



Results of an Amphibian, Reptile, and Turtle Survey of Mammoth Cave National Park, Kentucky



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ON THE COVER

Timber Rattler photo taken on April 30, 2007

Photograph by: John MacGregor

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Prepared for the National Park Service under Contract **H5028 02 0245** to John MacGregor

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1. Introduction

The historical management of Mammoth Cave National Park (MACA) as it has passed from a prehistoric pristine wilderness to a mixture of privately owned farmland and forest to a heavily forested park has undoubtedly affected many species of amphibians, reptiles, and turtles.

The purpose of this project was to document as many amphibian, reptile, and turtle species as possible within the park. The officially stated goal of the surveys, as described by the National Park Service, was to detect and document 90% of the species reasonably expected to occur in the park. This goal was not achieved.

A variety of methods were employed in the attempt to document species richness of the MACA herpetofauna. During the three year survey period and one supplemental year covered by this report, the success of the effort varied among species groups and ranged from a high of 100% (14 of 14 species expected) for frogs and toads to a low of 75% (6 of 8 species expected) for lizards.

2. Methods

The initial list of potential occurrence in the parks was compiled by examining the author's current set of county distribution maps for Kentucky amphibians, reptiles, and turtles and by reviewing various field guides to reptiles and amphibians of the Eastern U.S. (Conant and Collins 1998, Ernst et al. 1994, and Petranks 1998). Field guides typically have geographic range maps depicting the overall extent of occurrence, rather than the actual area of occupancy, and as such usually overestimate the actual precise geographic ranges of the various species. Nonetheless, they offer a starting place for producing lists of potential species. Habitat requirements of each of these species along with habitats present within the park were also considered here. A total of 69 species of amphibians, reptiles, and turtles appeared on the initial list (see Appendix 1: MACA Herp Summary Sheet 2006). The smallmouth salamander (*Ambystoma texanum*) was added later after Steve Thomas discovered a specimen in western Edmonson County to the west of the park boundary. Tables 1-5 include all species of amphibians, reptiles, and turtles that have been found historically or recently in one of more of the three Kentucky counties (Barren, Edmonson, Hart) that include portions of MACA regardless of whether or not each is known or expected from within the park boundary proper.

Much of the actual sampling effort consisted of unconstrained search efforts by experienced herpetologists. During unconstrained searches, an investigator moves through a habitat likely to support reptile and amphibian populations, using both visual searches and active searches (raking through leaf litter, rolling over logs, turning rocks, peeling off loose bark, and examining other potential refugia). Some use was also made of road cruising (driving roads at night) to find snakes and some amphibians, conducting voice surveys for calling frogs at ponds, and dipnetting in ponds and streams for amphibian larvae. The primary field method for snakes and lizards was

the use of cover boards (sheets of roofing tin and/or heavy paneling) placed on non-random plots in the park.

Data was recorded for each observed specimen using descriptive terminology. For many specimens, data from handheld global positioning systems (GPS) was also used. The datum used was NAD83. This technologically-challenged author entered locations in the voucher database as a mixture of Universal Transverse Mercator (UTM) units in meters, decimal degrees, degrees-minutes-seconds, or as GPS waypoints (accompanied by a UTM conversion database).

Live animals were photographed as vouchers. Most were released in the field at the time and place of capture, but some were removed temporarily for photography or (in the case of a few tadpoles) for rearing. All such animals were returned to the point of capture at the earliest possible time and released unharmed.

MACA was visited by one or more investigators a total of 86 times from 2003-2005. During 2004 and 2005, the author was participating in field studies of the bat fauna of the park and was often in the field during evening hours. Bat study activities were counted as herpetological trips if herpetological data was recorded during these surveys. Additional amphibian and reptile monitoring was done during 2006, and much of this new data (representing 28 total visits) was woven into this final report. Amphibian and reptile data that was passed along to the author from park personnel was also incorporated into the results.

3. Results and Discussion

If two species (coal skink in 2005, midland mud salamander in 2006) found and documented by NPS personnel are included, a total of 14 species of frogs (100% of the 14 expected), 13 salamanders (81.3% of 16 expected), 6 lizards (75% of 8 expected), 18 snakes (81.8% of the 22 expected), and 8 turtles (80% of the 10 expected) were recorded from MACA during the first three years of the survey (Appendices 1, 6, and 7); these totaled 59 of the 70 expected species (84.3%).

Species observations made during the study period and in 2006 are broken down by species group and by year in Tables 1-5 and Appendices 2, 6, and 7. Reptiles and turtles were recorded individually; amphibians were not counted as individuals since many observations included breeding choruses, larvae, and/or egg masses. Numbers of lizards, snakes, and box turtles recorded at all artificial cover sites from 2003-2006 are given in Table 6. Tables 1 through 6 and Appendices 1, 2, and 4 include 2006 data, while Appendices 6 and 7 have been completed only for the years 2003-2005.

All observations of amphibians, reptiles, and turtles made within ABLI and MACA have been tabulated in the accompanying Access file (**NPS Database 6-9-2007**), and the 1,897 field records for these taxa are listed by species group, species, location, and date in Appendix 2. A selection of recent and historical records of these animals from various museum collections and field notes is presented as Appendix 3, and a 1-page summary of past amphibian field work that has been conducted in the park by Hibbard (1936), Brandon (1965), and Hale (1984) appears as Appendix 2. In addition, considerable herpetological data from various writings stored in MACA files has been combined into a single document to provide historical perspective concerning the fauna of the park (Appendix 5).

3-A. Results of Amphibian Surveys

Frogs and Toads

Table 1 below is a summary of the total number of observations for each of the 14 species of anurans (frogs and toads) that were encountered on the park from 2003-2006 and provides county-level distribution data for each species in the three counties that include MACA. All 14 had been previously documented from MACA. The set includes 13 species found by Hibbard (1936) plus one additional species (upland chorus frog) later heard by Hale (1984) and others.

All of the anuran species that occur here are normally categorized as pond-breeding species even though several (American toad, American bullfrog, green frog, pickerel frog) often utilize the backwater areas of rivers and streams for breeding and at least one (Fowler's toad) seems to prefer shallow sluggish sections of rivers, streams, and man-made lakes. Generalized statements can be made concerning the types of ponds that certain species most often select as breeding sites. Cricket frogs, American bullfrogs, and pickerel frogs often tend to use relatively large permanent ponds as breeding sites on the park. American toads, Cope's gray treefrogs, mountain chorus frogs, southern leopard frogs, and wood frogs often use shallow temporary pools such as those created by road relocation or bicycle trail and water line construction. Eastern narrowmouth toads and upland chorus frogs prefer to breed in shallow grassy pools and wet meadows although narrowmouths will sometimes use the grassy margins of larger ponds (i.e. the "pine ponds" near the old sewage treatment facility at the Job Corps Center) as well. Small woodland ponds of various origins (natural sinkhole ponds and caprock depressions, man-made wildlife water holes, and old farm ponds eventually overtaken by forest) within the park are often used by Cope's gray treefrogs, spring peepers, green frogs, southern leopard frogs, wood frogs, and eastern spadefoots.

Table 1. MACA Frogs and Toads (14 species observed).

E = expected during present study (14 species) O = observed during present study (14 species) P = previously documented from MACA (14 species)	Total MACA observations by year				Past county records
	2003	2004	2005	2006	
<i>Acris crepitans</i> (Cricket Frog) – E+O+P	16	25	7	4	BEH
<i>Bufo americanus</i> (American Toad) – E+O+P	21	41	20	7	BEH
<i>Bufo fowleri</i> (Fowler's Toad) – E+O+P	9	32	98	16	BEH
<i>Gastrophryne carolinensis</i> (E Narrowmouth Toad) – E+O+P	1	6	1	3	BEH
<i>Hyla chrysoscelis</i> (Cope's Gray Treefrog) – E+O+P	17	44	9	4	BEH
<i>Pseudacris brachyphona</i> (Mountain Chorus Frog) – E+O+P	3	25	4	3	EH
<i>Pseudacris crucifer</i> (Spring Peeper) – E+O+P	14	51	5	3	BEH
<i>Pseudacris triseriata</i> (Upland Chorus Frog) – E+O+P	0	4	0	1	BEH
<i>Rana catesbeiana</i> (American Bullfrog) – E+O+P	27	81	3	6	BEH
<i>Rana clamitans</i> (Green Frog) – E+O+P	18	213	39	10	BEH
<i>Rana palustris</i> (Pickerel Frog) – E+O+P	3	26	0	0	BEH
<i>Rana sphenoccephala</i> (Southern Leopard Frog) – E+O+P	10	39	6	5	BEH
<i>Rana sylvatica</i> (Wood Frog) – E+O+P	26	11	5	0	EH
<i>Scaphiopus holbrookii</i> (Eastern Spadefoot) – E+O+P	3	7	0	1	BEH
MACA SPECIES TOTALS	13	14	11	12	14

The large majority of the frogs and toads recorded from the park by Hibbard (1936) and Hale (1984) were considered common by those authors (see Appendix 4). However, Hibbard (1936) found only a single wood frog on the park and considered it to be rare here, and failed to discover any populations of upland chorus frogs, and Hale (1984) heard upland chorus frogs at only one site and was not able to secure any

specimens. The early breeding dates for these two species, coupled with Hibbard's failure to study amphibian larvae in the ponds, undoubtedly caused him to miss these two species during survey work.

Most of the anurans that were found at MACA during the present study appear to be doing well and seem to be in no immediate danger of being extirpated. Such species include the cricket frog, American and Fowler's toads, Cope's gray treefrog, mountain chorus frog, spring peeper, American bullfrog, green frog, pickerel frog, southern leopard frog, and wood frog. Three other anuran species, however, including the eastern spadefoot, eastern narrowmouth toad, and upland chorus frog, appear not to be doing quite so well.

Although the eggs and/or tadpoles of the eastern spadefoot were found several times on the park during this project, none of these breeding efforts are known to have successfully produced offspring during this 4-year study period because (a) the breeding ponds went dry before the tadpoles could transform or (b) the tadpoles were killed by disease in the breeding pond. In one instance, literally thousands of eastern spadefoot tadpoles suddenly died at the Floyd Collins Pond in June 2004 along with tadpoles of other species and various *Ambystoma* larvae but no exact cause could be determined due to delays in obtaining permission from the NPS to collect the dying tadpoles for laboratory analysis. This latter problem needs to be rectified quickly so that future disease problems can be dealt with in a timely manner.

The eastern narrowmouth toad and upland chorus frog are both quite rare within MACA. During this study, eastern narrowmouth toads were found only at and near a single breeding pond near the Job Corps Center, and upland chorus frogs were found only in very low numbers at three locations (Roy Davis Road, Bruce Hollow Pond on Mammoth Cave Ridge near the campground, and the former Job Corps site off Flint Ridge Road). Proper habitat management should allow both of these species to recover on the park.

Salamanders

Table 2 below is a summary of the current park status for the 18 salamander species that are presently known from Barren, Edmonson, and/or Hart counties in west-central Kentucky along with the numbers of observations made during the survey period within the park for each species that was found there.

In the past, 16 kinds of salamanders have been found at MACA. Hibbard (1936) found 14 species during the initial surveys, Brandon (1965) later added the four-toed salamander to the known park fauna, and Hale (1984) found 13 species while adding the mud salamander to the park list.

A total of 13 salamander species were encountered on the park from 2003-2006 during this survey, all of which had been previously documented from MACA. Three other species (tiger salamander, hellbender, mudpuppy) that had been earlier recorded by Hibbard (1936) were not rediscovered during the survey; of these, Hale (1984) was able to document only one (the tiger salamander). Two taxa (smallmouth salamander, spring salamander) that have never been found within the park but are known from other parts of Barren, Edmonson, or Hart counties were likewise not found at MACA during the survey.

Six of the 16 salamanders that have been reported historically from the park here are categorized as pond-breeding species; these include the Jefferson, spotted, marbled, tiger, and four-toed salamanders and the red-spotted newt. Five of these are completely terrestrial as adults while the red-spotted newt features a terrestrial subadult "red eft" stage and even the mature adults divide their time between an aquatic existence in ponds and a terrestrial existence in nearby forests. Six others, including the northern dusky, southern two-lined, Longtail, cave, midland mud, and northern red salamanders, breed in springs, seepages, and headwater streams (including cave streams). Two forms (hellbender, mudpuppy) are large, completely aquatic creatures that live and breed in rivers and large streams. The remaining two species (northern zigzag and northern

slimy salamanders) are completely terrestrial; these animals lay their eggs in humid retreats on land - often using caves as nesting areas - and complete their larval development prior to emerging from the egg as miniature versions of the adults.

While most of the pond breeding salamanders typically use fishless woodland ponds as breeding sites, the tiger salamander greatly prefers ponds located in grasslands, agricultural fields, pastures, and other open habitats.

Table 2. MACA Salamanders (13 species observed including 2006 data).

E = expected during present study (16 species) O = observed during present study (13 species) P = previously documented from MACA (16 species)	Total MACA observations by year				Past county records
	2003	2004	2005	2006	
<i>Ambystoma jeffersonianum</i> (Jefferson Salamander) - E+O+P	2	8	13	2	BEH
<i>Ambystoma maculatum</i> (Spotted Salamander) - E+O+P	0	33	11	4	BEH
<i>Ambystoma opacum</i> (Marbled Salamander) - E+O+P	12	42	10	3	BE
<i>Ambystoma texanum</i> (Smallmouth Salamander)		(a)			none
<i>Ambystoma tigrinum</i> (Tiger Salamander) - E+P				(b)	BEH
<i>Cryptobranchus alleganiensis</i> (Hellbender) - E+P					EH
<i>Desmognathus fuscus</i> (N Dusky Salamander) - E+O+P	0	1	0	0	BEH
<i>Eurycea cirrigera</i> (S Two-lined Salamander) - E+O+P	0	4	12	0	BEH
<i>Eurycea longicauda</i> (Longtail Salamander) - E+O+P	2	12	6	0	BEH
<i>Eurycea lucifuga</i> (Cave Salamander) - E+O+P	3	9	8	0	BEH
<i>Gyrinophilus porphyriticus</i> (Spring Salamander)					B(c)
<i>Hemidactylium scutatum</i> (Four-toed Salamander) - E+O+P	0	9	15	0	EH
<i>Necturus maculosus</i> (Mudpuppy) - E+P					EH
<i>Notophthalmus viridescens</i> (Red-spotted Newt) - E+O+P	3	14	60	1	BEH
<i>Plethodon dorsalis</i> (Northern Zigzag Salamander) - E+O+P	7	9	0	3	BEH
<i>Plethodon glutinosus</i> (Slimy Salamander) - E+O+P	0	2	4	1	BEH
<i>Pseudotriton montanus diastictus</i> (Midland Mud S) - E+O+P	0	0	0	1(d)	EH
<i>Pseudotriton ruber</i> (Northern Red Salamander) - E+O+P	1	17	17	1	BEH
MACA SPECIES TOTALS	7	12	10	8	18

(a) – found AOR near western edge of Edmonson County by Steve Thomas (NPS), 2004.

(b) - reliably reported AOR to Bill Moore from Flint Ridge Road just east of MACA, 2006.

(c) – previously known from several sites in SW Barren and E Warren counties (JRM data).

(d) – captured in MACA in pitfall trap in boggy area N of Green River by Steve Thomas (NPS), 2006.

Most of the salamander species recorded from the park by Hibbard (1936) and Hale (1984) were considered common to abundant by those authors (Appendix 4) and continue to remain so to this day. There are, however, some possible exceptions here.

Neither Hale (1984) nor the present author was able to figure out a reliable way to search for hellbenders or mudpuppies in the Green River; the best way to obtain current data for both would likely be for park personnel to try to elicit cooperation from local fishermen during the late winter and early spring months when these two salamanders are most easily caught on hook and line.

Southern two-lined salamanders are relatively uncommon on the park, probably because they have fairly long larval periods (ca 14-16 months) and the slender larvae are not built for burrowing into the substrate when many of the small surface streams go dry most years in summer and fall.

One pond-breeding salamander (tiger salamander), one stream-breeder (northern dusky salamander), and one completely terrestrial species (northern slimy salamander) all seem to be in decline at Mammoth Cave National Park. Tiger salamanders seem to have disappeared as open habitats have been replaced by forest, and semi-permanent breeding ponds have become shallower and more temporary or have disappeared entirely from the landscape. Only an active management program is likely to recover this large and colorful amphibian at MACA. Northern dusky salamanders seem to have declined drastically from springs and headwater streams where they once were common despite a complete lack of obvious physical changes in these habitats. It is possible that water quality problems related to the burning of coal at power plants located to the west of the park have played some role in this process, but much research will be needed to prove this. Coal-burning power plants have been linked to dusky salamander declines in the northeastern U.S. as well. The apparent decline of the northern slimy salamander at MACA is difficult to demonstrate or explain; my gut feeling during this entire study was that slimy salamanders were much less common in good forest habitat at MACA than at nearby ABLI. Highton (2005) has demonstrated widespread and significant declines in many populations of woodland salamanders (genus *Plethodon*) throughout the eastern U.S. during the time period from the 1970's through the 1990's; 180 of his 205 study populations (including many northern slimy salamander populations) had declined to at least some degree over that time span. Populations at MACA should be monitored carefully.

It is doubtful that anything can be done any time soon to stem the apparent decline of northern dusky or northern slimy salamanders in the park. A better understanding of the problem (if there is one) is needed before anything further can be contemplated. For starters, however, the author suggests that several large deer exclosures be constructed at various locations in the park and that coverboard sites for slimy salamander monitoring be established both inside and outside these structures. It may be that the impacts of the MACA deer herd on the forest floor vegetation may be in turn adversely affecting habitat suitability for the northern slimy salamander.

Management Recommendations for amphibians are probably largely limited to activities that favor pond-breeding species at MACA and should include:

(1) The construction of several shallow grassy seasonal and permanent wetland habitats within the recently restored prairie area near the Job Corps Center and in other areas where grasslands and/or prairie habitats are restored or created. Such sites are needed to provide essential breeding habitat for amphibians that appear to require open areas in order to thrive (i.e. eastern narrowmouth toads, upland chorus frogs) and can also be used by other amphibians (including eastern tiger salamanders) and even a few reptiles.

(2) The periodic inspection and (where necessary) rejuvenation of natural upland ponds throughout MACA. The combination of past and recent modification by the hand of modern man, the gradual thickening of forest cover within the park, and the long-term policy of fire suppression appears to have caused many natural ponds to become largely filled with leaf litter and/or sediment, reducing the projected life spans of these important features on the landscape and limited their suitability as amphibian breeding sites.

(3) The construction of several additional permanent and seasonal woodland and/or forest edge breeding ponds in the uplands, particularly to the north of the Green River where natural ponds and old man-made ponds tend to be scarce.

(4) The design and implementation of a program to monitor the success of amphibian reproduction annually at MACA for several species of amphibians from egg laying through the

larval period and into transformation. Frog voice surveys and pond-breeding salamander egg counts do not tell the entire story; when ponds go dry early or disease outbreaks occur the entire reproductive effort for some species on the park will have been for naught. My suggestion is that larval progress and transformation in at least two frog species (wood frog, eastern Spadefoot) and one ambystomid salamander (marbled, spotted, or Jefferson salamander) at a few selected ponds should be checked at least once every two weeks from the time that the eggs are laid, and that plans be in place for samples of dying larvae to be collected for analysis in the event of another disease outbreak.

Constructed and restored ponds and wetlands will in turn restore breeding sites for frogs, toads, and pond-breeding salamanders and will also provide habitat for a variety of plants and invertebrates as well as drinking water sources for bats and other wildlife.

(5) Reintroducing eastern tiger salamanders into constructed and/or restored breeding sites at MACA from a nearby source population. This species was not encountered on the park during the present survey but at least one individual was observed crossing Flint Ridge Road near a pond on private land on a rainy evening by park personnel during this study (Bill Moore, pers. commun.), indicating that populations remain in open agricultural areas adjacent to the park. This should be attempted only in areas where open grassland habitats have been restored and clusters of fishless breeding ponds are present that can support natural reproduction; the Wondering Woods site and the restored prairie at the current Job Corps site come immediately to mind. The life stage most likely to “take” and reproduce successfully would be half-grown larvae that could be collected locally from ponds in May and June.

3-B. Results of Reptile and Turtle Surveys

Lizards

Table 3 below is a summary of the current park status for the 8 lizard species that are presently known from Barren, Edmonson, and/or Hart counties in west-central Kentucky along with the numbers of observations and sites (locations) documenting each during the survey period within the park for each species that was found there.

In the past, 7 lizard species have been found at MACA; all were originally reported from the park by Hibbard (1936). Some of his notations from his published paper and miscellaneous park files can be found in Appendix 5 of this report.

Six kinds of lizards were encountered on the park from 2003-2006 during this survey. All had been previously documented from MACA. The seventh species (six-lined racerunner) that had been earlier recorded by Hibbard (1936) were not rediscovered during the survey and has likely been extirpated from the park as the open sunny habitat that it requires has been replaced by forest. The southeastern five-lined skink has never been found within the park but is known from other parts of Barren, Edmonson, and Hart counties and occurs adjacent to MACA at Park Mammoth Resort. This lizard, which is difficult to recognize in the field due to its similarity to the other two species of five-lined skinks, probably occurred in the park during Hibbard’s survey period but was overlooked. Like the racerunner it prefers dry open habitats and does not occur in heavily forested areas.

Only one (ground skink) of the 7 lizards that have been reported historically from the park can be categorized as a creature of largely forested habitats, but even this species is most common in and near small forest openings and edges. Four others (coal skink, five-lined skink, broadhead skink,

and fence lizard) tend to prefer forest edges and open forests, while the remaining two (six-lined racerunner, slender glass lizard) along with the southeastern five-lined skink require much more open conditions.

Table 3. MACA Lizards (6 species observed including 2006 data).

E = expected during present study (8 species) O = observed during present study (6 species) P = previously documented from MACA (7 species)	Number observed/number of sites within MACA, 2003-2006				
	2003	2004	2005	2006	Totals
<i>Cnemidophorus sexlineatus</i> (Six-lined Racerunner) - E+P		(e)	(e)		
<i>Eumeces anthracinus</i> (Coal Skink) - E+O+P	0	0	0	1/1(f)	1/1
<i>Eumeces fasciatus</i> (Five-lined Skink) - E+O+P	4/4	24/7	2/1	6/3	36/11
<i>Eumeces inexpectatus</i> (Southeastern Five-lined Skink) - E	(g)				
<i>Eumeces laticeps</i> (Broadhead Skink) - E+O+P	0	3/3	0	1/1	4/4
<i>Ophisaurus attenuatus</i> (Slender Glass Lizard) - E+O+P	0	8/4	4/2	1/1	13/5
<i>Sceloporus undulatus</i> (Fence Lizard) - E+O+P	1/1	13/6	6/4	3/3	23/13
<i>Scincella lateralis</i> (Ground Skink) - E+O+P	8/3	47/9	60/7	32/6	187/12
MACA SPECIES TOTALS	3	5	4	6	6

(e) – observed by Bird, Peak, and JRM north of MACA at old Nolin Dam Quarry, 2004-2005.

(f) – documented by Bill Moore (NPS) at Cedar Sink cover boards, 2006.

(g) – observed by JRM at just south of MACA at Park Mammoth Resort, 1983-2003.

The ground skink was by far the most commonly seen lizard on the park during this survey. This is largely a lizard of forested habitats and its abundance today contrasts sharply with the observations of Hibbard (“rare in the park area; only one was seen in 15 months of work” – see notations in Appendix 5). Five-lined skinks and fence lizards were found in moderate numbers and can probably be considered common at MACA. Slender glass lizards are undoubtedly much less widespread at MACA than they were in Hibbard’s time (“common on ridges and in old fields”) but these animals do seem to be holding on around the remaining openings and they should become more common as the prescribed burning program expands (opening up some of the closed canopy forest) and as additional grassland restoration takes place within the park.

Broadhead skinks and coal skinks are very difficult to survey for and nothing truly meaningful can be said at this time about the abundance of either species on the park. Southeastern five-lined skinks were likely living at MACA during Hibbard’s day but were undocumented, and six-lined racerunners were extremely common on the park at that time (“abundant along paths and in old fields with clearings”) but seem to have vanished as the once-open areas have become overgrown with forest. Both of these species should be able to return as habitat on MACA becomes more open. Abandoned quarries and some road cuts offer great opportunities for restoration for both of these species (and also for coal skinks and slender glass lizards!) if adjacent open habitat is provided.

Management Recommendations for lizards at MACA should include:

(1) the maintenance of snags and hollow or damaged trees and leaving stumps, logs, and large fallen limbs on the ground in woodlands and along woodland edges for coal, five-lined and broadhead skinks and fence lizards – such trees serve as important sources of food (insects, spiders, and other invertebrates), perching sites for territorial males, egg-laying sites for females, and refugia from predators for lizards of all ages.

(2) the use of fire and various forest thinning techniques to create variation in the forest canopy to benefit virtually all of the lizards that occur in the park and nearby. Even the six-lined racerunner and slender glass lizard will occasionally use open forested habitats from time to time while traveling between open areas.

(3) the use of fire, herbicides, and/or mowing to maintain at least some open weedy grassland and/or prairie and dry open woodland for coal skinks, southeastern five-lined skinks, six-lined racerunners, and slender glass lizards. These sites should have a good component of bare ground with scattered cover. Rocks, well-decayed logs, and perhaps plywood and low piles of wood chips should be provided in open areas to serve as egg-laying sites for these lizards.

Snakes

Table 4 below is a summary of the current park status for the 22 species that are presently known from Barren, Edmonson, and/or Hart counties in west-central Kentucky along with the numbers of observations and sites (locations) for each within the park during the survey period.

In the past, 21 species have been found at MACA; 20 of these were originally reported from the park by Hibbard (1936) and another (western earth snake) was later documented from MACA by the author and others (see Appendix 3). Some of Hibbard's notations from his published paper and miscellaneous park files can be found in Appendix 5 of this report. The queen snake was added to the known MACA fauna by the author and Bill Moore during the present survey when a single specimen was discovered and photographed on a Green River rock bar located downstream from Dennison Ferry.

A total of 18 snake species were encountered on the park from 2003-2006 during this survey. All but the above-mentioned queen snake had been previously documented from MACA. Four others (scarlet snake, scarlet kingsnake, northern pine snake, southeastern crowned snake) that had been earlier recorded by Hibbard (1936) were not rediscovered during the survey. The pine snake may have been gradually extirpated from the park as the large tracts of open grassy forest mixed with fields that it requires has been replaced for the most part by dense forest and the openings that remain are quite isolated from one another. The scarlet snake, scarlet king, and crowned snake likewise use open woodlands but may yet occur in small numbers in and around MACA. All three of these small crepuscular to nocturnal snakes are difficult to find in the field and one of the most effective survey methods - slowly driving along paved roadways on warm nights - is of limited value on the park due to the small number of suitable low-traffic roads. Perhaps some of the park employees who are on active patrol at night could be persuaded to search for these animals while on duty.

The majority of individuals of the 18 kinds of snakes documented during this study were found under artificial cover (roofing metal and plywood) that had been placed in remnant openings. Exceptions here included the queen snake and northern water snake (most were found near ponds and waterways), timber rattlesnake (most were at a rookery that was discovered in 2003 but received little subsequent use), and the single rough green snake that was found crossing a paved road at midday.

Table 4. MACA Snakes (18 species observed).

E = expected during present study (22 species) O = observed during present study (18 species) P = previously documented from MACA (21 species)	Number observed/number of sites within MACA, 2003-2006				
	2003	2004	2005	2006	Totals
<i>Agkistrodon contortrix</i> (Copperhead) - E+O+P	4/3	38/13	58/9	135/9	235/22
<i>Carphophis amoenus</i> (Worm Snake) - E+O+P	2/2	15/9	12/6	7/5	36/19
<i>Cemophora coccinea</i> (Scarlet Snake) - E+P					
<i>Coluber constrictor</i> (Black Racer) - E+O+P	11/4	105/17	71/8	63/10	250/22
<i>Crotalus horridus</i> (Timber Rattlesnake) - E+O+P (h)	61/3	8/6	14/4	10/7	93/14
<i>Diadophis punctatus</i> (Ringneck Snake) - E+O+P	20/5	135/17	166/9	108/9	429/22
<i>Elaphe guttata</i> (Corn Snake) - E+O+P	2/1	32/7	9/4	12/4	56/7
<i>Elaphe o. obsoleta</i> (Black Rat Snake) - E+O+P	2/2	5/4	3/2	3/3	13/9
<i>Heterodon platirhinos</i> (Eastern Hognose Snake) - E+O+P	0	7/1	6/2	6/1	19/2
<i>Lampropeltis c. calligaster</i> (Prairie Kingsnake) - E+O+P	0	14/4	4/2	4/1	22/5
<i>Lampropeltis elapsoides</i> (Scarlet Kingsnake) - E+P					
<i>Lampropeltis getula nigra</i> (Black Kingsnake) - E+O+P	0	8/2	17/1	15/2	40/3
<i>Lampropeltis triangulum</i> (Milk Snake) - E+O+P	1/1	7/4	4/1	6/2	18/5
<i>Nerodia sipedon</i> (Northern Water Snake) - E+O+P	1/1	14/8	0	6/2	21/9
<i>Opheodrys aestivus</i> (Rough Green Snake) - E+O+P	1/1	0	0	0	1/1
<i>Pituophis m. melanoleucus</i> (Northern Pine Snake) - E+P				(i)	
<i>Regina septemvittata</i> (Queen Snake) – (E)+O	0	1/1	0	0	1/1
<i>Storeria dekayi</i> (Brown Snake) - E+O+P	1/1	16/8	2/1	4/2	23/9
<i>Storeria o. occipitamaculata</i> (N Redbelly Snake) - E+O+P	2/1	9/5	2/2	0	13/6
<i>Tantilla coronata</i> (Southeastern Crowned Snake) - E+P					
<i>Thamnophis s. sirtalis</i> (Eastern Garter Snake) - E+O+P	2/1	69/9	78/6	90/8	239/15
<i>Virginia valeriae elegans</i> (Western Earth Snake) - E+O+P	3/2	20/9	9/4	2/2	34/12
MACA SPECIES TOTALS	14	17	15	15	18

(h) - 2003 Timber Rattlesnake totals include 2 visits to an active rookery during the fall birthing season.

(i) – A yearling male Northern Pine Snake was found by Will Bird and Phil Peak just north of the MACA boundary in 2006.

The Queen Snake captured and photographed by JRM and Bill Moore (NPS) along the Green River in 2005 was unexpected and represented a new record for both MACA and Edmonson County. For the purpose of data analysis for this report the queen snake was added to the “expected” list.

Four kinds of snakes were encountered in extremely large numbers and at numerous locations on the park during this survey. These most abundant species were the ringneck snake (429 total individuals at 22 locations), black racer (250 individuals at 22 locations), eastern garter snake (239 at 15 locations), and copperhead (235 at 22 locations). These 1,153 individuals made up about 75% of all snakes encountered on the park during 2003-2006 by survey personnel. All four are common, widespread species that occur essentially throughout Kentucky.

A second tier of abundance was represented by the timber rattlesnake (93 individuals at 14 sites although more than half of these observations were made at the one rookery that was accidentally discovered during an avian monitoring survey in 2003), corn snake (56 animals at 7 locations), worm snake (36 individuals at 19 locations), western earth snake (34 individuals at 12 locations), brown snake (23 at 9 locations), northern water snake (21 at 9 locations), black rat snake (13 at 9 locations), northern redbelly snake (13 at 6 locations), prairie kingsnake (22 at 5 locations), and milk snake (18 at 5 locations). Included among these are several common and wide-ranging forms (worm snake, northern water snake, black rat snake, milk snake) along with several that

have more restricted distributions in Kentucky (timber rattlesnake, western earth snake, brown snake, northern redbelly, prairie kingsnake) and one (corn snake) that occurs here only in two widely-scattered relict populations (Mammoth Cave region in west-central Kentucky and the Red River Gorge area in eastern Kentucky).

Two kinds of snakes were found in fair numbers but appear to be restricted to just a few areas on the park. Although 40 black kingsnakes were encountered during the survey, nearly all were at a single site (the roofing tin array at the Job Corps Center) with only single individuals at each of 2 other sites (one of these was found twice and was easily recognized by its distinctive markings). The other restricted but locally common species was the eastern hognose with 19 animals at only 2 sites (18 at Wondering Woods and 1 at the Great Onyx picnic shelter). Both of these species show distinct preferences for open habitats and it is likely that they would be headed for extirpation on the park unless a concerted effort is made to continue the restoration of prairie, grassland, and open canopy forest at MACA by the use of prescribed burning and selective tree removal.

The two snake species that were represented only by single individuals during the survey (rough green snake and queen snake) are probably more common within the park than these records indicate. The rough green snake is both arboreal and diurnal and rarely occurs beneath any kind of cover; it is usually found only by accident (as when crossing a road or trail). The queen snake is restricted to open rocky areas along rivers and streams and likely occurs in the park only along the Green River.

Management Recommendations for snakes at MACA should be generally similar to those for lizards and should include:

(1) the maintenance of snags and hollow or damaged trees and leaving stumps, logs, and large fallen limbs on the ground in woodlands and along woodland edges for nearly all snake species – such trees serve as food sources by harboring various kinds of invertebrates, mice, and lizards, important retreats during periods when snakes are preparing to shed their skins and are particularly vulnerable, egg-laying sites for gravid females, and ready refugia from predators for snakes of all ages.

(2) the general use of fire and various forest thinning techniques to create variation in the forest canopy to benefit many of the snake species that occur in the park and nearby.

(3) the use of fire, herbicides, and/or mowing specifically to create and maintain a component of open weedy grassland and/or prairie and/or dry open woodland for the benefit of most snake species but especially including scarlet, corn, eastern hognose, prairie king, scarlet king, black king, northern pine, and southeastern crowned snakes. These sites should have at least some bare ground with scattered cover and should also contain some permanent and seasonal ponds and wetland areas to provide permanent habitat for mud turtles (another rare species that may be recoverable on the park through habitat restoration) and breeding habitat for the frogs and salamanders that some of these snakes feed upon. Rocks, well-decayed logs, and perhaps plywood or old boards and low piles of wood chips should be provided in open areas to serve as egg-laying sites for these snakes (and for their lizard prey!).

For many of these species, particularly the larger, wide-ranging forms like the corn snake, northern pine, eastern hognose, and various kingsnakes, it is very important for the park to aggressively manage these open habitats in clusters rather than as single sites separated by large expanses of relatively dense forest. As these reptiles begin to recover within the park, there must

be areas available for both the normal seasonal movements of adults and for the dispersal of young.

(4) the retention, improvement, and restoration of some open native yellow pine habitat on the park. This should benefit most kinds of lizards and snakes on the park and could become an important factor in the restoration of such species as the scarlet snake, scarlet kingsnake, northern pine snake, and southeastern crowned snake along with certain lizards (six-lined racerunner, southeastern five-lined skink) and even a few amphibians (i.e. eastern narrowmouth toad and eastern spadefoot).

Turtles

Table 5 below is a summary of the current park status for the 10 turtle species that are presently known from Barren, Edmonson, and/or Hart counties in west-central Kentucky. Seven of these 10 had previously been documented and reported from the Park (Hibbard 1936); six from this group (all but the mud turtle) were confirmed as still present during the survey and two new turtle species (see below) were added.

One additional turtle (Midland Painted Turtle) that had subsequently been observed at Sloans Crossing Pond on the Park by the author in 1999 (Appendix 3) was “officially” added to the known fauna by Bill Moore (at Bruce Hollow Pond) and James Kiser (at Sloans Crossing Pond) during this survey. Another species (Ouachita map turtle) that was previously known from Nolin Reservoir just north of MACA was observed basking near Houchins Ferry on two occasions and was also added to the known park fauna.

A total of 77 eastern box turtles were found at 29 locations during the present survey. Four kinds of semiaquatic turtles were repeatedly observed basking along the Green River between Dennison Ferry and the Green River Ferry during canoe trips including spiny softshells (58 individuals observed), common map turtles (58 observed), red-eared sliders (29 observed), and river cooters (10 observed). Common snapping turtles were seen at several upland ponds on the park.

The mud turtle, several individuals of which were found during the Hibbard survey, has not been seen on the park since the 1930's and may have become extirpated with forest expansion and encroachment the most likely responsible factors. A population may yet occur nearby on private lands; Phil Peak and Will Bird found a large adult crossing Ollie Road in 2004 to the east of the entrance to the Job Corps Center.

No common musk turtles were found during this survey, and this relatively common, widespread species has never been reported from MACA. It almost surely occurs in the Green River and in the mouths of some of the tributary streams.

Table 5. MACA Turtles (8 species observed).

E = expected during present study (10 species) O = observed during present study (8 species) P = previously documented from MACA (7 species)	Total MACA observations by year				Past county records
	2003	2004	2005	2006	
<i>Apalone spiniferus</i> (Spiny Softshell) – E+O+P	0	32	0	26	BEH
<i>Chelydra serpentina</i> (Common Snapping Turtle) – E+O+P	2	2	0	3	BEH
<i>Chrysemys picta</i> (Painted Turtle) – E+O	0	0	1 (j)	2 (j)	BEH
<i>Graptemys geographica</i> (Common Map Turtle) – E+O+P	1	39	0	18	E
<i>Graptemys ouachitensis</i> (Ouachita Map Turtle) – E+O	1(k)	1 (k)	0	0	EH
<i>Kinosternon subrubrum</i> (Mud Turtle) – E+P	0	0 (l)	0	0	EH
<i>Pseudemys concinna</i> (River Cooter) – E+O+P	0	9	0	1	BEH
<i>Sternotherus odoratus</i> (Common Musk Turtle) – E only	0	0	0	0	H
<i>Terrapene carolina</i> (Eastern Box Turtle) – E+O+P	7/7	24/15	20/8	26/11	77/29*
<i>Trachemys scripta elegans</i> (Red-eared Slider) – E+O+P	0	23	3	6	BEH
MACA SPECIES TOTALS	4	7	3	7	10

(j) – adult photographed by Bill Moore (NPS) at Bruce Hollow Pond, 2005; two observed at Sloans Crossing Pond by James Kiser, 2006.

(k) - observed basking in Green River just below Houchins Ferry by JRM and Brainard Palmer-Ball, Jr (KSNPC).

(l) – one adult captured by Bird & Peak (KHS) on Ollie Ridge Road just north of MACA, 2004.

(*) - the Eastern Box Turtle was previously known from Barren, Edmonson, and Hart counties; data from 2003-2006 has been treated in a similar manner to data from lizards and snakes for discussion purposes since this species was frequently found during checks of tin sites.

Eastern box turtles are common and widely distributed throughout the park and are most plentiful in open woodlands and forest edge habitats. Common snapping turtles are likely common as well and probably occur in virtually all ponds as well as in the Green River and the lower reaches of tributary streams.

Four riverine turtle species (spiny softshell, common map turtle, river cooter, and red-eared slider) were observed basking in good numbers between Dennison Ferry and the main Green River Ferry during canoe trips. Common musk turtles, which were not found during this survey and which have never been formally documented from MACA, are likely common in the Green River as well; this species is highly aquatic and is difficult to find without a concerted trapping effort.

Two Ouachita map turtles were seen during the survey; both were seen basking on debris in the Green River near Houchins Ferry. This species is probably fairly common along the impounded section of the river; it had not previously been observed within the Park but has been taken nearby in Nolin Lake. A total of three midland painted turtles were found during the survey period; Bill Moore photo documented an adult from Bruce Hollow Pond near the campground in 2005 and James Kiser found two individuals at Sloans Crossing Pond during 2006. This species was previously unreported from the Park but the author has observed painted turtles at Sloans Crossing Pond in the recent past.

Only a single mud turtle was found during the survey, a large adult that was picked up by Will Bird and Phil Peak just outside the Park along Ollie Ridge Road. Although mud turtles are fairly common in the extensive shallow wetlands of far western Kentucky, they also occur in small isolated colonies in the well-vegetated (and often seasonal) sinkhole swamps of the Mammoth Cave Plateau in Edmonson, Hart, Larue, and Hardin counties. Several mud turtles were found at

MACA in the Union City area during the Hibbard surveys of the 1930's but none have been seen in the Park since that time. Optimal habitat for a colony of these turtles would consist of a series of shallow wetlands intermixed with prairie/grasslands and open woodland; it is likely that the thick forest that has developed in the Park over the past 70-odd years has significantly impacted the mud turtle here.

Management Recommendations for turtles at MACA could include:

(1) continue to restore open woodland and glade/prairie habitat for mud turtles (and eastern box turtles); restore shallow wetland complexes for mud turtles and consider featuring this species during all prairie/grassland restoration projects (also see similar Management Recommendations for lizards, snakes, and amphibians).

(2) create and maintain small openings as safe egg-laying sites for box turtles and pond turtles along little-used or abandoned woods roads so that they do not remain dependent upon mowed roadsides for successful reproduction. All turtles must nest in areas where soils are well-drained and sunlight reaches the ground.

(3) provide additional open nesting habitat for aquatic turtles by creating small open sites that face west and south along the Green River corridor.

3-C. Data Summary from Surveys at 10 MACA Tin and Plywood Sites

Table 6 presents data for 19 species of lizards and snakes and the eastern box turtle at 10 tin and plywood sites. I have included this data here because it is somewhat interesting.

The Wondering Woods area had the largest number of artificial cover objects and yielded 19 species of reptiles and turtles (all that could be anticipated except for the corn snake).

Black racers and ringneck snakes were found at 9 of these 10 sites each; eastern garter snakes and earth snakes were found at 8 sites; and ground skinks, copperheads, worm snakes, and box turtles were found at 7 sites.

Table 6. Lizard, Snake, and Box Turtle numbers from Tin and Plywood Sites (2003-2006).

species	doyel 20 ply	floyd collins 40 tin	frozen niagara 20/25 t/p	onyx meadow 20 tin	onyx picnic 29 tin	water tanks 25 tin	job corps 25 tin	little** hope 20 tin	SRM office 5 tin	WWoods 101/20 t/p 7 setups
eum fas	3	1			(1)		1			4
oph att		5	3	1		1				3
sci lat		29	12	5	11	38		1		39
sce und	1		4							4
agk con	4	36		33	51	9		1		81
car amo	1	2	3	2	3	4				3
col con		52	22	28	16	36	1	9	2	57
cro hor		5		11						4
dia pun	16	49	35	12	50	14		6	2	208
ela gut		2	12	19	7	8			2	
ela obs		(1)	1							5
het pla					1					18
lam cal					2		7			11
lam get						1	36			2
lam tri			6			6			2	1
sto dek		5			4	7				2
sto occ	2	2	2		1					2
tha sir		38	41	30	2	1		1	2	113
vir val	2	5	2		1	1	1	(1)		13
ter car	1		6	3	1	2		1		25
Total # Species	8	14	13	10	14	13	5	7	5	19

4. Conclusions

Mammoth Cave National Park supports a rich and diverse herpetofauna. However, the results of this survey, coupled with the large amount of field work that has taken place in and around the park during the past two decades, indicate that several species of reptiles and turtles (six-lined racerunner, northern pine snake, southeastern crowned snake, mud turtle) that require and/or utilize open habitats may have disappeared from MACA since the initial park surveys (Hibbard 1936) were performed in the mid-1930's. The most likely reasons for this include: (1) the gradual development of the thick forest cover which now blankets well over 95% of MACA; (2) the loss of fire in the ecosystem; (3) the gradual filling in and loss of ephemeral natural ponds and wetland complexes on the flat sandstone ridges; (4) the tremendous alteration of the herbaceous vegetation layer in the park due to the grazing activities of the vastly overpopulated white-tailed deer herd; (5) the slow reforestation of former fallow fields, glades, patches of prairie, and open rocky areas; and (6) the loss of connectivity between the few patches of such habitats that remain. During this survey, Will Bird and Phil Peak discovered single individuals of the northern pine snake and mud turtle on private lands just to the north of the park boundary. A small population of six-lined racerunners occurs in an abandoned quarry near Nolin Dam just northwest of the park.

Several other species that appear to prefer open habitats (eastern narrowmouth toad, upland chorus frog, eastern tiger salamander, corn snake, prairie kingsnake, black kingsnake, slender glass lizard) are scarce and/or locally distributed at MACA. Although individuals of most of these were documented during this inventory, the tiger salamander may now be gone although

Hale (1984) found a few larval specimens in the park in the early 1980's. A strong and active management program will be needed to restore high quality open habitats for these species; such management should include the construction of complexes of shallow permanent and seasonal fishless breeding ponds in grasslands and open forests for the eastern narrowmouths, upland chorus frogs, and tiger salamanders. Such habitats would also be of great value to mud turtles if these animals still persist within the park.

Several additional species that were previously known from MACA were not found during this inventory. The scarlet snake and scarlet kingsnake are notoriously difficult to find in Kentucky and are most readily captured by road cruising at night on paved roads in forested areas. Hellbenders and mudpuppies are large aquatic riverine salamanders that are occasionally caught on trotlines by fishermen; biologists typically discover them by searching beneath large flat rocks in free-flowing rivers. It is entirely possible that all of these still occur within MACA.

Park personnel found a single midland mud salamander, a coal skink, and a midland painted turtle in 2005-2006; James Kiser also found 2 midland painted turtles during fall 2006.

The northern dusky salamander - a species that was common in springs and along small creeks during the Hibbard survey - has all but disappeared from MACA. Despite much searching in suitable habitats (including historic locations) only a single individual northern dusky was found during this inventory. This semiaquatic salamander has a short winter larval period and may be vulnerable to water quality problems, but adults and larvae of three other small semiaquatic salamanders that also have aquatic larvae (southern two-lined, longtail, and northern red salamanders) were found in fair to moderate numbers in historic dusky salamander sites. The descriptions of the larval northern dusksies found by Hale (1984) indicate that these were most likely the misidentified larvae of the cave salamander. If these larvae are discounted then Hale actually found northern dusky salamanders at two locations on the park. Multiple searches were made at both of her sites during this survey and no northern dusksies were found.

Despite much searching in apparently good habitat during what should have been ideal weather conditions, only a few northern slimy salamanders were discovered at MACA during this survey. The author is at a loss to explain the apparent scarcity of this common, completely terrestrial woodland species in the areas that were visited, but Highton (2005) has documented long term declines in many populations of northern slimy salamanders and other members of the genus *Plethodon* throughout the eastern U.S. This may be highly speculative, but it is possible that changes in the forest floor vegetation brought on by the proliferation of the deer herd in the park may be contributing in some way to the slimy salamander decline.

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