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A Review of Common Mudpuppy (*Necturus maculosus*) Capture Methods and Description of a Revised Trap Design

Necturus maculosus is a widespread, aquatic salamander native to both lentic and lotic systems in eastern North America (Petranka 1998). These salamanders typically occur under cover such as large flat rocks or logs, especially in areas with layers of mud substrate and debris (Petranka 1998; Matson 2005). Adults often exhibit high site fidelity (Shoop and Gunning 1967; Matson 1998). *Necturus maculosus* has a long lifespan (~30 years; Bonin et al. 1995), and plays an integral role in its environment as a predator, feeding on fish, crayfish, and mollusks (VanDeValk and Coleman 2010). Breeding occurs in the fall; females store sperm in spermatheca over the winter with ovulation and fertilization delayed until spring (Petranka 1998; Matson 2005). Egg deposition occurs under large flat rocks in the spring and summer (Petranka 1998; Matson 2005). Larvae hatch in early summer, and there is evidence that adult *N. maculosus* attend and guard clutches of eggs (Hime et al. 2014). Additionally, *N. maculosus* is the only known host for the Salamander Mussel (*Simpsonaias ambigua*), a regionally imperiled freshwater mussel.

Although thought to be common throughout its range (Barbour 1971; Petranka 1998), much of the life history of *N. maculosus* is unknown. For example, habitat preferences, seasonal movements, population structure, gene flow, and dispersal are poorly understood (but see McDaniel et al. 2009). The lack of information is due, in part, to its cryptic nature and capture difficulty (Matson 1990). Here we review various capture methods for *N. maculosus*, as well as illustrate and highlight a new trap design for their efficient capture.

MASON O. MURPHY*
Department of Biology, University of Kentucky, Lexington, Kentucky 40546, USA
STEVEN J. PRICE
Department of Forestry, University of Kentucky, Lexington, Kentucky 40546, USA
PAUL M. HIME
Department of Biology, University of Kentucky, Lexington, Kentucky 40546, USA
ANDREA N. DRAYER
Department of Forestry, University of Kentucky, Lexington, Kentucky 40546, USA
DAVID W. WEISROCK
Department of Biology, University of Kentucky, Lexington, Kentucky 40546, USA

**Corresponding author; e-mail: mason.murphy@uky.edu*

Review of Capture Methods

A number of methods are commonly used for *N. maculosus* sampling, including electroshocking, manual surveys, seining, and trapping using minnow traps (Table 1).

Electroshocking.—Electroshocking uses a mild electric current to stun aquatic vertebrates for easy capture with nets. Although electroshocking has been used to successfully capture *N. maculosus* (Shoop and Gunning 1967; Schmidt et al. 2004; VanDeValk and Coleman 2010), it has numerous drawbacks, and may be ineffective (Matson 1990). Backpack electroshocking is limited by navigability and depth of the water, and is typically feasible in water where the sampler is able to wear waders (< 1 m deep). Boat-mounted electroshocking enables the sampling of larger systems, but limits smaller stream sampling and is cost prohibitive. Drawbacks of both electroshocking methods include dependency on adequate water conductivity to deliver the shock, known as a limited shock radius. Furthermore, *N. maculosus* tend to stay under large flat rocks, reducing the chance of netting a shocked *N. maculosus*, as the rock prevents the mudpuppy from rising to the surface (Matson 1990). Nickerson et al. (2002) and Nickerson and Krysko (2003) discourage the usage of electroshocking, given the possible non-target and negative effects on Hellbender (*Cryptobranchus alleganiensis*) larvae. These concerns may apply to *N. maculosus* larvae as well.

Manual surveying.—Manual surveying, by wading or skin diving, is also commonly used to sample for *N. maculosus*, especially in shallow water (Nickerson et al. 2002). This method involves walking or floating upstream while flipping large flat rocks typically used by *N. maculosus* for refuge. Benefits of this method include the opportunity to directly observe mudpuppies in their habitat, as well as a relatively high level of capture efficiency (Matson 1990). Drawbacks to this method include a dependency on low, clear water conditions, wadeable study sites, and an inability to sample deep water pools. Furthermore, when utilizing this method, skill is needed to hand capture or net each *N. maculosus*. Given the wide range of *N. maculosus* habitats, this method has had variable results, with better results in smaller lotic areas and shallow lentic areas (Gibbons and Nelson 1968; Matson 1990; Trauth et al. 2007).

Seining.—Seining typically involves dragging a seine net through a river or stream, with at least one person disturbing debris and rock piles ahead of the seine, in order to remove mudpuppies from their habitat on the bottom of streams. Cagle (1954) found little success capturing adult *N. maculosus* using

Table 1. Summary of previous Common Mudpuppy capture events. 0 indicates that method was tried, but with no capture success. – indicates a method was used, but was largely ineffective and/or not recommended. + indicates that a method was used and was successful and/or recommended. ** Indicates mudpuppies were caught using fishing poles rather than traditional set lines.

Author	Year	Location	Time of year	Electro-shocking	Manual surveys	Minnow traps	Seines	Trapnets	Set lines
Cagle	1954	Big Creek, LA	Jan–Feb				0	0	+
Shoop and Gunning	1967	Big Creek, LA	Year-round	+		0	+		–
Gibbons and Nelson Jr	1968	Gull Lake, MI	Apr-May		+				
Matson	1990	Grand River, OH	Mar–July	0	–	–	+		
Bonin et al.	1995	St. Lawrence River, Can.	Winter			+			+**
Gendron et al.	1997	ON & QC, Can.	Jan–Mar			+			
Nickerson et al.	2002	Little Pigeon River, TN	Aug–Oct		+				
Schmidt et al.	2004	Hudson River, NY	Summer	+					
Harper et al.	2006	West-Central MN	May, Jun, Sep	+			+		
Trauth et al.	2007	Spring River, AR	Year-round		+	0			
McDaniel et al.	2009	Sydenham River, ON	Nov–Mar			+			
Chellman and Parrish	2010	Lamoille River, VT	Year-round			+			
VanDeValk and Coleman	2010	Northern NY	Oct–Nov, Apr	+				–	
Palis	2010	Lusk Creek, IL	Sep–Oct, May–Jun		–	0			

seines, however Matson (1990) found seining to be the most successful of four techniques tried. Seining seems to work best for capturing larval and immature *N. maculosus*, especially in streams where primary refuge sites are in leaf litter, rather than beneath large flat rocks (Cagle 1954; Matson 1990).

Modified minnow traps.—Modified minnow traps have been the most-utilized form of *N. maculosus* trapping in the last 50 years (McDaniel et al. 2009; Chellman and Parrish 2010). This method uses a standard minnow trap that has enlarged openings to allow for *N. maculosus* entry. These traps are typically baited with chicken liver, cat food, or raw fish (Gendron et al. 1997; Trauth et al. 2007), and are placed near perceived *N. maculosus* refugia in streams. Benefits of these traps include the ability to sample in deep and turbid water, as well as the ability to sample in freezing conditions without undue risk for hypothermia. Disadvantages to this capture method include low trap success at zero to 0.02 *N. maculosus* per trap night (Matson 1990; Trauth et al. 2007; McDaniel et al. 2009; Chellman and Parrish 2010; Palis 2010). Given low trap rates associated with this method, the use of modified minnow traps is best executed when a large number of trap nights can be implemented, as few trap nights may result in no *N. maculosus* captures (Trauth et al. 2007; Palis 2010).

Other methods.—Other less commonly used methods include fish trapnets and set lines (Shoop and Gunning 1967; Bonin et al. 1995; VanDeValk and Coleman 2010). Trapnets have not been frequently used in the last 50 years, but were used with minimal success in capturing *N. maculosus louisianensis* in Louisiana in the 1950s, though recently VanDeValk and Coleman (2010) obtained *N. maculosus* captured incidentally in trap nets for their analyses. While baited trot lines had a similarly poor success rate (Cagle 1954), the use of set lines has been more successful (Cagle 1954; Shoop and Gunning 1967). These two methods are characterized by baited hooks tied to trees or the shoreline, and are either floated (trot line) or not floated (set line). These methods have seen less use primarily due to a bias toward large juveniles and adults, as well as increased mortality rates from hook swallowing (Cagle 1954; Shoop and Gunning 1967; Matson 1990). Similar to the use of set lines, Bonin et al. (1995) were able to acquire a few samples from fisherman for use in their analyses; however, this method is not commonly used.

New trap design.—Our trap design is derived from hellbender traps created by Briggler et al. (2013), which they modified from traps designed by Foster et al. (2008). Briggler et al. (2013) observed a few capture events of mudpuppies during tests of their traps; here we focused our efforts on the use of traps modified specifically for *N. maculosus*. The "Briggler traps" were constructed of aluminum wire and plastic mesh, with six panels bound together with zip ties to form a box. These traps were collapsible, with only 3–4 zip ties binding each panel together. Our traps are constructed from 9-gauge aluminum wire, plastic net mesh, and zip ties. See Fig. 1 for a list of materials per trap. Our traps have dimensions of 61 cm long × 46 cm wide × 22 cm tall, with a funnel diameter of 10 cm (Fig. 2). Key modifications were made to improve ease of use, durability, and trap success. One modification was winding zip ties around the edges of the panels to bind them together. While this eliminated the collapsibility of the traps, it increased the durability. Because traps were no longer collapsible, we further modified the trap and added trap doors on the top of the trap to allow for the addition of bait and weight, as well as for the extraction of animals. Given that mudpuppies tend to keep their limbs om the substrate, we used a thicker, more durable plastic mesh, with 1-cm holes, which potentially allows for a sturdier surface for a sturdier footing.

Our modified Briggler traps sat flush on the benthic substrate, enabling a mudpuppy to walk up into the trap, rather than swim, potentially increasing the chance of capture relative to modified minnow traps. Time needed for construction of these traps was approximately 5–8 person hours per trap, though this process can be accelerated by forming a multi-person assembly line. Materials for these traps came to approximately US $15 per trap, and materials can be purchased at most hardware stores.

To deploy, each trap was baited with raw fish scraps contained in a mesh bag (we used zip-tied plastic sleeves designed to pad wine bottles). Each trap was weighted by placing rocks found

Table 2. Summary of Common Mudpuppy sampling from present study for both manual surveys and trapping surveys using modified Briggler traps. Absence of a number indicates no sampling took place in that watershed during that month.

Watershed	Sampling method	Total person-hrs	Total *Necturus*	Jan	Feb	——	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Kentucky	Manual	353	12					0	0	12		0		
	Trapping	120	4		0			0	0		0	3		1
Kinniconick	Manual	41	1								1			
	Trapping	8	4									4		
Licking	Manual	621	36				4	2	3	3	17	7		
	Trapping	104	16	2	6			0				6	2	

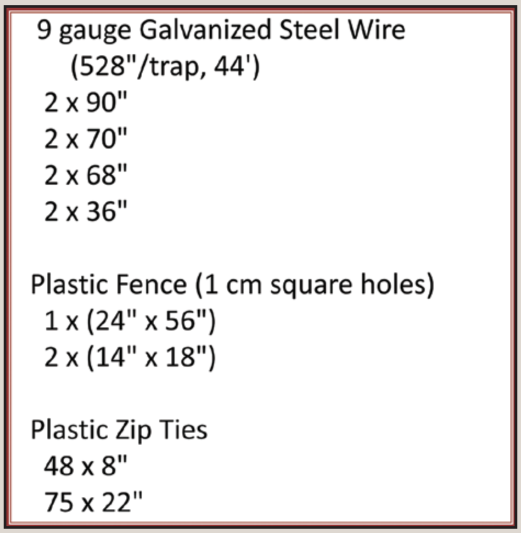

Fig. 1. Materials needed per trap.

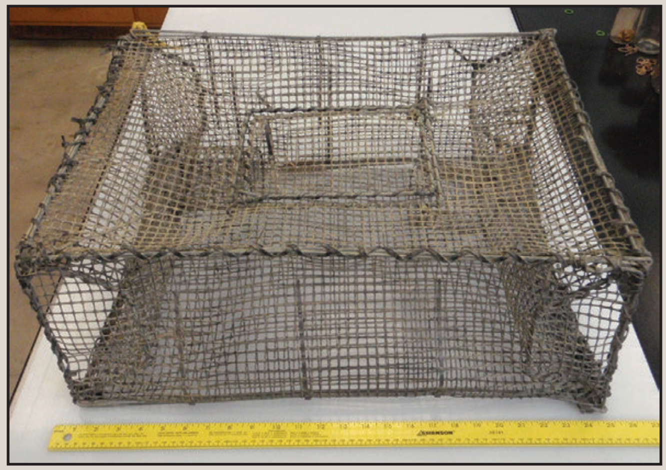

Fig. 2. Modified Briggler trap. Note the trap door on top for accessing trap compartment, as well as funneled ends, which allow for mudpuppies to walk into the trap while positioned on stream floor.

on the bank inside the trap, the trap door was zip-tied closed, and then the trap was placed on a flat part of the stream bed, preferentially in deep pools or next to large flat rocks. Traps were secured to the bank using 6-mm polypropylene rope tied to a tree or other stable structure. Each trap was left in the river for 1–2 nights. Manual surveys were also conducted, in which 2–4 surveyors walked/snorkeled upstream in rivers, lifting large flat rocks and other potential refugia, and then capturing observed individuals by hand or with a mesh bag.

Trapping was conducted for 528 trap-nights by deploying 9–10 traps at a time on a semi-regular basis from February 2014 to February 2015 (except for the months of April, May and August). We captured 24 *N. maculosus* (Fig. 3), with a trap success of 0.045 *N. maculosus* per trap night. No *N. maculosus* were caught from June to September. All *N. maculosus* were caught between October and February 2015. Eliminating summer trapping hours results in 441 trap nights and a success rate of 0.054. This success rate was comparable to some studies using modified minnow traps (McDaniel et al. 2009), and better than other trapping methods described above (Matson 1990; Trauth et al. 2007; Chellman and Parrish 2010; Palis 2010). Deploying and removing 10 traps required two people and approximately two hours per visit. Converting trap nights to person-hours equates to approximately 8 person-hours per trapping event, 4 person-hours for deployment, and 4 person-hours for collection. Our modified Briggler trapping took place over 232 person-hours and resulted in capture at a rate of 0.10 *N. maculosus* per person-hour (Table 2). Our modified Briggler trap method was

Fig. 3. Mudpuppy captured in trap near Cynthiana, Kentucky, USA

more efficient than our manual surveys, which resulted in 49 *N. maculosus* over 1225 person-hours from May–September 2014 and October 2015, for 0.040 *N. maculosus* per person-hour. However, excluding a single highly productive site, at which we caught 33 *N. maculosus*, our manual survey success rate dropped to 16 *N. maculosus* over 924 person-hours, resulting in a capture rate of only 0.017 *N. maculosus* per person-hour.

Conclusions

Overall, sampling *N. maculosus* using any trapping method results in low capture rates, however trapping seems to work best from late fall through early spring (Cagle 1954; Matson 1990; Bonin et al. 1995; Gendron et al. 1997; Nickerson et al. 2002; VanDeValk and Coleman 2010). Late summer and fall seem to be ideal times for manual surveys, as *N. maculosus* are relatively easily accessed due to larval guarding by females and the occurrence of breeding pairs under flat rocks and other cover objects, as well as generally low water levels (Petranka 1998; Hime et al. 2014). Winter through mid spring is a primary foraging period for *N. maculosus* (Shoop and Gunning 1967), potentially explaining the higher trapping success rate during this time (McDaniel et al. 2010). Regardless of sampling method, researchers and managers need to be aware of the varying success rates based on time of year, and schedule their sampling dates accordingly.

Necturus maculosus can occupy a wide range of habitats, from small streams to large rivers, and from small ponds to the Great Lakes (Bishop 1926; Petranka 1998; Matson 2005). This calls for flexibility in sampling methods depending on habitat type; manual surveys are most successful in clear and shallow water, seining works best in more debris-laden stream systems that are absent of large flat rocks, electroshocking works well in areas with few rocks and high conductivity, and trapping is ideal in deep and murky water, especially during the winter and early spring.

In conclusion, there is not a single, universally successful method for capturing *N. maculosus* at all times of the year or in all habitats. It is vital that researchers and managers be flexible with *N. maculosus* capture methods, and are prepared to utilize different methods for different habitat types and seasons. Although not to be used as a single, paramount method, we suggest the addition of modified Briggler traps to the *N. maculosus* capture arsenal, based on cost, time, and capture efficiency. Optimizing capture methodology will lead to the best chance for high capture rates, and will enable the further study of these understudied creatures.

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