searches, N = 14; Trapping, N = 22; recaptures are not included in these numbers).

(it took two people approximately 15 min to bait, set, and check a trap). All Hellbender captures, including recaptures, were included in this analysis.

Effectiveness.—Each of the three methods was evaluated in terms of its effectiveness at locating Hellbenders of different sizes. Hellbenders were grouped into seven size classes, and the percentage of Hellbenders in each size class was determined for each method. Each animal was only counted once for this analysis, regardless of how many times it was captured. Each technique also was assessed in terms of its ability to capture Hellbenders at different water depths.

RESULTS

Study Sites.—Site areas ranged from 2355 to 15,741 m^2. Substrate in all sites included rocks > 30 cm diameter covering 4–8% of the stream bed, and fine particles (sand and silt) and gravel were prevalent. Site No. 8 also contained large areas of exposed

TABLE 1. Capture efficiency, measured as catch per unit effort, for three methods used to locate Hellbenders in the Allegheny River drainage in New York State. For rock turning and bank searches, effort was measured in person hours. For the trapping method, effort was measured in trap nights. One trap night is roughly equivalent to 0.5 person hours since it takes two people approximately 15 minutes to set a trap. Site No. 3 is excluded because no Hellbenders were observed.

Site	Rock Turning (No. of captures)[1]	Rock Turning (Captures / person hour)	Bank Searches (No. of captures)	Bank Searches (Captures / person hour)	Trapping (No. of captures)	Trapping (Captures / trap night)
1	5	0.21	2	0.50	1	0.03
2	19	0.35	7	0.47	2	0.03
4	33	0.49	0	0.00	4	0.05
5	32	0.55	0	0.00	4	0.03
6	12	0.32	0	0.00	2	0.02
7	33	0.83	5	1.00	1	0.01
8	23	0.64	0	0.00	8	0.10
total	157		14		22	

[1]These numbers include recaptures.

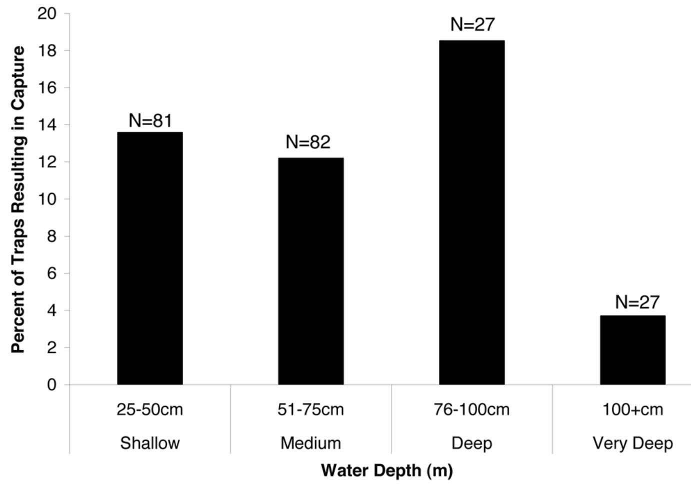

FIG. 3. Relative success of traps placed at different depth ranges. N = number of traps placed at each depth.

bedrock. Substrate embeddedness was greater than 50% at all sites. The study streams were all relatively shallow (< 1 m deep in most places) and very clear during the study period.

Efficiency.—Capture efficiency varied by site for both manual search methods (Table 1). A total of 317 person hours were spent on rock turning and 55 person hours were spent on bank searching. A total of 157 captures (including recaptures) resulted from rock turning searches. Rock turning yielded 0.2 to 0.8 captures/person hour. Bank searches resulted in a total of 14 captures. In four of the seven sites, no Hellbenders were captured using the bank searching method. In the remaining three sites, capture efficiency was higher for bank searching than for rock turning, ranging from 0.47 to 1.0 captures/person hour. Traps were set for a total of 627 trap nights among all seven sites, resulting in 22 captures. Capture efficiency was highly variable between sites, ranging from 0.01 to 0.10 captures/trap night (Table 1). Only rock turning resulted in recaptures.

Effectiveness.—Each of the three methods was successful at locating both adult and juvenile Hellbenders, but only the two manual search methods resulted in the capture of gilled larvae. The smallest animal, less than 11 cm total length, was captured using the rock turning method. Captures of very large Hellbenders, greater than 60 cm total length, resulted only from the use of traps. No method was capable of locating all size classes equally (Fig. 2). Rock turning searches were biased toward middle-sized adults, between 41 and 50 cm total length. Of 123 individual Hellbenders captured using this method, 48% were in this size class. Bank searches were biased toward immature animals. Of the 14 Hellbenders captured in bank searches, 53.8% were between 11 and 20 cm total length. An additional 30.8% were between 21 and 30 cm total length. Trapping was most successful in capturing large adults. More than 80% of the 22 Hellbenders captured in traps were greater than 40 cm total length.

Each method was capable of locating Hellbenders at a range of depths, although manual search methods were limited to water <1 m deep. Bank searches were successful within the narrowest depth range, from 0.145 to 0.540 m. Rock turning captures ranged in depth from 0.155 to 0.85 m. Trapping had the greatest successful depth range, with Hellbenders captured from 0.28 to 1.25 m depth.

TABLE 2. Summary of advantages, disadvantages, and limitations associated with three Hellbender capture methods used in the Allegheny drainage in 2004 and 2005.

Method	Advantages	Disadvantages	Limitations
Rock Turning	- High capture efficiency - Locates some juveniles	- Labor intensive - May damage habitat - Risk of injury to Hellbender - May reduce reproductive success (if done during breeding season)	- Wind - Rain - High turbidity - Low light - Rock size and mobility - Depth - Minimum of five person hours per site recommended
Bank Searches	- Effective for finding juveniles - High capture efficiency where successful	- Does not result in high capture rate for larvae - Habitat disturbance - Potential impacts to reproduction of other stream organisms - May fail to detect presence	- High turbidity - Rock density - High flow
Trapping	- Little habitat disturbance - Useful for water slightly exceeding maximum depth of other methods - Useful for areas with unliftable rocks or ledges - Captures largest size class - Only method that detected Hellbenders at all sites	- Labor intensive - Low capture success - Requires large supply of bait - Risk of injury to Hellbender - Incidental catch may result in mortality of turtles - Cannot use during breeding season - Did not detect larvae	- Shallow water (< 0.25 m deep) - Deep water (> 1 m deep) - Minimum of 100 trap nights / site recommended

Trapping appeared to be most successful in deep water, between 0.76 and 1.0 m (Fig. 3). Of 27 traps set at this depth range, 18.5% resulted in captures. Less than 15% of traps set in shallower areas resulted in captures, and fewer than 4% of traps set in water >1 meter were successful in capturing Hellbenders.

Discussion

Of the three methods examined, rock turning was the most efficient when viewed in terms of overall catch per unit effort. However, in some streams, bank searches were also highly efficient. Capture efficiency for trapping was lower than for rock turning in all sites, and was lowest in terms of overall catch per unit effort.

Bank searches were notable in the "all or nothing" type of capture success seen between sites. At all three sites where the method was successful, it exceeded the capture efficiency of rock turning. In the remaining four sites, it yielded no captures. This disparity is most likely due to differences in habitat between the sites. Bank searches were successful where stream margins included deep cobble piles interspersed with larger rocks. These areas presumably provide refuge from predation and an abundant food supply.

Sites at which bank searches were unsuccessful fell into two categories: those at which bank habitat was poor, and those at which bank habitat was exceptionally good. Poor bank habitat was characterized by silt and sparse rock cover. Exceptionally good bank habitat was characterized by dense piles of various-sized cobble and boulder along the stream edges. These areas were difficult to search thoroughly. It is possible that employing seines, buried into the substrate on either end of the search area, might increase the success of this method in areas with good habitat.

The capture rate for rock turning can be impacted by water and weather conditions. Hellbenders are difficult to see when the surface of the water is choppy. When turbidity is high, Hellbenders are often lost in the silt plume that is generated by lifting the rock. Under certain circumstances, a mask and snorkel might help alleviate these problems (Nickerson and Krysko 2003). Early in our study we tried using a mask and snorkel for both rock turning and bank searches, but because our streams were extremely shallow and clear this method did not prove useful. Even in our streams, SCUBA may have been useful for turning rocks in deep pools. However, we did not attempt this method and thus could not manually search for Hellbenders in areas deeper than ca. 1 m.

The usefulness of trapping may be limited by the nature of Hellbenders as predators. Hellbenders often lie in wait for prey, with only their noses protruding from rocks (Humphries and Pauley 2000), utilizing a powerful type of suction feeding enabled by unique jaw asymmetries and hyoid movements (Lorenz Elwood and Cundall 1994). This may limit their need to move about in search for food (Nickerson and Krysko 2003), reducing the likelihood of their capture using traps. On the other hand, Humphries and Pauley (2000) suggest that during times of high metabolic demand Hellbenders may forage more actively. This may increase trapping success at some times of the year, especially prior to the breeding season.

Prey availability may influence Hellbender foraging. Large numbers of crayfish were observed in our sites throughout the study period, which may have minimized trapping success. Bait choice also may affect trapping success. Although White Sucker was successful in capturing Hellbenders in our study, other baits may prove more enticing. For example, Hellbenders may be attracted to bait with fresh blood (Bishop 1941).

Traps appeared to be most successful when set at depths between 0.75 and 1.0 m. Few Hellbenders were trapped at depths >1 m, possibly due to difficulty in setting traps flat against the stream bottom at these depths. This problem could be corrected by diving to the bottom using a mask and snorkel or SCUBA equipment and properly setting the trap. Diving to set deep-water traps may be useful if rock ledges or unliftable rocks are present.

Each of these methods has associated advantages and disadvantages that affect their usefulness in various situations (Table 2). Rock turning may be the most efficient method for capturing Hellbenders, but may have serious repercussions during the breeding season. Hellbenders tend to select nest rocks that are mostly embedded in smaller substrate and have only a single opening, which the male defends (Bishop 1941). Once the nest is disturbed, several openings may exist, exposing the eggs or larvae to a variety of predators. In addition, overturning potential nest rocks may render them unsuitable as nest sites because they will no longer be sealed by small particles.

Bank searches are extremely useful for locating juvenile Hellbenders, but may be highly disturbing to the habitat. Many organisms may be affected, including crayfish, small fish, mudpuppies, tadpoles, and macroinvertebrates. While not impacting Hellbender reproduction, bank searches during the summer may affect the reproduction of some other organisms.

Trapping was the only method that did not cause substantial disturbance to the stream habitat. It also worked in situations where other methods failed, such as in habitat areas with very large rocks or rock ledges. Of the 22 Hellbenders trapped in 2005, 16 were not located using any other method. Of these, one was trapped near a rock ledge, seven were trapped near unliftable rocks, and five were trapped in deep water.

Trapping also has some disadvantages. Traps are heavy, bulky, and take a considerable amount of time to set. There is risk of injury to Hellbenders. Several Hellbenders sustained minor injuries on the original wire bait holder. As a result we removed the holders and used plastic zip ties to hold bait for the remainder of the study. There is also a risk to other animals that may become caught in the trap, particularly turtles. Trapping should not be conducted during the breeding season, since females captured in traps overnight could become stressed and drop their eggs, and captured males would be prevented from returning to their nests rocks, possibly exposing eggs to predation.

When determining which capture method to use for studying a particular group of Hellbenders, it is important to consider the attributes of the site and the advantages versus the disadvantages of each method. Our results suggest that no single method for Hellbender capture is capable of providing access to all portions of the population. Based on its high catch efficiency and ability to locate some juveniles, rock turning is most likely the best method for studies aimed at determining population size. The inclusion of rocks smaller than 30 cm diameter in bank areas may increase the ability of this method to provide information on age structure. However, the main advantage of rock turning in the breeding season, gathering sex ratio data, is outweighed by the potential negative impacts to reproductive success. To provide the most complete data on Hellbender population structure, including age structure and habitat usage, we recommend a combined approach using extensive summer rock turning, bank searches focused on appropriate cobble piles adjacent to large rock areas, and limited trapping in areas of deeper water, or where unliftable substrate renders other search methods impossible.

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