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NATURAL HISTORY OF THE MOLE SALAMANDER AMBYSTOMA TALPOIDEUM IN VIRGINIA

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by

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Abstract

NATURAL HISTORY OF THE MOLE SALAMANDER
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Michael Scott Hayslett

Director: Donald A. Merkle

The Mole Salamander (*Ambystoma talpoideum*) has been known from Virginia for over two decades, but no intensive research on this state-rare species had been pursued prior to this project. Various aspects of mole salamander natural history were studied over a seven-year period throughout a seven-county area of central Virginia. New state distribution records for the species were recorded from Amherst, Appomattox, Buckingham, Campbell, Nelson, and Pittsylvania Counties. These records include a range extension with the most northern occurrence known for this species in the United States.

Drift fence/pitfall trap studies were conducted on three ponds in two counties. Two distinct periods of immigration occurred in this species: one in the fall and another in late winter-early spring. The intensity of each period varied yearly depending on climatic conditions. Some individuals remained in breeding ponds for periods exceeding six months. Standard biometric measurements were taken, including values for: tail

length, snout-vent length, weight, and breeding condition. These values were recorded for all larvae, adults, and paedomorphs captured during this investigation.

This study reports the first documentation of paedomorphic individuals found in the state for this species. Paedomorphs were found in four counties. The occurrence of these individuals was dependent on the presence of breeding ponds with more permanent hydrologies than those of vernal pools. Metamorphosed paedomorphs appear to retain remnants of their paired ventral stripes, making identification of transformed paedomorphs possible.

Recommendations are presented for the conservation of this species in Virginia.

Acknowledgements

I wish to thank my committee members, Dr. Donald A. Merkle, Mrs. Dana P. Johnson, and Mr. Daniel C. Bowman for their support and longsuffering through this endeavor. I also appreciate the faculty and students from the Department of Natural Sciences at Longwood University who provided assistance and encouragement during this project.

My gratitude goes to Virginia Department of Forestry personnel of the Appomattox-Buckingham State Forest for providing advice and access to locate the first known Commonwealth-owned site for the Mole Salamander. My thanks go also to Brian Eike of the Appomattox Court House National Historical Park for access, maps, and general support to discover the only federal land site known to harbor the rare Mole in Virginia. Gary Fleming of the Virginia Department of Conservation and Recreation's Division of Natural Heritage conducted botanical and ecological assessment of sites in Amherst, Campbell, and Pittsylvania counties that were useful to this study.

I am indebted to several undergraduate technicians for their help with the Piney River research site: Carrie Jones Campbell of Randolph-Macon Woman's College, and Carrie Speck and Anne Marie Clarke of Sweet Briar College. I am particularly grateful to Anne Marie for her dedicated assistance in the field and for GPS mapping of the Piney River pond complex.

Dr. Paul Sattler & students from Liberty University provided valuable help in the first year of the study, seining up the first neotenic specimen identified in Virginia.

From Lynchburg College, Dr. Gwynn Ramsey provided plant identifications for the Piney River site, and Dr. David Perault produced the GIS map for the same.

Longwood graduate students Jennifer Ward and Lisa Wilkins aided in the field, as did a whole host of friends, associates, and acquaintances, including: Chris French, Tammy Schwab, Kent White (drift fence installation), David A. Dawson, Lori Lowther, Bryan Branch, Glenda and Joseph Gordon, Debra Troutman, Doug Eggleston, and many others.

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I appreciate Hank Rappleyea seeking me out and sharing information on his recent Mole Salamander finds in Campbell and Charlotte Counties, and I look forward to future explorations with him.

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My endless gratitude goes to "herp champ" David L. Dawson. His serendipitous rediscovery of the Mole Salamander, his good fortune to live adjacent to our first study population, and his friendship and assistance in the field since the beginning, have made this research odyssey a true pleasure.

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Introduction

Little is known about the Mole Salamander (*Ambystoma talpoideum*) in Virginia. The Mole Salamander had been recorded from only two counties in Virginia. The late Bob Bader first reported this species for the state from a small, man-made ice pond in a stream floodplain of southwestern Charlotte County in 1981 (Bader and Mitchell, 1982). The site has since been logged and its current condition is unknown (J. Mitchell, pers. comm.). Eggleston and Nagelmeyer found another site near Turnip Creek in Charlotte County, circa 1990 (D. Eggleston, pers. comm.). The species has been considered threatened (Pague and Mitchell, 1987) and is currently listed as a special concern species (Pague and Mitchell, in Terwilliger, 1991). Given the lack of knowledge about this species distribution in the state, efforts were undertaken to learn more about this animal in Virginia.

The impetus for this study resulted from the fortuitous discovery of two specimens by a colleague that submitted each of these live specimens to the author for identification. In March of 1995, David L. Dawson collected a Wood Frog (*Rana sylvatica*) from a pool complex located near his home in Melrose. This proved to be the first documented record for the species in Campbell County (Hayslett, 1995). Subsequently in March of 1996, Mr. Dawson returned to me with a live Mole Salamander. The latter discovery proved to be quite significant to state herpetological monitoring efforts, for this species had not been seen in the Commonwealth for about a decade (Hayslett, 1996). The discovery of the Melrose site represented the most western locality known from Virginia and the second and apparently most protected breeding site known for this species in the state (J. Mitchell, pers. comm.) The Melrose site is located approximately 23 km west of and upstream from Bader's original site.

The objective of this investigation was to conduct an intensive, observational study of the seasonally-phenomenal breeding cycles of the Mole Salamander (*Ambystoma talpoideum*), and to collect biological data on the same and on a congeneric species, namely the Spotted Salamander (*Ambystoma maculatum*), as are applicable to understanding the ecology of the Mole Salamander. Potential sites for the Mole Salamander throughout its possible range in Virginia would be examined.

Materials and Methods

The biogeographical distribution of the Mole Salamander in Virginia was assessed by examining known sites and then searching similar habitats within the expected range of this species: the Southside region of Virginia. Counties lying within the Danville Basin of the Triassic Lowlands were the primary targets. Extensive areas of seasonally flooded, forested wetlands or swamps were searched throughout Charlotte, Campbell, Pittsylvania, Amherst, Nelson, Appomattox, and Buckingham Counties. Searches were also conducted in the Culpepper Basin of northern Virginia over a five-year period, to ascertain if disjunct populations might have persisted in those areas of Triassic Lowlands and might extend the known range of the Mole Salamander well above the presumed latitudinal limits of Southside Virginia. To the latter end, appropriate habitats in Prince William, Loudoun, and Fairfax Counties were searched.

Morphological and phenological data was tracked at two sites for comparison: Melrose in Campbell County from 1998-2003 and Piney River in Amherst/Nelson Counties from 2001-2003. Morphological views of a typical Mole Salamander can be seen in Figure 1.

Relative size and dorsal coloration

Note pale dorsal tail stripe and digital amputation mark (HR4)

"Warty" texture present on lateral tail surface of breeding males

Note cranial pores and short limbs

Figure 1a. Morphological Views of the Mole Salamander

First specimen from Appomattox County, Virginia

Disproportionately wide head of the "Big Headed" Mole Salamander

Breeding male with enlarged cloaca

Figure 1b. Morphological Views of the Mole Salamander

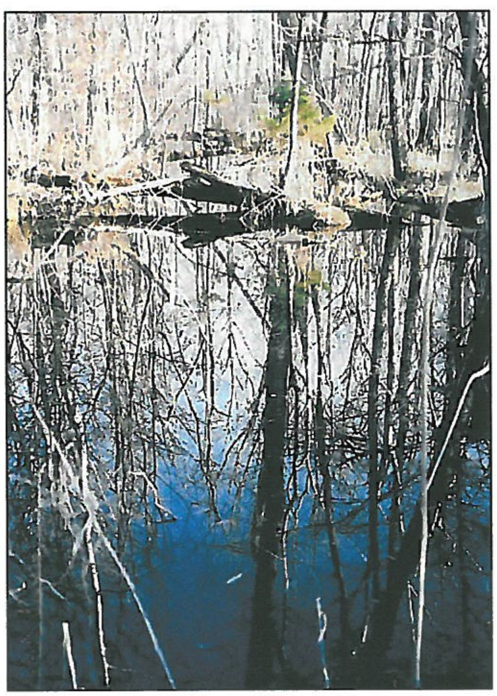
First specimen from Appomattox County, Virginia

Melrose Research Site Description (Figure 2)

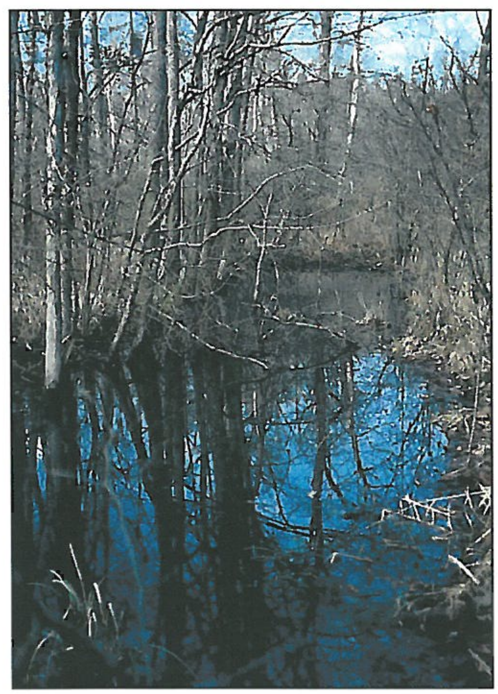
The site is located along the Staunton River in southern Campbell County, Virginia, USA. Ecologically, the site is characterized as a complex of vernal pools (temporary ponds) found in the floodplain of the Staunton river and generally formed and maintained by a combination of flood waters and seasonal precipitation. The site includes approximately six pools varying considerably in size, ranging from about 15 to 150 linear feet and with depths generally under three feet. One or more of the pools toward the eastern side of the site are remnant sections of an historical canal (D.L. Dawson, pers. comm.) but function in the same manner as a natural, floodplain pool. The riparian forest that houses the pool complex is in generally good health. It is afforded some protective status based on the land-use history (the lands associated with this amphibian community are a patchwork of privately-owned tracts). This site is adjacent to a section of the Staunton River which has been designated as a State Scenic River. Acquisition or easement of this site as a satellite to the State Scenic River section could provide one source of protective land status for the site and its riparian buffer (S. Smith/VDGIF, pers. comm.).

Additionally, a small pool, characterized as an enhanced, lateral spring head on a perennial drainage, is located about 300 feet ENE from the main complex of pools and was also part of the study. This latter pool is located along a migration corridor of several explosive amphibian breeders and receives considerable utilization as breeding salamanders and frogs move toward the vernal pool complex in the nearby floodplain.

Minnow Pool: permanent-water pond supporting Mole paedomorphs



Long Pool at Melrose



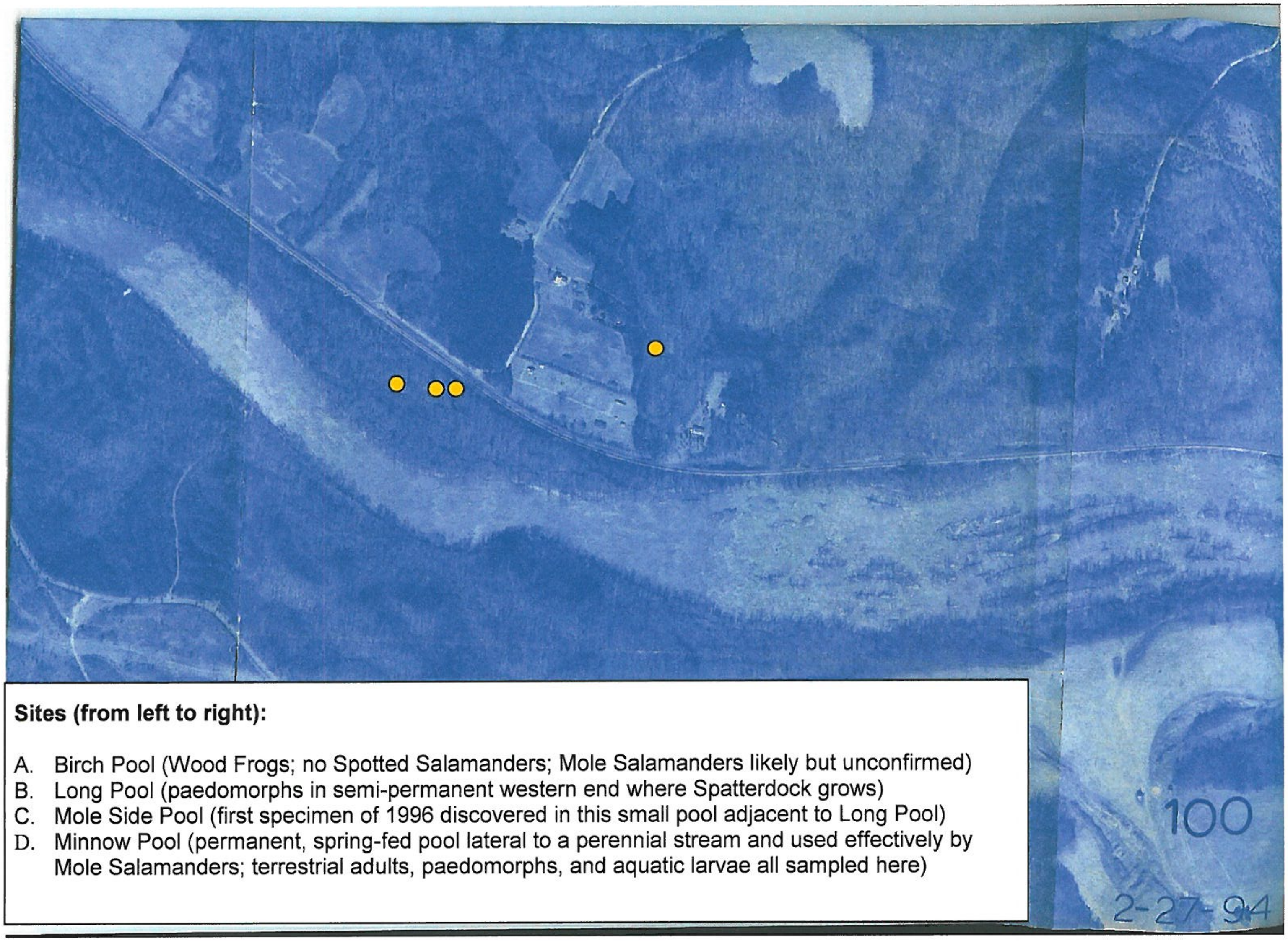
RR Pool downstream from Melrose

Figure 2. Mole breeding sites: Campbell County, Virginia

The vicinity surrounding the study site is characterized by a moderately altered landscape which includes gravel roads, rural lawns and agricultural fields, residential structures, power line rights-of-way, and a railway corridor (Figure 3).

Piney River Research Site Description (Figure 4)

This location is on industrial property long quarried for anorthosite aggregates, and contains numerous isolated wetlands on an upland plateau above the Piney River. This site is located on the edge of the Blue Ridge Mountains, far from the Triassic Lowlands of Southside Virginia and likely represents a relict population of much significance. Based on literature search and personal communication with Natural Heritage personnel of southern Illinois, the Piney River meta-population appears to represent the most northern known locality for the species in the United States (Conant, 1991: Petranka, 1998). The number of confirmed and potential breeding ponds certainly exceeds any other site known to date in Virginia. This plateau in the Blue Ridge foothills is a geologically and ecologically unique area. The underlying anorthosite yields a saprolite. These hydric surface soils of the surrounding Roseland District are characterized by a highly plastic, gray clay approximately 48" deep. This hardpan results in hydric forest depressions throughout the area. Additionally, the area forests are dominated by mature Willow Oak (*Quercus phellos*), a hydrophytic tree more typical of the eastern Piedmont and Coastal Plain of Virginia (G.Ramsey, pers. comm.). These extreme soils have precluded extensive agricultural use of this region and passively contributed to the preservation of the forest cover and preserving the character of this relict, upland swamp forest.



Sites (from left to right):

A. Birch Pool (Wood Frogs; no Spotted Salamanders; Mole Salamanders likely but unconfirmed)
B. Long Pool (paedomorphs in semi-permanent western end where Spatterdock grows)
C. Mole Side Pool (first specimen of 1996 discovered in this small pool adjacent to Long Pool)
D. Minnow Pool (permanent, spring-fed pool lateral to a perennial stream and used effectively by Mole Salamanders; terrestrial adults, paedomorphs, and aquatic larvae all sampled here)

Figure 3. Aerial Photograph of Melrose (Campbell County) showing sites found since 1996

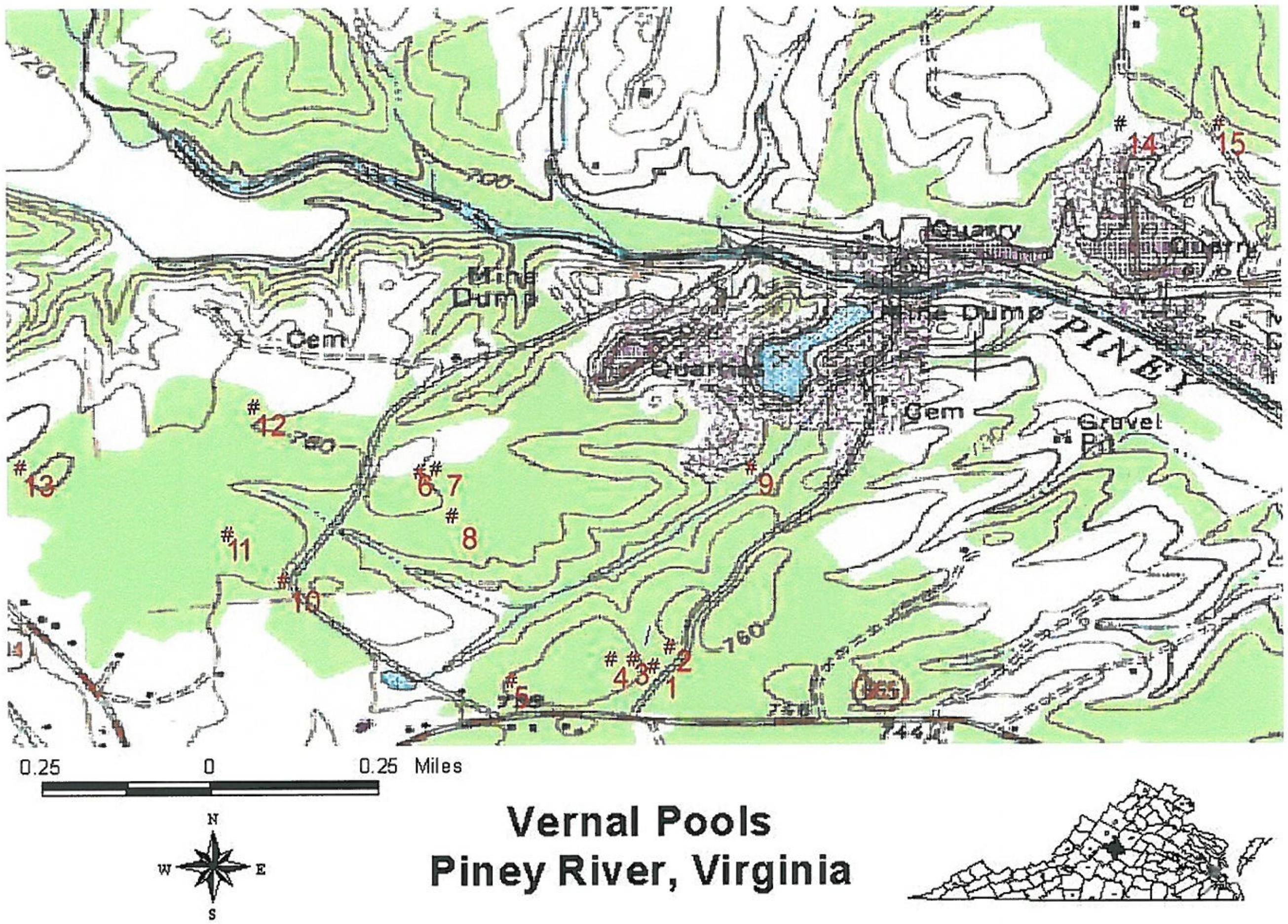


Figure 4. GIS Map of Piney River Meta-population
(Amherst and Nelson Counties) showing GPS-located ponds known to support Mole Salamanders and potential breeding populations in similar habitats (Produced by A.M. Clarke, with assistance from D. Orvos and D. Perault)

Ponds 2, 3, and 6 were sampled routinely; others were sampled for the presence or absence of salamanders. Pond 2 is an approximately one-acre, semi-permanent depressional wetland and the largest of nine ponds in this study complex on the quarry property. Pond 2 has unique, upland swamp characteristics of mossy hummocks and buttressed trees, and it appears similar to like environs in Prince William County in Virginia's coastal plain. Virginia Natural Heritage assessed the site botanically and found it to be a natural community unique for the western half of the state (G. Fleming, pers. com.).

Pond 3 was fitted with an encircling drift-fence and pitfall array. Pond 6 located on the West side of the quarry property and across a drainage, was also fenced to provide a contrasting site to sample. The hydrology of the east-side complex of forest depressions (Ponds 1-4) proved to exceed the expected high water level, and Pond 3 was swamped and the fence had to be relocated to a position further from the pond perimeter. Rising groundwater levels pushed the one-gallon bucket pitfalls out of the ground. Due to resource limitations, the new fence array at Pond 3 was unable to encircle the pond. Instead it covered the most critical migration corridors on the south, west, and north sides of the pond. The re-installed drift fence was painted with a three-color camouflage to reduce visibility from the nearby entrance road in the quarry, and one-gallon metal cans were used for pits.

Sphagnum-filled Pond 4 (adjacent to Pond 3) appeared to provide comparable habitat. Ponds 1-4 were occasionally fused or nearly so during times of high water. Pond 8, a permanent, artificial pond, is located close to Pond 6. Pond 6 is located on the west side of the quarry property, and is an exemplary example of a seasonally-flooded, forested wetland, or vernal pool. Similar habitats were found in the vicinity on the plateau (two on adjoining private properties). Two artificially created ponds on the north side of the Piney River (in adjacent Nelson County) were also found to support Mole salamander breeding. This site is an abandoned quarry. A total of 15 ponds were located, assessed, and searched at the Piney River site (Table 1).

Sampling Techniques

Breeding biology was monitored using standard sampling methodology for pond-breeding amphibians. The small, spring-fed pool ("Minnow Pond") at Melrose, and Ponds 3 and 6 at Piney River were enclosed with a drift fence and pitfall array. Drift fences were constructed of two foot high, rolled aluminum flashing entrenched about 8-10 cm underground, with one-gallon metal pits positioned on approximately three-meter intervals, both inside and outside the fence line.

Dip netting was employed in numerous sites to randomly sample adult Mole Salamanders, their larvae, and congenerics. A standard, aluminum minnow-basket trap equipped with cyalume glow sticks was employed in numerous locations to determine the presence of Mole Salamanders at new sites and those without drift fence arrays.

Pond	County	Description
1	Amherst	Wind-thrown tree and road shoulder ditch
2	Amherst	Upland depressional swamp forest (long-cycle to semi-permanent)
3	Amherst	Vernal pond of first Mole finds
4	Amherst	Long vernal pond (*Sphagnum* filled)
5	Amherst	Small vernal pond (no obligate amphibian evidence)
6	Amherst	Large vernal pond on West side of Quarry
7	Amherst	Small vernal pond on West side of Quarry (short-cycle)
8	Amherst	Road-trap pond (artificial and apparently permanent)
9	Amherst	Beaver swamp (impounded stream) on South side of Quarry entrance road
10	Amherst	Bog-like wetland in curve of Quarry Road (819)
11	Amherst	Vernal pond in old clear-cut on Brockman property
12	Amherst	Vernal pond on Volz property
13	Amherst	Long vernal pond on Brockman property (West scarp of Roseland terrace)
14	Nelson	Upland vernal pond on Mooney property (artificial; quarry abandonment)
15	Nelson	Quarry abandonment on Mooney property (artificial; semi-permanent)

Table 1. Physical Descriptions of Ponds at Piney River

These effective traps were submerged in the deeper areas of selected pools to sample benthic-active animals, during appropriate migration times for adults and in various other seasons for larvae. A modified version of a standard, digital-amputation technique (Twitty, 1966) was employed for the mark-recapture aspect of the study.

Standard biometrics were taken for all Mole Salamanders captured (adults, pre-metamorphic and paedomorphic larvae) at all sites investigated. Data collected included: SVL (snout-vent length); Tail length, Total Length and Weight. Mean values were calculated for weight and two length values for various gender and age classes. In addition, four morphological features were assessed for all individuals captured. These features included: 1) head color; 2) background color; 3) presence or absence of a tail stripe; and 4) presence or absence of speckling.

An undergraduate technician was engaged to assist with capture monitoring at the Piney River site and to collect environmental data for the site. Coordinates and relative elevations for 15 ponds within and around this study site were mapped using a standard GPS hand-held unit. Maximum pond depths were recorded with a meter stick at pond epicenters during full-water conditions (Table 2). Pond numbers and physical descriptions were assigned to distinguish each of the ponds sampled (see Table 1). The project technician also developed a GIS map of the pond locations using Archview® software (see Figure 4).

Pond	GPS Coordinates*	~ Max. Depth @ Epicenter	~ Elevation
1	N 37.70154,W 079.04837	16.275"	810'
2	N 37.70201,W 079.04802	20.5"	846'
3	N 37.70179, W 079.04872	10.275"	811'
4	N 37.70176, W 079.04922	9.75"	822'
5	N 37.70131, W 079.05136	10"	808'
6	N 37.70593, W 079.05530	10.175"	862'
7	N 37.70596, W 079.05296	11"	-
8	N 37070496, W 079.05259	39.25"	861'
9	N 37.70597, W 079.04621	-	-
10	N 37.70357, W 079.05620	14"	-
11	N 37.70454, W 079.05741	13.25"	815'
12	N 37.70739, W 079.05687	9"	852'
13	N 37.70601, W 079.06186	21.25"	945'
14	N 37.71355, W 079.03828	33.5"	699'
15	N 37.71352, W 079.03616	~42" +	-

Table 2. Pond Coordinates, Depths, and Elevations for the Piney River complex
Data collected and prepared by A.M. Clarke.

Results

Distributional Discoveries

After the Mole Salamander's first discovery in Charlotte County in the spring of 1981 and an initial interest in searching that area, the pursuit for this new Virginia species seemed to die along with its discoverer (Eggleston, 1999). With the exception of one undocumented road find around 1986 (Figure 5), the Mole Salamander became Virginia's "forgotten amphibian" for over a decade.

Dawson's serendipitous 1996 rediscovery of the Mole Salamander upstream on the Staunton River revived interest in determining the true extent of its distribution in Virginia. During this study, several other researchers have recently discovered new populations.

As a result of this study, five new county distribution records for the Mole Salamander in Virginia have been discovered during five years of investigations. In order of discovery, they are: Pittsylvania (Figure 6), Amherst, Nelson, Appomattox, and Buckingham Counties. In addition, two previously known sites were examined, and the discoveries of three other researchers were reviewed. Those separate finds were: Appomattox County (Mitchell, March 2003), Pittsylvania County (Gibson, June 2003), Campbell County (Rappleyea, November 2002) and Charlotte County (Rappleyea, October 2003). Henry Rappleyea's Campbell County site has revealed significant numbers of migrants, despite impacts from road mortality and land clearing (Rappleyea, pers. comm.). Mole Salamanders are currently known from 15 sites in Virginia (Table 3).

Following seven years of search to determine the biogeographical distribution of the Mole Salamander in Virginia, the majority of known populations were found to occur in or adjacent to the Danville (Triassic) Basin of Southside Virginia. The Piney River site is an obvious exception, being located well outside the expected range of the Mole Salamander in Virginia, and is in a very different physiographic region. A revised range map for the Mole Salamander in Virginia was successfully determined (Figure 7).

VA 618: Site of road-crossing adult find (circa. 1986) examined and documented

Turnip Creek floodplain: likely breeding habitat adjacent to the above road find

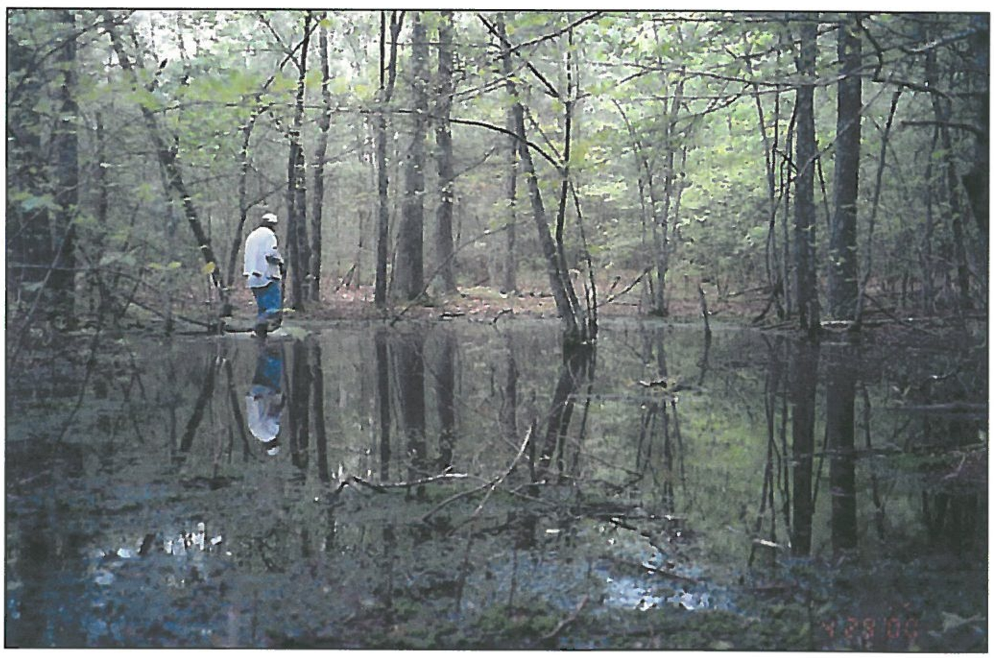
Figure 5. Mole Breeding Sites: Charlotte County, Virginia

Site 1: Upland pool where larvae were found (North of Spring Garden, Virginia)

Site 2: Roadside swamp with severe impacts where adults where found (Mt. Airy)

Figure 6. Mole Salamander Breeding Sites: Pittsylvania County, Virginia

Piney River Pond 3 Supports a Sizeable Population of Mole Salamanders



Piney River Pond 6 had many Spotted Salamanders but few Moles Salamanders

Figure 7a. Mole Salamander Breeding Sites: Amherst County, Virginia

Pond 4 appears like ideallic habitat but supported only incidental activity

Pond 2 is semi-permanent and supports numerous paedomorphs in most years

Figure 7b. Mole Salamander Breeding Sites: Amherst County, Virginia

County	Location	Order	Year	Finder(s)
Charlotte	South Isle Plantation along Staunton River (SSW of Phenix)	1st	1981	Bader (et al)
Campbell	"15.7 km ENE Gladys" (also in Bader and Mitchell, 1982)	2nd	1981	Jones
Charlotte	VA 618 at Turnip Creek	3rd	circa. 1986	Eggleston & Nagelmeyer
Campbell	Pond complex along the Staunton River at Melrose	4th	1996	Dawson & Hayslett
Pittsylvania	VA 663 / Cedar Hill Road (plateau on W side of Banister R.)	5th	1998	Hayslett
Amherst	Piney River complex (Boxley, Brockman, & Volz tracts)	6th	1999	Hayslett & Bowman
Campbell	RR near Bradner tract (ca. 5.5 km ESE of Melrose)	7th	1999	Hayslett & Dawson
Pittsylvania	Starkey Road (ca. 3 km N of Mt. Airy)	8th	2000	Dawson & Hayslett
Nelson	Abandoned quarry on Mooney tract at Piney River	9th	2002	Hayslett
Campbell	VA 600 near the intersection of VA 616	10th	2002	Rappleyea
Appomattox	Tibbs/quarry pond in Appomattox Court House NHP	11th	2003	Hayslett
Appomattox	Sweeney Wayside thicket in Appomattox Ct. House NHP	12th	2003	Mitchell
Buckingham	Holliday Creek floodplain in Appom.-Buck. State Forest	13th	2003	Hayslett
Pittsylvania	White Oak Mountain Wildlife Management Area	14th	2003	Gibson
Charlotte	VA 616 (ca. 4 mi. SSW of Red House)	15th	2003	Rappleyea

Table 3. Known Mole Sites in Virginia
Public lands indicated in red.

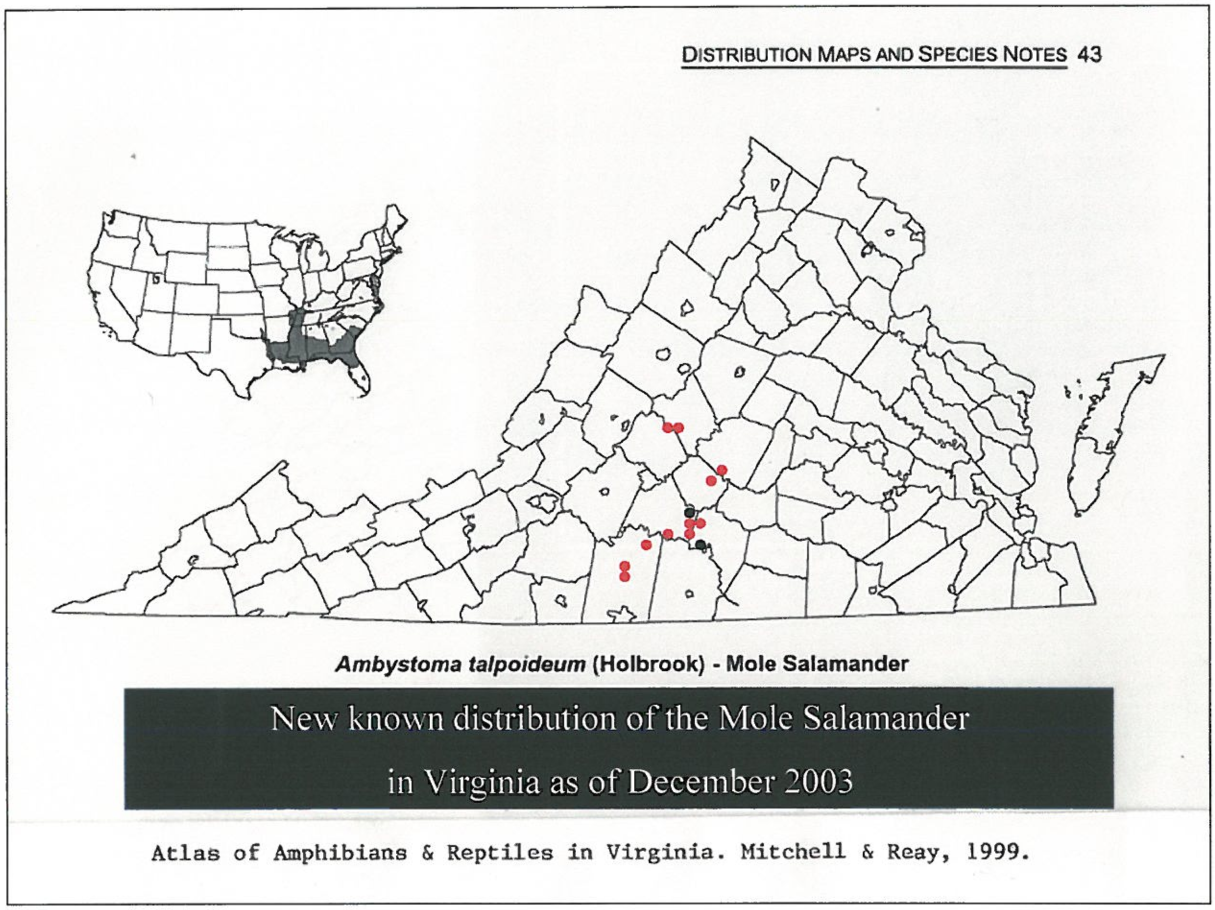


Figure 8. Revised Range of the Mole Salamander in Virginia
Red dots indicate localities found during the time of this study.
Black dots indicate previously documented localities.

Charlotte County

The site of an undocumented Mole Salamander find was assessed on 15 December 1998 to determine if it might yield a location for investigating breeding biology (Figure 5). Eggleston and Nagelmeyer encountered an adult Mole Salamander migrating across Rt. 40 at Louse Creek around 1986 (D. Eggleston, pers. comm.). Potential habitat existed in a flooded bottom and roadside ditches, but recent and extensive land clearing was present in the vicinity of the floodplain.

Pittsylvania County

The first Pittsylvania County find on 10 February 1998 in the Spring Garden area of the Danville Basin, is located on a plateau atop bluffs about 100 feet above the Banister River and on the southeast side of state route 663, at approximately 580' elevation (Figure 6). One larva was vouchered from a woodland vernal pool, situated southwest of a beaver pond in mixed hardwood forest. The Mole Salamander larva was sympatric with Spotted Salamanders (*Ambystoma maculatum*) in an oak-dominated forest.

Numerous areas of seasonally-flooded forest in the Stinking River area were examined on 25 February 1998. Congenerics, Spotted and Marbled (*Ambystoma opacum*) Salamanders, were present in this potential target habitat, but no Mole Salamanders were found.

The second Mole Salamander population in Pittsylvania County was discovered on 4 March 1999 while investigating an impact site north of Mt. Airy, along state route 916 (Starkey Road), 0.1 mile east of VA 640. A sizeable swamp with a large population of Spotted Salamanders had been piped and rapidly drained during road expansion by the Department of Transportation. Approximately 300 Spotted Salamander egg masses were discovered (most stranded above water), as well as two adult Mole Salamanders (one predated carcass and one live female). The live female was spent, had a snout to vent length of 54 mm, a tail length of 44 mm, and a weight of 7.0 grams. The dead female was also spent, had an SVL of 45 mm, a tail length of 31 mm, and a weight of 4.25 grams. The pond had also been degraded previously by a severe cutover, which left no contiguous forest buffer for the wetland. Other breeding habitats with potential for future search were found in the vicinity.

Campbell County

The night of 21 February 1997 was a classic, punctuated breeding event for two amphibian species sympatric with Mole salamanders at the Melrose site. With an air temperature of about 60° F at 18:30, a downpour occurred at about 19:00 and persisted for an hour. Minnow Pool pits yielded 17 Spotted Salamanders and 23 Wood Frogs (*Rana sylvatica*). Dip-netting produced 40 Spotted Salamanders and 0 Wood Frogs from Long Pool, 0 Spotted Salamanders but 30 Wood Frogs from Birch Pool. Table 4 shows

Species	Pool	N	M	F	ratio M:F
Rana sylvatica	Minnow	23	18	5	
Rana sylvatica	Long	0	0	0	
Rana sylvatica	Birch	30	22	8	
Totals		**53**	**40**	**13**	**3 to 1**
Ambystoma maculatum	Minnow	17	14	3	
Ambystoma maculatum	Long	40	34	6	
Ambystoma maculatum	Birch	0	0	0	
Totals		**57**	**48**	**9**	**5 to 1**
Ambystoma talpoideum	Minnow	0	0	0	
Ambystoma talpoideum	Long	1	0	0	
Ambystoma talpoideum	Birch	0	0	0	
Totals		**0**	**0**	**0**	**0 to 0**

Table 4. Melrose Sample of 21 February 1997

details on these sympatric captures. These floodplain pools (less than 100 yards apart) showed a species segregation between Spotted Salamanders and Wood Frogs for breeding during this peak of activity. No terrestrial Mole Salamanders were encountered through any sampling techniques during this "frenzy" of sympatric activity.

Also on 21 February 1997, the first paedomorph of the study was seined from the enlarged western end of Long Pool in the Staunton River floodplain at Melrose (Figure 8.) This area is characterized by a deeper basin with minor groundwater feed, and a colony of the indicator plant, Spatterdock (*Nuphar polysepala*). This area retains water in wet years, forming a seepy basin that can support paedomorphs.

Minnow Pool supported numerous paedomorphs, due to its permanent water supply. A gravid, female paedomorph captured in Minnow Pool on 15 February 2001 had been fertilized and was retained in captivity for laboratory observation. Details on the development of her spawn and the transformation of this paedomorphic female were noted daily. The significant details of this chronology are summarized in Table 5. Captive paedomorphs held in a confined volume of water initiated transformation to their terrestrial form rapidly. Paedomorphs were often larger than their terrestrial counterparts (Table 6).

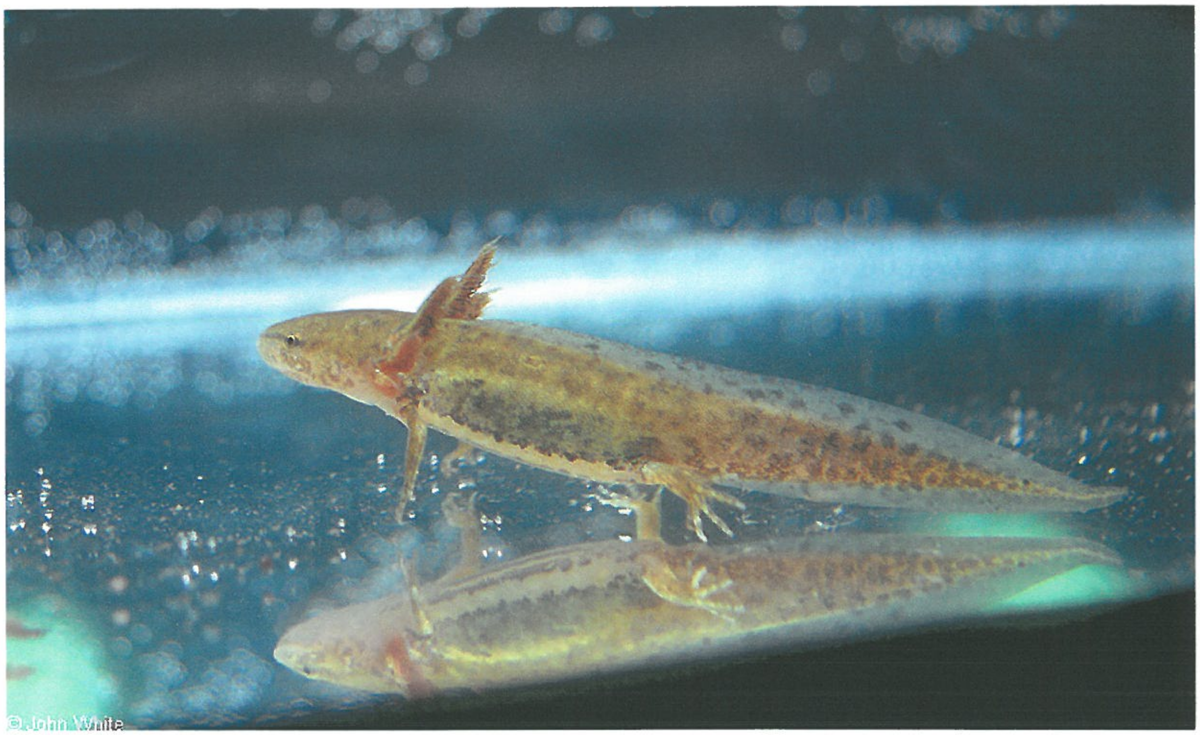


Figure 9. First Paedomorphic Mole Salamander from Long Pool at Melrose
Note ventral stripes, body fin, and "leopard spotting" on the tail.
Photo by P.W. Sattler

15 February – 11 March 2001		
DAY	**PAEDOMORPH**	**SPAWN**
1	• Gravid (fertile) female placed in lab captivity (1 gallon DI water @ room temperature)	
3	• female lays 190 eggs singly and in small clusters	• 190 eggs separated from female (1 gallon DI water @ room temperature)
6		• vitalene diameter = 5mm • cell differentiation first noted
12	• transformation begins with gills shrinking	• vitalene diameter = 8mm • 31% of the eggs still viable • first embryonic movement noted
17		• vitalene diameter = 11mm (maximum) • eyes and gills of embryos visible
19	• color change from olive to gray complete • head shape now changing • tail fins shrinking	• first hatchlings emerge from egg cells
25	• female emerges from water onto platform	• final hatchlings emerge from egg cells

Table 5. Summarized Chronology of Captive Paedomorph and Her Spawn

Date	SVL (mm)	Tail (mm)	Total L	Wt (g)	M/F	Condition	Recap	Mark
15-Jan-99	63	52	115	8	M	breeding	23 Jan	40
24-Jan-99	0	0	0	0	no data	paedomorph	no data	no data
25-Jan-99	59	54	113	7.9	F	gravid paedom.	new	20
30-Jan-99	55	43	98	5.25	F	gravid	new	40
03-Feb-99	58	52	110	6.75	F	spent paedom.	**YES**	20
07-Feb-99	58	39	97	5.5	F	gravid	new	4
28-Apr-99	0	0	0	0	no data	subadult	**YES**	no data
29-Sep-99	42.5	36	78.5	3	larva	late-stage	possible	1400
29-Sep-99	45.5	43	88.5	3.75	larva	transforming	possible	no FR limb
29-Sep-99	38.5	34	72.5	2.5	larva	no data	**YES**	40
29-Sep-99	41	39	80	3	larva	no data	new	14000
29-Sep-99	38	39	77	2.5	larva	no data	new	9
29-Sep-99	37	36	73	1.9	larva	no data	new	90
29-Sep-99	36	34	70	2	larva	no data	new	12
29-Sep-99	35.5	30.5	66	1.5	larva	no data	**YES**	600
29-Sep-99	42	43	85	3	larva	late-stage; stripe	**YES**	4000
29-Sep-99	48	48	96	4.75	no data	paedomorph	new	pr. vnt. stripes
05-Dec-99	63	49	112	7.6	M	breeding	possible	43
14-Dec-99	0	0	0	0	M	breeding	**YES**	4
27-Feb-00	41	40	81	3.25	larva	no data	new	30
27-Feb-00	47	48	95	4	larva	no data	new	40
27-Feb-00	42	46	88	3	larva	no data	new	50
27-Feb-00	42	42	84	4	larva	no data	new	2
27-Feb-00	51	41	92	5.25	larva	no data	new	3
27-Feb-00	42	41	83	2.5	larva	no data	new	4
27-Feb-00	43	48	91	4	larva	no data	new	2000
11-Mar-00	52	0	0	4.6	larva	late-stage	**YES**	43
11-Mar-00	51	46	97	4.1	larva	late-stage	new	40
11-Mar-00	41	41	82	2.1	larva	no data	new	42
11-Mar-00	49	43	92	4	larva	late-stage	new	43
11-Mar-00	45	41	86	3.75	larva	late-stage	new	4
11-Mar-00	40	38	78	2.1	larva	no data	new	4
11-Mar-00	42	32	74	2.55	larva	no data	**YES**	30
11-Mar-00	39	37	76	2.1	larva	no data	new	45
11-Mar-00	41	38	79	2.6	larva	no data	new	30
11-Mar-00	42	47	89	3.25	larva	changing	**YES**	2000
19-Mar-00	0	0	0	6	F	N/A	**YES**	4
18-Jan-01	0	0	0	0	F	no data	**YES**	no data
19-Jan-01	64	53	117	9.5	M	breeding	**YES**	4

Table 6. Melrose Capture Data for Minnow Pool

Numerous pre-metamorphic larvae were easily netted from Minnow Pool, due to their habit of nocturnal stratification in the water column (Branch and Altig, 1981).

Morphological descriptions were recorded for most terrestrial adult specimens. Five characters were noted qualitatively: background dorsal color, head color, dorsal tail stripe, blue flecking, and lateral tail texture. The typical appearance consisted of a dark gray dorsal background color, a head color tending toward olive-brown; the presence of a narrow, cream-colored stripe on the tail dorsum, varying amounts of blue flecking over the body (concentrated primarily on the lateral surfaces of the tail and body). Breeding males exhibit a warty texture on the lateral surface of the tail.

Data for Melrose specimens can be found in Table 6. A selected sample of biometric data from Minnow Pool specimens showed that breeding males had an average weight of 6.71 grams, with a median weight of 6.2 grams (N=10). Breeding females had an average weight of 5.8 grams and a median weight of 5.5 grams (N=14). Paedomorphic females showed a slightly higher average weight than their terrestrial counterparts at 5.93 grams, with a median weight of 5.75 grams (N=7). Pre-metamorphic larvae had an average weight of 2.91 grams and a median weight of 3.0 grams (N=26).

Amherst County Research Site

Investigations on one industrial and three adjoining private properties revealed over 15 ponds with confirmed or potential Mole Salamander breeding activity, in an area of an approximate mile-and-a-half radius. Data for Piney River specimens from Pond 3 can be found in Table 7.

Of significance to the mark-recapture aspect of the study was the recovery of recaptured individuals that revealed durations on site at the breeding pond. Mole Salamanders are known to remain in (or around) the breeding pond for much longer periods than most of their congenerics. The 2002-2003 breeding season was particularly productive in Pond 3 of the Piney River site. An abundance of early fall rain filled this and neighboring ponds sooner than usual and continuing rains through the winter maintained above-normal water levels in these ponds. This allowed Mole Salamanders to arrive early and stay longer, increasing their chances of successful matings. Male #705 (ID= Tilley equivalent) immigrated into Pond 3 on 25 October 2002 and emigrated from the pond on 25 April 2003, having stayed for a duration of 181 days and gained 1.5 grams of body weight. Male #30 (Tilley equivalent) immigrated into Pond 3 on 11 November and emigrated from the site on 4 May, after a stay of 172 days and a weight gain of 0.5 grams. Female #7700 (Tilley equivalent) immigrated into Pond 3 on 12 November and emigrated out of the site on 25 April, after a 164-day duration and a

Date	Pit	SVL (mm)	Tail (mm)	Total L	Wt (g)	M/F	Condition	Recap	Mark
13-Apr-00	no data	no data	no data	no data	6.70	F	gravid	new	no data
13-Apr-00	no data	no data	no data	no data	4.50	F	no data	new	no data
20-Jan-01	no data	67	49	116	8.00	M	breeding	new	100
20-Jan-01	no data	48	32	80	3.75	F	gravid transf. paed.	new	200
15-Feb-01	2	42	29	71	2.50	F	no data	new	10
15-Feb-01	9	58	43	101	7.50	F	gravid	new	400
15-Feb-01	11	42	27	69	2.40	F	gravid	new	700
17-Feb-01	9	42	26	68	2.25	F	no data	new	100
17-Feb-01	10	52	36	88	4.40	F	gravid	new	200
03-Mar-01	8	48	34	82	3.75	F	spent/laid in Pond 2?	new	50
11-Apr-01	ingress	no data	no data	no data	no data	ND	no data	new	no data
11-Apr-01	ingress	no data	no data	no data	no data	ND	no data	new	no data
27-Apr-01	N	58	33	91	5.75	F	spent	new	41
27-Apr-01	M	59	42	101	6.50	F	dead/skunk predated	new	4
27-Apr-01	L	no data	no data	no data	no data	F	survived predation	new	no data
30-Apr-01	no data	50	32	82	4.25	F	no data	new	500
30-Apr-01	no data	51	38		4.25	F	no data	new	730
24-Nov-01	21	no data	no data	no data	0.00	M	breeding	no data	no data
24-Nov-01	8	50	32	82	4.10	F	dead/spider predation?	new	no data
24-Nov-01	2	no data	no data	no data	no data	F	no data	no data	no data
25-Nov-01	ingress	no data	no data	no data	no data	ND	no data	no data	no data
09-Dec-01	11	51	36	87	5.80	M	breeding	new	7000
18-Dec-01	S	41	28	69	2.25	JUV	metamorph	new	2040
18-Dec-01	11	57	41	98	6.20	M	breeding	new	1040

Table 7a. Piney River Capture Data for Pond 3

Date	Pit	SVL (mm)	Tail (mm)	Total L	Wt (g)	M/F	Condition	Recap	Mark
18-Dec-01	8	57	37	94	5.40	M	breeding	new	104
18-Dec-01	7	47	28	75	2.90	M	breeding transf.paed.?	**YES**	45
18-Dec-01	4	64	50	114	9.40	F	gravid	new	4040
18-Dec-01	N	58	39	97	5.75	F	gravid	new	7040
21-Jan-02	7	57	35	92	5.49	M	breeding	new	1003
21-Jan-02	13	53	34	87	4.95	M	breeding	new	7003
24-Jan-02	10	47	35	82	3.00	M	breeding transf. paed.	new	2004
03-Mar-02	K	no data	no data	no data	no data	F	dead predated	Pond 2?	40
13-Mar-02	N	53	31	84	4.2	M	breeding	new	250
20-Mar-02	21	56	38	94	5.75	F	gravid	new	201
20-Mar-02	14	55	35	90	5.50	F	gravid	new	203
25-Mar-02	19	no data	no data	no data	no data	F	gravid	no data	no data
14-Oct-02	no data	66	46	112	7.6	M	breeding transf. paed.	new	704
14-Oct-02	no data	no data	no data	no data	no data	F	dead	no data	no data
25-Oct-02	no data	57	36	93	5.7	M	breeding transf. paed.	**YES**	7010
25-Oct-02	no data	58	41	99	5.75	M	breeding	new	705
25-Oct-02	no data	58	41	99	7.75	F	gravid	**YES**	400
25-Oct-02	no data	51	37	88	4.75	M	breeding transf. paed.	new	702
25-Oct-02	no data	57	41	98	5.8	M	breeding	new	703
25-Oct-02	no data	54	39	93	6.75	F	gravid	new	701
29-Oct-02	no data	50	25	75	4.75	F	spent	new	1700
05-Nov-02	no data	55	37	92	5.50	F	gravid	new	2700
12-Nov-02	no data	52	22	74	5.25	F	gravid	new	7700
12-Nov-02	no data	62	45	107	6.6	M	breeding	new	30
12-Nov-02	no data	52	41	93	5.00	F	gravid	**YES**	2700

Table 7b. Piney River Capture Data for Pond 3

Date	Pit	SVL (mm)	Tail (mm)	Total L	Wt (g)	M/F	Condition	Recap	Mark
16-Nov-02	no data	57	43	100	7	F	gravid	new	no data
30-Mar-03	O	51	37	88	5.75	M	breeding	new	300
17-Apr-03	1	no data	no data	no data	no data	M	waning breeding	new	no data
25-Apr-03	K	57	39	96	6.25	M	waning breeding	**YES**	4
25-Apr-03	K	59	41	100	7.25	M	waning breeding	**YES**	705
25-Apr-03	K	61	44	105	9	F	spent	new	706
25-Apr-03	K	55	35	90	5.9	M	waning breeding	new	707
25-Apr-03	K	60	36	96	6.9	M	waning breeding	new	708
25-Apr-03	L	59	25	84	7.25	F	spent	**YES**	7700
25-Apr-03	L	59	42	101	7.5	M	waning breeding	new	709
25-Apr-03	M	53	37	90	5.3	M	waning breeding	new	710
25-Apr-03	N	59	42	101	7.25	F	spent	**YES**	711 **2001:41**
25-Apr-03	O	61	31	92	7.25	M	waning breeding	**YES**	8
25-Apr-03	14	60	42	102	7.3	F	gravid	new	712
01-May-03	F	61	40	101	7.9	F	spent	new	721
01-May-03	N	59	38	97	6.9	F	spent	new	722
01-May-03	Q	57	36	93	6.25	M	waning breeding	new	723
01-May-03	S	56	41	97	7.1	F	gravid	**YES**	712
03-May-03	2	60	43	103	7.1	M	waning breeding	**YES**	30
03-May-03	4	59	43	102	6.1	F	spent	new	724

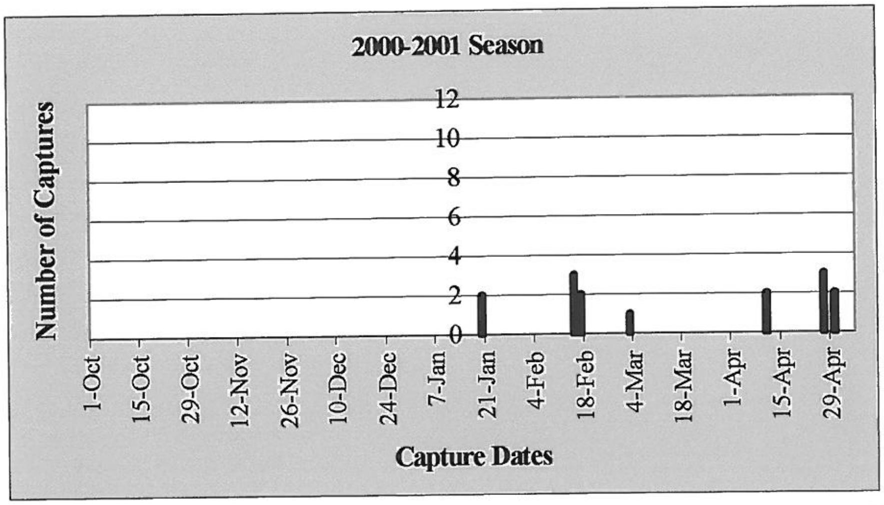
Table 7c. Piney River Capture Data for Pond 3

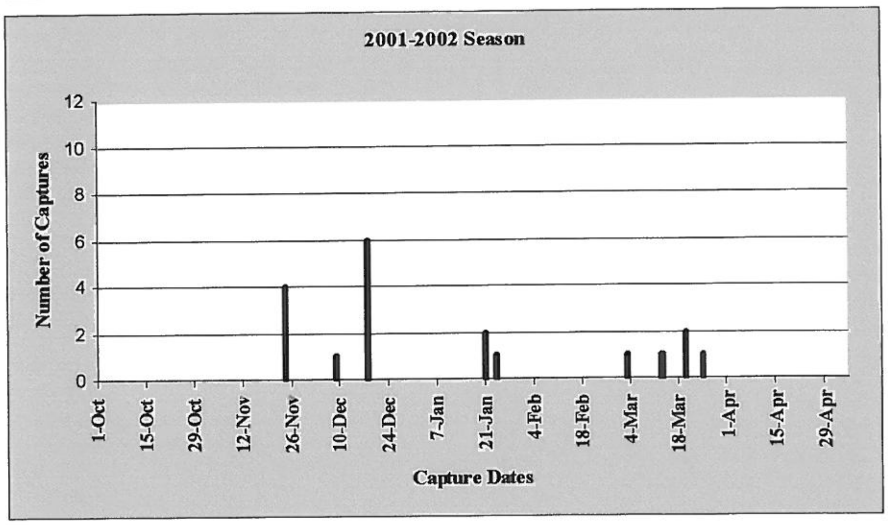
weight gain of 2.0 grams; this gain was in addition to being "spent" (i.e., having deposited her egg load). Though no gut analysis was conducted during the study, aquatic isopods, or sow bugs (Family *Asellidae*), were observed to be ubiquitous in these ponds and likely supply an important prey base for Moles during these long periods at the breeding site. This could explain the weight gains in certain animals.

In contrast to these long durations, female #2700 entered Pond 3 on 5 November 2002 and egressed on 12 November, after only one week. She had lost 0.5 grams of her egg load. The next spring, female #712 entered Pond 3 on 25 April 2003 and left on 1 May, after only one week. She showed no change in weight.

Where the 2002 season was a "boom" for Pond 3 Mole Salamanders, the fall of 2001 was characterized by a drought. Mole Salamanders arriving at Piney River breeding ponds in that fall found the ponds empty and were forced to remain on the site in fossorial refuges (tree root networks as noted at Ponds 3 and 6). They had to wait for 3-4 months (through the winter freeze) before water would fill the pools and permit reproduction to occur.

Capture dates indicate that the Mole Salamander in Virginia exhibits a bimodal migration season (Figure 10). Movement to breeding ponds occurred from mid-October through mid-December and then again from mid-January to early May. The migration season appears to be interrupted by the winter freeze for approximately four weeks. The length of this interlude depends on annual weather patterns.





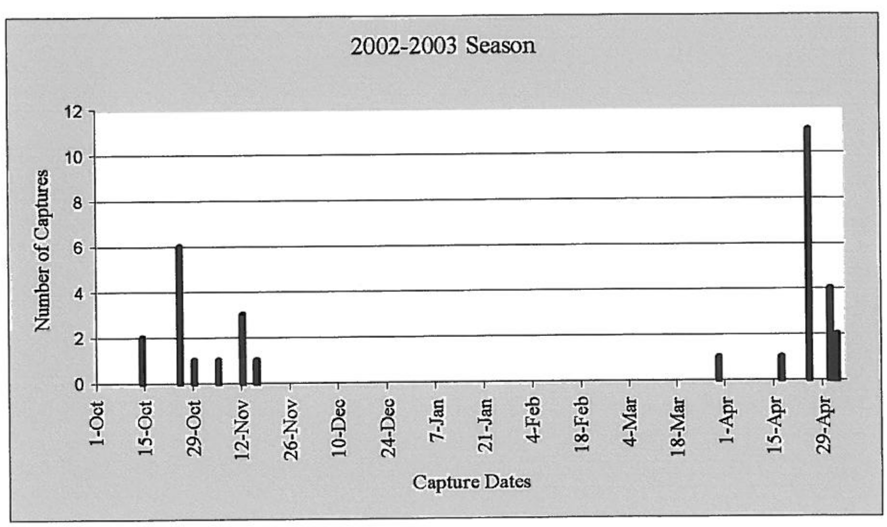


Figure 10. Three Years of Mole Salamander Migrations at Piney River Pond 3

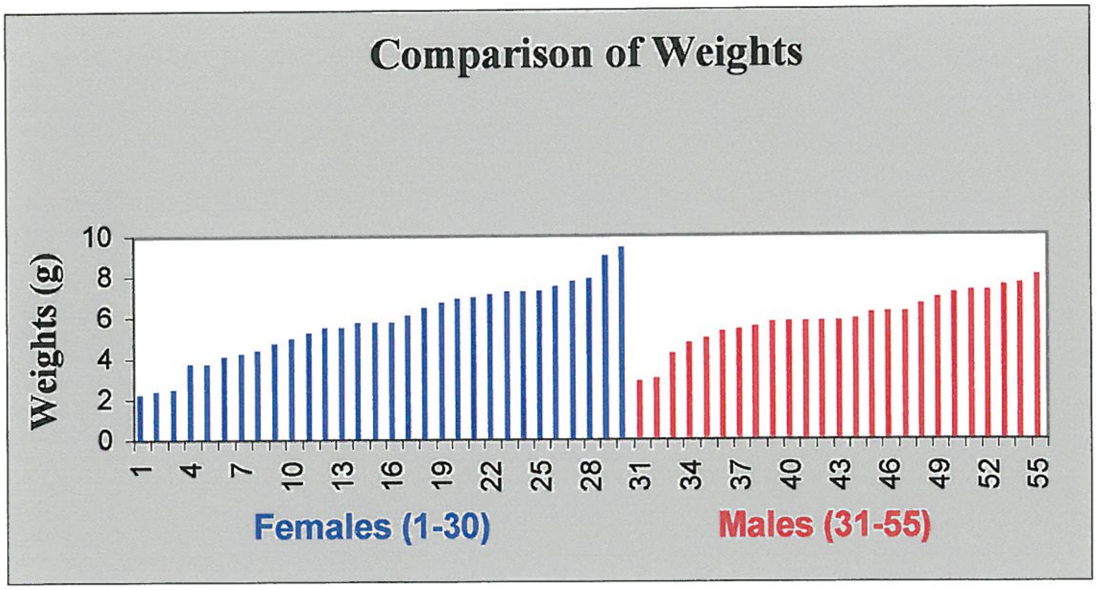
Date	Pit	Pond	SVL (mm)	Tail (mm)	Total L	Wt (g)	M/F	Condition	Recap	Mark
20-Mar-02	trap	1	56	40	96	6.75	M	brdng. (drowned)	**YES**	30
21-Mar-02	trap	1	ND	ND	ND	ND	ND	breeding	ND	ND
30-Apr-01	trap	2	57	45	102	6.8	F	trans. paed.	new	1005
30-Apr-01	trap	2	59	49	108	6	F	spent trans. paed.	new	7000
30-Apr-01	trap	2	47	51	98	6.5	F	trans. paed.	new	40
30-Apr-01	trap	2	45	54	99	5.8	F	trans. paed.	new	4
30-Apr-01	ND	2	54	43	97	5.25	F	spent trans. paed.	new	2000
25-Jan-02	trap	2	51	35	86	3.95	M	brdng. trans. paed.	ND	110
25-Jan-02	trap	2	60	44	104	6	M	brdng. trans. paed.	**YES**	50
25-Jan-02	trap	2	60	40	100	5.5	M	brdng. trans. paed.	ND	130
25-Jan-02	trap	2	64	46	110	7.75	M	breeding	ND	140
25-Jan-02	trap	2	54	39	93	5.5	F	gravid	ND	150
25-Jan-02	trap	2	66	48	114	8.25	M	brdng. trans. paed.	ND	101
25-Jan-02	trap	2	63	49	112	7.1	M	brdng. trans. paed.	ND	102
25-Jan-02	trap	2	57	42	99	6.2	M	breeding	ND	103
25-Jan-02	trap	2	57	37	94	5.28	M	breeding	ND	104
25-Jan-02	trap	2	50	30	80	3.8	F	spent trans. paed.	ND	105
25-Jan-02	trap	2	63	40	103	7	F	spent trans. paed.	ND	210
25-Jan-02	trap	2	58	43	101	6.25	M	breeding	ND	220
25-Jan-02	trap	2	46	30	76	3	M	breeding	**YES**	240
01-Mar-02	trap	2	54	40	94	4.5	M	brdng. trans. paed.	ND	230
01-Mar-02	trap	2	ND	ND	ND	ND	F	ND	ND	ND
21-Mar-02	trap	2	ND	ND	ND	ND	M	breeding	ND	ND
10-Dec-01	1	6	58	42	100	6.1	M	breeding	new	204
17-Dec-01	6	6	63	48	111	7.75	M	breeding	new	440
24-Jan-02	F	6	58	44	102	5.75	M	breeding	**YES**	240
19-Mar-02	B	6	63	42	105	7.3	M	brdng. trans. paed.	**YES**	440
19-Mar-02	7	6	50	30	80	4.46	F	gravid	new	202
09-Mar-02	trap	8	60	42	102	6	M	brdng. trans. paed.	new	240
20-Mar-02	trap	8	ND	ND	ND	6.9	M	brdng. trans. paed.	ND	204
21-Mar-02	trap	8	60	48	108	6.9	M	breeding	new	244
11-Oct-02	trap	8	52	33	85	5.1	F	gravid paed.	new	3
11-Oct-02	trap	8	55	47	102	6	F	gravid paed.	new	4
11-Oct-02	trap	8	54	45	99	5.75	F	gravid paed.	new	2
30-Mar-02	trap	14	ND	ND	ND	ND	ND	no data	ND	ND
30-Mar-02	trap	14	ND	ND	ND	ND	ND	no data	ND	ND
30-Mar-02	trap	14	ND	ND	ND	ND	ND	no data	ND	ND
30-Mar-02	trap	15	ND	ND	ND	ND	ND	no data	ND	ND
30-Mar-02	trap	15	ND	ND	ND	ND	ND	no data	ND	no data
30-Apr-01	ND	ND	51	36	87	4.3	F	spent	new	750

Table 8. Piney River Capture Data for Miscellaneous Ponds

Two recaptured individuals from Pond 3 showed an alternation of years for migration to their breeding pond. Female #400 immigrated to Pond 3 on 15 February 2001, did not appear as a capture during the 2001-02 season, but immigrated again on 25 October 2002. She was gravid both times and showed negligible size change in 2002. Female #41 left Pond 3 on 27 April 2001, was not seen the following year, but emigrated from Pond 3 again on 25 April 2003. She was spent and captured in the same pit on both occasions. She had gained 1.5 grams of weight and regrown nearly one centimeter of tail length during her absence.

No significant difference between Pond 3 males and females was noted for weights or total lengths (Figure 11). Pitfall captures at Pond 3 spanned a period from 20 January 2001 to 3 May 2003. Of 69 total captures made during that period (2.3 years), 56 specimens with complete data yielded 11 recaptures, for a 5.1% rate of recapture. The range of total lengths for this sample was 68-116 mm. The average total length for this sample of 56 specimens was 92 mm. In addition to the 69 total captures recorded from Pond 3, 40 Mole Salamander captures were made from other ponds within the Piney River complex (Figure 8).

The largest Mole Salamander reported during this study was a breeding male from Melrose in Campbell County. It measured 117 mm in total length and weighed 9.5 grams. By comparison, Smith (1961) reported a maximum total length of 114 mm from southern Illinois.



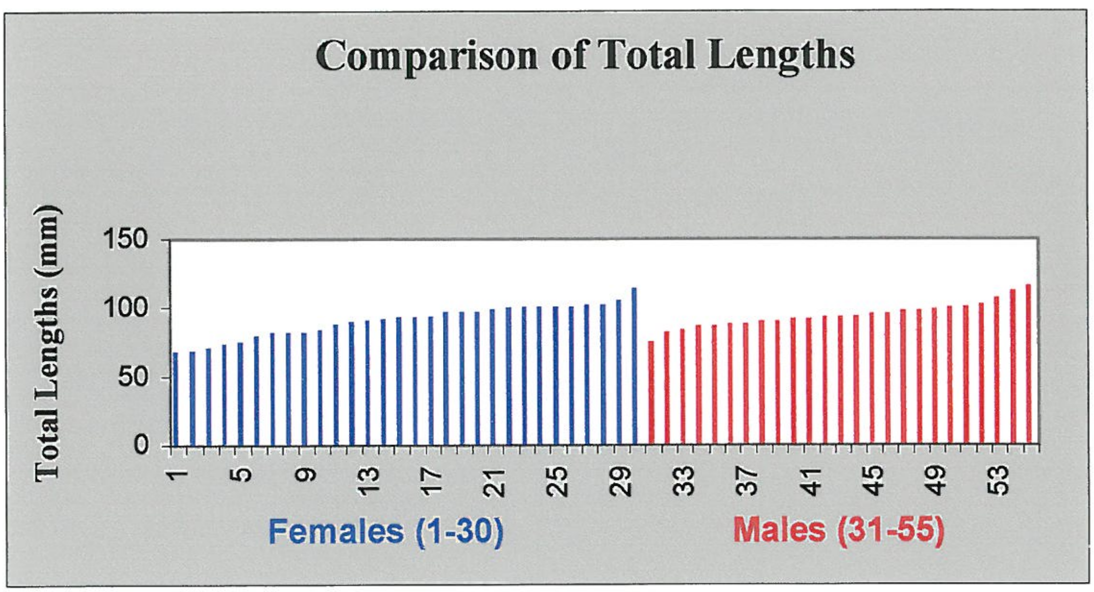


Figure 11. Comparison of Weights and Total Lengths for Females and Males from Piney River Pond 3 (January 2001-May 2003)

Discussion

Distribution

Numerous new distribution records for the Mole Salamander in Virginia were acquired as a result of this study. Five new county records were discovered during seven years of investigation throughout the state. In order of discovery they are: Pittsylvania, Amherst, Nelson, Appomattox, and Buckingham Counties. In addition, several known sites were revisited, and the discoveries of three other researchers were reviewed (Table 3). Those separate finds were: Appomattox County in March, 2003 (Mitchell, pers. comm.), Charlotte County in November 2002 and Campbell County in October 2003 (Rappleyea, pers. comm.) and Pittsylvania County in June 2003 (Gibson, pers. comm.). The range of the Mole Salamander in Virginia is clustered around the Danville Basin of the Triassic Lowlands, with the obvious exception of the Amherst/Nelson County site (Figure 8).

Floodplain pools along the James River in Buckingham, Nelson, and perhaps even Albemarle Counties could yield new finds. This river corridor, like the Piney River site, is fairly close to a band of Triassic Lowland. This idea is supported by a collection record for the Narrow-mouthed Toad (*Gastrophryne carolinensis*) from the Wingina area of Nelson County (Mitchell and Reay, 1999). This coastal plain frog species is also found in the interior of the state (especially in the Danville Basin of southern Pittsylvania County), and is regarded as a hypsi-thermal relict in the Virginia Piedmont, like the Mole Salamander (R. Hoffman, pers. comm.). Hypsi-thermal species extended their ranges northward during interglacial periods. The nearby James River Wildlife Management Area may harbor a third state-owned locality for the Mole Salamander.

The Piney River complex in Amherst and Nelson Counties represents the most significant site known in Virginia to date, because of the size and complexity of its Mole Salamander meta-population. The Piney River location is the northern most locality for the species and warrants further study and serious efforts to ensure its preservation. Examination of aerial photographs and further ground search could likely reveal additional ponds in the Piney River area, on the west side of the plateau and perhaps in the bottoms along the Piney River.

Numerous sites with the potential for Mole Salamander populations need examination. The region of the Charlotte-Campbell County line needs thorough surveying to locate and assess declining populations. This area has suffered from a long history of land clearing, but has a high number of disjunct populations. Glow trap sampling in late fall could prove effective.

The Stinking River area of Pittsylvania County should be re-examined, as Mole Salamanders are likely present in the area. Forests in this area are threatened by forthcoming land-use changes (extensive timbering). The bluffs and bottomlands of the Banister River warrant further search, as do forests northeast of Mt. Airy. A high-quality, Sweet Gum swamp (*Liquidambar styraciflua*) which its large and hummock-filled character was found by D.L. Dawson along Glade Road on Mead-Westvaco Corporation land in northeastern Pittsylvania County. This site is near a known Mole Salamander population and likely supports Mole Salamanders as well, in addition to a sizeable Spotted Salamander population (Cheater, 2001). Gibson's site in Pittsylvania County is the southernmost location in Virginia and closest to the disjunct population in North Carolina (Braswell, 1977).

The Danville Basin in Pittsylvania County has more habitat appropriate for the Mole Salamander than perhaps any other area of Virginia. The Culpepper Basin area of Loudoun, Prince William, and Fairfax Counties offers a comparable region of isolated wetlands, but is apparently too far north for the species to occur.

Future survey sites have been identified in every Virginia County where the Mole Salamander is now known to exist. Examples include the headwaters of Cub Creek and the Appomattox River in Appomattox County. The south bank of the Staunton River likely holds a Halifax County record waiting to be found.

Paedomorphs

The discovery of paedomorphic individuals represented a new find for Virginia. Paedomorphism had not been previously reported in any species of the family *Ambystomatidae* (J. Mitchell, pers. comm.). The Tiger Salamander *(Ambystoma tigrinum)* exhibits paedomorphism in other states throughout its range but has not been shown to do so in Virginia.

During the course of this study paedomorphs were found in four Counties: Campbell, Amherst, Nelson, and Buckingham. They likely occur in others. The first specimen was found at Melrose in Campbell County on 21 February 1997. Numerous additional paedomorphs were collected from the Minnow Pool at the Melrose site. The one individual that deposited fertile eggs yielded significant information on the chronology of egg development (Table 5) and her subsequent transformation to terrestrial form. This clutch, consisting of 190 eggs that were laid singly, was consistent with other records (Mosimann and Uzzell, 1952; Raymond and Hardy,1990).

Recently transformed paedomorphs were usually identifiable by a characteristic pair of yellow ventral stripes. These stripes are distinctive to paedomorphs (Semlitsch and Gibbons, 1985). As observed in the lab and in the field, paedomorphs retain pale remnants of those stripes, suggesting that transformed paedomorphs can be distinguished by these persistent stripes, at least for a time following their transformation to terrestrial adults. This was noted in numerous captures at Piney River. Two paedomorphs from Pond 2 (which dried out during the 2002 summer drought) were later captured as terrestrial adults at nearby Pond 3. These individuals possessed the characteristic ventral stripes.

Populations with semi-permanent ponds within their range can exhibit paedomorphism to enhance their survival (Semlitsch, 1987). Sites with wetlands that allowed for this strategy appeared to harbor the largest and healthiest populations.

Breeding Biology

Many of this study's findings support (and a few supercede) information presented in the Mole Salamander overview in *Salamanders of North America and Canada* (Petranka, 1998). The breeding season length of 108 days reported by Hardy and Raymond (1980) was exceeded by a number of individuals from Piney River. The longest duration of a Mole Salamander at a breeding site during this study was 181 days.

The earliest immigration date of 8 November, from southern Illinois (Smith, 1961) was preceded by captures at the Piney River site during the "wet" fall of 2002. The earliest immigration date reported in this study was 14 October (2002). The latest emigration date reported in this study was 3 May (2003). Above normal rainfall during the fall and winter of 2002-03 provided suitable conditions for early immigration, long in-pond durations, and late emigrations. These dates represent the only other apparent notes on migration dates from a site of comparable northern latitude within the species range (Smith, 1961).

Contrasts in migration dates and breeding site durations at the Piney River site (2001-02 versus 2002-03) support the idea that environmental variations are the primary factor affecting Mole Salamander migration times and breeding season lengths (Semlitsch, 1985). The summer/fall drought of 2001 caused immigrants to arrive later in the season. They were unable to breed due to a lack of water in the ponds until late January 2003, the breeding season lasting only two and a half months. In contrast, many individuals arrived early during the wet fall of 2002, stayed longer, and were able to breed throughout a season that lasted for about six and a half months.

Early in this study it appeared that Mole Salamander activity withdraws into the background during the "assault" of Spotted Salamander breeding. As Spotted Salamanders emigrate, Mole Salamanders then resume their activity in the pools they share with these congenerics. Mole Salamander migrations in Virginia appear to typically be facilitated by a cold front with sustained rains and temperatures in the 40-45° F range. This is consistent with other studies (Shoop, 1960).

Mole Salamanders are apparently poor competitors with Spotted Salamanders and therefore will not be abundant in pools where Spotted Salamanders abound. This study found Mole Salamanders most abundant in ponds with lower Spotted Salamander numbers or in more permanent waters where paedomorphs could exist.

Conservation

Loss of habitat represents the greatest threat to the Mole Salamander in Virginia (Mitchell in Terwilliger, 1991). Clearing of bottomland and upland forests that surround known breeding sites will cause the decline and eventual loss of certain populations. These buffering forests are critical as residential habitats for breeding adults and for regulating the hydro-period of breeding ponds. The aquatic component of Mole Salamander habitat can be restored or replicated, but forest clearing tends to destroy breeding adults outright and degrade populations severely over time. Examples of this loss of habitat within the range of known Mole Salamander populations were noted in nearly all locations surveyed. Protection of forests adjoining Mole Salamander breeding sites is essential to the conservation of this species in Virginia (Mitchell in Terwilliger, 1991).

The area to the immediate north of the first Spring Garden site in Pittsylvania County was slated for a residential development in 1998. Extensive areas of cleared forest to the northwest of this site contributed to the vulnerability of this population. Similar pools were found denuded of their forest cover. Flooded pastures on the southeast side of this escarpment and the river suggest that these bottomlands historically held many of these forested wetlands and Mole Salamanders were likely common here. Unfortunately, the isolated wetlands observed on the west shoulder of VA 663 were surrounded by extensive clear-cutting, and the planned residential lots further jeopardized the future of the Mole Salamander population discovered at this site.

The loss of the tobacco farming tradition of this region also threatens the mature forests that have not been surveyed for this special concern species. Tobacco farming utilizes a small percentage of acreage on farms and the forests have remained undisturbed for nearly a century, but the loss of tobacco farming income has encouraged the liquidation of timber on many farms. This was the scenario observed in the Stinking River area of Pittsylvania County in 1998. An extensive, fiber optics cable right-of-way (cutting through Triassic forests) also eliminated and separated much potential habitat. These impacts all seemed to foreshadow a large-scale shift in land use, to more suburban settings (primarily residential development), leaving the future of the southern Danville Basin area for the Mole Salamander uncertain.

There are only three sites currently known where Mole Salamanders exist on public-owned lands in Virginia (one federal, two state-owned properties). Even here, their protection is subject to awareness and management priorities. The majority of Mole Salamander sites in Virginia are located on privately owned lands and are afforded no protection or conservation voice, save grassroots efforts to inform. Acquisition of or easement on some of these lands could help preserve valuable habitat for this state-rare species. The two best candidates for this conservation strategy are the Campbell and Amherst/Nelson County sites.

The site of the Melrose pool complex is partially owned by the Norfolk Southern Railway Corporation and serves no functional value to them, other than standard right-of-way. This site is adjacent to the 10-mile State Scenic River section of the Staunton River and could conceivably be added as a satellite to that preserve, by the Virginia Department of Conservation & Recreation, through a conservation easement.

The Piney River system includes sites where two private owners have expressed interest in the species conservation. In addition, the industrial quarry, where most of the Mole Salamander population exists, also has a history of conservation sympathy. This area is ripe for an easement that could unite these owners to protect the most significant Mole Salamander location in the Commonwealth of Virginia.

An important conclusion of this study is that it appears evident that those populations which posses semi-permanent to permanent breeding ponds within their range are the most successful. To date, the most significant site known for Virginia (Piney River in Amherst and Nelson Counties) has three or more such ponds. This has important, practical conservation implications for the Mole Salamander in Virginia.

The provision of fishless, permanent-water ponds within the range of existing populations could bolster their recruitment capabilities. Creating such permanent-water ponds would enable Mole Salamander populations to monopolize paedomorphism as a survival strategy. This could be particularly beneficial to those populations that are experiencing severe impacts. This conservation practice is now receiving attention as a viable option (Biebighauser, 2003). Examples where artificially created or enhanced pools provided such an advantage to Mole Salamanders were found during this study in Campbell, Amherst, Nelson, Buckingham, and recently Pittsylvania (J. Gibson, pers. com.) Counties.

Several sites in Charlotte, and one in neighboring Campbell County suffer impacts from road mortality as migrating adults attempt to enter ponds separated from their residential forest habitat by paved roads. Amphibian underpasses have been used successfully to mitigate this impact but are expensive and mostly unprecedented in Virginia. Site modifications (such as relocation/recreation of the breeding facility to intercept migrating salamanders before they cross roads) are a complex undertaking but merit experimentation for severe cases where few alternatives exist.

Assisted salamander road crossings by grassroots groups have been used successfully in Virginia (e.g., Central High School in Lunenburg Co.) and elsewhere, but these require local contacts to orchestrate, champion, and sustain for effectiveness.

Though this special concern species is now known from many more localities than previously thought, assumptions about its security should be cautioned. Mole Salamander numbers were observed to be consistently low throughout investigations at all sites during this study. Some population numbers appeared dangerously low, especially in contrast to their congeneric competitors. Very limited recruitment of young Mole Salamanders was observed during this study (i.e., few metamorphs were captured in pitfalls at Pond 3, and observations of aquatic larvae there were also limited).

Populations with low numbers are at risk of extirpation from both natural and anthropogenic effects. The total number of Mole Salamanders encountered at all sites during this study was under 200 individuals.

A continued recommendation of "threatened status" for this species in Virginia seems advisable.

Literature Cited

Bader, R. N., and J. C. Mitchell. 1982. Geographic distribution: *Ambystoma talpoideum. Herpetological Review* 13:23.

Biebighauser, Thomas R. 2003. *A Guide to Creating Vernal Ponds*. Published by the USDA Forest Service in cooperation with Ducks Unlimited, Inc. and the Issac Walton League of America; 36 pp.

Branch, L.C., and R. Altig. 1981. Nocturnal stratification of three species of *Ambystoma* larvae. *Copeia* 1981: 870-873.

Braswell, A. 1977. *Ambystoma talpoideum* (Holbrook), mole salamander. Pp. 318-319 in: J.E. Cooper, S.S. Robinson and J.B. Funderburg (eds.), Endangered and threatened plants and animals of North Carolina. Raleigh: North Carolina State Museum of Natural History.

Conant, R., and J.T. Collins. 1991. A Field Guide to Reptiles and Amphibians of Eastern and Central North America, 3rd Edition. Houghton Mifflin, New York, 450 pp.

Eggleston, D.W. 1999. Robert N. Bader: A Personal Profile of a Unique Herpetologist: Part Two. Reptile Report: The Blue Ridge Herpetological Society Newsletter. Vol. 9 No. 1, March/April 1999.

Hardy, L.M., and L.R. Raymond. 1980. The breeding migration of the mole salamander, *Ambystoma talpoideum*, in Louisiana. *J. Herpetol.* 14:327-335.

Hayslett, M.S. 1995. Field notes: *Rana sylvatica* (Wood Frog). *Catesbeiana* 15(2):51-52.

Hayslett, M.S. 1996. Field notes: *Ambystoma talpoideum* (Mole Salamander). *Catesbeiana* 16(1):22-23.

Mitchell, J.C. in Terwilliger. 1991. Virginia's Endangered Species. McDonald and Woodward Publishing Company.

Mitchell, J.C. and K.K. Reay. 1999. Atlas of Amphibians and Reptiles in Virginia. Special Publication Number 1. Wildlife Diversity Division, Virginia Department of Game and Inland Fisheries. Richmond, VA.

Mosimann, J.E., and T.M. Uzzell, Jr. 1952. Description of the eggs of the mole salamander, *Ambystoma talpoideum* (Holbrook). Chicago Academy of Sciences, Natural History Miscellany 104.

Pague, C. A., and J. C. Mitchell. 1987. The status of amphibians in Virginia. *Virginia Journal of Science* 38:304-318.

Pague, C. A., and J. C. Mitchell. in Terwilliger. 1991. *Virginia's Endangered Species.* McDonald and Woodward Publishing Company, pp. 429-431.

Petranka, J.W. 1998. Salamanders of the United States and Cananda. Smithsonian Institution Press, Washington, D.C. 587 pp.

Raymond, L.R., and L.M. Hardy. 1990. Demography of a population of *Ambystoma talpoideum* (Caudata: Ambystomatidae) in northwestern Louisiana. *Herpetologica* 46:371-382.

Semlitsch, R D. 1985. Analysis of climatic factors influencing migrations of the mole salamander (*Ambystoma talpoideum*). *Copeia* 1985:477-489.

Semlitsch, R D. 1987. Relationship of pond drying to the reproductive success of the salamander *Ambystoma talpoideum. Copeia* 1987:61-69.

Semlitsch, R.D., and J.W. Gibbons. 1985. Phenotypic variation in metamorphosis and paedomorphosis in the salamander *Ambystoma talpoideum. Ecology* 66:1123-1130.

Shoop, C.R. 1960. The breeding habits of the mole salamander , *Ambystoma talpoideum* (Holbrook), in southeastern Louisiana. *Tulane Studies in Zoology* 8:65-82.

Smith, Phillip W. 1961 (reprinted 1986). The Amphibians and Reptiles of Illinois. Illinois Natural History Survey Division, Volume 28, Article 1; pp. 33-35.

Twitty, V. C. 1966. Of Scientists and Salamanders. Freeman, San Francisco.