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Natural History and Conservation Biology of a Southern West Virginia Contour Surface Mine Reptile and Amphibian Community

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by

Zachary James Loughman

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Abstract

NATURAL HISTORY AND CONSERVATION BIOLOGY OF A SOUTHERN WEST VIRGINIA CONTOUR SURFACE MINE REPTILE AND AMPHIBIAN COMMUNITY

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During the 2004-2005 field seasons, natural history of a herpetofaunal community was studied on an abandoned contour surface mine in Eccles, Raleigh County, West Virginia. This study is the first natural history investigation of amphibian and reptile populations present on an abandoned mine site. Specific natural history parameters for each order on the mine were investigated to determine what effect the post mining landscape had on herpetofaunal communities. Pond breeding caudates population success was dependent on life history parameters. Anurans were efficient at re-colonization, with 12 of a possible 14 species collected on the mine site. Anuran diversity was linked to niche partioning. Testudine populations were limited by the mine's landscape, and were not successful at colonizing the mine. Ophidians utilized the mine seasonally when mine thermal regimes did not lead to physiological stress. Overall, the mine favored reptiles and amphibians that displayed generalist species characteristics and favored "*R*" selection.

Acknowledgements

The amount of acknowledgment to the many people who assisted me throughout the duration of my thesis is endless. Given the hard, brutal nature of working on an abandoned mine site in burning summer heat, torrential pop up thunderstorms, and on cold spring days, the fact that people voluntarily went onto the mine with my obsessive personality alone is worth acknowledging the entire Marshall herpetology lab. Specific people assisted me to a point of special recognition. Bill Sutton and Deborah Merrit helped me with initial mine surveys, and construction of a quarter mile of drift fence. Bill's pep talks early on in the research helped me get through some initial discouragement, thanks a bunch for that! Jamie Sias helped me more than anyone else during the summer portion of this research. I truly enjoyed introducing you to "Zac's Method" of doing things in the field, and the fact you would do what I asked when I asked was well respected and noticed. Thank you very much for your help!

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The Schrader center's staff has been incredibly supportive of me during the latter portion of this endeavor. Actions like letting me take time off of work two write to showing interest in my overall well being let me know that you care about me as a person, and not just an employee. Thank you Scott, Greg, Jessi, Jane and Erics. The West Virginia Department of Natural Resources Heritage Program funding enabled me to do this research with proper equipment and financial compensation. I would like to thank Jennifer Wykle of the WVDNR for putting up with my constant barrage of questions during this and other projects. Thank you very much for your patience.

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Chapter 1

Natural History and Reproductive Biology of Pond Breeding Salamanders on an Abandoned Mine Land in Southern West Virginia

Zachary Loughman

Abstract

Amphibian decline is an area of increased conservation concern in Appalachian ecosystems. While stream and forest species have received considerable attention, pond-breeding species have not received the attention they deserve. Surface mining efforts represent an important ecological disturbance within the Appalachian region. An abandoned surface mine in Eccles, Raleigh County, West Virginia was surveyed for pond breeding salamander species utilization of mine lands for breeding purposes. Haphazard searches and aquatic trapping during peek breeding activity were utilized to capture salamanders. Two species, *Ambystoma maculatum* and *Notophthalmus v. viridescens*, were the only species captured during this study. *Notophthalmus v. viridescens* were present in all aquatic macrohabitats, and were successful at reproducing on the mine. All demographic groups (larvae, efts, and adults) were captured on the mine. *Ambystoma maculatum* reproduced in all aquatic macrohabitats, but demonstrated preference for lentic habitats close to forest edges. Egg masses and adults were observed on the mine, with no larvae captured or observed. The mine was detrimental in reproductive success for this species. The true factor leading to low reproductive success was not identified, and is an area in need of future investigation. Possible hypothesized factors include life history strategy parameters and fluctuations in the mines abiotic environmental conditions during the early spring season

Introduction

Global amphibian decline is a pressing issue in conservation biology today. Several causal agents have been identified including global warming, habitat degradation, parasites and increases in UV radiation (Semlitsch 2003). Most biologists agree that one of the above decline vectors is not more important than another, and the root of amphibian decline lies in synergistic relationships between these vectors. Declines in eastern North America have been documented several times over, with their origin identified in specific instances (Semlitsch 2003). Habitat degradation, fragmentation and destruction along with air and water pollution were likely the most pressing effects driving the eastern North American declines (Semlitsch 2003).

Mining practices present an interesting problem for amphibians living in mined areas. Surface mining practices initially involve clearing the land of vegetation, and ultimately end with the removal of a mountain side (contour strip mining) or the majority of a mountains vertical profile (mountain top mining). Reclamation efforts dictate that all wetlands destroyed during mining efforts be replaced with anthropogenically created wetlands. Mining operations are responsible for controlling heavy metal lichgates exposed from minerals during the active mining period. Retention pools are created to trap heavy metals lichgates after rain events and during times of high water. Creation of post-mining lentic water bodies warrants colonization of pond-breeding amphibians that survive mining efforts or immigrate onto mine lands in the post activity environment.

Few scientific investigations have determined if mine wetlands are successfully colonized by pond breeding salamanders. Retention ponds are created with the surrounding watershed in mind, and not the pond breeding amphibian community present in the immediate environment. The major mining importance of anthropogenically produced wetlands is to trap heavy metals and other pollutants from escaping into the surrounding watershed. Mercury and other heavy metals reach high levels in retention pool waters and sediments. Effects, if any at all, that these heavy metals might have on salamander colonization rates have not been documented to date.

Surface mining also lends itself to creating wetlands, given that impermeable surfaces are left behind after mining efforts are completed. Bench low points hold water, which then gather soils, ultimately resulting in the creation of marshes and bogs. These wetlands are not present to target heavy metal deposition, and occur through natural succession events which may ultimately lend themselves more to amphibian colonization than anthropogenically created wetlands. The purpose of this investigation is to document the salamander community present on an abandoned strip mine in southern West Virginia, and to determine how different salamander species utilized various wetland habitats present within the mines landscape.

Methods

Salamanders were captured using a variety of methods. Haphazard searches were performed during diurnal and nocturnal hours for both larval and adult salamanders. Capture methodologies employed during haphazard searches included dip netting, turning cover objects, and hand collection. Duration of haphazard searches was 1-3 hours.

Minnow traps were placed in the following 5 mine aquatic environments: disturbed marsh, naturalized marsh, outlet pool, roadside ditch, *Typha* marsh. Comparisons were made between macrohabitat types to determine which habitats are most important to lentic salamander species. Number of traps used per location was calculated from the total surface area of a given wetland, with 1 trap placed every 10 m^2. All captured salamanders were identified to species. Data collected on each post larval salamander included snout-vent length (SVL), tail length (TL), total body length (TBL), cranial width (CW), sex, and any individual characteristics of note.

Trapping time was early to mid spring to capture explosive spring breeders (*Ambystoma maculatum*). Permanent lentic species (*Notophthalmus viridescens*) were also active and breeding at this time as well.

Results and Natural History

Ambystoma maculatum / Spotted Salamander

Ambystoma maculatum on the Eccles mine were typical in appearance of their species. Three color-phases were present: typical phase, orange spotted phase, and light colored phase (Colburn 2004). Males were smaller than females, with an average SVL of 87.6 mm, and an average TBL of 123.7 mm . Female SVL and TBL averaged 99.6 mm, and 138.7 mm respectively.

Ambystoma maculatum are noted for being explosive early-mid-spring breeders, following this trend on the Eccles mine (Petranks 1998). Peek breeding time was 23 March 2005 with steady declines in captures over the following 14 days. All breeding activity ceased by 5 April 2005. At this time, surface debris near all macrohabitats were turned, unveiling no additional *A. maculatum*. This likely indicates adult maintenance behaviors (burrowing) were initiated immediately following breeding efforts on the mine (Husting 1965, Paton 2000).

Egg masses were discovered in all 5 macrohabitats. The number of egg masses present in a water body was loosely correlated ($r^2 = 0.8201$) to the distance of the water body to forest edges (Figure 3). Water bodies closest to forest edges had higher egg mass counts. Water quality and complex riparian habitats did not appear to be the major determining factor for *A. maculatum* breeding efforts.

Though hundreds of egg masses were observed during the 2004 and 2005 spring season, no *A. maculatum* larvae were captured. Large numbers of egg masses went full term, but died in the last pre-hatching larval stages. Egg masses were observed with iron deposits throughout the masses matrix. Algae also were observed in several masses, specifically in the region of each follicles yolk sac. No larval *A. maculatum* were captured or observed during the duration of this study.

Adult *A. maculatum* did not display any morphological abnormalities. This species in particular has been noted in recent years for various anatomical abnormalities derived from various environmental factors (Petranka 1998). Snout-vent length histograms on adults (Figure 1) indicate recruitment is occurring. Future investigations of this population are needed to determine if (1.) egg masses hatch in future seasons and if (2.) adult recruitment is occuring from the mine or neighboring metapopualtions.

Notophthalmus v. viridescens / Eastern Red Spotted Newt

Notophthalmus v. viridescens was the most abundant caudate species on the Eccles mine. *Notophthalmus v. viridescens* were typical of their species, with the dominate olive green adult morph present on the mine (Petranka 1998). There were no significant differences in SVL or TBL between the sexes, with female SVL and TBL averaging 58.2 mm and 85.1 mm, and male SVL and TBL averaging 56.2 mm and 83.4 mm. Beginning in early spring, males started exhibiting secondary sexual characteristics. Black, corneous nuptial pads appeared on the inner thighs of adult males. Male’s tails also developed large dorsal and ventral tail fans. Females at this time were obviously gravid, exhibiting large swellings in the posterior region of their abdominal cavity.

Notophthalmus v. viridescens breeding reached its peek following *A. maculatum* breeding times, between 25 March through 25 April. *Notophthalmus v. viridescens* were ambiguous in macrohabitat use, utilizing all lentic macrohabitats on the mine for breeding**.** Limiting factors for aquatic macrohabitat use appeared to be total area of a wetland, with *N. v. viridescens* using water bodies with varying distances to forested corridors.

Breeding behaviors were observed several times on the Eccles mine, indicating breeding occurred during both diurnal and nocturnal hours. Males would grasp females with their hind limbs around the female's shoulders. Immediately following grasping behaviors, males would take their tail and fan water in the direction of the females head. Previous research has determined that males use their tails fans to fan pheromones to pheromone pores located in the females skull (Bishop 1965). *Notophthalmus v. viridescens* lay individual eggs, so egg masses could not be counted for this species.

All *N. v. viridescens* larval stages were observed on the Eccles mine. Peak larval behavior occurred for the first 2-3 hours after night fall. At this time, larvae would move vertically through the water column, from the benthos of a water body to the nekton zone. On several occasions larval *N. v. viridescens* were observed feeding on *Daphnia*, copepods, and other small invertebrates. *Notophthalmus v. viridescens* larvae also were observed in one instance cannibalizing smaller conspecifics. Larvae were collected in all aquatic macrohabitats on the mine.

Terrestrial stage of *N. v. viridescens* (Red Eft) were collected in forested regions on the mine, particularly in railroad track environments. Eft activity peaked immediately following precipitation events (6 May – 18 June), and during times of low pressure and low temperatures (16.6 C). Eft mass migration behaviors were not observed during this study.

Adult *N. v. viridescens* were the most successful caudate species on the mine. Adults were observed feeding on macroinvertebrates and *A. maculatum* egg masses. *Notophthalmus v. viridescens* adults also did not demonstrate a particular 24-hour behavioral cycle, with adults captured all hours of the day and night. Adults were only observed outside of water immediately following precipitation events. These animals likely were migrating to various water bodies on the mines surface. *Notophthalmus v. viridescens* are quite toxic, with no predation events recorded for *N. v. viridescens* during the duration of this study (Pauley & Green 1987). *Notopthalmus v. viridescens* age histogram were bell shaped indicating that *N. v. viridescens* population on the Eccles mine was stable (Figure 2).

Discussion

A. maculatum and *N. v. viridescens* were the only pond-breeding salamanders present on the mine. *Ambystoma jeffersonianum* and *A. opacum* have been recorded from the area, but no distributional records placed them within 10 km of the Eccles mine, indicating that they probably were not present during pre-mining times. Of the species that were present, *N. v. viridescens* was successful at reproducing on the mine, while *A. maculatum* produced several egg masses with little to no hatching success.

N. v. viridescens in the literature have been documented a multitude of times for their success at colonizing degraded systems (Petranka 1998, Semlitsch 2003). Physiological adaptations such as advanced lymphatic systems, semi-permeable skin layers, and a large critical thermal maxima range all enable this species to live in degraded habitats. *N. v. viridescens* also are noted for traversing across the landscape frequently when abiotic conditions in their ponds reach detrimental levels (Petranka 1998). Within the mine proper, these events likely occur when temperature, pH, or various chemical levels reach levels that place *N. v. viridescens* under physiological stress.

A. maculatum represents an altogether different life history strategy. While *N. v. viridescens* breed through out the spring season, *A. maculatum* breed over a very short period of time.This short window results in a surge of adult surface activity in the early spring, and then an ebb in surface activity throughout the remaining period of the year. Eggs and larvae do not have the ability to exit ponds and move when physiological stressors appear. Temperature and pH have both been documented in mass *A. maculatum* egg mass kills (Ireland 1989, Stangel 1988). Both of these factors were not stable abiotic factors on the Eccles mine. Acid mine drainage (AMD) was present along high walls bordering the bench. When increased precipitation events occurred throughout the spring season, AMD leaked into all major aquatic macrohabitats resulting in acidic water conditions. Temperature also peeked given the shallow nature of the majority of wetlands present.

A. maculatum adults however appeared in large numbers. Given that no larvae were captured over a two-year period, where did these adults come from? *A. maculatum* recapture studies indicate that these salamanders are long lived organisms (Homan *et al* 2003). Age estimates for this species indicate that on average if an *A. maculatum* survives the first 2-3 years of life, it is not uncommon for them to live as long as 50 years . Demographic studies of the mines *A. maculatum* population indicate that older age cohorts were the dominate cohorts for the mine (Figure 1). These animals may have metamorphosed in the mines wetlands when abiotic conditions were suitable, and then returned to their natal ponds and reproduced when abiotic conditions were not suitable for embryonic development.

Given the abundance of breeding sites within the mines boundaries, and the fact that no larvae were captured or observed, the mines presence ultimately may be detrimental to *A. maculatum* greater population in the Eccles area. Previous studies on breeding site fidelity showed that the majority of *A. maculatum* migrate from brumation sites to their natal ponds (Homan et al 2003, Pauley & Green 1987). A small subset of the populations, usually 5-10%, switch over to the first pond they come in contact with (Colburn 2004). Utilizing this breeding strategy results in decreased genetic homozygosity by adding new genetic materials into every metapopulation year after year. If these new animals are successful in their breeding efforts, they then adopt their new ponds, and do not return to their natal ponds. If the Eccles mine site is truly detrimental, then this works against this breeding strategy, with breading events on the mine ultimately leading to very little recruitment to the overall *A. maculatum* population.

The true reason for the lack of breeding success on the Eccles mine was not determined, and is an area in need of future research efforts. This event ultimately could be an isolated incident, or could be a common occurrence on abandoned mine lands. Given that *Rana sylvatica* also did not reproduce successfully on the Eccles mine, and is the other obligate early spring breeding amphibian, this seasonal breeding demographic warrants future investigation on abandoned mine lands across southern Appalachia.

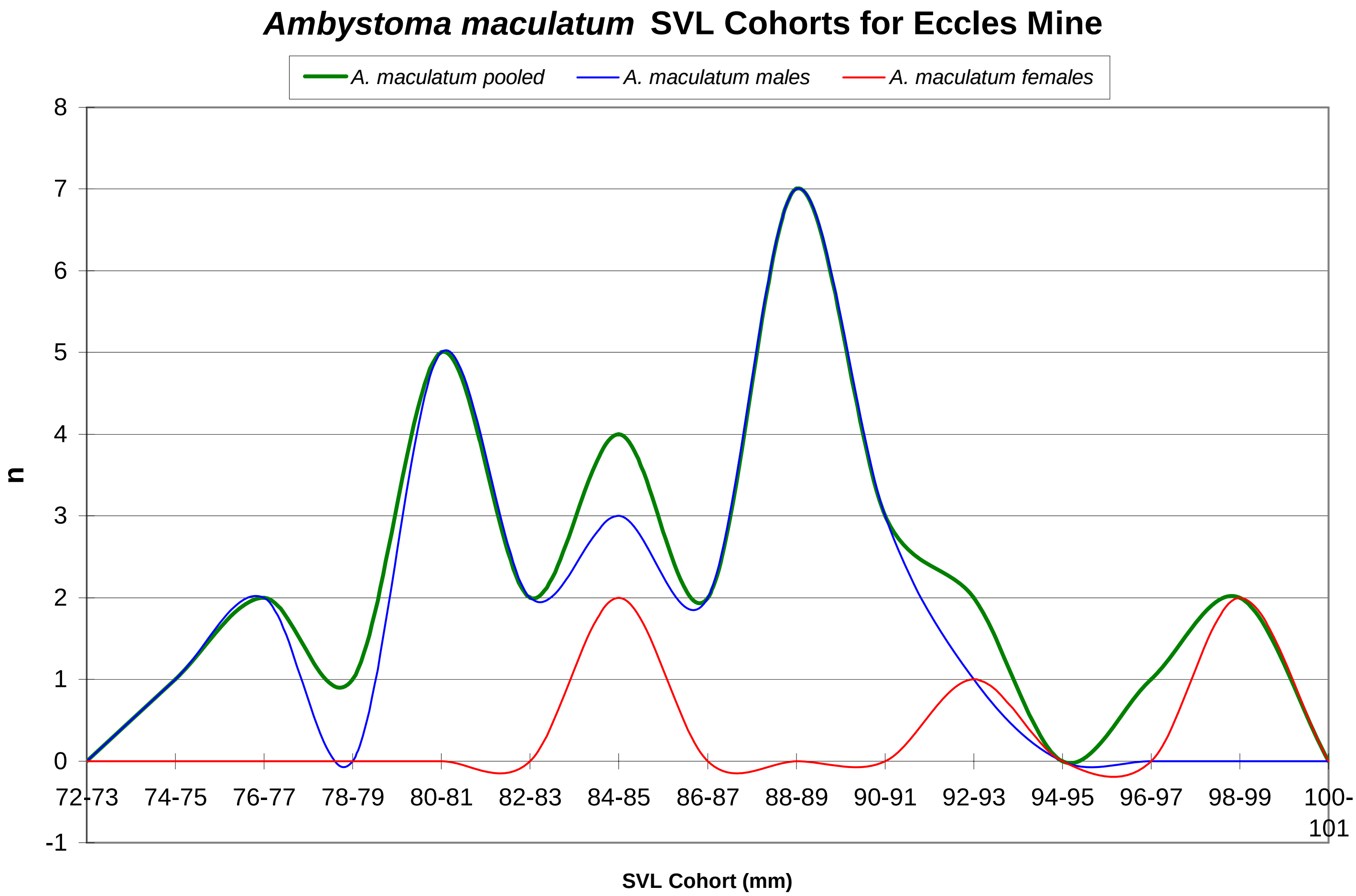

Figure 1: *Ambystoma maculatum* snout vent length (SVL) distribution

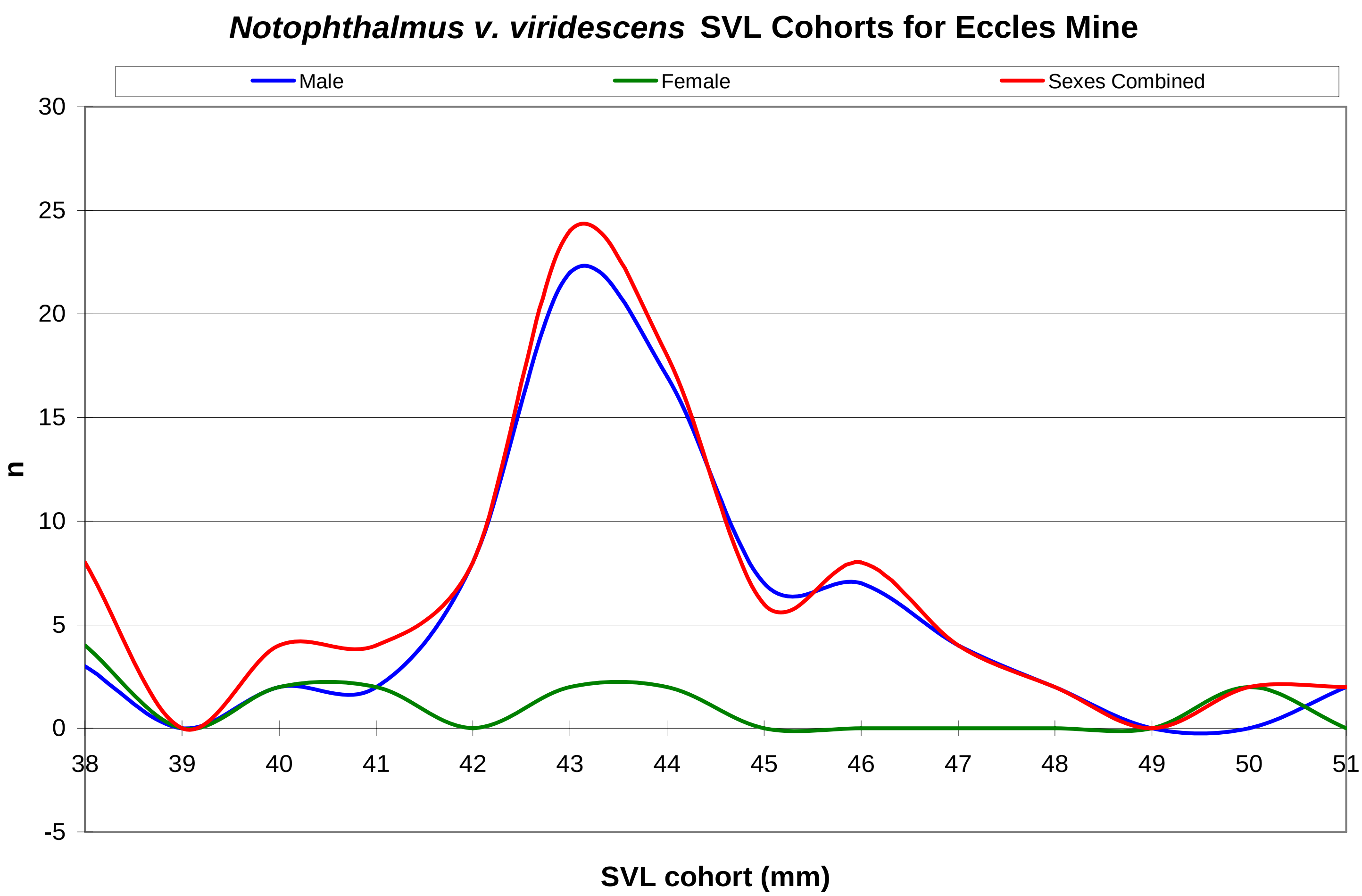

Figure 2: *Notophthalmus v. viridescens* snout vent length (SVL) distribution

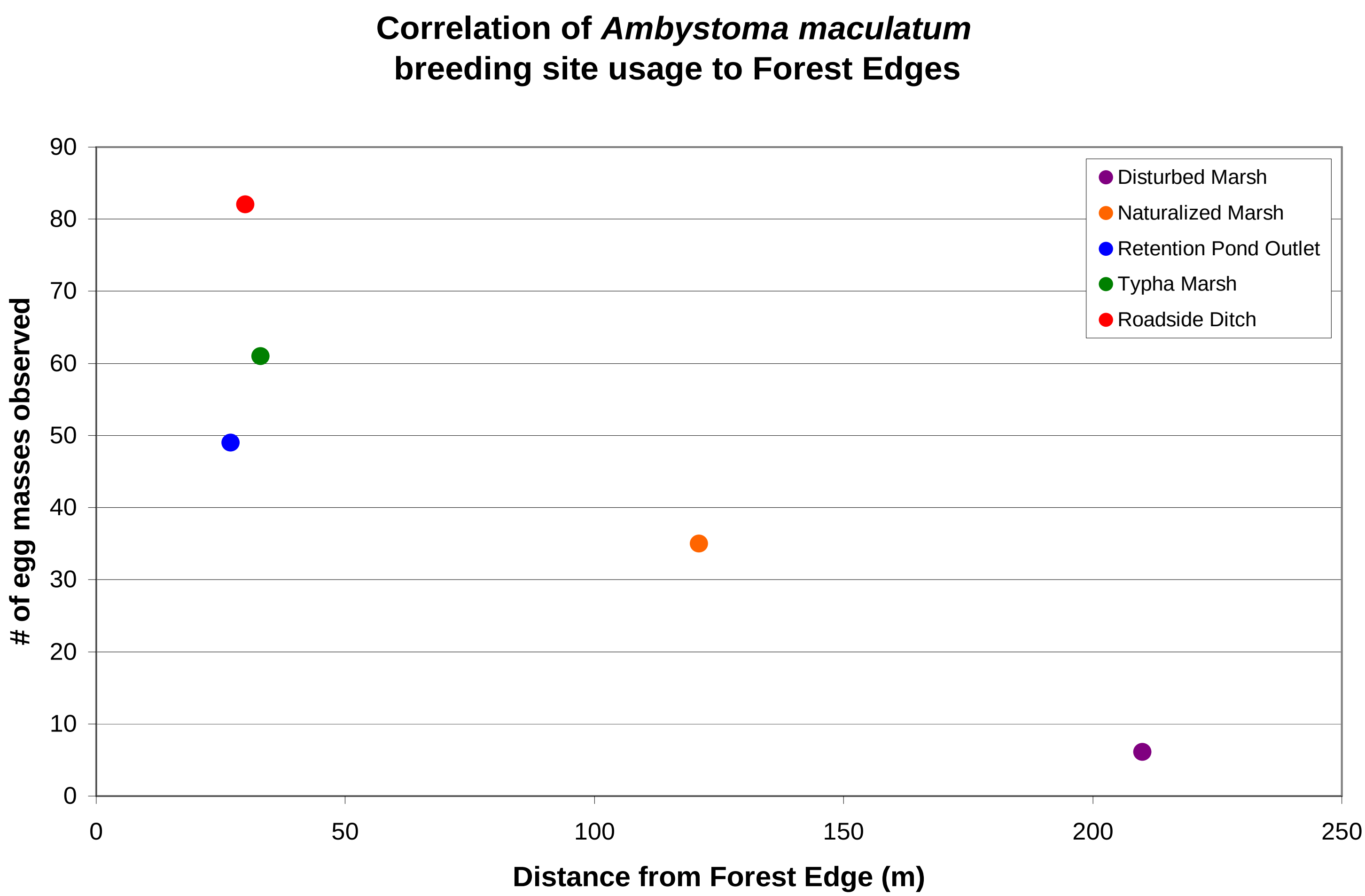

Figure 3: Linear regression between total number of egg masses per macrohabitat and distance of to forest edges

Figure 4: *Ambystoma maculatum* egg masses in roadside ditch on the Eccles Mine. These egg masses eventually desiccated after water levels in the ditch evaporated completely. Environmental conditions like this were present in all aquatic macrohabitats on the mine. *A. maculatum* egg masses in particular collected various dissolved solids from ponds.

Figure 5: Male *Ambystoma maculatum* from the Eccles Mine disturbed marsh site. Three color phases were present in the marsh, (top) normal phase, (middle) orange spotted phase (bottom) light colored phase.

Chapter 2

Natural History of an Anuran Community on an Abandoned Southern West Virginia Surface Mine

Zachary Loughman

Abstract

Surface mining activities represent an important economic and cultural identity for southern Appalachia. Environmental implications on anuran communities resulting from these activities currently are poorly understood. Amphibians represent a group of organisms that warrant understanding, because of recent documented declines, both at a global and regional scale. Anuran biodiversity and usage of an abandoned contour surface mine was studied on the Eccles Surface mine in Raleigh County, West Virginia. Anurans were captured in natural and anthropogenically created mine wetlands through trapping and haphazard searches. Call surveys were performed during early, mid, and late summer and spring seasons to determine when anuran species breeding behavior peaked. Seven anurans utilized the mines surface waters for breeding. Peak anuran breeding behavior occurred in late spring, with 4 species breeding during this time. Breeding behaviors ebbed during late summer, with only 2 species breeding. *Rana sylvatica* (Wood Frog) did not utilize the mine for breeding, though populations were present within 2 km of the study site. Naturally successional macrohabitats received more anuran species breeding effort than anthropogenic environments. The large number of anuran species utilizing the mine during breeding and non-breeding times indicates that with proper planning and creation of wetlands, mine lands can be converted into important breeding sites for anuran species if their populations are able to survive the active mining effort period of a surface mine.

Introduction

Global amphibian decline is a pressing issue in conservation biology today. Several causal agents have been identified including global warming, habitat degradation, parasites and increases in UV radiation (Semlitsch 2003). Most biologists agree that one of the above decline vectors is not more important than another, and the root of amphibian decline lies in synergistic relationships between these vectors. Declines in eastern North America have been documented several times over, with their origin identified in specific instances (Semlitsch 2003). Habitat degradation, fragmentation and destruction along with air and water pollution were likely the most pressing effects driving the eastern North American declines (Semlitsch 2003).

Mining practices present an interesting problem for amphibians living in mined areas, with commencement of mining activities representing the first problematic situation for anurans. Surface mining practices initially involve clearing the land of vegetation, and ultimately end with the removal of a mountain side (contour strip mining) or the majority of a mountains vertical profile (mountain top mining). Reclamation efforts dictate that all wetlands destroyed during mining efforts be replaced with anthropogenically created wetlands. Mining operations are responsible for controlling heavy metal lechates exposed from minerals during the active mining period. Retention pools are created to trap heavy metals lechates after rain events and during times of high water. Creation of post-mining lentic water bodies warrants colonization of pond-breeding amphibians, particularly anurans that survived initial mining efforts or immigrate onto mine lands in the post activity environment.

Few scientific investigations have determined whether mine wetlands are successfully colonized by anurans. Retention ponds are created with the surrounding watershed in mind, and not the pond breeding amphibian community present in the immediate environment. The major mining importance of anthropogenically produced wetlands is to trap heavy metals and other pollutants from escaping into the surrounding watershed. Mercury and other heavy metals reach high levels in retention pool waters and sediments. Effects, if any at all, that these heavy metals might have on anuran colonization rates have not been documented to date.

Surface mining also lends itself to creating wetlands, given that impermeable surfaces are left behind after mining efforts are completed. Bench low points hold water, which then gather soils, ultimately resulting in the creation of marshes and bogs. These wetlands are not present to target heavy metal deposition, and occur through natural succession events may ultimately lend themselves more to amphibian colonization than anthropogenically created wetlands. The purpose of this investigation is to document the anuran community present on an abandoned strip mine in southern West Virginia, and to determine how different anuran species utilized various wetland habitats present within the mines landscape.

Methods

Anurans were captured using a variety of methods. Haphazard searches were performed during diurnal and nocturnal hours for both larval and adult anurans. Capture methodologies employed during haphazard searches included dip netting, turning cover objects, and hand collection. Duration of haphazard searches was 1-3 hours.

Minnow traps were placed in all mine aquatic environments. Total number of traps used per location was calculated from the total surface area of a given wetland, with 1 trap placed every 10 m^2. All captured anurans were identified to species. Data collected on each post larval anuran included snout-vent length (SVL), cranial width (CW), sex, and any individual characteristics of note.

Call surveys were utilized to determine (1.) the exact breeding season of a given species and (2.) breeding habitat preference of a species. Call surveys were similar to those used with the North American Amphibian Monitoring Project (NAAMP). The activity seasons were modified for this study into 6 sub seasons, instead of the standard 3. Sub seasons for this study are described in **Table 2**. Call surveys were performed once a wetland was identified as potential anuran breeding habitat. An investigator listened for calling anurans approximately 5 minutes. All calling anurans were identified to species. Choruses were given numeric values of 1-3 based on chorus intensity. If 1-3 individual anurans were heard during the 5-minute survey, a value of 1 was recorded. If more than 3 individuals were calling, or 1-2 second gaps could be heard between individual calls, a value of 2 was documented. If a full chorus was heard, a value of 3 was recorded.

At the end of each sub season, a call survey average was calculated for each species, indicating the importance of a sub season towards breeding activity. Call survey averages also were calculated for specific aquatic macrohabitats to determine which mine habitats were most important for an anuran species breeding efforts.

Results

BUFONDIAE = Toads

Bufo a. americanus/ American Toad

Bufo a. americanus utilized all aquatic environments on the mine. *B. a. americanus* commenced calling in mid spring (7,April), calling primarily from disturbed (road-rut pools, large puddles) aquatic habitats. During late April and early May, *B. a.*

americanus calling activity reached its apex. During this time *B. a. americanus* began calling primarily from larger aquatic habitats (natural marsh, Outlet 101) with long duration hydro periods. *B. a. americanus* utilized several aquatic environments in late spring; however natural marshes on the mine were used for breeding more frequently than all other aquatic environments combined.

Egg masses were first observed 3 April 2005. Larval development took 30-55 days based from this date and the first and last observed toadlet. Disturbed habitats, particularly road-rut pools, experienced desiccation events resulting in low *B. a. americanus* metamorphic success. Toadlets were present in large numbers in vegetation surrounding the natural marsh from 13, June 27, June, 2004 with no other habitat types producing toadlet numbers comparable to those from the natural marsh

Adult *B. a. americanus* SVL averaged 61.2 mm, with males averaging 52.9 mm and females averaging 82.8. Cranial widths averaged 13.1 mm, with male and female cranial widths averaging 22.1 mm and 28.1 mm, respectively.

HYLIDAE = Tree Frogs

Hyla chrysoscelis/ Cope's Gray Treefrog

Hyla chrysoscelis utilized disturbed environments for the majority of breeding activity. Calling commenced in late spring (21, April) with satellite males calling infrequently. Beginning in May (early summer), *H. chrysoscelis* choruses became more robust. By the end of early summer mean chorus values were consistently 3 and maintained this value throughout mid summer. By late summer calling activity was isolated to the appearance of low pressure systems. *H. chrysoscelis* did not appear to use larger water bodies for breeding. Majority of calling activity came from road-rut pools, large puddles, and quick dry pools. Calling activity did occur in aquatic environments with long hydro periods (natural marsh, *Typha* marsh, retention pools), with calling in these macrohabitats isolated to 1-2 indivudals.

Hyla chrysoscelis males demonstrated high-calling site fidelity. A large (25 m long X 30 m wide) puddle centrally located on the bench was used by large numbers (> 30) of males. Results from a mark-recapture study of this puddle demonstrated that males used the same calling locations for consecutive nights. The farthest distance any one individual was found from his original capture location was 2 m, with the majority of males found within 30 cm of their original point of capture. Males used Rushes (*Juncus effuses*) as calling perches more frequently than other available vegetation. Males also did not call from vertical perches within the immediate vicinity of the puddle, preferring to call most often from the land/water interface.

Egg masses were first observed 21 May 2004. Larval development was rapid, with froglets first observed on 23 June 2004. *H. chrysoscelis* appeared to have a reproductive strategy that adequately coped with short- hydro period situations. Low numbers of *H. chrysoscelis* larvae were observed in desiccation events. *H. chrysoscelis* larvae also demonstrated high thermal tolerance. In mid June, water temperature in shallow puddles on the bench reached temperatures as high as 33.3 C. *H. chrysoscelis* larvae were the only larvae observed that were able to tolerate these high temperatures.

Adult *H. chrysoscelis* SVL averaged 40.1mm, with males averaging 35.5 mm and females averaging 43.8 mm.

Pseudacris brachyphona/ Mountain Chorus Frogs

P. brachyphona used ephemeral wetlands for breeding, and had the shortest breeding season of all anurans on site. *P. brachyphona* were heard calling once in early spring (28, March) from ephemeral pools in forest-edge environments. These pools were aquatic environments that did not appear to be a result of the mining process. On 4 April 2004 and 8 April 2005, *P. brachyphona* chorus values reached 2. No adults, egg masses, or larvae were captured in these pools, even though multiple collection attempts were made.

Pseudacris crucifer crucifer/ Spring Peeper.

Pseudacris c. crucifer used all aquatic environments on the mine for breeding, but showed a preference for *Typha* marshes. *P. c. crucifer* were the first anurans to call on the mine during both years of the study. Calling commenced with isolated males vocalizing from shallow pools in early spring. By mid spring, full choruses were common from wetlands with moderate to long hydro periods. Locations harboring large *Typha latifolia* marshes produced the most deafening and dominate choruses. Other aquatic habitats with large choruses included natural marsh, disturbed marsh, and retention pools with large *T. latifolia* communities.

Maximum chorus values were maintained throughout the spring until early summer (12-14, June). During periods of low pressure, *P. c. crucifer* switched calls from the typical breeding call to rain calls, with calls changing from typical “peeps” to “peecreep-creep". Chorus values of 2 were common events during early summer, dropping off considerably through mid to late summer. *P. c. crucifer* were the last frogs heard calling in the fall of 2004. Individuals calling at this time were calling from *Juncus effuses* plants along marsh margins.

P. c. crucifer preferred calling perches were mats of decaying *T. latifolia* leaves. When *T. latifolia* was not present, *P. c. crucifer* frequently would call from the base of rushes (*Juncus* sp.), or other vegetation present at the land water interface. Eggs were not observed in the natural environment, but were deposited in collecting containers on 13 April 2004. Egg deposition based on other populations studied in West Virginia likely occurred during the duration of the spring season (March – May) (author personal observation). *P. c. crucifer* larvae were the dominate larvae encountered in *Typha* marshes, often outnumbering other anuran larvae 6:1. *P. c. crucifer* larvae were not observed in temporal habitats, such as road-rut pools, even though calling males were observed in these habitats.

Adult *P. c. crucifer* SVL averaged 29.83 mm, with males averaging 24.2 mm and females averaging 31.9 mm. Cranial widths averaged 19.1 mm, with male and female cranial widths averaging 11.9 mm and 23.2 mm, respectively.

RANIDAE = True Frogs

Rana catesbeiana / American Bullfrog

Rana catesbeiana preferred aquatic habitats with long hydro periods and were the last anuran to begin calling. Calling commenced in early summer (June) and continued throughout the summer season. Habitat males utilized for calling were deep water bodies (retention pools) and had long hydro periods. Within these water bodies, *R. catesbeiana* called from *Typha* marshes in shallow regions of these water bodies. Males were territorial, and were witnessed actively defending calling sites. No full choruses were documented, with the most males calling at once from one location being 6. *R. catesbeiana* nocturnal activity began later than other anurans, usually beginning between 21:00-22:00 h.

R. catesbeiana on the mine demonstrated an ontogenic shift in habitats. Adults and larvae were only found in large, long hydro period water bodies. Metamorphs and juveniles however, were found most frequently in disturbed habitats. Larger sized road rut-pools with *Typha latifolia* communities in particular housed large numbers of this demographic. *R. catesbeiana* has been documented multiple times in the literature being cannibalistic towards smaller members of their species (Bury & Welman 1982). This shift in metamorphs and juvenile preferred habitat is likely a mechanism to avoid predation by larger conspecifics and reduce competition for prey items between adults and Juveniles.

No *R. catesbeiana* egg masses were observed during this study. Several *R. catesbeiana* larvae were captured in retention pools at various stages of development. Larval development in this species occurs over a period of 1-2 years (Ryan 1980), and the Eccles mine population likely follows this time period as well. Metamorphs were observed on 13, 21, 26 July 2004.

Adult *R. catesbeiana* SVL averaged 62.8 mm, with males averaging 59.9 mm and females averaging 181.0 mm. This data is skewed because no adult male *R. catesbeiana* were captured. Cranial widths averaged 31.8 mm, with male and female cranial widths averaging 29.0 mm and 51.2 mm, respectively.

Rana clamitans melanota / Green Frog

Rana c. melanota were the dominate ranid on the mine, and utilized all available aquatic habitats. Breeding preference appeared to be habitats with long hydro periods with large amounts of emergent vegetation (*Juncus* sp., *Carex* sp. *Potamegaton* sp). *R. c. melanota* choruses and larvae captures were highest in the natural marsh. *R. c. melanota* numbers were also high in *Typha* marshes and road-rut pools with long hydro periods.

R. c. melanota were first heard calling on 24 March 2004 and 3 April 2004. Calling began with isolated males in mid-late spring (26-28, May), gradually increasing to moderate choruses in early summer (12-15 June). Peak breeding activity occurred in mid summer (4-15 July), reducing to moderate choruses by late summer. Isolated calling events were observed in late summer through early fall. *Rana c. melanota* was the second to last frog calling at the end of the activity season.

Juveniles and metamorphs were encountered in all moist environments on the mine. This demographic was not frequently observed in wetlands harboring adults. *Rana. c. melanota* appeared to leave their natal pools and migrate across the landscape. Like *R. catesbeiana*, *R. c. melanota* juvenile and metamorphs were frequently encountered in road rut pools. Unlike *R. catesbeiana*, *R. c. melanota* has not been documented to have cannibalistic tendencies. These radiations of metamorphs into the surrounding landscape likely represented juveniles seeking out territories that were not occupied by larger, dominate conspecifics.

Rana c. melanota eggs were not observed during this study. Larvae were captured in all aquatic habitats with long hydro periods. When large *R. catesbeiana* were present (Retention Ponds), *R. c. melanota* larvae numbers were considerably lower than in areas where *R. catesbeiana* were not present (natural marsh). Metamorphs were observed during the duration of the study

Rana. c. melanota larvae were prey for a multitude of aquatic organism inhabiting the mine. Juvenile snapping turtles (*Chelydra serpentina*) were observed feeding on larvae in the natural marsh, and *R. c. melanota* larvae likely represent an important forage item for this species. Giant water bugs (*Lethocerus americanus*) were encountered several times inside minnow traps placed in the natural marsh feeding on *R. c. melanota* larvae and in 1 instance on metamorphs. These large insects were encountered in several water bodies (disturbed marsh, natural marsh, *Typha* marsh) and likely represent an important *R. c. melanota* predator.

Adult *R. c. melanota* SVL averaged 60.7 mm, with males averaging 61.9 mm and females averaging 54.8 mm. Cranial widths averaged 32.6 mm, with male and female cranial widths averaging 33.9 mm and 26.8 mm respectively.

Rana palustris / Pickerel Frog

One *Rana palustris* was heard calling from a retention pool in mid spring 2004. Attempts to observe and collect *R palustris* larvae and adults failed during the 2 years of this study. This likely was an isolated calling incident, with *R. palustris* not using the mine for breeding purposes.

Discussion

Majority of anurans present in Raleigh County were found on the Eccles mine, with colonization of the mine integrally connected to species life history traits (Green and Pauley 1987). Species found in abundance on the mine (*H. chrysoscelis*, *R. c. melanota* and *P. c. crucifer*) were classic pioneer amphibian species (Semlitsch 2003). These anurans (1.) thrive in anthropogenically disturbed habitats, (2.) evolved larval mechanisms to cope with adverse growing situations, and (3.) produced large numbers of offspring (Semlitsch 2003). *H. chrysoscelis*, for example, were able to metamorphose in quick-dry and road-rut pools which reached critical thermal maximums for all other species on the mine. By successfully colonizing macrohabitats such as these, *H. chrysoscelis* eliminated interspecific resource competition on both a habitat and feeding scale.

Additional successful colonizers either utilized habitats with long hydro periods (*R. catesbeiana*), or evolved desiccation avoidance mechanism (*B. americanus*). These species did not display pioneering qualities *per se*, but rather had one specific life history parameter that enabled them to successfully inhabit and breed on the mine. In order for these species to inhabit the mine, long-term environmental conditions must remain stable in regards to their single adaptation. If anything places the particular habitat they have specifically evolved for in peril, extirpation events are likely.

Unsuccessful colonizing species (*R. sylvatica* and *R. palustris*) were species that evolved to live in two different habitats during their biphasic life times. In order for these species to succeed, one specific habitat (ephemeral pool) has to be present for their time as larvae, while another habitat (upland forest) has to be present for their adult life (Wilbur 1980, Pechman and Wilbur 1994). In the case of *R. sylvatica*, quality larval habitat was abundant; however there was a complete lack of adequate adult habitat (mature forest). Even though larval habitat was present, the majority of *R. sylvatica's* life time is spent in mature forest ecosystems. *R. sylvatica* were likely present prior to mining efforts given breeding populations were located within a 2 kilometers (Lilly Mountain, author personal obs.) of the study site. The fact that no *R. sylvatica* were found during 2 spring seasons indicates that an extirpation event occurred with this species on the Eccles mine.

Anuran diversity was also linked to habitat diversity. Eight specific (2 long hydro-periods, 6 short hydro-periods) were present on the landscape. This diverse range of available macrohabitats aided in controlling interspecific competition, with all species showing preference toward a specific macrohabitat. In no instance did 2 species dominate 1 habitat. Diversity in available wetland types in a given areas landscape has been linked in previous studies to promoting high anuran diversity (Wilbur 1980, Pechman and Wilbur 1994, Semlitsch 2003).

Site-specific amphibian diversity has also been linked to total available larval and adult habitat at the landscape level (Semlitsch 1983,Bergen 1990, Semlitsch et al 1986). Several wetlands were present near Eccles, enabling active amphibian recruitment from these surrounding metapopulations during initial post-mining times. If these metapopulations were not available to the Eccles mine anuran community in the years immediately following mining activity, the current amphibian community's diversity may not have reached its current level. This aspect of amphibian biology is an area that needs to be taken into consideration prior to mining activities.

The Eccles mine serves as a model of the potential abandoned surface mines may represent to anurans. Lentic water bodies were not present in abundance prior to mining activities in the Eccles area. The creation of diverse lentic habitats in the post mining environments resulted in a diverse anuran community, with relatively few species ultimately suffering after mining activity ceased.

Future studies should investigate anuran community dynamics in situations where mine lentic water bodies range from diverse to monotypic. Long hydro-periods (retention pools) are an area of potential research as well. In most situations long hydro-period water body fish populations are thought of as detrimental to a landscapes amphibian fauna (Heyer *et al* 1975, Bradford 1989, Hechart & Mc Cluskey 1997). During rain events, floodwaters invade ephemeral wetlands, depositing fish which act as major larval amphibian predators (Bradford 1989). Fish populations in the Eccles mine retention ponds were low, and after a massive flooding event which encompassed the entirety of the bench, no fish were trapped from any of the bench's water bodies. Low fish populations in long hydro-period water bodies on abandoned surface mines may lend themselves more towards amphibian colonization than other long hydtoperiods present in the landscape.

Table 1: Mean Call Survey Values for Anuran Eccles Mine Survey.

Anuran Species	Early Spring	Mid Spring	Late. Spring	Early Summer	Mid. Summer	Late Summer
Bufo a. americanus	0	1	3	1	0	0
Pseudacris c. crucifer	1	3	3	2	1	1
Pseudacris brachyphona	1	2	0	0	0	0
Hyla chrysosceliss	0	0	1	3	3	1
Rana c. melanota	0	1	1	2	2	1
Rana catesbeiana	0	0	0	1	2	2
Rana palustris	0	0	1	0	0	0

Table 2: Anuran Survey Macrohabitat Types and Defining Characteristics. Species abbreviations are explained below*. Three dominate emergent vegetation genera (*Juncus*, *Carex* and *Typha*) percentages were used as defining characteristics due to the presence of these species at most habitat types

Macrohabitat Type	Hydroperiod Length	Mean Water Depth	% Canopy	Vegetation Type	Anuran Species Present
Successional Marsh	Long Hydroperiod	.5 m	20%	40% *Juncus* 40% *Carex* 20% *Typha*	PC, HC, RM, RC, BA
Anthropogenic Marsh	Moderate Hydroperiod	.5 m	0%	40% *Typha* 30% *Juncus* 30% *Carex*	PC, RCM
Cattail Marsh	Short Hydroperiod	.33 m	0%	80% *Typha* 20% *Juncus*	PC, RM, HC
Road Rut Pool	Short Hydroperiod	.1 m	0%	Various Species	PC, RC, RM, HC, BA
Ephemeral Pool	Short Hydroperiod	.2 m	80%	Herbaceous Species	PB
Retention Ponds	Long Hydroperiod	3 m	40%	90% *Typha* 10% *Juncus*	RC, RP. PC

*Species abbreviations = BA = *Bufo a. americanus*, HC = *Hyla chrysoscelis*, PC = *Pseudacris crucifer*, PB = *Pseudacris brachyphona*, RC = *Rana catesbeiana*, RM = *Rana c. melanota*, RP = *Rana palustris*

Figure 6: Two dominant ranids found on the Eccles surface mine, Top: *Rana c. melanota*, Bottom: *Rana catesbeiana*. *R. c. melanota* colonized natural and disturbed wetlands. *R. catesbeiana* primarily inhabited large, anthropogenically created wetlands.

Chapter 3

Natural History and Ecology of *Chelydra s. serpentina* and *Terrapene c. carolina* on an abandoned surface mine in southern West Virginia

Zachary Loughman

Abstract

Chelonian conservation biology has received considerable attention in recent years. Habitat degradation, fragmentation and destruction have left many of the world's turtle populations currently in varying levels of imperilment. Within the Appalachian region, little research has been performed investigating these effects on native turtle populations. This study focused on two common Appalachian turtle species, *Terrapene c. carolina* (eastern box turtle) and *Chelydra s. serpentina* (northern snapping turtle), and investigated the effects of surface mine abandonment on turtle populations inhabiting the Eccles surface mine, Raleigh County, West Virginia. Turtles were captured by hand through haphazard searches and aquatic turtle trapping. Results indicated that *C. s. serpentina* populations were low relative to other studies performed on this species. This likely is a result of limited prey availability, habitat homogeneity, and toxicity due to heavy metal deposition in retention ponds. *T. c. carolina* populations also appeared low, though this could be due to surveying techniques (haphazard search). Abandoned mine sites appeared to benefit turtle populations through creation of quality nesting sites. Mine sites were detrimental to turtles through creation of habitat unsuitable for large core turtle populations, creation of metapopulation type system, and ultimate destruction of quality Appalachian forest ecosystems.

Introduction

Turtle populations worldwide have witnessed increased conservation attention in recent years because scientists are only now beginning to understand anthropogenic influences on long-lived organisms (Swarth *et al* 2003). In certain areas of the world, up to 86% of turtle species are witnessing some form of imperilment at the hands of humanity (Swarth *et al* 1999). With an increased interest in anthropogenic disturbances on turtle populations and the resulting conservation implications, a detailed investigation of 2 two turtles species, *Chelydra s. serpentina* (Common Snapping Turtle) and *Terrapene c. carolina* (Eastern Box Turtle) was performed on an abandoned surface mine in Eccles, Raleigh County, West Virginia.

No previous investigations have been performed regarding the effects of surface mining on turtle populations in Appalachia. Several herpetological presence/absence type studies have been performed on mine lands, but these research efforts were not focusing exclusively on turtle populations. This study focuses on the effect mining efforts have on two turtle species. *Terrapene. c. carolina* is a terrestrial emydid turtle found throughout eastern North America (Dodd 2001). *Terrapene. c. carolina* populations in recent years have witnessed steady declines in certain areas of their range due to habitat fragmentation and degradation (Dodd 2001). Degradation and fragmentation effects of surface mining in Appalachian systems have not been investigated with this species.

Chelydra s. serpentina is a large aquatic turtle species in the family Chelydridae (Ernest *et al* 1994). These turtles are noted for being common in all major aquatic environments throughout North America (Conant & Collins 1998). Like *T. c. carolina*, studies have not been performed regarding the effects of surface mining on this long-lived species. Creation of wetlands and lentic water bodies through the mining process possibly could benefit this species, however the true effects of these environments on *C. s. serpentina* are not known. This aspect of *C. s. serpentina* biology will be the primarily focus for this research with this species.

Methods

Turtles were collected using 2 methods: haphazard searches and aquatic trapping. Haphazard searches were performed during all hours of the day and in all mine habitats. Microhabitats known to harbor turtles, such as leaf litter packs and marsh margins, were given special attention. When survey events ceased, the total amount of time searched was documented in order to calculate catch per unit effort values.

Aquatic turtle trapping was used to capture *C. s. serpentina*, with 2 two trap types used. Large Hoop traps (30 inch diameter) were used to capture juvenile and adult *C. s. serpentina*. Large hoop traps were placed in retention ponds and baited with Jack Mackerel and Tuna. Small hoop traps (15 inch diameter) were used to catch neonates and juveniles. These traps were placed in retention ponds and marshes. Trap placement in marshes were always in the thalweg, a microhabitat that *C. s. serpentina* juveniles were known to frequent. Traps were baited with tuna. All traps were left for 3 trap nights and then checked.

The following measurements were recorded on all captured turtles: carapace length (CL), carapace width (CW), carapace height (CH), plastron height (PH), plastron width (PW), and mass. All measurements were in millimeters, with mass recorded in grams. When nest were encountered, nest depth and width were recorded, as well as nest habitat. Time of capture and any behaviors turtles exhibited pre and post capture were recorded. Micro and macrohabitat parameters were all noted for each capture event.

Results/ Natural History

Common Snapping Turtle/ *Chelydra s. serpentina*

C. s. serpentina were typical of their species, with 2 two distinct demographic groups (juveniles and adults) inhabiting the mine. Juveniles had mean carapace lengths of 80.2 mm, with mean carapace widths of 69.6 mm. Plastron lengths averaged 59.0 mm, with an average plastron width 63.5 mm. Juvenile mass averaged 69.8 grams. Adult *C. serpentina* mean carapace lengths were 49.7 cm, with mean carapace widths being 42.6. Adult plastron lengths averaged 36.8 cm, with mean plastron widths being 39.7 cm. Adult mean mass was 3.5 Kg.

Sample size for this population was small (n = 10) compared to other studies (Burghardt & Hess 1966, Christianson & Burken 1979), so morphometric comparisons to other populations are made with caution. Adult mean carapace lengths were smaller compared to *C. s. serpentina* studied in Virginia, North Carolina, and Pennsylvania (Hulse *et al* 2001 No date in Lit.Cit., Mitchell 1997 1994 in Lit. Cit., Palmer *et al* 1995). This is likely a result of lack of habitat, with environmental pressures selecting turtles whose size best fits the relative small size of available habitat. Retention ponds, the primary habitat for adult turtles, were smaller than nearby lentic environments (Lake Stephens for example). Large adult *C. s. serpentina* likely migrated to larger habitats than available habitats on the mine.

There was an ontogenic shift in preferred habitat for *C. s. serpentina* inhabiting the mine. Based on trapping efforts, juvenile *C. s. serpentina* selected marshes (naturalized marsh and *Typha* marsh) 100% over retention ponds, with zero juveniles captured in the ponds, even though considerable trapping efforts were performed. *C. s. serpentina* in Alongonchin Park in Ontario Canada also displayed this ontogenetic shift in macrohabitat selection (Obbard & Brooks 1981). Prey availability for juveniles was much more diverse within marshes than within retention ponds. Amphibian larvae, macroinvertebrates, oligichaetes, and various species of reptiles all inhabited marshes on the mine, with only limited populations of these organisms in retention ponds. Previous feeding ecology studies have shown that juvenile *C. s. serpentina* selected habitats with abundant amphibian and invertebrate faunas for feeding over habitats dominated by fish (Burghardt & Hess 1966).

Adult *C. s. serpentina* were all captured in retention ponds. Trapping efforts revealed low adult *C. s. serpentina* densities on the mine relative to other populations (Christianson & Burken 1979). Retention pond prey resources were severely limited, with only one fish species (green sunfish, *Lepomis cyanellus*) found in the ponds. Adult *C. s. serpentina* have been noted to scavenge carrion, and were observed on 12 June 2004 feeding on a dead ground hog (*Marmota monax*) within retention pond #1. Another limiting factor for adult *C. s. serpentina* was retention pond size. Retention ponds were limited by mining standards to 70 m long by 30 m wide. *C. s. serpentina* males are territorial, with available food resource combined with the size of the ponds ultimately is limiting to *C. s. serpentina* adults (Ernest et al. 1994).

Both *C. s. serpentina* demographic groups utilized littoral zones for foraging. Juvenile foraging behaviors were observed several times in marshes. Juveniles were more nocturnal than adults, with 100% of juvenile observations occurring between 21:00-24:00 h. Juveniles were observed patrolling *Juncus effuses* edges within the marsh, walking deliberately and slowly across the marsh bottom. When movement occurred near a juvenile, turtles would freeze, and orient in the direction of movement. Predation on Northern Green Frog larvae (*Rana c. melanota*) was observed on 7 July 2004 at 22:47 h.

A juvenile *C. s. serpentina* patrolling a *Juncus* edge was observed walking along the marsh substrate when a tadpole swam along the right side of the turtle. When the larvae reached the buccal region of the turtle, the turtle reacted with a lunge followed by the inhalation of the frog larvae.

Adult *C. s. serpentina* were only observed within the ponds on 2 occasions. The first occurred on 8 July 2004 at 13:00 h. A large adult *C. s. serpentina* was observed basking in direct sunlight in retention pond #2. The turtle was floating just under the waters surface in the middle of the pond directly over the thalweg. The second observation occurred on 12 August 2004. An adult was observed migrating across the mine, using the mine road as a corridor. Rain had occurred earlier in the day. Rain events previously had been documented to coincide with *C. s. serpentina* migrations over land, and probably triggered this adult into movement (Christianson & Burken 1979).

C. s. serpentina behavior was typical for their species. When captured, all age groups would attempt escape by either walking towards water or swimming quickly into deeper water. If the turtles were retained, the head was pulled into the carapace, with loud hisses as the turtle exhaled. If the carapace were touched, the turtle would elevate the posterior region of the body and move in the direction of the perceived threat. If further provocation occurred, turtles would lunge quickly and accurately at the pursuer. Immediately following each lunge, turtles would back up, opposite of their pursuer and attempt escape. Juveniles utilized two musk glands located along the plastron/carapace bridge more frequently than adults, with odors produced by these glands quite pungent

Leeches (*Placobedella* sp.) were present on all *C. s. serpentina* adults **(Figure 11).** Juveniles leech loads were much less than adults. Leeches were frequently found along the back limbs of adults, in the region of the knees of the turtles. In one instance, 22 leeches were found within one cluster in this region. Leeches also were found taking blood meals on the dorsal surface of the carapace, along the vertebral/coastal scute margins. Algal mats of *Chelodinia* sp. were present on the carapaces of all adult turtles. This algae species is endemic to the genus *Chelydra.*

C. s. serpentina bio-magnification of organochlorines and other biomolecules has been documented in the literature (Bryan *et al* 1987, Stone *et al* 1987). Although the technology was not available to test *C. s. serpentina* for biomagnification, it likely occurred within *C. s. serpentina* inhabiting the mine. Retention ponds are utilized by the mining industry as heavy metal depositories, resulting in these metals not escaping the mine and ending up in the surrounding watershed. The overall effect of heavy metals present in retention ponds on *C. s. serpentina* health and population dynamics remains to be seen. All retention ponds on the mine tested positive for selenium, a known bio-magnifying chemical. Mercury levels also were elevated from the norm in retention ponds on the mine, however mercury levels were not abnormally high. Both of these chemicals have been shown in previous studies to magnify in *C. s. serpentina* tissues (Bryan *et al* 1987).

Terrapene c. carolina/ Eastern Box Turtle

T. c. carolina morphometrics were typical of their species. Mean carapace length was 13.8 cm, with a mean carapace width of 11.6 cm. Plastron widths averaged 9.5 cm, with mean plastron length of 10.8 cm. Mass was not taken with *T. c. carolina*. Virginia, North Carolina, and Pennsylvania *T. c. carolina* morphometrics were not significantly different than the Eccles mine population (Hulse *et al* 2001, Mitchell 1997, Palmer *et al* 1995).

T. c. carolina sample size was low due to capture technique. Trapping methods used to capture *C. s. serpentina* were not applicable to *T. c. carolina (Dodd 2001)*. The only reliable capture method was haphazard search, which is notorious for low turtle capture rates. Because this methods inaccuracy is somewhat standard, total number of turtles per unit effort can be used as a rough indicator of *T. c. carolina* population size. Based of this premise, the Eccles mine *T. c. carolina* population was likely smaller than surrounding environs.

All *T. c. carolina* captured during this study were encountered in ecotonal areas. Four of the 5 encounters occurred on mining roads along the western margin of the bench. Turtles were walking along highwalls immediately adjacent to the road. High walls may act as natural drift fences, with turtles walking across the bench during cool morning hours, ultimately ending their jaunts at these surfaces and "drifting" along their margins. High walls also harbored large Raspberry (*Morrus* sp.) populations, a preferred *T. c. carolina* forage, with turtles possibly seeking out high walls to forage on these abundant fruits (Dodd 2001).

T. c. carolina usage of ecotones has been well documented. In Delaware, *T. c. carolina* utilizing an isolated forest fragment spent 80% of their time in ecotonal regions (Niederriter & Roth 1999). By utilizing these environments, *T. c. carolina* increase prey availability, refugia abundance and types, and widen potential temperature gradients for thermoregulation (Niederriter & Roth 2003). On the Eccles mine, *T. c. carolina* never were encountered in sucessionary forest habitats. This does not mean that turtles do not use these forest environments. Three *T. c. carolina* were captured within 20m of a forest edge. As temperatures rose throughout the day on the mine, turtles likely aestivated in these succesionary forests until dusk when mine temperatures would again reach safe levels. This hypothesis was not proven, and represents an area of future investigation.

Several *T. c. carolina* nest (n=11) were found on the Eccles mine. Most nests were found on the southwest-facing slope immediately adjacent to retention pond #1. This hillside was dominated by loose, loamy exposed soil. Average soil depth to bedrock for 5 study plots was 360 mm. Nest were all within 30 m of a forest edge, and immediately adjacent to large structures (logs, boulders, etc.). Mean nest depth was 196.27 mm, with mean width of 129.09 mm. Nest success was determined from egg fragments. Long vertical slits produced by egg teeth on the neonates rostrum indicated successful hatching events. Using this as a measure of success, 8 of the 11 nests found were successful in producing neonates. Whether or not these neonates were then predated while escaping their nesting chambers is not known.

Abandoned mine sites usage as *T. c. carolina* nesting locations needs further investigation. The disturbed nature of soils on mines after mining efforts have terminated lend themselves to turtle nesting. *Terrapene c. carolina* have temperature dependent sex determination, with high temperature having feminization effects on *T. c. carolina* populations (Dodd 2001). This may have been observed on the Eccles mine, with 4 of the 5 adults found on the mine being female . The high surface temperature abandoned surface mines reach during incubation periods could alter *T. c. carolina* sex ratios dramatically. This area of *T. c. carolina* ecology in coal baring environments is in need of future investigation.

Several potential *T. c. carolina* predators inhabited the Eccles mine. Virginia Opossum (*Didelphis virginiana*) and Raccoons (*Procyon lotor*) were present in large numbers. These mammals represent important *T. c. carolina* nest predators. Raccoons have been documented in several instances as important *T. c. carolina* predators. One raccoon on an island in Florida was responsible for 26 individual predation events on *T. c. carolina* in an 8-day period (Dodd 2001). Coyotes (*Canis latrans*) and feral dogs (*Canis familiaris*) were also present on the Eccles mine. Canids predated heavily on adult turtles, an age cohort that normally receives very little predation pressure. Coyotes in particular were abundant on the mine, with two resident "groups" inhabiting the mine during the study.

Discussion

Turtle populations were limited by abiotic and biotic factors, the most important being habitat fragmentation. Surface mining converts mixed deciduous forest into fragmented savannah type habitats. Abiotic factors such as surface temperatures, relative humidity, moisture levels and water body types are quite different between these2 two habitats, resulting in changes in biota between pre- and post-mining times. These effects appear to be more detrimental to *T. c. carolina* than *C. s. serpentina*, with the creation of wetlands during post mining times acting as a potential positive for *C. s. serpentina*.

Habitat fragmentation from mining efforts creates environments where metapopulations appear. Bench thermal environments during daylight hours in mid to late summer exceed *T. c. carolina* critical thermal maximums, likely creating 3 distinct *T. c. carolina* metapopulations, with one metapopulation per forest fragment. Bench abiotic factors (surface temperature, relative humidity, and available cover) separated *T. c. carolina* populations into 3 separate metapopulations during summer months. Carrying capacity per forest fragment is then limited to available biotic conditions within each forest fragment. Habitat fragmentation of this nature has had dramatic effects on *T. c. carolina* populations in Delaware and Maryland (Froth & Bushby 1999). In both of these studies, resource availability per habitat fragment was directly correlated with overall population sizes. Fragments with habitat heterozygosity and higher levels of forage availability produce larger metapopulations than metapopulations with limited resources.

Had reclamation efforts such as tree plantings been performed on the bench which would limit surface temperatures to non-lethal levels, then the total available habitat would increase, potentially resulting in a more robust *T. c. carolina* population. Active habitat management resulting in shade sanctuaries (i.e. brush piles), replacement of topsoil, and plantings of groundcover been performed on the bench, would limit surface temperatures to levels congruent with *T. c. carolina* activity during the late summer season.

Creation of quality turtle nesting habitat from surface mining is one positive aspect of mining activities. Both species are noted for extensive journeys in search of quality nesting habitats, with *C. s. serpentina* females traveling up to 10 km from the nearest water source in search of nesting habitats (Ernest *et al.* 1994). Both turtles nested on the mine, with *T. c. carolina* nests more abundant than *C. s. serpentina*. This also could be a bias given nesting habitats of these species. Temperature dependent sex determination could lead to feminization in both species given the correlation of high soil temperatures and female skewed populations (Ernest *et al* 1994).

Creation of wetlands in the post-mining environments acted both positively and negatively with *C. s. serpentina*. Prior to mining, 2^{nd} –3^{rd} order streams dissected the mine. *C. s. serpentina* likely inhabited these streams, with this population representing the founding mine *C. s. serpentina* stock. No data was collected on *C. s. serpentina* prior to mining so the total population size was unknown prior to mining efforts. *C. s. serpentina* populations reach considerably higher densities per unit area in lentic environments compared to lotic environments, so the creation of several lentic habitats post mining may have benefited this population if it survived through the active mining phase of the mine.

C. s. serpentina populations on the mine were severely limited compared to other lentic situations (Majors 1975). Biotic communities in retention ponds were quite homogeneous, with one species of sunfish (*Lepomis cyanellus*) representing the only available forage for *C. s. serpentina*. Habitat heterozygosity in both the benthos and littoral zones of the retention ponds was limited. The lack of ambush sites and complex habitats limited available habitats for prey species, ultimately limiting available habitat for *C. s. serpentina*.

Post-mining environments, which undergo active habitat manipulation and management, could produce quality habitats for both species of turtles. Creation of "brush islands" on mine benches would give turtles cooler thermal refuges in the event they are trapped on the bench during extreme temperatures. Tree plantings and soil replacements, also along this theme, could result in a decrease of heat retaining bedrock surfaces, and an increase in heat absorbing surfaces. This would directly affect evapotransporation from wetlands, which naturally occurs in the acidic bench environment. Simply placing snags and planting native aquatic plant species into retention pools eliminates habitat homozygostiy resulting in higher quality habitat for turtle prey species. Resulting increase in prey availability will result in total turtle holding capacity increasing closer to normal levels. If actions of this nature were completed, the Eccles mine negative effects on the present turtle populations would decrease, resulting in a possible increase in turtle numbers.

Species	*Collection Date*	*Water Body*	*Age Cohort*	*Sex*	*CL (mm)*	*CW (mm)*	*PL (mm)*	*PW (mm)*	*Mass (grams)*
C. s. serpentina	4/25/2004	Nat Marsh	Juvenile	F	117	103.2	88.1	94.8	3.25 K
C. s. serpentina	6/8/2004	Nat Marsh	Juvenile	M	86.8	72.9	64	64.8	2.85 K
C. s. serpentina	6/29/2004	R. Pond #1	Adult	F	27	22.5	20.9	21.2	112 g
C. s. serpentina*	**6/29/2004**	**R. Pond #2**	**Adult**	**M**	**218**	**175**	**160**	**175**	**46.0 g**
C. s. serpentina	7/28/2004	Nat Marsh	Juvenile	M	84.5	71.4	61	66.8	51.5 g
C. s. serpentina	7/28/2004	Nat Marsh	Juvenile	F	54.3	48.9	39.7	44.8	4.85 K
C. s. serpentina	8/9/2004	Nat Marsh	Juvenile	M	57.9	52.1	42.5	47.4	4.6 K
C. s. serpentina	8/28/2004	Beaver Pond	Adult	M	281	230	210	220	3.4 K
C. s. serpentina	8/28/2004	Beaver Pond	Adult	F	250	215	190	220	2.85 K
C. s. serpentina*	**8/28/2004**	**R. Pond #2**	**Adult**	**M**	**231**	**178**	**166**	**188**	**3.25 K**
C. s. serpentina	8/28/2004	R. Pond #2	Adult	F	215	179	164	175	2.85 K

* = Adult male *C. s. serpentina* captured twice during study

Table 3: Field data for *Chelydra s. serpentina* collected on abandoned Eccles Mine, Raleigh County, West Virginia.

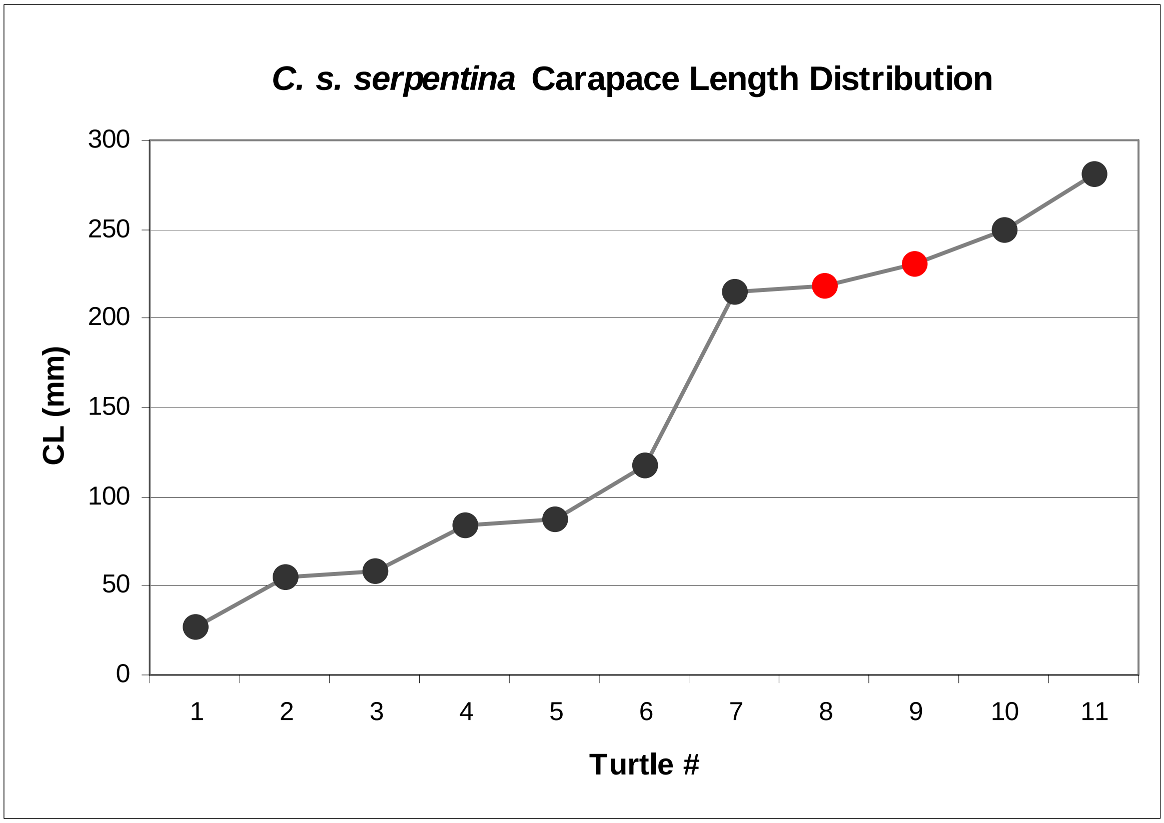

Figure 7 = *Chelydra s. serpentina* carapace length distribution. One recapture occurred during the study, with this individual's data represented by red points in the graph

Species	*Collection Date*	*Location on Mine*	*Age Cohort*	*Sex*	*CL (mm)*	*CW (mm)*	*PL (mm)*	*PW (mm)*
T. c. carolina	4/17/2004	along high walll	Adult	F	61.6	103.2	53	79.4
T. c. carolina	4/24/2004	along high walll	Adult	F	142	72.9	123.5	84.1
T. c. carolina	5/12/2004	along high walll	Adult	F	120.3	22.5	104.3	67.8
T. c. carolina	5/31/2004	High wall road	Adult	F	131.3	175	112.9	75.7
T. c. carolina	8/4/2004	R. Pond #1 hill	Adult	M	130.3	71.4	133.1	75.2

Table 4: Field data for *Terrapene c. carolina* collected on Abandoned Eccles Mine, Raliegh County, West Virginia

Nest Location	*Nest Depth (mm)*	*Nest Width (mm)*	*Number of Egg Fragments*
R. Pond #1 hillside	179	132	6
R. Pond #1 hillside	181	130	4
R. Pond #1 hillside	195	126	3
R. Pond #1 hillside	198	119	2
R. Pond #1 hillside	199	127	4
R. Pond #1 hillside	200	128	5
R. Pond #1 hillside	200	134	4
R. Pond #1 hillside	201	122	2
R. Pond #1 hillside	201	133	2
R. Pond #1 hillside	202	133	6
R. Pond #1 hillside	203	136	5

Table 5: Field data for *Terrapene c. carolina* nest found on the Eccles mine, Raleigh County, West Virginia.

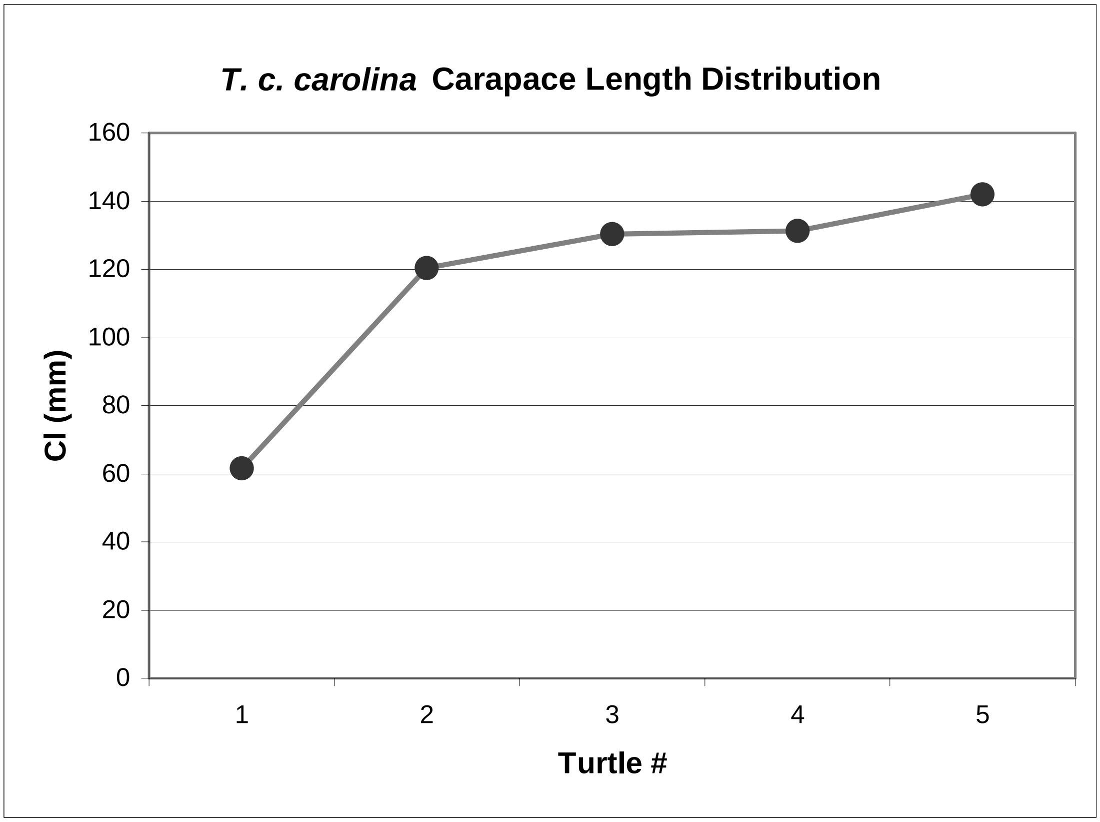

Figure 8: *Terrapene c. carolina* carapace length distribution

Figure 9 = Adult male *Chelydra s. serpentina* collected on 29, June 2004 from a Retention Pond. This specimen is typical of *C. s. serpentina* collected on the Eccles Mine.

Figure 10: **Two juvenile *Chelydra s. serpentina* collected from the naturalized marsh on 28, July 2004.** Juvenile’s carapaces housed large *Chelodinia* sp. algal mats.

***Figure 11: Placobedella* sp. leaches.** Leaches were present on all adult *C. s. serpentina* collected in this study and represent important ecto-parasites for the mines *Chelydra* population. Leeches attached on the ventral side of the legs in clusters of 5-15 individuals and directly to the carapace along the vertebral scutes.

Figure 12:* Adult male *Terrapene c. Carolina. Male collected while foraging on *Morrus* sp. along the mine road

Chapter 4

Snake Community Dynamics and Natural History of an Abandoned Mine Land in Southern West Virginia

Zachary J. Loughman

Abstract

Surface mining in Appalachian ecological systems have received considerable biological investigations in recent years because of the environmental consequences present at the initiation of mining activities, and effects on biodiversity while coal is harvested. Abandonment effects on repatriation of native species into reclaimed mine lands have received little attention; with reptile repatriation rates receiving no scientific investigation. Snake assemblages at 6 distinct macrohabitat types (high wall, successional forest, savannah, retention pond, marsh, railroad cut) were surveyed on a 25-year post reclamation contour surface mine in Raleigh County, West Virginia. Survey methods included drift fence arrays, trapping, and haphazard searches. Macrohabitats were surveyed for 100 investigator hours, and snake per unit effort (snakes/hour) values were calculated. Five of 14 snake species known to be present in Raleigh County were discovered inhabiting the abandoned mine lands. Habitat types with higher amounts of habitat complexity (high wall) resulted in more diversity than habitat types with low habitat complexity (bench). Snake per unit effort values were highest in macrohabitats with high levels of habitat complexity (high wall), or where habitat specialists were present (*Nerodia s. sipedon*). Overall snake diversity values for the reclaimed mine land (5 species) were lower than values from other local disturbed areas indicating that mining processes were negative to the snake community present.

Introduction

Several autecological snake studies have been conducted over the past century (Fitch 1960, Fitch 1999, Reinert 1984, Blanchard *et al* 1979), but very little work has been done focusing on snake community dynamics. The majority of snake community research has been performed when reptile communities were assessed for government purposes or future land use. Detailed natural history information was not the initiative behind this presence/absence style research. One factor for the small amount of snake community work is the inability to collect large sample sizes of any given species (Fitch 1960). Time is often a determining factor in relevant importance of any community study, and with snakes this appears to be the case as well. Unlike salamanders or turtles which can be collected in great numbers in relativity short periods of time, adequate capture rates for snakes often involve considerable effort with very little return.

The purpose of this investigation was to (1.) determine the snake community present on an abandoned mine land in southern West Virginia and (2.) elucidate specific natural history information for each snake species present on the mine. Southern West Virginia in the past century has received an increased surface mining effort, and the effect of this effort on present vertebrate communities pre and post mining has received very little scientific investigation. Studies have been performed on post mining effects on small mammals and passerine birds, but no research efforts have been conducted on reptile communities, leaving the true effects of mining on reptiles a mystery. That said, surface mining presents several potential positives and negatives for snake populations.

Unlike other herpetofaunal groups (salamanders, turtles, etc.) some authors have proposed that land altercation may ultimately benefit snake populations (Reinert *et al* 1984, Brown and Weatherhead in Lit Cit. 2000). Clearing canopies allows for increased solar radiation penetration, which is utilized by snakes for thermoregulatory purposes. Creation of highwalls and benches through the surface mining process produces structures on the landscape extremely similar to rock outcroppings, which are important landscape components for Appalachian snake communities. Fissure in bedrock produced by blasting may create important future hibernacula for snake communities present after mining efforts cease.

Mining also produces several potential negative aspects to ophidian populations. Several small fossorial snake species have been shown to have extremely small home ranges (Blanchard *et al* 1979, Fitch 1999). If these home ranges happen to be where a proposed bench is constructed, entire snake populations may be eliminated. Snakes ability to evacuate a mining area before initial mining efforts (land clearing and blasting) are begun may be the major factor that determines if they will be able to immigrate back into mine lands after abandonment occurs. Finally, habitat homogenization and the elimination of habitat complexity by creation of mining landforms (bench, retention ponds, gob piles) may make niche partitioning increasingly difficult for snake populations to resolve in the post mining landscape.

Material and Methods

Dominate macrohabitats were identified in order to compare and contrast habitat use on the mine. Habitats were identified based on previous research on abandoned mine lands and habitats readily identifiable by the mining industry. Resulting from literature searches, 6 readily recognizable macrohabitats were present on the mine. The following macrohabitats are listed in total mine surface area from largest to smallest: bench, successional forest, railroad track edge, retention pond, and naturalized marsh.

Snakes were captured using 3 distinct methodologies. Haphazard searches were used in all macrohabitat types both day and night. Searches consisted of approaching a particular macrohabitat type and performing an initial surface scan for any basking snake species. If no basking snakes were observed, active manipulation of the habitat type would commence with various substrate items (rocks, logs, detritus, etc.) turned in hopes of finding snakes. Total time for each search was recorded in order to calculate catch per unit effort values for each macrohabitat type.

Traps were constructed following Fitch's (1960) design and placed in all macrohabitat types along potential snake corridors. Though these traps proved to be quite successful for Fitch in Kansas, no snakes were captured using this trap design on the Eccles mine. Standard minnow traps were used in all water bodies present. Minnow traps were situated so entrance holes were 10-15 cm underneath the waters surface. This enabled the majority of the trap to be submerged and also have an adequate amount of air space for respiration to occur

The final capture method was utilization of a drift fence with traps. This method was only used in the bench based on suggestions by Fitch. Fitch noted that whenever possible, traps should be placed along natural drift fences such as boulders or logs (1960). No potential natural drift fences existed on the bench, so 100 m of drift fence was constructed along the west-facing wall that composed the western margin of the bench. Every 3m, a constructed snake trap was placed so the entrance was flush with the ground, and the lateral side made contact with the fence.

Upon capture snake snout-vent length, total body length, cranial width, cranial length, eye width, and mass were all noted. Observable behaviors prior to capture were noted, with specific microbehaviors (foraging, basking, cruising) timed. Feeding ecology was determined by palpating any objects present in the snake’s stomach into the oral cavity for identification. Reproductive condition of each individual (neonate, juvenile, adult) was noted. Macrohabitat and microhabitat type were both noted for each snake captured, as well as capture methodology. All snakes were marked with Passive Integrated Technology tags for mark recapture purposes. After data collection and PIT tag insertion all snakes were released at their point of capture

One gravid *Agkistrodon c. mokasen* was collected near the end of pregnancy and brought back to the laboratory. A 12h light dark cycle with air temperatures ranging from 20-24 c was maintained until parturition occurred. Female mass was calculated post and pre parturition in order to calculate relative clutch mass. The mother along with her neonates were each photographed with a scale bar in order to gain morphometric data (SVL, TBL, CW) from the clutch and not put the investigator in danger of snake bite. After data collection all snakes were released at the place of the mothers capture.

Results/Natural History

Five species of snakes were captured over the 2004 activity season. The following natural history data was collected from each species

Coluber c. constrictor/ Northern Black Racer

Coluber c. constrictor were the dominant large-bodied snake species found occurring on the mine. Phenotypically *C. c. constrictor* present on the mine were the normal *C. c. constrictor* phenotype, with stout bodies, well developed necks and robust heads. The dominate color phase of *C. c. constrictor* inhabiting the mine was the nominate morph for the subspecies, consisting of gun metal black dorsal and ventral coloration, with the ventral head scales being pure white grading into brown along the rostral scales. The color of the iris was either maroon or chestnut brown. All *C. c. constrictor* collected (n = 14) were healthy and showed no obvious evidence of physical maladies.

Mean SVL for *C. c. constrictor* was 75.2 cm, with a minimum SVL of 58.3 cm and a maximum SVL of 90.5 cm. Total body length averaged 95.7 cm with minimum TBL of 77.0 cm and a maximum of 90.5 cm. Snout vent lengths of *C. c. constrictor* within the mine were less than those calculated for *C. c. constrictor* within Virginia (mean SVL = 102.8 cm), but larger than Pennsylvania (mean SVL = 94.5 cm). (Hulse et al 2000, Mitchell 1994). There was a significant difference in mass between the sexes, with males averaging 246.0g, and females averaging 163.6g. This was contradictory to the finding of Fitch (1999) in Kansas and Mitchell

(1994) in Virginia. The average mass for *C. c. constrictor* mine population was 170.5g, with a minimum mass of 81g and a maximum mass of 337g. Females out numbered males 1.31 to 1.

C. c. constrictor were most frequently encountered along high walls of the mine. This macrohabitat was utilized heavily through May, when all *C. c. constrictor* capture events occurred. High walls probably represent important potential hibernacula for *C. c. constrictor* inhabiting abandoned mine lands. Of the 14 *C. c. constrictor* collected, 83% were found basking within a 10 m^2 area of high wall. The majority of these snakes were exhibiting some level of ecdysis, a condition common in snakes emerging from winter brumation. Within this small area *C. c. constrictor* utilized isolated grass clumps for basking sites. Snakes were found intertwined within the grass roots in a figure eight formation, with basking times ranging from 11:40h to 17:45h, with the majority of observed basking falling in the middle of this time range.

Upon provocation, *C. c. constrictor* was quick to retreat. Snakes along the highwall would utilize the near vertical nature of the wall to their advantage, with the majority of snakes basking near the top of the wall. Snakes would retreat by elongating their bodies and falling with the body held rigid in this manner. When any grass clumps, crevices or break down were encountered on the descent, snakes would immediately seek refuge in the structure.

Two *C. c. constrictors* were encountered moving through the bench. Both *C. c. constrictor* were moving, with one displaying foraging behavior similar to behaviors described by Fitch (1999). This snake was observed moving through short forbs, actively investigating grass clumps for durations of 10-30s. During the investigations, the snake's tongue flicked rapidly, and the snakes probed isolated grass clumps with their head. The other *C. c. constrictor* encountered on the bench was moving through a section of marginal wetland near naturalized marsh. Both snakes froze immediately once they realized they were being observed. During their capture the snakes took refuge in the densest section of vegetation they had access to. The snake that was moving through the marginal wetland regurgitated a large amount of liquid following capture.

Based of these observations, the bench may represent an important foraging ground for *C. c. constrictor*. Several potential *C. c. constrictor* prey species (*Microtus* sp., *Peromyscus* sp., *Sorex* sp.,) were collected within the bench. Also all *C. c. constrictor* encountered within the bench were moving through and actively investigating the macrohabitat. No *C. c. constrictors* were encountered in the longer more densely vegetated portions of the bench. This could be a product of collecting biases; however no *C. c. constrictor* were collected within the 100m of drift fence constructed in dense vegetation.

Three distinct behaviors (basking, foraging, defensive behaviors) were noted with *C. c. constrictor* collected during this study. All basking behaviors noted for this species were observed along the high wall. Snakes either basked in a linear pattern (22% of observations) or in a distinct figure eight (78% of observations) pattern. Linear basking always occurred in areas with 0% canopy cover and several potential cover objects. Figure-eight basking occurred 100% in grass clumps (*Andropogon* sp.). When basking in this fashion, *C. c. constrictor* would expose portions of the dorsal surface to the sun, with the majority of the snake being hidden within grass roots. The head was always exposed facing down hill. Basking behaviors were more frequently observed at the top of the high wall (72% of observations) than in the middle (20% of observations) or bottom (8% of observations) of the wall. By basking at the top of the wall, the potential number of possible escape routes increased dramatically than if the snakes were to bask in other vertical regions of the wall.

Defensive behaviors were displayed with 100% of captures. Upon capture, *C. c. constrictor* would immediately void the contents of the cloacae and musk glands, and bite profusely. *C. c. constrictor* did not mock bite like other snake species present on the mine. The majority of *C. c. constrictor* would chew for extended periods of times if they were successful with their attempted bite. When *C. c. constrictor* were released they slithered into the closest available crevice or hole or moved under a rock.

No mating or associated behaviors were witnessed with *C. c. constrictor* present on the mine. Several (n = 6) old nest sites were discovered. These nests were identified as *C. c. constrictor* by the proportion of egg length and width following the identification method described by Fitch (1999). All nests were discovered along various regions of the high wall, primarily along south east facing slopes. The mean number of eggs per clutch was 18, with maximum number of 22 and a minimum number 13. The majority of eggs investigated appeared to have produced neonates.

The mine abandonment process appears to have a cyclic effect on *C. c. constrictor* populations based on observations made on the Eccles site. This same cyclic effect was observed by Fitch (1960) in Kansas over a much longer period (48 years) than the time of this study. *C. c. constrictor* in Kansas immigrated into pasture land that had not experienced major succession and were abundant in these habitats. As succession occurred, vegetation density increased. With this increase, *C. c. constrictor* captures rates declined until a canopy was formed. With the addition of the canopy, shade pruning events caused vegetation density to decrease at which point *C. c. constrictor* re-colonized those areas. *C. c. constrictor* were also collected more frequently along ecotones in Kansas.

C. c. constrictor were encountered actively foraging in the section of the bench with short (.5m high) vegetation, and were not collected in areas of dense (+ .5m high) vegetation. *C. c. constrictor* collected along the high wall, which experiences large amounts of shade pruning, were all found actively thermoregulating. The same ecological factors that effected *C. c. constrictor* in Kansas appear to affect the snake in abandoned mine lands as well. *C. c. constrictor* evolutionary adaptations for diurnal activity allow this snake to utilize the bench at higher surface temperatures than other snake species. That said, this species was not discovered actively thermoregulating or foraging when mine surface temperatures exceeded 30 ^{o}C, which was a frequent occurrence in June, July and August.

Mine lands appear to be colonized as hibernacula sites and foraging grounds in early summer and early fall, and are vacated during the more extreme temperatures of mid to late summer months. Mine lands may only be utilized as hibernacula, and initial foraging grounds after spring emergence. During the majority of the activity season, *C. c. constrictor* may move into ecotonal areas with a more constant thermal regime than those found on the mine, and vacate the bench. When the summer season ends, *C. c. constrictor* will re-colonize the bench when thermal regimes become more homogeneous.

Diadophis punctatus edwardsii/ Northern Ring-Necked Snake

Diadophis punctatus edwardsii was the most abundant terrestrial snake species on the mine. The dominant phenotype was the nominate form. Dorsal coloration was bluish-black, with a marked black margin along each scale. Ventral coloration was orange yellow to vibrant yellow. Supralabials were white, grading to chestnut brown along the rostral scales. Immediately behind the occipital region of the head was a marked yellow – orange ring. Coloration was more vibrant in adults than neonates.

D. p. edwardsii was the smallest snake present on the mine. Snout vent lengths averaged 29.5 cm, with a minimum of 13.3 cm and a maximum of 43.4 cm. Total body lengths averaged 32.7 cm, with minimum lengths of 16.0 cm and maximum length of 54.5 cm. *D. p. edwardsii* mass averaged 8.6 g, with a minimum of 2g and a maximum of 20g. Snout vent lengths, total body lengths and mass were larger at the Eccles mine than measurements taken in Kansas, Virginia and Pennsylvania (Fitch 1999, Mitchell 1997, Hulse *et al* 2001). The male to female ratio was 2:1. This mirrors ratios for Kansas (Fitch 1999).

D. p. edwardsii were most frequently encountered in successional areas with a minimum 30% canopy cover. The majority of *D. p. edwardsii* were captured along a southwest-facing hillside immediately adjacent to retention pond #1, with the remaining captures occurring along an active railroad track that composed the west margin of the mine. Both the railroad track and RP#1 hillside were experiencing moderate amounts of succession. Sunlight amounts for microhabitats were reduced compared to bench sunlight amounts. Both macrohabitats were complex in nature, with several distinct types of microhabitats present in each. Fitch (1999) commented at length about the importance of habitat complexity with this species, stating that in homogenous environments *D. p. edwardsii* numbers were drastically reduced relative to abundance in heterogeneous complex habitats.

Microhabitat usage for *D. p. edwardsii* followed a distinct pattern. *D. p. edwardsii* were found with regularity primarily in mesic environments. Soil moisture was a major determinate of *D. p. edwardsii* abundance, with capture rates peaking after rain events. Small fossorial snakes like *D. p. edwardsii* have been correlated with soil moisture rates in several studies (Blanchard *et* *al* 1979, Fitch 1975, Fitch 1993), and this trend appears to be followed by *D. p. edwardsii* on the Eccles mine. Soil moisture and the link to *D. p. edwardsii* abundance may be linked more to the requirements of potential prey sources than the requirements of the snakes. Terrestrial salamander and earthworm abundance was also positively correlated to rain events, and this surge in potential prey abundance may have an effect on *D. p. edwardsii* movements and abundance.

D. p. edwardsii link to moisture rates is vividly displayed when the total number of *D. p. edwardsii* captured across the activity season is analyzed. *D. p. edwardsii* captures steadily increased as the activity season progressed. Very little precipitation fell from 15 July through the end of August. During this time, *D. p. edwardsii* captures rates went from a peak (n = 12) to no captures in an extremely short amount of time. Top soil quality on the mine site was poor, and the lack of a true canopy resulted in rapid moisture loss. By 5 August, top soil moisture was near 10%. No *D. p. edwardsii* were capture again until precipitation event returned with regularity in late August. Immediately after precipitation events returned, *D. p. edwardsii* were again captured with regularity.

D. p. edwardsii were captured underneath artificial cover 100% of time. The most frequented cover objects were sandstone slabs ranging from small 10 cm x 10 cm pieces to large 1m x 3m slabs. *D. p. edwardsii* also frequented spaces between 2 sandstone slabs. If fissures were noticeable, often a *D. p. edwardsii* would be resting in the deepest region of the fissures. These sites were frequented by snakes in the middle of an ecdysis cycle, and may be important refuges during this time in the snake's life cycle. Snakes were also found aggregating underneath sandstone slabs. In on incidence, 3 *D. p. edwardsii* were found underneath a piece of sandstone 10 cm wide x 17 cm long. Aggregating behavior has been documented numerous times for *D. p.*

edwardsii, and the true reasoning behind this behavior is yet unknown (Blanchard *et al* 1979, Fitch 1999).

One particular region of the mine produced large numbers of neonates. Along the rail road section of the mine the ridge line had been dissected through its peak, producing 2 artificial rock outcroppings. Along these outcropping were several "piles" of sandstone break down. These breakdown piles differed from other areas of high erosion by having very small sized pieces of cobble of a homogeneous nature. In these piles of breakdown, several neonate *D. p. edwardsii* were collected. No adult specimens were captured in these piles. Along with *D. p. edwardsii*, these breakdown piles harbored several ant colonies, a proposed food source for neonates *(*Blanchard *et al* 1979*)*. The thermal regime present in the breakdown piles also could have an effect on neonate total abundance within them.

No *D. p. edwardsii* with obvious palpable meals were captured. Based on work by Fitch (1999) and Mitchell (1994), several potential prey species were collected on the mine site. Mitchell found that *D. p. edwardsii* in Virginia predated heavily on various salamander species. Several of the salamander species preyed upon in Virginia were captured on the mine sight. The dominant potential prey species was the Long-tailed Salamander (*Eurycea l. longicauda*). This species required the same living conditions as *D. p. edwardsii*, and was collected frequently along with the snakes. Other potential prey species included Northern Slimy Salamanders (*Plethodon glutinosus*), Southern Two lined Salamanders (*Eurycea cirrigera*) and various earthworm (*Lumbricus* sp.) species.

The only behaviors observed for *D. p. edwardsii* on the mine were defensive. When sandstone slabs were flipped and a *D. p. edwardsii* was discovered, 100% of snakes froze for 3-10s. Upon provocation snakes tried to escape with rapid, wide lateral undulations of the body.

When grasped, *D. p. edwardsii* always voided the contents of the musk glands. In other regions of this species range, aposomatic color displays of the tail are utilized for defense (Ernst & Ernst 2003). *D. p. edwardsii* on the mine did not employ this defensive technique. Snakes never calmed during the data collection process.

Gravid females (n = 4) were collected between 4 June and 10 June. All gravid females were in the middle of an ecdysis cycle. Ecdysis usually occurs just prior to egg deposition, which probably occurred shortly after the females were capture. Neonates were collected in Early June and were young of the previous year. Fitch (1999) noted in Kansas that neonates stayed within the same 10 m2 area after hatching. Neonates on the Eccles mine were collected in breakdown piles, which probably represent a primary location for egg deposition

D. p. edwardsii is preyed upon by several animal species. Species known to prey on them that were present on the Eccles mine site included Coyotes , Raccoons , Virginia Opossums , Striped Skunks, Domestic Cats, Domestic Dogs, Red -shouldered Hawks , Red-tailed Hawks , Coopers Hawks, American Kestrels , Barred Owls, Screech Owls , Blue Jay , Common Grackles , Northern Black Racers , and Black Rat Snakes.

Moisture gradients appear to be the major limiting factor for *D. p. edwardsii* on the abandoned mine. The only macrohabitat type where *D. p. edwardsii* were not encountered was the bench. Soil moisture levels on the bench were constantly in flux, leading to very little moisture homogeneity. Soil moisture levels had a substantial influence on potential prey abundance. Moisture levels also limited microhabitat usage for this species. In past studies *D. p. edwardsii* has been shown to dehydrate rapidly when in xeric environments (Ernst & Ernst 2004). Though several *D. p. edwardsii* were collected on the mine, relative to other locations near the Eccles mine, the mine *D. p. edwardsii* population was not as large as other near by disturbed environments (Road cuts and Right of Ways along Rt. 3).

Pantherophis obsoleta/ Black Rat Snake

Pantherophis obsoleta were found in marginal (n = 6) numbers during this study. The dominate phenotype present on the mine was similar to most *P. obsoleta* found within central West Virginia. Dorsal coloration was black, with the ventral scutes being a dusty white anterior and grading into black posterior. The interstitial spaces between scales were white. This differs markedly from *P. obsoleta* found along the Ohio River and in northern West Virginia, where the interstitial spaces are dominated with reds, yellows and browns (Loughman personal obs.). The labial scales were various shades of white and cream. Iris coloration was black in all individuals captured (n = 6).

P. obsoleta SVL averaged 117.2 cm, with a minimum SVL of 103.1 cm and a maximum SVL of 128.0 cm. Average SVL was larger than *P. obsoleta* SVL calculated for Kansas (Fitch 1999), but smaller than SVL lengths calculated for Virginia (Mitchell 1994). Mean total body length for *P. obsoleta* on the mine was 137.2 cm, with a minimum of 125.1 cm and a maximum of 150 cm. This was larger than TBL calculated for Kansas (Fitch 1999), and Pennsylvania (Hulse *et al* 2000), but smaller than TBL calculated in Virginia (Mitchell 1994). Average adult mass for *P. obsoleta* was 463 g, with a minimum mass of 318g and a maximum mass of 600g. Average *P. obsoleta* mass was smaller than average mass calculations for Kansas (Fitch 1999). All *P. obsoleta* captured were sexually mature adults based on data for *P. obsoleta* populations present in Canada (Weatherhead & Haysuck 1989), and Kansas (Fitch 1999). The ratio of males to females was 2:1.

All *P. obsoleta* captures were associated with ecotones, with 67% of captures occurring along the high wall/ forest ecotone, and the remaining 33% of captures occurring along the entrance path to the bench. The macrohabitat of the entrance path is a successional forest with several ecotone characteristics, such as an open canopy, large amounts of herbaceous vegetation, and multiple open patches of earth. Like *C. c. constrictor*, the majority (67 %) of *P. obsoleta* captured were along the same section of high wall hypothesized to be a den site.

All *P. obsoleta* found in the hibernacula site were basking. Dominate basking behavior was the figure eight pattern. Snakes were situated underneath over hanging rocks, with various sections of their coils exposed to sun light. No linear basking was observed with this species. Vertical utilization of the hibernacula site was similar to *C. c. constrictor,* with all snakes found basking at the highest point of the high wall. Upon approach, basking snakes froze, and appeared to rely on crypsis for protection.

P. obsoleta found along the bench entrance path were actively moving across the path. Cruising *P. obsoleta* were not observed exhibiting any specific foraging behaviors while on the move, and appeared to simply be moving from point A to point B. Upon detection, *P. obsoleta* froze, and proceeded to flick the tongue rapidly. All *P. obsoleta* captured were aggressive upon initial contact, but calmed down rapidly after handling. Snakes would elevate the first third of their bodies in an undulated "S" pattern and strike repeatedly. All strikes were mock strikes, and strictly for intimidation purposes. During the duration of this defensive display, the tail was rapidly vibrated in vegetation producing an audible "buzzing" sound.

Most *P. obsoleta* captures occurred in early May (67%), with the remaining captures (33%) occurring throughout July. Hibernacula captures all occurred in May, with basking occurring during 100% of captures. The first *P. obsoleta* captured was captured on 13 May, and was in the middle stages of ecdysis. Ecdysis occurs in snakes after spring emergence, and this incidence is evidence of early May being the primary time of *P. obsoleta* emergence. The fact that so many observations of *P. obsoleta* occurred along the same section of high wall as *C. c. constrictor* , and that this particular 10 m^2 section of high wall has several hibernacula characteristics (southeast-facing aspect, surface fissures) is strong evidence for highwall use as potential snake hibernacula. All other *P. obsoleta* observations occurred in additional ecotone areas (bench entrance path) of the mine, in later portions of the activity season.

Several *P. obsoleta* potential predators were found inhabiting the mine including Coyotes , Raccoons , Virginia Opossums , Domestic Cats , Domestic Dogs , Red-shouldered Hawks, Red-tailed Hawks , Coopers Hawks , Barred Owls , Screech Owls, Northern Black Racers, and Black Rat Snakes. One potential predator, Red-tailed Hawks, frequently hunted above the bench through out the activity season. Fitch (1999) noted this raptor as an important *P. obsoleta* predator in Kansas. Several pairs utilized the Eccles mine as a primary hunting ground. Passerine birds were also abundant on the Eccles mine, and though these birds represented an important potential food source for *P. obsoleta*, their mobbing behavior has been theorized to lead raptors to potential snake predators (Fitch 1999). Throughout the study multiple mixed passerine flocks were found mobbing a perceived threat. Several unsuccessful attempts were made to identify the cause of these mobbings. There is little doubt that at least a few of these events were directed toward *P. obsoleta*.

No *P. obsoleta* captured during this study had direct evidence of feeding. Based on previously recorded food items, several potential prey species inhabited the mine including White Footed Mice, Eastern Chipmunks, Eastern Cottontails, Meadow Voles, Common Shrews, and several passerine bird species. No direct evidence of reproductive behaviors was observed for *P. obsoleta*

P. obsoleta was not observed to actively utilize the bench of the mine. They have been noted in several studies to prefer cooler environments than *C. c. constrictor* (Ernest &Ernest 2003, Fitch 1999). This aspect of *P. obsoleta* biology was responsible for the high occurrence of *P. obsoleta* in ecotonal areas. The complex microhabitats present in an ecotone afford several potential thermal regimes that *P. obsoleta* could actively utilize. The habitat homogeneity present on the bench likely limits its potential use for *P. obsoleta*. This lack of potential habitat for *P. obsoleta* is hypothesized as the major limiting factor for this their presence in mined areas.

Highwalls along mine lands may represent important potential hibernacula for *P. obsoleta*. Several studies show that *P. obsoleta* migrate distances up to 1 km to potential hibernacula (Ernst & Ernst 2004, Fitch 1999, Weatherhead & Haysuck 1989). Snakes may utilize highwalls and the complex microhabitats associated with them for the duration of brumation, and then with spring emergence move onto more constant thermal environments.

Nerodia s. sipedon / Common Watersnake

Nerodia s. sipedon was the only snake species that complete and detailed natural history data was collected. All major wetland systems on the mine were surveyed for *N. s. sipedon*, with only 1 resident population found in a (60 m^2) naturalized marsh.

Mean SVL was 43.9 cm, with a minimum SVL of 27.0 cm and a maximum SVL of 70.4 cm. Total body length averaged 61.5 cm, with a minimum of 35.1cm and maximum of 92.2 cm. Mean total mass was 43g, with a minimum of 15.5 g, and a maximum of 295g. Snout vent length, total body length and mass all averaged smaller than *N. s. sipedon* populations studied in

Kansas and Virginia (Fitch 1999, Mitchell 1994). Male to female ratio was 1:1 and matched data collected for *N. s. sipedon* in Kansas (Fitch 1999).

The largest population of *N. s. sipedon* was present in a naturalized marsh in the north western region of the bench. This area was the low point of the bench, and has been an established wetland for at least 18 years based on aerial photographs. Marshes built during the reclamation process harbored no *N. s. sipedon* populations. Retention pools were also trapped with no results. Heavy metal deposition occurs in these pools, resulting in little aquatic life. One centrarchid species (Green Sunfish, *Lepomis cyanellus*) was present in the ponds and possibly represent a potential food source for *N. s. sipedon*. Even though an adequate food source was in the retention ponds, no *N. s. sipedon* were captured after several trapping efforts. *N. s. sipedon* aquatic macrohabitat preference appears to be limited to naturalized wetlands on the mine and was not present in anthropogenic produced water bodies.

Several specific microhabitats were present in the marsh, and various *N. s. sipedon* age classes utilized specific microhabitats over others. The majority of the marsh was 10 – 20 cm deep. This section of the marsh was dominated by *Juncus effuses*, *Carex* sp, and *Cyprinus esculenta*, with no species dominating over another. Several *Poliginum* species were present, including a large crop of tearthumb (*Polygonum* sp.) This “vegetation zone” composed 65% of the marsh. Moving in from the edge, the next microhabitat type was an edge to open water. Water depth increased to 25-35cm. This microhabitat was dominated by 2 two plant species, *Juncus effuses* and *Typha latifolia*, and composed 30% of the marsh. Open water in the center of the marsh was the final microhabitat type, and composed the remaining 5% of the marsh. One algae species was present in a monoculture, *Chara* sp. Water depth increased to 35-50 cm. *Chara* mats ranged from 5cm-20cm in depth, with the largest mats growing in the deepest water. No trees were present along the marsh margins.

Traps (n = 30) were placed in each microhabitat zone (10 traps per zone) in an effort to determine microhabitat utilization across age classes and the sexes. Neonates and juveniles utilized the vegetation zone more frequently than adults, with 86% of neonate/juvenile captures occurring in this microhabitat. Adults did not use the vegetation zone (0% of captures), but utilized the edge (78% of captures) and open water (22% of captures) much more than juveniles. Between the different types of edge vegetation types, *Juncus* (78 %) were used more often than *Typha* (32 %) edges. Open water captures were limited to the 4 largest females captured in the study. Several *N. s. sipedon* were recaptured in the same microhabitats multiple times indicating high microhabitat/site fidelity.

Although *N. s. sipedon* is known for its piscivorous habits, *N. s. sipedon* in the marsh fed 100% on anurans. Two anuran species, *Rana clamitans melanota* and *Rana catesbeiana*, both inhabited the marsh, with *R. c. melanota* the dominant of the 2 species. Both anurans were captured in traps along the edge more frequently than other microhabitats in the marsh. These results mirror adult *N. s. sipedon* capture rates, indicating that the open water edge was a probable preferred foraging ground for adult *N. s. sipedon*. Along with trap data, actual *N. s. sipedon* foraging behavior was observed twice during the study.

On 31 May, at 22:37 h, an adult female *N. s. sipedon* was observed displaying foraging behavior. The snake was swimming using small undulations along a *Juncus* edge. As the snake neared a *Juncus* tussock, she submerged her head and proceeded to prod the *Juncus* root masses. Each investigation lasted between 10 – 15 s. The snake would surface and slowly move on to the next plant. As the snake neared each clump, she would submerge and actively investigate each root mass. The female was observed for 15 minutes in this fashion before being captured and actively investigated 15 m of open water. Upon capture the snake regurgitated an adult male *R. catesbeiana* with a SVL of 9.8 cm.

An additional 4 snakes were captured with palpable meals. All 4 *N. s. sipedon* had preyed on *R. c. melanota*. The 4 *R. c. melanota* were males, which call from both the *Juncus* and *Typha* edges. No food data was acquired for juveniles or neonates. Anurans species utilized various microhabitats present in the marsh with different prevalence. *Pseudacris crucifer*, *Bufo a. americanus,* and *Hyla versicolor* all used the vegetation zone of the marsh much more than *R. c. melanota* and *R. catesbeiana*, and possibly represented important potential prey species for juvenile *N. s. sipedon*.

Basking behaviors were not observed for *N. s. sipedon* in the marsh. *Typha* regions of the marsh were likely important basking areas for *N. s. sipedon* based of previous research (Ernst & Ernst 2004). The marsh was situated in the Northwestern portion of the bench, and like the bench, was subject to extremely high mid-afternoon temperatures. Basking probably occurred in early to mid-morning, with snakes using the constant water temperature as a thermal buffer for the strong afternoon sun. The majority of behaviors were observed after dark, indicating that *N. s. sipedon* on the mine were primarily nocturnal. Colder temperatures, safety from diurnal predators, and prey activity were probable reasons for *N. s. sipedon* nocturnal behavior on the mine.

N. s. sipedon defensive behaviors varied among age classes. Juveniles displayed sematic behaviors (flattening the lateral region of the body and the occipital region of the head), more rapidly than adults, and also relied on biting (76 % of captures) more readily than adults (29 % of captures). Adult *N. s. sipedon* relied heavily on voiding cloacal and musk gland contents (89% of captures) much more readily than biting. Successful musking events were often followed with biting attempts directed towards the musked area. Gravid females were collected on 4, 17, and 21 June 2004. Snakes were not brought into the laboratory in hopes of gathering recapture data through out the activity season.

N. s. sipedon captures steadily increased from May through July, and markedly decreased in August (figure?). As surface temperatures reached their peak in late July, *N. s. sipedon* captures almost ceased entirely, with only 2 snakes being captured from 26 July through 31 August. Given that traps were the primary mean of *N. s. sipedon* captures, and *N. s. sipedon* enter traps often in response to foraging, this gap in captures may represent a summer brumation period. Previous research shows that as thermal maximums are reached in the summer season, *N. s. sipedon* go into a state of dormancy and wait out the thermally extreme portion of their activity season (Fitch 1999). This appears to be the case with *N. s. sipedon* on the Eccles mine. At this period of the summer season, the marsh was experiencing summer draw down, with water levels in the vegetation zone less (5 cm-10 cm) than other times during the summer season. Water depths in the open water zone averaged 22 cm, which is markedly low compared to the beginning of the summer season. *N. s. sipedon* also could possibly immigrate to other water sources during this time. Beginning in mid-August precipitation events returned, and shortly after water levels returned to early summer levels, *N. s. sipedon* were again captured in the marsh

Two potentially important predators were marsh obligate species. *Lethocerus americanus* (Giant Water Bug) were abundant in the marsh. These large carnivorous insects have been documented to be important predators on juvenile *Nerodia fasciata* in coastal plains swamps (Mushinsky & Miller 1993). On several occasions these insects were trapped and upon investigation were preying on trapped amphibians. There is little doubt that these impressive insects could easily overpower and devour neonate *N. s. sipedon*. Snapping turtles (*Chelydra serpentina*) also inhabited the marsh. While *C. serpentina* have not been documented to actively seek out *N. s. sipedon* as a potential prey source, it is probable these opportunistic carnivores readily prey on *N. s. sipedon* when encountered.

N. s. sipedon population present probably was limited by resource size. The marsh studied was relatively small, and as a result supported a small *N. s. sipedon* population. Population size was calculated using the Craig – du Feu population estimate based of recapture data. *N. s. sipedon* population was estimated to be 16.2 individuals, with a correction factor of +/- 2.42 individuals. Fourteen individual snakes were captured, with 10 individuals captured 1 time, 3 individuals captured 2 times, and 1 individual captured 4 times. *N. s. sipedon* did not utilize anthropogenic derived wetlands on the mine, and only used naturalized wetlands. Naturalized wetlands were limited to the northwestern and southeastern portions of the bench, and were not a dominate macrohabitat type for the mine. Acid mine drainage was present in the southwestern naturalized wetlands, and drastically limited its use to extremely pollution resilient amphibians species.

Several potential wetlands were present on the mine, and immigration into these wetlands probably has occurred with *N. s. sipedon*. A potential cause of population decline is selenium pollution which was documented in all the retention ponds (Anker Energy communication). This heavy metal has been shown to limit ova growth and maturation in *Nerodia fasciata* (Ernst & Ernst 2004). In southern swamps, *N. fasciata* appeared healthy, but were totally sterile from selenium contamination. This is a possible hypothesis for the limited total population size for *N. s. sipedon* on the mine. If *N. s. sipedon* were to immigrate to retention ponds and feed on selenium contaminated fish stocks, possible *N. sipedon* population declines would occur. The adult/juvenile ratio (3:1) shows signs of limited population recruitment from younger age classes. The only way for selenium contamination determination is to collect tissues from various *N. s. sipedon* on the mine and have them processed. This unfortunately is quite expensive, but an area of future research and a possible major population limiting factor on the Eccles mine.

Northern Copperhead/ *Agkistrodon contortrix mokasen*

A. c. mokasen were a rare on the mine. *A. c. mokasen* subspecies have 2 distinct color phases (Ernst & Ernst 2004). The copper phase is dominated by pinks, oranges and coppers, while the platinum phase displays dusky browns, grays, and various shade of silver. All *A. c. mokasen* collected in this study were the platinum color phase, with the dominate colors being various shades of gray. The head scalation was orange to copper in coloration and homogeneous in nature. Saddle bagged markings ran the length of the body, with a distinct spot of brown in each bag. Irises were various shades of yellow, and pupils were elliptical in shape

All *A. c. mokasen* collected in this study were females. Snout-vent length ranged from 55.2 cm to 62.2 cm with an average SVL of 58.5 cm. Mean total body length was 68.7 cm with a minimum of 64.8 and a maximum TBL of 71.8 cm. Mass was not calculated for 2 of the 3 snakes due to safety concerns. A gravid female was collected on 23 August and brought into the laboratory until parturition occurred. Pre parturition mass was 189.2g, with a post parturition mass of 99.9g.

Parturition occurred on 29 August in the early morning hours. Average neonate snout vent length was 12.1 mm, with a minimum of 9.9 and a maximum of 13.9 mm. Total body length ranged from 14.3 mm to 11.9 mm with an average of 12.8 mm. Mean neonate mass was

4.2 g, with a minimum of 2.2 g and a maximum of 5.0 g. Male to female ratios were determined based of tail/body ratios calculated for *A. c. mokasen* in Kansas (Fitch 1960). Based on Fitch's percentages, the male to female ratio was 1:1.2. All neonates went through ecdysis within 30h of birth.

Of the 3 *A. c. mokasen* collected, 66% were collected at the high wall hibernacula, with the remaining 33% captured along railroad tracks that make up the western margin of the mine. Two *A. c. mokasen* were collected in early June, with the obviously gravid female collected on 23 August. The railroad track specimen was captured by turning a large (17 cm X 31 cm) sandstone slab near a break down pile. This individual was in the midst of an ecdysis cycle, and highly defensive in nature. The remaining 2 *A. c. mokasen* were collected at the highwall hibernacula site. Both snakes were thermoregulating along a cliff, 10m from the bottom.

Two pregnant females were collected along the highwall. The first snake, taken at the highwall was collected on 2 June and showed signs of ovulation. The last 2/3 of the snake's length was distended. This snake was not taken into the laboratory because it was in the beginning part of pregnancy. The *A. c. mokasen* collected on 23 August was basking within 3.4 m of the female collected on 2 June. The fact that 2 gravid females were collected within the immediate vicinity of each other is evidence that the highwall hibernacula is an important rookery for *A. c. mokasen* on the mine.

Specific microhabitat regimes for the cliff face where the gravid *A. c. mokasen* were basking included a southeast-facing aspect, open canopy, and a large amount of breakdown and herbaceous vegetation. The dominant vegetation for the cliff was multiflora rose (*Rosa multiflora*), with one large plant taking up the majority of the cliff face. The female collected on 2 June was basking with 2/3 of its body exposed to the sun in an open section of the cliff face.

The snake was basking underneath a sandstone slab. The female collected on 23 August was basking in dappled sunlight at the base of the *R. multiflora* bush.

Reinhardt (1984) studied the movements of *A. c. mokasen* in Virginia and found that the microhabitat needs of gravid *A. c. mokasen* are different than male or non-gravid females. Specific requirements needed by gravid females included southeastern-facing slopes, with an open canopy, large amount of habitat complexity, and rock breakdown. All of these components were present at the hibernacula site, making this particular site an important component of the reclaimed mines landscape for *A. c. mokasen*.

No diet information was gathered for *A. c. mokasen*. Pregnant snakes, especially vipers are known to consume little or no food during the duration of their pregnancies (Brown and Weatherhead 1996). Fitch in 1960 did an exceptional autoecological study of *A. contortrix* and determined the principle component of adult *A. contortrix* diet to be rodents, ectotherms, and insects in that order. Based of this work, potential prey items known to inhabit the Eccles mine included White Footed Mice , Meadow Voles , Jumping Mice , House Mice , Black Racers , Ring-necked Snakes , Grasshoppers, and Cicadas.

The dominant behavior displayed by *A. c. mokasen* on the mine was thermoregulation. Both females found basking at the hibernacula sight were basking in a 100% coil typical of viperine snakes. The latter third of the body was wrapped in a circular shape, with the second third of the body resting on top of the last third. The first third of the body is then formed into a loose figure eight, with the head resting in the middle of the coil. Both snakes had positioned themselves with the back of their coil touching the highwall proper, and their heads facing the open cliff face. When the snakes were approached their tongues were flicked vigorously, but they did not move from their coiled position. The only act that caused the snakes to flee from their resting place was when they were grasped by snake tongs. At this point the snakes immediately rattled their tales in vegetation, released the contents of their musk glands, and struck repeatedly at the tongs head. When released the snakes took to cover and did not stand their ground.

Highwalls may represent important rookeries for *A. c. mokasen*. This species has been shown to readily take to disturbed areas, especially when tree canopy cover is limited (Fitch 1960). Ecotones are particularly suitable for *A. c. mokasen* populations, and the ecotone creation process of strip-mining could possibly benefit *A. c. mokasen* populations if they are able to survive the active mining phase of an operation. Fitch (1960) found that gravid *A. c. mokasen* would move considerable distances from winter hibernacula to birthing rookeries. The fact that only gravid *A. c. mokasen* were collected in this study possibly shows an immigration into the Eccles mine of gravid *A. c. mokasen* from neighboring core *A. c. mokasen* populations not present on the mine.

Like all snakes species except *C. c. constrictor*, *A. c. mokasen* were not found actively using the mine's bench. The extreme temperature range present on the bench most likely limits *A. c. mokasen* usage of this macrohabitat. Since only gravid females were found on the Eccles mine, this may truly limit *A. c. mokasen* usage of the bench, given that strict thermal regimes are necessary for a female to go full term with her pregnancy.

Discussion

Compared to other ecological systems present in southern West Virginia, ophifauna was not diverse (Green & Pauley 1987). Raleigh County has 14 recorded snake species, but just 5 species were found on the mine. Species found in Raleigh County but not found inhabiting the Eccles mine shared several life history traits. The majority of species not found on the Eccles mine were either specialist (*Storeria o. occipitomaculata*, *Opheodrys vernalis*, and *Carphophis amoenus*) or species that follow K strategies (*Crotalus h. horridus*). Specialist species often are the first species to be eliminated when increased anthropogenic pressures appear. Initial land clearing activities result in extirpation of specialist species because they are not able to survive the 10 + years of active mining. Mining limits the ability for these species to repatriate mine lands when they become inhabitable during the reclamation/abandonment phase of the mine

The main determinate of snake community diversity in previous studies was high levels of habitat complexity (Fitch 1999, Fitch 1960, Ernst & Ernst 2004). When the 6 macrohabitat types present on the mine are compared to each other, Eccles mine results mirror those of previous studies. Snake catch per unit effort values were highest in highwall, successional forest and railroad macrohabitats in that order .These habitats had several unique microhabitats within each macrohabitat type. The highly heterogeneous nature of microhabitat types within these environments presents the snakes with diverse thermal regimes, diversity of prey types, and multiple potential refuges within each macrohabitat type. Microhabitat diversity also limits intraspecific competition by providing several potential refuges to a given snake community.

Macrohabitats with low levels of habitat complexity, like the bench and retention ponds, had low catch per unit effort values compared to habitats with high levels of microhabitat diversity. These macrohabitat types also were subject to extreme environmental fluxes. During rain events retention pond levels would increase by meters, with littoral zones disappearing for up to 17 days at a time. Bench surface temperatures often peaked above 30 ^{o}C for the duration of diurnal hours. Also during rain events, the access road to the northern regions of the mine would become a creek bed, with the bench serving as the creeks floodplain. One instance in particular on 2 June 2004 resulted in 100% of the bench surface being inundated by flood waters. Water depth on 3 June across the bench averaged .45m, and water existed on the bench surface for approximately 4 days after initial flooding occurred. Extremes of this nature would be extremely difficult for an ectotherm to overcome and persist in for the duration of an activity season.

The bench also was the macrohabitat type that composed the majority of the mines surface, with the majority (68%) of available habitat taken up by the bench. Given that this habitat in particular composed the majority of the mines surface yet harbored the smallest snake populations indicates that surface mining efforts are detrimental to local snake populations. Immigration back into mine lands after mining activity has ceased appears also to be limited to species with high levels of survival ability and generalist life history traits.

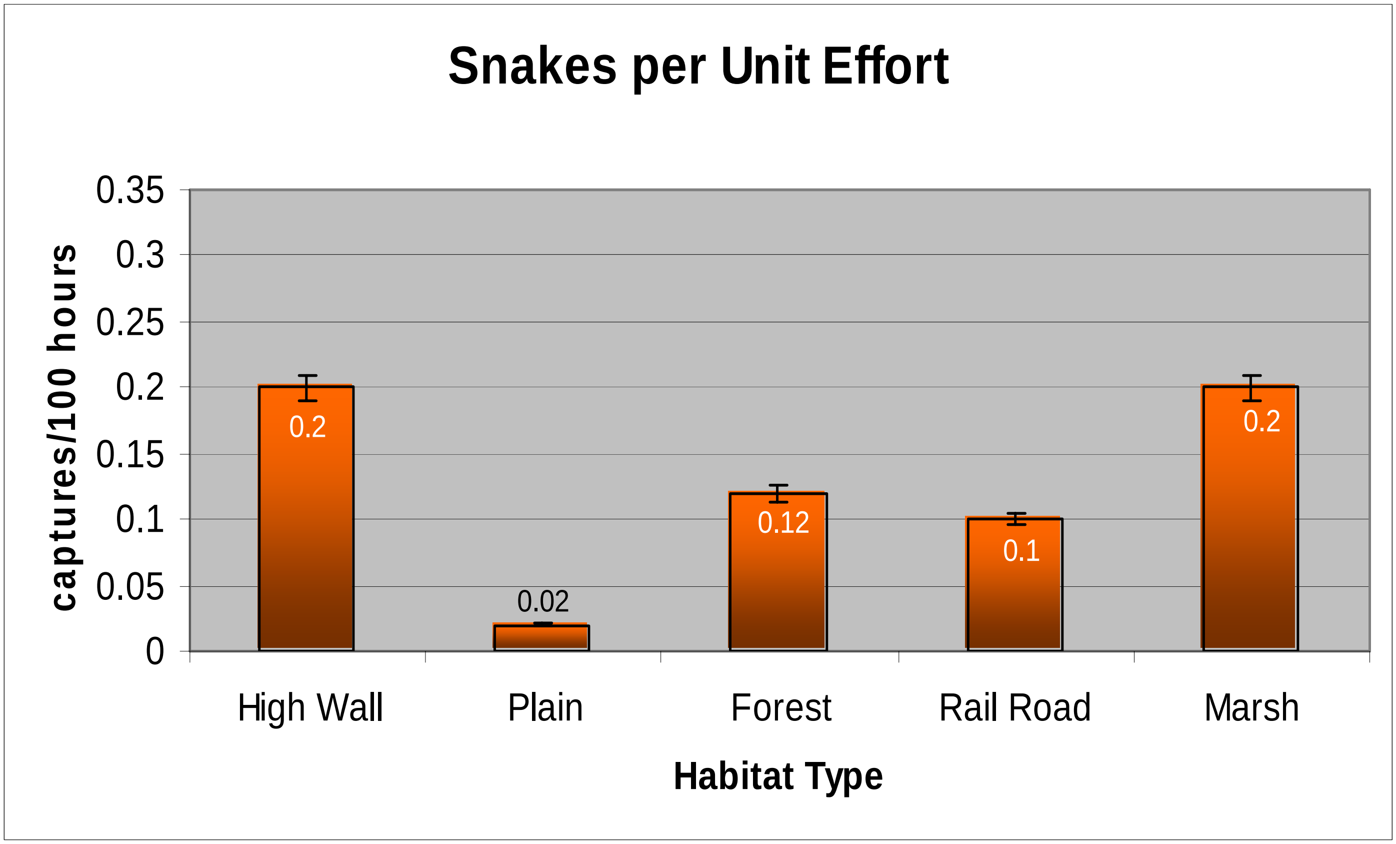

Figure 13: Capture per unit effort values for each dominate macrohabitat type

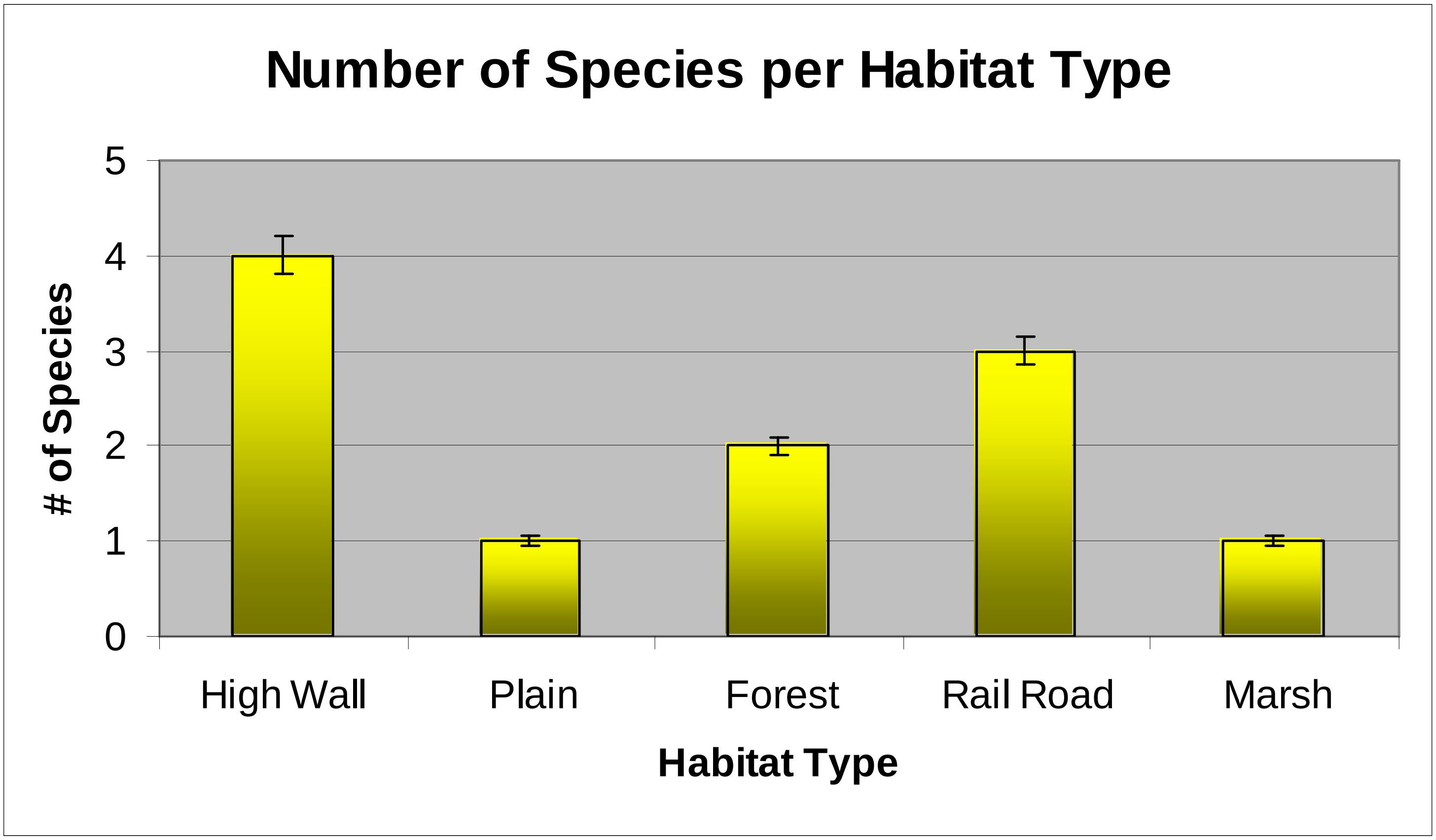

Figure 14: Number of snake species captured in each dominate macrohabitat type.

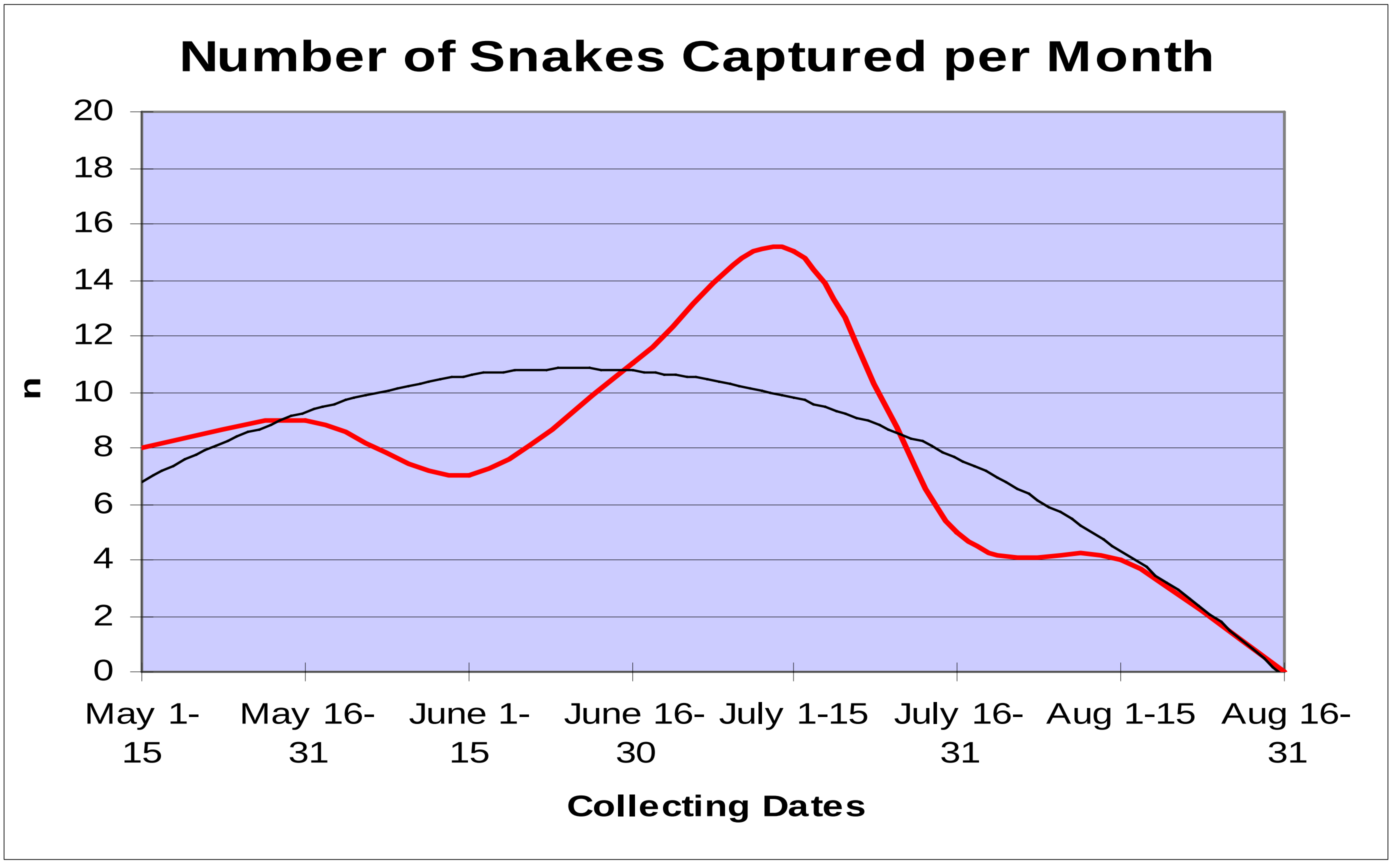

Figure 15: Total number of snakes captured on the Eccles Mine Site during the 2004 activity season

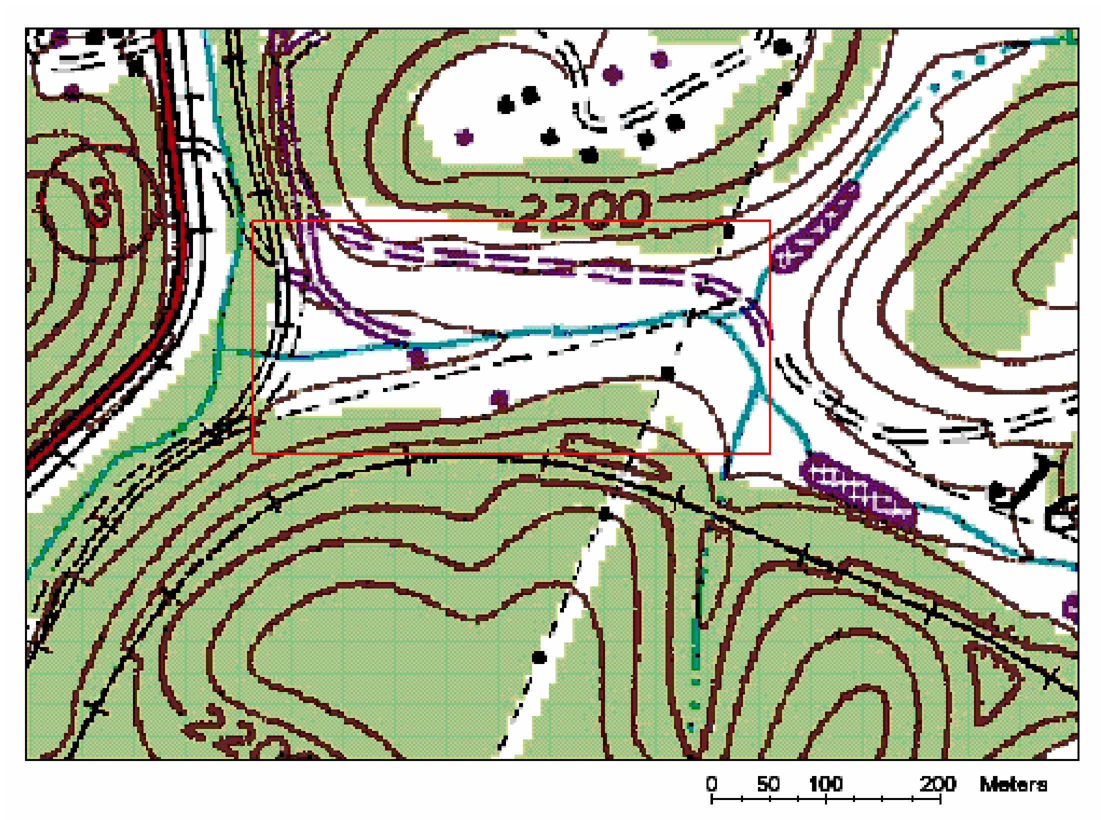

Figure 16: Eccles Mine Bench. Bench boundaries are outlined in red. Bench macrohabitat characteristics included variable surface temperature, low habitat stability, homogeneous microhabitats

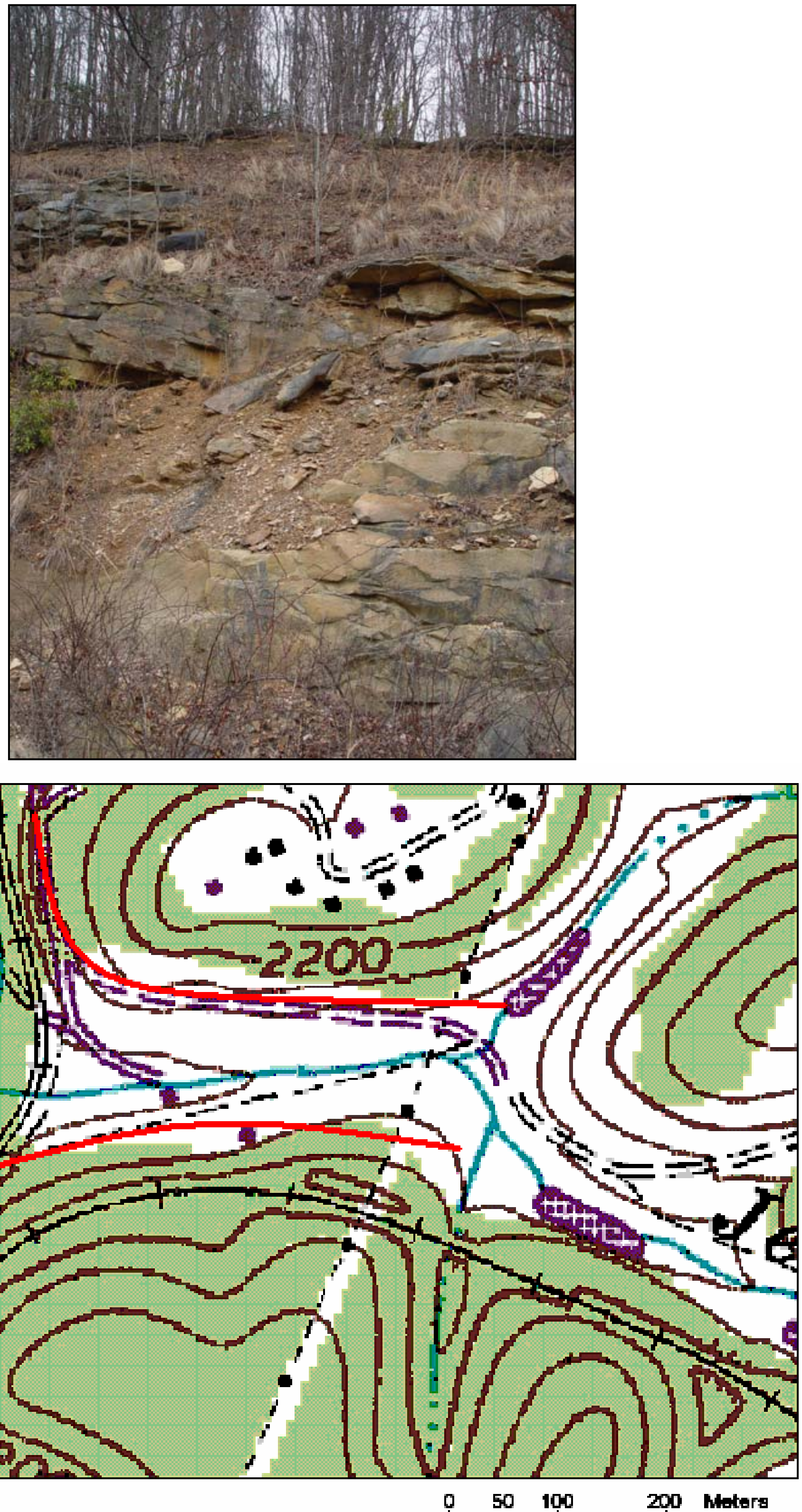

Figure 17: Eccles Mine High Wall. High Wall outlined in red. High Wall macrohabitat characteristics included extreme vertical profiles, thermal stability, and heterogeneous habitat complexity

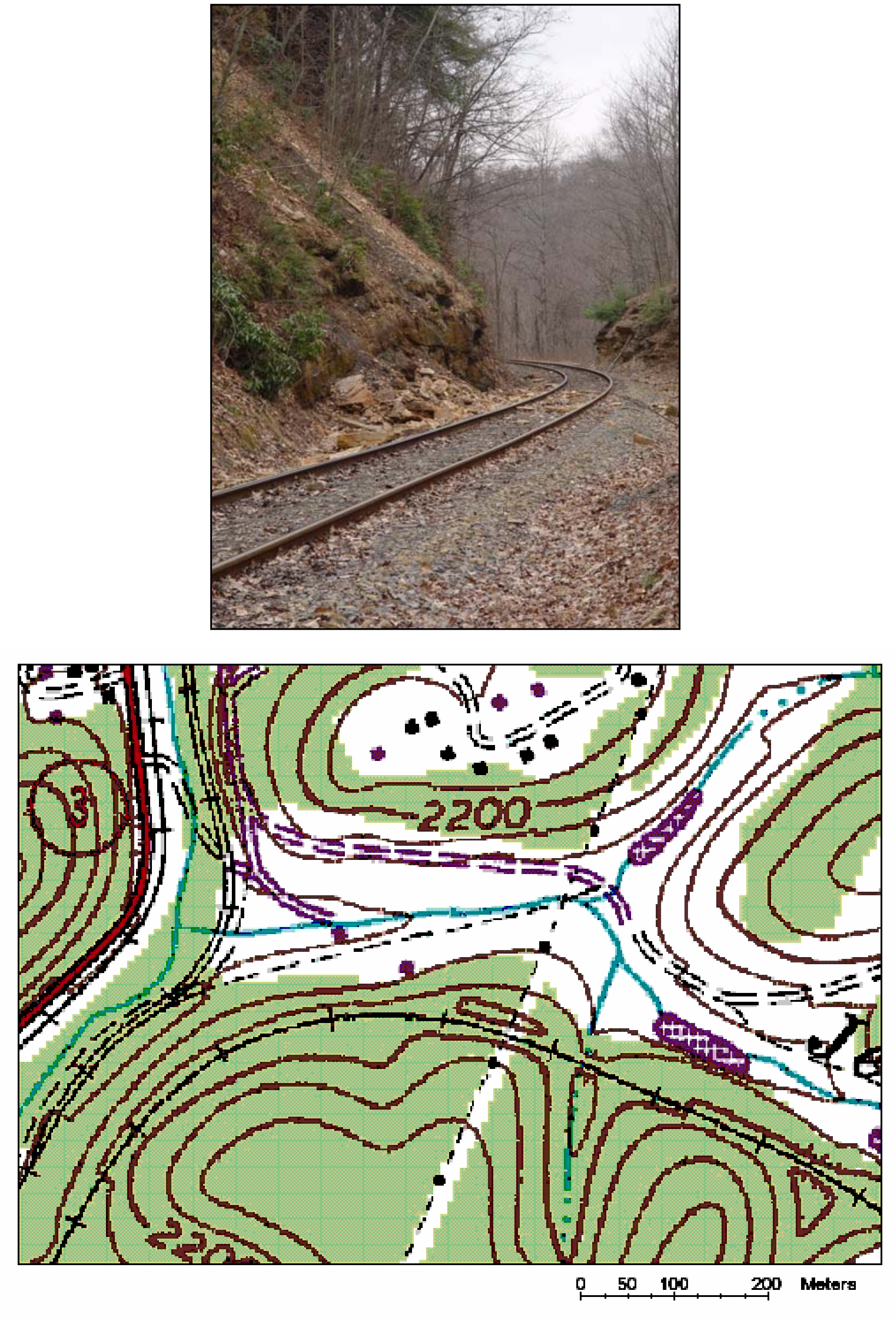

Figure 18: Eccles Mine Railroad. Railroad macrohabitat characteristics included breakdown piles, thermal stability, and heterogeneous habitat complexity

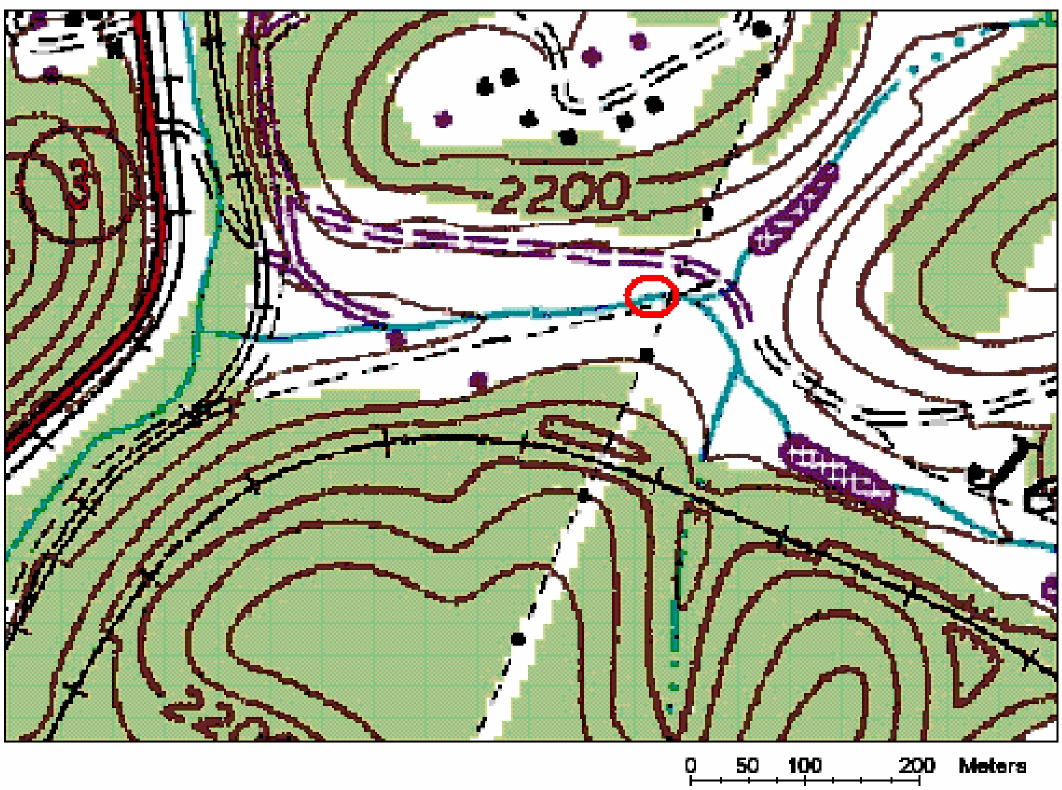

Figure 19: Eccles Mine Naturalized Marsh. Naturalized Marsh margins outlined in red. Naturalized marsh macrohabitat characteristics included developed litoral zone, emergent vegetation, and *Typha* stands.

Figure 20: ***Coluber c. constrictor*** **(top) and** ***Pantherophis obsoleta*** **(bottom).** These species frequented highwalls and preyed on the mines rodent population.

Figure 21: Adult female *Nerodia s. sipedon* collected while nocturnally foraging in the "natural marsh". This species was the only snake species that appeared to thrive on the Eccles mine. *N. s. sipedon* were only collected in marshes that were created through ecological succession.

Figure 22: *Diadophis p. edwardsii* captured in breakdown pile along Eccles Mine Railroad Track. *D. P. edwardsii* were the most common snake in this macrohabitat type.

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