# Population Monitoring and Habitat Characterization for the Conservation and Recovery of the Northern Population of the Copperbelly Water Snake (*Nerodia erythrogaster neglecta*)

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Top right: Close-up of head of Copperbelly Water Snake, 2001. Photo by Glenn Fox.
Center: Copperbelly Water Snake, Hillsdale County, MI, 2001. Photo by Glenn Fox.
Bottom left: Inundated shrub swamp, copperbelly habitat, Hillsdale Co., MI, 2004. Photo by Michael A. Kost.

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# STUDY PERFORMANCE REPORT

STATE: Michigan

COOPERATORS: Michigan Natural Features Inventory, Indiana-Purdue University at Ft Wayne, Michigan Department of Natural Resources, U. S. Fish and Wildlife Service

PROJECT TITLE: Michigan's Endangered and Threatened Species Program

PROJECT NO: E-8

STUDY TITLE: Surveys for the conservation and recovery of the northern population of the Copperbelly Water Snake (*Nerodia erythrogaster neglecta*)

PERIOD COVERED: October 1, 2004 through December 31, 2006

## OBJECTIVES:

1. Determine the current status and distribution of the Copperbelly Water Snake in Michigan, Ohio, and Indiana.
2. Characterize habitat at multiple spatial scales to clarify ecological requirements.
3. Maintain and enhance Michigan, Ohio, and Indiana's information base to aid in the conservation and recovery of this species.
4. Increase public awareness to aid in the conservation and recovery of this species.

## SUMMARY/FINDINGS:

The project objectives identified in the grant proposal were addressed, and significant progress was made toward accomplishment of these objectives in 2005 and 2006. Detailed summaries of project activities and findings from 2005 and 2006 are provided in the following report and in the attached report entitled "Habitat Characterization and Evaluation of Community Types Utilized by Copperbelly Water Snake (*Nerodia erythrogaster neglecta*) in Michigan and Northern Ohio" by Kost et al. (2006).

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## INTRODUCTION

The Copperbelly Water Snake (*Nerodia erythrogaster neglecta*), a subspecies of the Plainbelly Water Snake (*Nerodia erythrogaster*), is a medium to large, stout-bodied, non-venomous snake that can reach adult lengths of 76 to 158 cm (30 to 62 in) (Conant 1949, Conant and Collins 1998, Harding 1997). The Copperbelly Water Snake is solid black or dark brown on top with an unmarked, bright orange, red, or yellow underside. This snake inhabits bottomland forests, shrub swamps, temporary and permanent ponds, lakes, slow-moving rivers and streams, oxbows, sloughs, wet meadows, and other scrub-shrub, shallow water wetlands (Harding 1997, U. S. Fish and Wildlife Service (USFWS) 1997, Conant and Collins 1998, Coppola 1999, Hyslop 2001, Kingsbury et al. 2003). In addition to wetlands, Copperbelly Water Snakes also utilize adjacent uplands including upland shrub-scrub habitats, upland forests, old fields, pastures, and mowed grass (Sellers 1991, Kingsbury 1996, Herbert 2003, Kingsbury et al. 2003). Copperbelly Water Snakes feed primarily on anurans and overwinter in crayfish burrows (Roe 2002).

The Copperbelly Water Snake has declined dramatically and now only persists in scattered, isolated population clusters across its range (USFWS 1997). The Copperbelly Water Snake is known from two disjunct populations in the United States. The southern population segment represents the core of the species' range and occurs primarily in the lower Ohio and Wabash River valleys in western Kentucky and adjacent southeastern Illinois and southwestern Indiana (Smith 1961, Harding 1997, Conant and Collins 1998). The northern population segment is comprised of small, disjunct populations in south-central Michigan, northwestern Ohio and northeastern Indiana (Conant and Collins 1991, Harding 1997). The species' decline has been particularly dramatic in the northern part of its range (USFWS 1997). As a result, the northern population of the Copperbelly Water Snake is currently protected under the U.S. Endangered Species Act as a federally threatened species. The species also is currently listed as state endangered in Michigan, Ohio, and Indiana. The southern population also is protected under two conservation agreements, and the species has been given special protected status in Illinois and Kentucky.

Habitat loss and fragmentation are the principal causes for the decline of the Copperbelly Water Snake and the main threats to this species' persistence across its range (Sellers 1991, Evers 1994, USFWS 1997). Much of the Copperbelly Water Snake's wetland and upland habitats have been modified or destroyed due to agricultural use, dredging/ditching, stream channelization and other hydrological alterations, road construction, coal mining (primarily in the southern part of its range), and commercial and residential development (Dahl and Johnson 1991, Evers 1994, USFWS 1997). Additional factors that have contributed to this species' decline include human persecution, collection of snakes for scientific and commercial purposes, road mortality, and potentially pollution in parts of the species' range (Sellers 1991, Evers 1994, Harding 1997). A severe drought which occurred in the range of the northern population in the late 1980's also may have adversely impacted population sizes due to reduced wetland availability (i.e., fewer wetlands and shorter hydroperiods) and reduced prey base (Sellers 1991). By 1990, wetlands had fully recovered from the drought, but it was noted that copperbellies and available prey (i.e, frogs/ tadpoles) seemed to be reduced in abundance (Sellers 1991).

Despite its protected status, the long-term viability of the northern population of the Copperbelly Water Snake remains precarious. Regional species experts have identified seven priority activities for promoting conservation of the northern population of the Copperbelly Water Snake. These include the following: 1) conducting baseline research on the species' ecology to identify basic ecological requirements such as habitat needs, seasonal movements and use of corridors; 2) continuing annual surveys for population, habitat quality and threat assessment; 3) developing methodology for quantifying status of individual populations; 4) developing landscape-level habitat characterizations based on known sites to interpret why these sites retain copperbellies and predict other areas that might contain them; 5) restoring habitat including wetland restoration and buffer and travel corridor development; 6) protecting habitat including voluntary registration, conservation agreements, easements or acquisition from willing landowners; and 7) educating the public (USFWS 1999).

Recent surveys and research conducted on the Copperbelly Water Snake in Michigan, Ohio, and Indiana from 2001-2003 reconfirmed the species at only three habitat complexes in Michigan and Ohio (Kingsbury et al. 2003, Lee et al. 2005). Copperbellies also likely still occur at an additional previously documented site in northern Indiana, resulting in a total of four currently extant copperbelly populations or metapopulations (Kingsbury pers. comm.). Additionally, the numbers of Copperbelly Water Snakes that have been observed at these sites have been fairly small, and an initial estimate of population size at one of these sites, based on observations documented during a copperbelly radio-telemetry study, was much lower than originally anticipated (i.e., population size likely in the hundreds rather than the thousands) (Kingsbury et al. 2003). At the same time, though, recent surveys and research have been able to document Copperbelly Water Snakes on several new private parcels or wetlands associated with previously known sites. Suitable habitat also was found at many historical and several new sites. Several site leads also have been reported from reliable sources and the general public. Thus, continued surveys and monitoring are needed to determine the current status, distribution, and viability of the northern population of the Copperbelly Water Snake. Identification of viable populations is critical for assessing the species' overall status and prioritizing sites for conservation and recovery efforts.

Additional efforts to enhance our understanding of the Copperbelly Water Snake's habitat use and requirements at multiple spatial scales in the northern part of its range also are warranted. Recent research efforts employed radio-telemetry to investigate and compare Copperbelly Water Snake habitat use with that of the more common Northern Water Snake (*Nerodia sipedon sipedon*) at a known copperbelly habitat complex in southern Michigan and northern Ohio. These studies revealed important information regarding the Copperbelly Water Snake's vagility, larger mean home range size, greater tendency to use multiple and diverse wetlands as well as upland habitats, and more specific prey preferences than the Northern Water Snake (Herbert 2003, Roe et al. 2003, 2004). These efforts also provided information on Copperbelly Water Snake habitat use and preferences at the macrohabitat and microhabitat spatial scales (Herbert 2003). The macrohabitat categories were based on general habitat types included in the National Wetland Inventory classification system such as palustrine forest, palustrine scrub-shrub, and palustrine open water wetlands (Cowardin et al. 1979, Herbert 2003). Microhabitat analyses focused on structural characteristics such as percent ground cover, canopy closure, and herbaceous and woody stem densities as well as distance to water, nearest cover, and macrohabitat edge (Herbert 2003). However, detailed characterizations of natural community types, vegetation, soil, and physiographic context of Copperbelly Water Snake sites in the northern population are lacking (Kost et al. 2006). Information about specific and current threats to copperbelly habitat at known sites (e.g., invasive species) also has been unavailable, incomplete, or out-of-date. Efforts to characterize and model Copperbelly Water Snake habitat at the landscape scale have been conducted but could use further refinement (Kingsbury et al. 2003, Lee et al. 2005). More detailed and improved characterizations of Copperbelly Water Snake habitat at landscape, macrohabitat, and microhabitat spatial scales will complement our current understanding of this species' habitat use and ecological requirements. This information also can help prioritize sites and help guide habitat management and restoration efforts.

In addition to obtaining information on the Copperbelly Water Snake's current status, distribution, and habitat requirements, conservation efforts must focus on influencing local land use and land management decisions. Most of the extant or known Copperbelly Water Snake sites that comprise the northern population occur on private lands, and are isolated and scattered across the landscape. Therefore, conservation of this species will require working with private landowners and local agencies and land managers. Establishing strong, long-term working relationships with landowners, conducting education and outreach, and providing them with the necessary stewardship information and resources will be critical to conservation efforts for the Copperbelly Water Snake. These efforts also will require successful collaboration and coordination among local land management agencies, conservation organizations, and other partners across the northern Copperbelly Water Snake population's range.

The purpose of this project was to continue efforts to increase our understanding of the current status and habitat needs of the northern population of the Copperbelly Water Snake and to share this information to promote and facilitate conservation and recovery of this species in Michigan, Ohio, and Indiana. The specific objectives of this project were to:

1) Determine the current status and distribution of the Copperbelly Water Snake in Michigan, Ohio and Indiana.

2) Characterize habitat at multiple spatial scales to clarify ecological requirements.

3) Maintain and enhance Michigan, Ohio, and Indiana's information base to aid in the conservation and recovery of this species.

4) Increase public awareness to aid in the conservation and recovery of this species.

Project activities included conducting field surveys to monitor extant populations and identify additional populations, characterizing habitat at multiple spatial scales, assessing habitat quality and threats, conducting landowner contact and education, and providing information and technical assistance to government agencies, conservation organizations, landowners, general public, and other stakeholders.

This project represents a collaborative effort between researchers from Michigan Natural Features Inventory (MNFI) and Indiana-Purdue University at Fort Wayne (IPFW) to investigate the status, distribution, and habitat requirements and address conservation needs of the northern population of the Copperbelly Water Snake. This project spanned three years and involved data collection, analyses, and summary across the species' northern range in Michigan, Ohio, and Indiana. Researchers from MNFI took the lead in coordinating and conducting project activities in Michigan, and researchers from IPFW were responsible for coordinating and conducting project activities in Ohio and Indiana. The project was initiated during 2003-2004, and activities during this first year of the project focused on assessing the status, extent, and habitat of known extant populations in Michigan (due to a substantial delay in processing and establishing a contract with IPFW in 2004). Project activities during 2003-2004 are summarized in Lee et al. (2005). Project activities continued in Michigan and were initiated and conducted in Ohio and Indiana in 2005 and 2006. This report summarizes project activities and findings from the survey, monitoring, and landscape- and microhabitat-scale habitat characterization efforts in 2005 and 2006. The project activities and findings associated with the macrohabitat- or community-level habitat characterization efforts are summarized in an accompanying report by Kost et al. (2006).

## METHODS

### Study Area

Project activities in 2005 and 2006 were primarily conducted at three known extant Copperbelly Water Snake sites in south-central Michigan in Hillsdale County and in adjacent northwestern Ohio in Williams County on public and private lands. One of the extant sites occurs along the Michigan-Ohio border and includes several habitat complexes that occur partially in Michigan and continue into Ohio. The three extant copperbelly occurrences are considered three separate local population clusters at this time given the lack of recent records or confirmed observations in the areas between or connecting these occurrences. However, these occurrences may have comprised one large population or metapopulation historically because there are previously documented Copperbelly Water Snake occurrences and areas with apparently suitable habitat surrounding and potentially connecting the extant occurrences. These three occurrences are located on one state-owned property and nine private parcels owned by ten different landowners.

The study area contains a variety of wetland sizes and types, including both ephemeral wetlands and larger, permanent wetlands that were often artificially created, with water levels controlled for game fish and birds. Wetland community types documented in the study area include inundated shrub swamp, southern wet meadow, emergent marsh, southern floodplain forest, and southern swamp (Kost et al. 2006). Wetlands in the study area are fed by spring, river, lake, and local runoff. The St. Joseph of the Maumee River also flows through the study site. The upland landscape consists of a matrix of forested, shrub-scrub, old field, agricultural fields, roads, and residential habitats. Upland community types include mesic southern forest, dry-mesic southern forest, pasture, and old field (Kost et al. 2006).

## Copperbelly Status and Distribution

### Surveys and Monitoring

Surveys in 2005 and 2006 focused on monitoring and assessing the status and extent of the three known extant Copperbelly Water Snake populations or occurrences in Michigan and Ohio (Hillsdale County EO .005, .008, and .010 and Williams County-Ohio site). Copperbelly Water Snakes were observed regularly at these three sites from 2001 to 2003. Surveys during earlier studies had been broader in scope and were in part detection surveys to find remaining populations. In 2004-2006, the intent was to survey individual wetlands more narrowly in and adjacent to wetland complexes known to contain copperbellies to assess population status and extent and provide management recommendations for maintaining extant populations. As a result, due to limited time and resources, we were only able to conduct very limited surveys at other known or historical copperbelly sites or potential sites with suitable habitat in Michigan, Ohio, or Indiana (i.e., 2 known sites in Hillsdale and Calhoun counties in southern Michigan).

Surveys focused in and around suitable wetland habitats in which Copperbelly Water Snakes had been documented during previous surveys or were in the vicinity of such sites and had potential for copperbelly use. In 2005, we surveyed a total of 111 wetlands associated with the three known extant copperbelly sites in southern Michigan (Hillsdale County EO .005, .008 and .010) and northwestern Ohio (Williams County site), with an approximate total shoreline length of 50,383 m. We walked about 90% of that shoreline. MNFI staff primarily surveyed the wetlands associated with the two extant copperbelly sites that occur exclusively in Michigan (Hillsdale County EO .008 and .010), and IPFW staff focused on the wetlands associated with the extant population that occurs in Michigan and Ohio (Hillsdale County EO .005 and Williams County-Ohio site). Each wetland was surveyed three times between 15 April and 15 June, 2005. Several wetlands associated with the two extant sites in that occur only in Michigan were surveyed more frequently (4-5 times) and later in the field season (up to 15 July). Survey effort per site ranged from about 23 to 34 hours in 2005.

In 2006, given the very low number of Copperbelly Water Snakes that were seen in 2005, only 22 wetlands that were considered copperbelly “hotspots” were surveyed at the extant site that occurs in Michigan and Ohio. These wetlands occurred in five habitat complexes at this site. Wetlands were surveyed four times each in 2006 in the attempt to catch more individuals for mark-recapture data. Surveys at this site were conducted between 15 April and 15 June, 2006. At the other two extant sites in Michigan, fifteen individual wetlands were surveyed in 2006. Surveys were conducted from 6 May to 20 June. Individual wetlands on each parcel were surveyed 1-6 times with most wetlands surveyed 3-4 times during the survey period. Survey effort per site ranged from about 18.5 to 24 hours in 2006.

Surveys were typically conducted by a team of two to three individuals to maximize survey effort and potential for detecting and capturing copperbellies. On a few occasions, surveys were conducted by only one individual or four individuals. Surveys in 2006 at the Michigan-Ohio site were conducted by only one surveyor. Surveys consisted of conducting visual surveys along a survey path or transects. Line-transect visual surveys consisted of individuals slowly walking a transect parallel and immediately adjacent to the shoreline of a wetland as well as some distance away from the shoreline wading through shallow water in the wetland (Appendix I). Surveys were conducted along the entire length of a wetland shoreline. Fixed-point visual surveys also were incorporated. This consisted of surveying the vegetation and open water with binoculars from a single or several fixed locations. In a few cases when it was not possible to walk or wade around a portion of a wetland, we were only able to survey the area using binoculars. Surveys were conducted during appropriate weather and survey conditions when the snakes were expected to be basking and most visible.

Observed Copperbelly Water Snakes were captured, weighed, measured (snout-vent length, total length, etc.), and sexed, when possible. Snakes were categorized into four age classes (adults, sub-adults, juveniles, and young-of-the-year) based on length and coloration pattern. Captured adult and sub-adult snakes were marked by PIT (passive integrated transponder) tags and juvenile and young-of-the-year snakes were marked by scale clipping so that recaptures could be identified. Tissue samples (i.e., scale clippings) were obtained from all captured snakes, when possible, for a Copperbelly Water Snake genetics study that is being conducted by John Marshall, a doctoral student of Dr. Bruce Kingsbury at Purdue University. After all processing was completed, snakes were released at their original capture sites. Photographs were taken for verification of species occurrence at a site. For the survey sites in Michigan, a Copperbelly Water Snake field survey form was completed for each survey (Appendix II), and a Copperbelly Water Snake observation form and a MNFI Special Animal Survey Form were completed for each Copperbelly Water Snake observation (Appendix III and IV).

Population Estimation

To the best of our knowledge, there are no published population estimates for the northern population of the Copperbelly Water Snake. We used distance sampling to estimate the population size and density of this northern population of the Copperbelly Water Snake. We also estimated the population density of the Northern Water Snake for a comparison between a rare and a common species (Gibbons and Dorcas 2004).

We treated each wetland shoreline as a transect which would allow for a comparison of densities from different Copperbelly Water Snake populations (Lacki et al. 1994) and other watersnake species (Hebrard and Mushinsky 1978, Mills et al. 1995). We sampled 34 wetlands associated with the three extant sites in Michigan and Ohio by walking the entire length of the wetland shoreline edge or wading through the water when necessary to estimate Copperbelly Water Snake population size and density. The wetlands ranged in size from 0.02 – 5.26 ha which resulted in a total surface area of 34.99 ha, and wetland shoreline lengths ranged from 57 – 2,357 m which resulted in 20,366 m of total shoreline length surveyed. We estimated Northern Water Snake density by sampling only twenty wetlands (total area: 27.97 ha; total shoreline length 12423 m) at one site because of logistical considerations. For one wetland, we only surveyed 83 m of 373 m of shoreline because vegetation and water depth prevented the remaining shoreline from being accurately surveyed. Wetland size and shoreline length were obtained from past studies (Roe et al. 2003, Roe at el. 2004, Attum et al. 2007). The surveyed wetlands included all the areas known to have the highest Copperbelly Water Snake densities based on previous radio-telemetry studies and survey efforts (Roe et al. 2003, Roe et al. 2004, Attum et al. unpublished). Additional wetlands in the study area, totaling 26.31 ha, had received little to moderate use by copperbellies and were not surveyed for this portion of the study. We also did not survey wetlands in the area that were not considered suitable copperbelly habitat. Each wetland was surveyed four times between 26 April and 13 June, 2006, when snakes were most likely to be observed because of little vegetation growth and time spent basking. For each observation, we recorded the perpendicular distance in 0.5-m intervals between the wetland edge and the snake. The transect centerline was within 0.5 m of the wetland edge.

We used DISTANCE 5.0 to estimate population size and density through distance sampling (Thomas et al. 2006). Distance sampling fits the perpendicular distances of observed animals from the transect to various detection functions to estimate density (Buckland et al. 2001). The three major assumptions of distance sampling are the following: 1) animals on the transect centerline are always detected but that a proportion of animals within a distance of the transect can be missed; 2) animals are detected at their original location; and 3) perpendicular distance measurements are accurate (Buckland et al. 2001). We assume that animals on the centerline line are always detected because the observer walking along the transect would eventually flush snakes from the centerline. We believe we met the second assumption because a review of a histogram representing perpendicular distance to observed snakes does not suggest that snakes moved away from the observer. We also grouped perpendicular distances post hoc into one meter intervals prior to analysis to minimize measurement error.

We used the nine recommended available detection functions and only report the results for the best model (Buckland et al. 2001). We pooled our data together for our analysis, but used the multiplier function in DISTANCE to divide the estimates by four to account for multiple surveys. Prior to analysis, we examined the distribution of perpendicular distance from shoreline and truncated the data at 6 m for Copperbelly Water Snakes and 11 m for Northern Water Snakes to remove spikes in the data and to improve fit as suggested by Buckland et al. (2001).

## Copperbelly Habitat Characterization

### Landscape-Scale Habitat Modeling / Predicted Distribution Modeling

In 2003, MNFI developed a landscape-level species characteristics habitat model for the Copperbelly Water Snake in Hillsdale County in southern Michigan using geographic information systems (GIS). The species characteristics model was an additive, deductive type of model (Corsi et al. 2000). Five data layers, each representing a different species habitat characteristic, were derived from other data layers. The five data layers were then added together, with those areas scoring the highest being more likely to contain habitat favorable to the Copperbelly Water Snake. Species characteristics that were considered for the deductive model were the importance of crayfish burrows for hibernation sites (Roe 2002), the need for multiple wetlands and a variety of wetlands within a snake's home range (Roe 2002, Kingsbury et al. 2003, Roe et al. 2004), and the need for both wetlands and uplands during different phases of the copperbelly life cycle (Roe 2002, Roe et al. 2003). Based on these characteristics, the following five spatial data layers were produced for the model: upland heavy soil (clay, silt, and muck), wetland density, habitat density, wetland variety, and slope change. Habitat ranks ranged from 0 (unsuitable) to 5 (very suitable), except for the slope change layer, which was ranked either 0 or 1. Lee et al. (2005) provides a detailed description of the species characteristics habitat model for the Copperbelly Water Snake in Hillsdale County. Known copperbelly occurrences in Hillsdale County were overlaid on a map of the habitat model output as an initial evaluation of model results.

Our original intention for this project was to test and refine previously developed landscape habitat models for the Copperbelly Water Snake by incorporating new copperbelly locations, if found, or additional information (e.g., new habitat information) or expanding the area covered by the model (e.g., modeling additional counties within the copperbelly's range). Although surveys from 2004-2006 had documented Copperbelly Water Snakes in a few new individual wetlands at the three known extant sites, we did not identify any new copperbelly populations or habitat complexes. We also did not identify substantial new information that could be incorporated into the species characteristics habitat model. As a result, we decided to develop a different landscape-level habitat model or predictive distribution model for the Copperbelly Water Snake using a new statistically-based species distribution modeling approach and software that had only recently been developed and made available to researchers.

Predictive modeling of a species' potential distribution is an important tool in conservation biology because it describes the conditions suitable for survival of the species. The data available for distribution modeling usually consist of known locations of the species and a group of spatially continuous environmental layers or variables, such as precipitation, land cover, and elevation. When both species presence and absence locational data are available, general-purpose statistical model algorithms such as general linear models (GLM) or general additive models (GAM) can be employed. But often only species presence locations are available to the modeler.

Maximum entropy modeling is a new approach to modeling species geographic distributions using a program called Maxent (Phillips et al. 2004, 2006). The Maxent program for maximum entropy modeling of species' geographic distributions utilizes presence-only locational information (Phillips 2006). Maxent estimates a target probability distribution by finding the probability distribution of maximum entropy (i.e., most spread out or closest to uniform). The information in a set of environmental or predictor layers is used to estimate the target distribution, and the constraints are that the expected value of each feature should match its empirical average (i.e., average value for a set of sample points taken from the target distribution) (Phillips et al. 2004, 2006).

Maxent may be a more suitable algorithm for modeling situations where the available number of species occurrences is relatively small. Maxent is a generative approach, whereas GLM/GAM's are discriminative. Generative methods may give better predictions when the amount of training data is small (Ng and Jordan 2001), as is often the case for rare species. Hernandez et al. (2006) found Maxent to be the most capable of four modeling methods in a comparative study, producing useful results with sample sizes as small as 5, 10, and 25 occurrences. Elith et al. (2006) in a comparison of many modeling techniques concluded that Maxent is one of the best distribution modeling algorithms presently available.

*Copperbelly occurrence data*

Similar to the species characteristics habitat model, the maximum entropy model focused on Hillsdale County in southern Michigan. The copperbelly presence data available for the model consisted of eight element occurrences comprised of 40 polygons or specific locations at which copperbellies had been documented previously (MNFI 2007). Locations clustered in a heavily sampled area can bias the model towards those environments (Vaughan and Ormerod 2003), and would violate the assumption that the points are independent samples. As a result, we decided to use the centroids of the individual polygons or locations and filtered them so that no two points were closer than 500 meters. Five hundred meters approximates the seasonal range of the species (Kingsbury et al. 2003). After filtering, 18 presence points were available for modeling.

*Environmental variables*

Five landscape-scale attributes were selected based on our hypothesis that they are important in providing essential copperbelly habitat: upland heavy soil (clay, silt), wetland density, habitat density, wetland variety, and slope change. The map-algebra modeling tools in the GRID module of ArcInfo (ESRI 2002) were used to derive the layers in the model. These are identical to the layers used in the 2003 deductive landscape-level model of copperbelly habitat mentioned earlier.

The upland heavy soils data layer consisted of soil types that have the ability to retain water including clay soil types, silt, and muck. Most Copperbelly Water Snakes hibernate in upland habitats in crayfish burrows (Roe 2002). Upland clay, in particular, is thought to be important because crayfish need primarily clay soils in order to burrow (Crocker and Barr 1968). Clay soil texture information was obtained from the Natural Resources Conservation Service's Soil Survey Geographic (SSURGO) database (2000). The polygons from the SSURGO database that met the heavy soil criteria were selected and converted to ArcInfo Grid format with 30-m pixel size. An upland mask grid was created by selecting all non-wetland land cover classes from the 2000 land cover dataset. Then the amount of clay in the upland was calculated and divided by the area of upland in 6 x 6 pixel or 180 m x 180 m blocks or kernels. Each cell in the resulting data layer represents the percentage of upland that contains heavy soil in a 180-m block. The kernel size of 180 meters was selected because it was thought to be a conservative estimate of the distance a copperbelly may travel. Roe (2002) found the mean distance traveled by Copperbelly Water Snakes was 143 m. The spatial error of the GIS datasets also was taken into account, as was the cell size of the raster data.

Wetland density was derived from land cover data from the Michigan Department of Natural Resources' Integrated Forest Monitoring Assessment and Prescription (IFMAP)/GAP land cover database (2000). The use of National Wetland Inventory (NWI) data was considered, but NWI data has a minimum mapping unit of about 1 ha. According to Roe (2002), of the palustrine wetlands used by copperbellies in his study, 81% were smaller than one ha in surface area. The IFMAP land cover data layer has a cell size of 30 $m^2$ or 0.09 ha. Hence, this layer was used in the model instead of NWI data because it may capture more of the small wetlands. A sum of all wetland classes in a 6 x 6 pixel or 180-m kernel was determined. In the resulting data layer, each cell represents the density of wetlands in a 180-m block.

For the habitat density data layer, copperbelly habitat included all land cover wetland classes in addition to upland forest and shrub (IFMAP 2000). Copperbellies use uplands for hibernating in the winter, but also frequently use adjacent uplands for traveling during the active season (Roe 2002). Again, the density of habitat in a 180-m block was calculated.

A diversity of wetland types also may be important to copperbellies, in addition to wetland density, to ensure adequate prey base and availability of suitable wetland habitats under varying conditions within an active season and over multiple years. A variety of wetland types were identified by the IFMAP land cover classification (2000). These include the following categories: lowland deciduous forest, lowland coniferous forest, lowland mixed forest, floating aquatic, lowland shrub, emergent wetland, and mixed non-forest wetland. The resulting wetland type values in the data layer represent the number of different wetland types in a 180-m block. The use of NWI wetlands for this layer also was considered, but was rejected because of the concern with NWI's minimum mapping unit that was previously discussed.

Development and inclusion of a slope change layer in the model resulted from observations of copperbellies in the field and potential association with areas that had a high groundwater table or groundwater discharge. Since a groundwater data layer was not available, we hypothesized that flat areas adjacent to steep slopes represents or results in areas with groundwater discharge and/or a very shallow water table. These conditions often support a variety of groundwater driven wetland types. Using the "slopeh" attribute in the SSURGO soils data layer, areas were identified where a slope of $\leq$ 2 % occurred adjacent to a slope of $\geq$ 12%. Since the soils layer was a vector dataset, it was first converted to a raster layer with a 30-m cell size and a value equal to the "slopeh" attribute. The resulting layer was expanded by 60 meters or two grid cells. The final layer had a categorical value of 1 in a slope change area and 0 if not in a slope change area.

Three distribution models were created with Maxent. The first model used the previously discussed environmental layers, which also were used in the deductive landscape habitat model created in 2003 (Table 1). The second model used the same data layers as the first model except that "upland clay soil" was substituted for "upland heavy soil." The third model used the same data layers as the second model except that a continuous elevation variable was substituted for the slope change categorical variable.

*Model evaluation and outputs*

A commonly used approach for comparing model performance is called a receiver operating characteristics (ROC) curve. The advantage of a ROC analysis is that it is threshold-independent, or characterizes the performance of a model at all possible thresholds by a single number, which is the area under the curve (AUC) (Elith 2002, Fielding and Bell 1997). This number can then be compared among models to evaluate their performance (Elith 2002, Fielding and Bell 1997). For presence-only models, ROC curves are generated by plotting sensitivity (the true positive fraction, or the proportion correctly predicted) on the X axis and 1-specificity (the proportion of all map pixels predicted suitable) on the Y axis. A curve that maximizes sensitivity for low values of specificity results in a high AUC value and is considered a good model. An AUC of close to 1 indicates a perfectly classified model, while an AUC of 0.5 is the expected value of a random prediction. The AUC generated with presence data and a random sample of background or non-presence data evaluates a model based on its prediction success but also penalizes it for predicting proportionally larger spatial areas (Phillips et al. 2006).

**Table 1**. Summary of predictive environmental layers that were derived from land cover and soils spatial data that were utilized in 2003 to develop a landsape-scale, deductive habitat characteristics model for the Copperbelly Water Snake in Hillsdale County, Michigan.

| **Layer** | **Description** | **Data Source** |
|---|---|---|
| Upland Heavy Soils | Clay, peat and muck surface texture in the upland | SSURGO soil layer, NRCS |
| Wetland Density | Proportion of wetland pixels in a 180-meter square block | IFMAP 2000 land cover |
| Habitat Density | Proportion of wetland, upland shrub and upland forest in a 180-meter square block | IFMAP 2000 land cover |
| Wetland Variety | Count of wetland types in an 180-meter square block | IFMAP 2000 land cover |
| Slope Change | Areas where soils with a slope <=2 % were adjacent to soils with >=12% slope (binomial categorical variable) | SSURGO soil layer, NRCS |

Assessment of model gain is another approach for model evaluation. Maxent is a maximum-likelihood method, and it generates a probability distribution over pixels in the model. The model “gain” starts at 0 and increases towards an asymptote during the modeling run. The gain is a measure of the likelihood of the samples. For example, if the gain is 2, it means that the average sample likelihood is $e^2$ or approximately 7.4 times higher than that of a random background pixel. A uniform distribution has a gain of zero, so the model gain can be interpreted as a representation of how much better the predicted distribution fits the sample points than the uniform distribution. The gain is closely related to deviance estimates in statistics (Phillips 2006).

Maxent also generates variable response curves which show how each environmental variable affects the Maxent prediction. The baseline Maxent model has the form *e*(…)/constant, and the variable response curves show how the exponent changes with each environmental variable, keeping all other environmental variables at their average sample value (Phillips 2006). For situations where prior knowledge of the predictor variable response is unclear, allowing the sample data to dictate the response is a potential advantage over deductive modeling where a species’ response to an environmental variable has to be determined a priori.

A jackknife test is available to analyze the relative importance of each environmental variable in the model. The jackknife test does this by determining the importance of each variable by itself to the model and also when it is excluded from the model. Each variable is excluded in turn, and a model is created with the remaining variables. Then a model is created using each variable by itself. In addition, a model is created using all variables. The highest gain for a variable by itself indicates which variable has the most useful information of its own accord. The variable that decreases the gain the most when omitted from the model indicates which variable has the most information that is not present in the other variables.

The Maxent program also can produce a model based on a binary classification of habitat presence and absence. In order to do this, a threshold value must be selected for the continuous model output. A threshold can be selected based on the objectives for generating the distribution model (Wilson et al. 2005). As larger thresholds are selected, commission errors tend to decrease while omission errors increase (Fielding and Bell 1997). If commission errors are more serious, then the model threshold can be increased at the expense of omission errors. When there is no inclination as to which type of error is more critical, an optimal threshold can be obtained from the ROC curve by finding the point where sensitivity and specificity are maximized (Manel et al. 2001, Hernandez et al. 2006). Two threshold methods were chosen and compared for each model in this study. First, a simple threshold was selected by choosing the minimum predicted value assigned to the training locations. This guaranteed a predictive success of 100% for the training data, or alternatively, an omission rate of 0%. The second method used the optimal threshold determined by the ROC curve.

Landscape Ecology and Distribution Analysis

We also used landscape ecology concepts to test the importance of upland-wetland linkages and wetland complexes on the distribution of the Copperbelly Water Snake. This analysis utilized presence/absence data from Copperbelly Water Snake surveys conducted at the three known extant sites in Michigan and Ohio in 2005. We surveyed a total of 111 wetlands between 15 April and 15 June, 2005, when the snakes would be more likely to be observed because of little vegetation growth and conspicuous basking or breeding behavior. In order to minimize the likelihood of false negatives (absences), we surveyed each wetland three times during the survey period. False negatives would be more likely to occur in wetlands with smaller populations or in wetlands with marginal use (Kery 2002). Thus, while false negatives dilute the precision of the modeling results, they do not negate them. Species presence/absence was determined by focal surveys that consisted of walking along the wetland’s entire shoreline and wading through the water when necessary. Surveys were conducted by a team of two to three individuals. Occasionally, when it was not possible to walk around a portion of a wetland, we used binoculars to visually survey the area from a fixed location or several locations.

We obtained wetland and upland habitat characteristics post hoc using ArcView 3.2 GIS software. Most of the wetlands were already mapped from past studies through digitizing aerial photographs (digital ortho-photo quarter-quadrangles images) and ground truthing (Roe et al. 2003, 2004). Additional wetlands and forest habitat were mapped as needed, following the methods from the previous studies. Wetland size (surface area), shoreline perimeter length, and forest area within various buffer zone sizes were calculated with the X-tools extension for Arc View GIS. We used a buffer zone of 30 m because this was the recommended buffer size for Northern Water Snakes (Roe et al. 2003), a 125-m buffer zone because this is the recommended size for the Copperbelly Water Snake (Roe et al. 2003), and 250-m, 500-m, and 1000-m buffer zones because they were recommended for other wetland species and have been used in past studies (Findlay and Houlahan 1997, Semlitsch 1998, Herrmann et al. 2005). Wetland distance to nearest wetland and wetland distance to a two-lane road was were measured by the Nearest Features v3.8 extension for Arc View GIS (Jenness 2005).

We ran a series of logistic regressions to analyze the effects of landscape habitat characteristics on distribution of the Copperbelly Water Snake. We used every possible combination of the variables describing wetland characteristics (i.e., wetland size, shoreline length, wetland distance to nearest wetland, and wetland distance to road) from full models containing every variable to the most simplistic models only containing one variable. The model with the lowest Akaike Information Criterion (AIC) score was chosen as the final model. We also ran a second analysis to test if forest area within a buffer zone around wetlands 1.5 ha or smaller affected distribution. Small wetlands have been shown to be important for copper-bellied watersnake conservation and also most of the wetlands (93/111) within our study occurred within this size range. In addition, wetlands of such small sizes had a wider range of forest area within buffer zone which would allow us to test the effects of forest area within a buffer zone on species distribution. Within each buffer zone, we corrected *p*-values ($\alpha_{adj}$) by the sequential Dunn-Sidak method to minimize type I errors for multiple tests (Quinn and Keough, 2002). We considered tests to be significant if the *p*-value was less than the new adjusted *p*-value ($\alpha_{adj}$). All data were log transformed prior to analysis to normalize the data.

<u>Community/Macrohabitat-Scale Habitat Characterization</u>

Habitat characterization for the Copperbelly Water Snake at the community or macrohabitat-scale continued in 2005. Community-level habitat evaluations were conducted in the field by MNFI Ecology and Zoology Program staff at the extant Copperbelly Water Snake site in Williams County, Ohio in September 2005. Some habitat characterization had been conducted at this site previously in 2002. Efforts in 2005 focused on characterizing additional portions of the site that had not been characterized previously, particularly areas that were used by copperbellies for hibernation. Community-level habitat evaluations were conducted in 2005 using the same methodology that had been employed during previous assessments from 2001-2004. The following habitat information was recorded: 1) estimates of the relative abundance of plant species in the ground layer, understory and overstory; 2) soil type, soil pH, and litter depth; 3) water depth; 4) short description of the general habitat; 5) description of the landscape context and surrounding land use(s); and 6) rankings of the quality of the vegetative community. A detailed field assessment of potential threats also was conducted as part of habitat characterization. The field assessment of threats included: 1) recording exotic plant species and estimating their relative abundance; 2) characterizing any hydrologic alterations; 3) recording evidence of habitat destruction or disturbance; 4) documenting habitat manipulation such as mowing and grazing; and 5) noting evidence of soil erosion.

The types of macrohabitats in which Copperbelly Water Snakes were found during surveys in 2005 and 2006 also were noted. The macrohabitat classifications used for this study were based on NWI classifications developed by Cowardin et al. (1979). The macrohabitat classifications used for this study include the following: palustrine forested wetland (PFO, standing water and tree canopy cover > 30%), palustrine scrub-shrub (PSS, shrub cover > 30% but tree cover < 30%), palustrine emergent (PEM, emergent vegetation present and < 30% shrub and tree cover), palustrine open water (POW, shallow wetlands with little or no vegetation), lacustrine open water (LIM, deep water (> 2m) of lakes), littoral (shoreline) zone of lakes (LIT), upland forest (UFO, > 30% tree canopy cover and above flood line), upland scrub-shrub (USS), old field (OLD, fallow fields with herbaceous or grassy cover), crop lands and farm fields (FRM), grazed or mowed areas (GRZ), and residential (RES).

Microhabitat Characterization

Information on microhabitat use was recorded in the field during copperbelly surveys. Microhabitat classifications used in this study include shrub, tree, grass, rock, log, herbaceous, water, bare, island, and detritus. More detailed microhabitat information (e.g., specific plant species) also was noted whenever possible. The microhabitat data from copperbelly surveys were summarized and analyzed qualitatively. Microhabitat use also was examined in relation to behavior of snakes observed. The behavioral classifications that were used include basking, resting, courting, mating, foraging, traveling and unknown.

## Maintenance and Enhancement of Copperbelly Information Base

Efforts to maintain, enhance, and disseminate information about the Copperbelly Water Snake continued in 2005 and 2006 to promote and facilitate conservation and recovery of this species. Project activities during this period included the following: 1) updating or providing information to update copperbelly element occurrence records in natural heritage databases in Michigan and Ohio; 2) providing study results and technical assistance to federal, state, and local government agencies, management and recovery efforts, conservation organizations, and other partners or stakeholders; 3) developing and recommending management and/or recovery strategies; 4) identifying high priority areas for management and recovery efforts; 5) working with partners to initiate management and/or recovery efforts; and 6) presenting information at professional meetings or conferences and in peer-reviewed publications.

## Public Education and Outreach

Public education and outreach also continued in 2005 and 2006 to increase public awareness and understanding of the Copperbelly Water Snake, to develop local expertise, and to strengthen working relationships with private landowners to promote and facilitate conservation and management efforts. Project activities in 2005 and 2006 in support of this objective included the following: 1) conducting public outreach through landowner contact during field work; 2) informing landowners of survey results; 3) discussing with landowners and providing information about opportunities, resources, and/or contacts for habitat management and restoration and/or site conservation such as conservation easements; and 4) distributing educational materials to landowners and other stakeholders. Additional public education and outreach activities such as making educational materials available on the Internet through MNFI and/or IPFW’s Center for Reptile and Amphibian Conservation and Management’s web sites and increasing public awareness through local and/or state media were not conducted in 2005 or 2006. However, these efforts will continue in the future as time and resources permit.

# RESULTS

## Copperbelly Status and Distribution

Surveys and Monitoring

In 2005, Copperbelly Water Snakes were found in only 20 of the 111 wetlands that were surveyed at the three extant sites in Michigan and Ohio. In the wetlands associated with the site that occurs in Michigan and Ohio (n=77 wetlands), only 20 Copperbelly Water Snakes were observed in 2005, of which only 9 individuals were actually captured and pit-tagged. At the other two extant sites in Michigan, Copperbelly Water Snakes were observed in only 8 of the wetlands surveyed. At these two sites, only 19 Copperbelly Water Snakes were observed, with 13 observations at one site (Hillsdale County EO .010) and 6 observations at the other site (Hillsdale County EO .008). Of these, only 10 were actually captured, of which 9 were new captures or unmarked snakes, 1 was a recapture, and 9 were of unknown status (i.e., was unable to capture so could not tell if new or recaptured snake) (6 new snakes at Hillsdale County EO .010, 3 new snakes and 1 recapture at Hillsdale County EO .008). Although mostly adult copperbellies were found during surveys, one juvenile and two subadults also were found. At these two sites, copperbellies were observed on six of the seven parcels surveyed, with 1-7 observations per parcel. Copperbellies also were documented in three wetlands which had been surveyed during recent surveys but copperbellies had not been observed in them previously. One of these wetlands had undergone some habitat management (i.e., buttonbush removal) specifically for the Copperbelly Water Snake during the winter of 2005.

In 2006, for the 22 wetlands that were surveyed at the extant site that occurs in Michigan and Ohio, Copperbelly Water Snakes were observed 33 times in 9 different wetlands. However, there were only 15 captures, with two individuals captured twice. At the other two sites that occur only in Michigan, copperbellies were observed in only 6 of 30 wetlands surveyed. Only 17 total Copperbelly Water Snake observations were documented at these two sites, with 12 observations at one site (Hillsdale County EO .010) and 5 observations at the other site (Hillsdale County EO .008). Copperbellies were observed on five of the seven parcels surveyed, with 1-10 observations per parcel. Copperbellies also were documented in three wetlands which had been surveyed recently but copperbellies had not been observed in them during previous surveys. Of the 17 Copperbelly Water Snake observations documented at these two sites in 2006, only 10 snakes were captured, of which 6 were new captures or unmarked snakes, 4 were recaptures (of three different snakes), and 7 were of unknown status (i.e., was unable to capture so could not tell if new or recaptured snake) (5 new snakes and 3 recaptures at Hillsdale County EO .010, 1 new snake and 1 recapture at Hillsdale County EO .008). All copperbellies found in 2006 were adults. At the Hillsdale County EO .008 site, the one recaptured snake was initially captured in 2004 in a different wetland within the complex and was recaptured in 2005 at another wetland in the complex about 800 m (0.5 mi) east of the original wetland in which the snake was captured. In 2006, this snake was captured in a wetland less than about 160 m (0.1 mi) to the west of and on the other side of a river from its original capture site and about 0.5 mi west of the wetland in which it had been recaptured in 2005. Also, the wetland in which this snake was found in 2006 had been surveyed in recent years but copperbellies had not been seen there during previous surveys. Recapturing this snake at several wetlands in this complex provides evidence that copperbellies at this site can move around and utilize multiple wetlands within this complex, similar to findings of previous radio-telemetry research on copperbellies in Ohio and Michigan.

Combining results from 2005 and 2006, a total of 89 Copperbelly Water Snake observations was documented at the three extant sites in Michigan and Ohio, with 53 total observations at the site that occurs in Michigan and Ohio (Hillsdale County EO .005/ Williams County site), and 36 total observations at the other two extant sites in Michigan (25 observations at the Hillsdale County EO .010 site, 11 observations at the Hillsdale County EO .008 site). A total of 44 captures was made at the three sites, with 24 total captures at the Michigan-Ohio site, and 20 total captures at the other two extant sites in Michigan(14 captures at Hillsdale County EO .010, 6 captures at

Hillsdale County EO .008). Of the 44 snakes that were captured, 37 new or individual snakes and 7 recaptures were found at all three sites combined in 2005 and 2006, with 22 new snakes and 2 recaptures at the site in Michigan and Ohio and 15 new snakes and 5 recaptures at the other two extant sites in Michigan (11 new snakes and 3 recaptures at Hillsdale County EO .010, 4 new snakes and 2 recaptures at Hillsdale County EO .008). Copperbellies were observed in only about 22 different wetlands of approximately 117 wetlands surveyed in 2005 and 2006 at all three extant sites combined.

During 2005 and 2006 surveys, MNFI and IPFW staff also observed in the field several Copperbelly Water Snakes with hard nodules, blisters or lesions along the body and damaged scales around the mouth and eyes. Snakes that were recaptured with this condition within the same year or across years seem to get worse over time. Snakes exhibiting this condition have been found on at least two parcels associated with two of the three extant sites. One of the Copperbelly Water Snakes found at one of the extant sites in Michigan (Hillsdale County EO .010) in May 2006 had numerous hard bumps or nodules underneath the scales along the body and the scales around the left eye and left nostril appeared corroded or worn away. This snake was an adult male which measured 88.8 cm total length (71 cm for snout-vent length and 17.8 cm tail length). We observed the snake again on 20 May and 8 June 2006 when it was captured and brought to the Detroit Zoo for diagnosis and treatment because we observed that the individual's head and neck were covered with blisters, and its left eye was filled with pus. The snake had been observed in the same wetland on a buttonbush brush pile. The Detroit Zoo staff has diagnosed this condition as blister disease which is apparently fairly common among snakes in captivity when the snakes have been exposed to very humid conditions. It is a condition associated with snakes occurring in very humid or wet conditions. Snakes often recover from blister disease after several sheds. For example, snakes may emerge from hibernation with blister disease but recover after a few sheds. However, some snakes may have a hard time recovering from blister disease – e,g. if it continues to occur under conditions which caused the blister disease originally. Andy Snider, formerly Curator of Reptiles at the Detroit Zoo, thought that blister disease seemed to make sense for the Copperbelly Water Snake given the habitat in which it occurs during the winter and active season. Samples from the blisters were tested and were found to contain bacteria ubiquitous in the environment, *Pseudomonas* and *E. coli*., although they can be pathogenic under certain circumstances, according to Snider (pers. comm.). The snake was treated with antibiotics and appeared to be recovering when the snake unexpectedly died. A necropsy was performed by Chris Tabaka, the veterinarian at the Zoo. Nothing unusual was found in the snake. Tissue samples from the snake's organs were sent to a lab for analysis to see if anything was unusual that might explain the cause of death (e.g., organ failure). Results from those analyses were inconclusive, and cause of death for this snake remains unknown.

A total of 32 Copperbelly Water Snakes were implanted with PIT tags at the three extant sites in 2005 and 2005, with 22 snakes PIT-tagged at the Michigan-Ohio site (Hillsdale County .005/Williams County), 7 snakes PIT-tagged at the Hillsdale County EO .010 site, and 3 snakes PIT-tagged at the Hillsdale County EO .008 site. During the surveys in 2005 and 2006, tissue samples (i.e., scale clippings) also were obtained from a total of 12 copperbellies at the two extant sites in Michigan (8 samples from the Hillsdale County EO .010 site, 4 samples from the Hillsdale County EO .008 site). In addition to Copperbelly Water Snakes, a number of other snakes were observed during surveys in 2005 and 2006 including over 300 observations of Northern Water Snakes (*Nerodia sipedon sipedon*), over 70 observations of Northern Ribbon Snakes (*Thamnophis sauritus septentrionalis*), over 5 observations of Eastern Garter Snakes (*Thamnophis sirtalis sirtalis*), and Northern Brown Snake (*Storeria dekayi dekayi*). Additionally, at the two extant sites in Michigan, approximately 16 to 19 observations of Blanding's Turtles (*Emydoidea blandingii*) were documented in seven different wetlands during surveys in 2005 and 2006.

<u>Population Estimation</u>

A total of 49 Copperbelly Water Snake observations was available for 34 wetlands that were surveyed and included in the population estimation analysis. However, after truncating the data, only 37 observations were used in the analysis with the uniform/cosine model. Copperbelly Water Snake density was estimated at 1.76 ± 0.42 snakes/ha (95 % CI 1.09 – 2.84 snake/ha), with a percent coefficient of variation of 23.91 %. Detection probability (0.77) and an encounter rate of 1.8 snakes/km of shoreline, accounted for 52.7% and 47.3 % of the variation, respectively. The population size for the area surveyed was estimated at 62 ± 15 individuals (95 % CI 38-99). If we extrapolate these copperbelly density estimates to the additional 29.31 ha of unsurveyed wetlands in the study area for a total of 64.3 ha, then the total Copperbelly Water Snake population size would be 113 ± 27 individuals. The linear density of the Copperbelly Water Snake was estimated at 3 individuals/km of shoreline.

A total of 178 Northern Water Snake observations was available for 20 wetlands surveyed for this analysis, with only 169 observations used after truncation in the analysis with the half-normal/cosine model. Northern Water Snake density was estimated at 8.16 ± 0.90 snakes/ha (95 % CI 6.56 – 10.41 snake/ha), with a percent coefficient of variation of 11.06 %. Detection probability (0.48) and an encounter rate of 13.6 snakes/km of shoreline accounted for 51.6 % and 48.4 % of the variation, respectively. The linear density of Northern Water Snakes was estimated at 18 individuals/km of shoreline.

## Copperbelly Habitat Characterization

Landscape-Scale Habitat Modeling / Predictive Distribution Modeling

The three maximum entropy predictive distribution models for the Copperbelly Water Snake in Hillsdale County all seemed to perform very well. Using the ROC curve analysis for model evaluation, the elevation model (model three), which substituted elevation for slope change, performed the best, having the highest AUC (0. 978). This was followed by the clay soil model (model two), which substituted upland clay soils for upland heavy soils, having the second highest AUC (0.948), and the heavy soil model (model one), with the lowest but still fairly high AUC (0.936) (Figure 1). All models performed much better than random (AUC = 0.5). While producing the 2003 deductive model, the decision of whether to include the clay soil or the heavy soil environmental variable was problematic and subjective. For the Maxent models, the ROC curves indicate the clay soil model (model two) preformed slightly better than the model with heavy soil (model one). Both the heavy soil and clay soil models (models one and two) are less informative than the model that included elevation (model three).

Similar results were obtained when model gain was used to compare and evaluate the three models. The elevation model (model three) again appeared to perform the best, with the highest gain at 2.164. The clay soil model (model two) had the second highest gain at 1.686, followed by the heavy soil model (model one) with a gain of 1.408. Looking at the difference between model gains, the elevation model fits the sample points (presence data) approximately 3.3 times better than the clay soil model (model two, $e^{2.164} - e^{1.686}$), and the clay soil model has an approximately 1.3 times better fit than the heavy soil model (model one).

The jackknife analyses of variable importance generated different results among the three models. The jackknife measures of variable importance for model one, the heavy soil model, indicated wetland density has the most useful information when used by itself in the model (Figure 2). Heavy soil decreased the total model gain the most when omitted from the model, indicating it appeared to have the most information not included in the other model variables. Similarly, wetland density was the most important variable by itself in model two, the clay soil model, while clay soil decreased the model gain the most when omitted (Figure 3). Elevation was the most important variable in model three, the elevation model, both by itself and when excluded from the model (Figure 4).

The variable response curves for model one, the heavy soil model, indicated highly positive responses for increasing habitat density, wetland density and wetland variety (Figure 5). Wetland density exhibited a strong positive response until it reached a maximum at

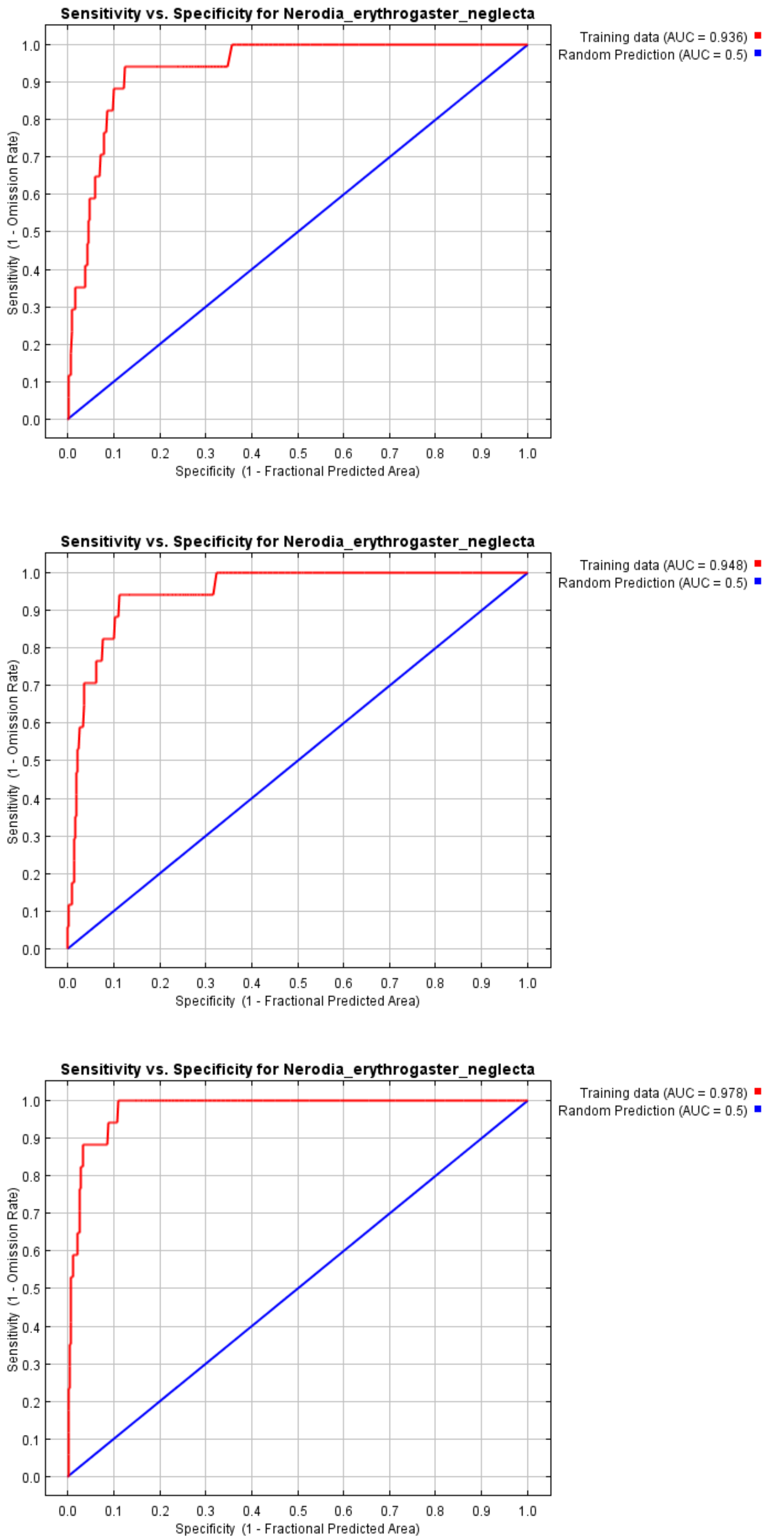


**Figure 1.** The three predictive distribution models that were developed for the Copperbelly Water Snake in Hillsdale County, Michigan using Maxent were evaluated based on the ROC (receiver operating characteristics) curves for model one “heavy soil” (AUC=0.936, top graph), model two “clay soil” (AUC=0.948, middle graph), and model three “elevation/DEM” (AUC=0.978, bottom graph). A higher AUC value indicates a higher probability of correct classification by the model, whereas an AUC of 0.5 is the expected value of a random prediction.

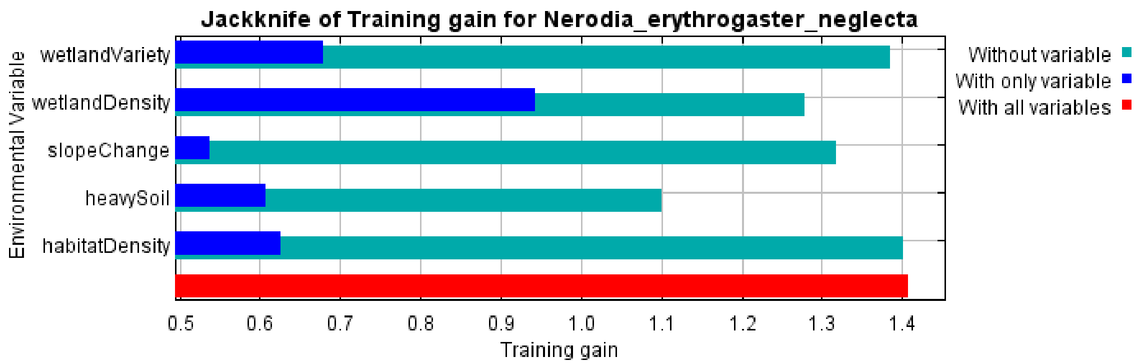


**Figure 2.** This graph shows the results of evaluation of Maxent model one, the "heavy soil" model, using the jackknife procedure. The environmental variable with the highest gain when used in isolation in the "heavy soil" model was wetland density. Heavy soil decreased the gain the most when it was omitted, indicating it appears to have the most information not present in the other variables. This model was based on historical and extant copperbelly occurrences in Hillsdale County, Michigan.

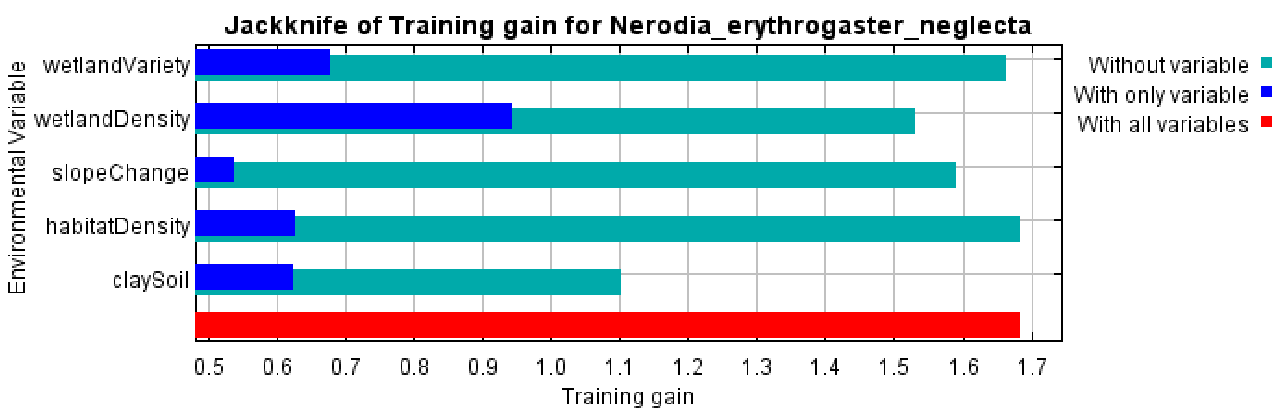


**Figure 3.** This graph shows the results of evaluation of Maxent model two, the "clay soil" model, using the jackknife procedure. The environmental variable with the highest gain when used in isolation in model two, the "clay soil" model, was wetland density, while clay soil decreased the gain the most when omitted. The overall gain for model two was 1.686 compared to 1.408 in model one. This model was based on historical and extant copperbelly occurrences in Hillsdale County, Michigan.

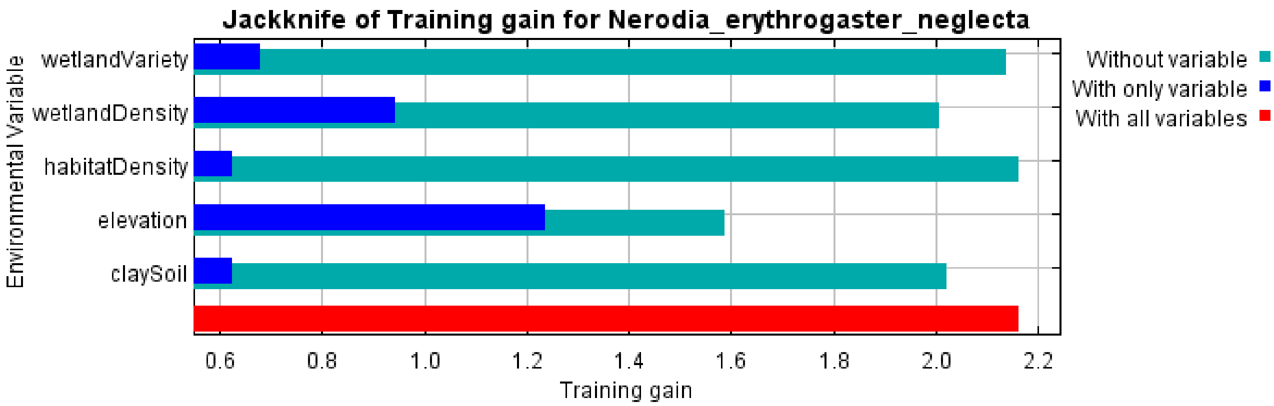


**Figure 4.** This graph shows the results of evaluation of Maxent model three, the "elevation" model, using the jackknife procedure. The environmental variable with the highest gain when used in isolation in model three, the "elevation" model, was elevation, which therefore appears to have the most useful information by itself. Elevation also decreased the gain the most when it omitted. Thi s model had the highest overall gain of all three Maxent models at 2.164. This model was based on historical and extant copperbelly occurrences in Hillsdale County, Michigan.

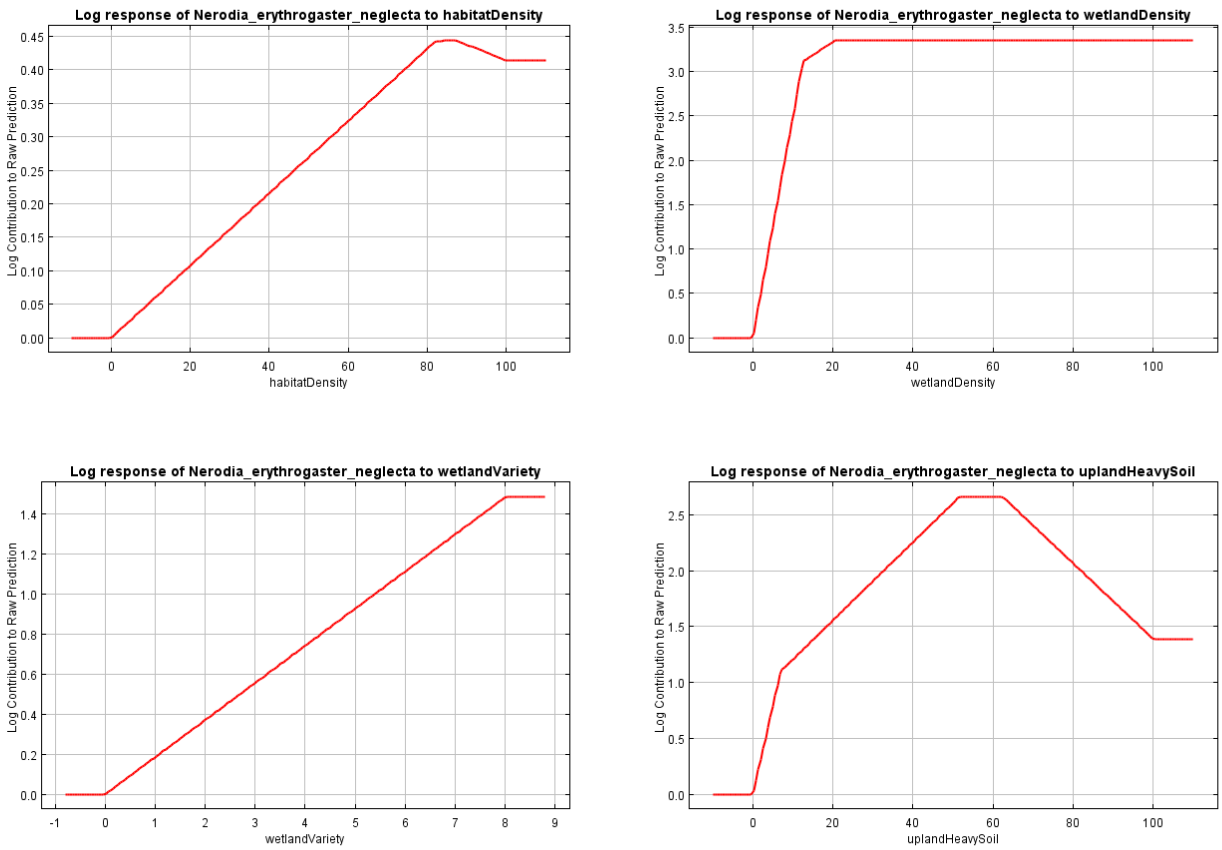


**Figure 5.** The variable response curves for model one, the "heavy soil" model, indicated positive responses to habitat density, wetland density, and wetland variety for the Copperbelly Water Snake Maxent predictive distribution model in Hillsdale County, Michigan. The model also showed a positive response to percent heavy soil in the upland until 62%.

approximately 20%, indicating strong predicted habitat suitability when wetland densities were greater than or equal to 20%. Habitat density increased steadily to a maximum of about 85% before decreasing slightly. The strength of the response for habitat density (the y axis) was not nearly as great as for wetland density. Increasing wetland variety improved the model response at each level. Percent heavy soil in the upland reached a maximum positive response at between 50-62%, and then declined moderately.

The variable response curves for model two, the clay soil model, were similar to the results for model one (Figure 6). Wetland density and wetland variety behaved almost identically, while habitat density had a lower positive response, reaching a maximum of 85%, before decreasing precipitously. Upland clay soil exhibited a strong positive response up to a maximum of 10% before declining slightly.

Model three, the elevation model, also demonstrated similar response curves for wetland density and variety, although the strength of the wetland density contribution was slightly higher than in the other two models (Figure 7). Habitat density showed no positive contribution, and a slight negative contribution at high densities. Upland clay soil exhibited a similar positive response as in model two, at first, also reaching a maximum of 10%, but then the response dropped sharply. Elevation had, by far, the greatest contribution to the model, contributing positively to the model's prediction until a maximum elevation of 295 meters. The elevation response became negative at 325 meters, and continued to fall sharply as elevation increased.

Using the simple threshold rule whereby the omission rate equals zero, model three, the elevation model, had the smallest fractional predicted area at 0.110 (Table 2). Models one and two, the heavy soil and clay soil models, predicted greater than three times as much area at 0.354 and 0.320, respectively. Selecting the optimum ROC curve threshold resulted in the same result for model three, but improved the fractional predicted areas of models one and two to 0.127 and 0.110 respectively. However the omission error for models one and two increased to 6%. The 2003 deductive model was included for comparison, showing a fractional predicted area of 0.15 with an omission rate of 22% (Table 2). The threshold for the 2003 deductive model resulted from the classification rule whereby if any of the five environmental layers were equal to zero, the model result for that area was set to zero. This is a very restrictive rule, but nevertheless, 15% of the study area was predicted suitable while the omission rate was 22%.

The continuous predicted output from the three models identified areas on the landscape that may provide more suitable habitat conditions for Copperbelly Water Snakes in Hillsdale County based on each model's parameters (Figures 8-10). The continuous output from models one and two, the heavy soil and clay soil models, appeared fairly similar. Both models predicted areas with more suitable habitat conditions for Copperbelly Water Snakes throughout the county, but primarily within the historical range of the species in the southern portion of the county and along river and stream corridors (Figures 8 and 9). The continuous output from model three, the elevation model, differed slightly from the other two models in that it predicted more suitable habitat conditions primarily in the southern and eastern portions of the county and less suitable habitat conditions in the northern and central portions of the county (Figure 10).

Predicted distribution maps showing areas classified as suitable or unsuitable for Copperbelly Water Snakes in Hillsdale County also were generated using the ROC thresholds for each of the three models (Figures 11-13). The copperbelly presence locations also are depicted on the maps (Figures 11-13), and a map showing the 2003 deductive model results also is included for comparison (Figure 14). Again, models one and two, the heavy soil and clay soil models, predicted areas with suitable habitat conditions throughout the county and produced fairly similar outputs, while model three, the elevation model, did not predict any suitable areas in the center of the county and minimal area in the north.

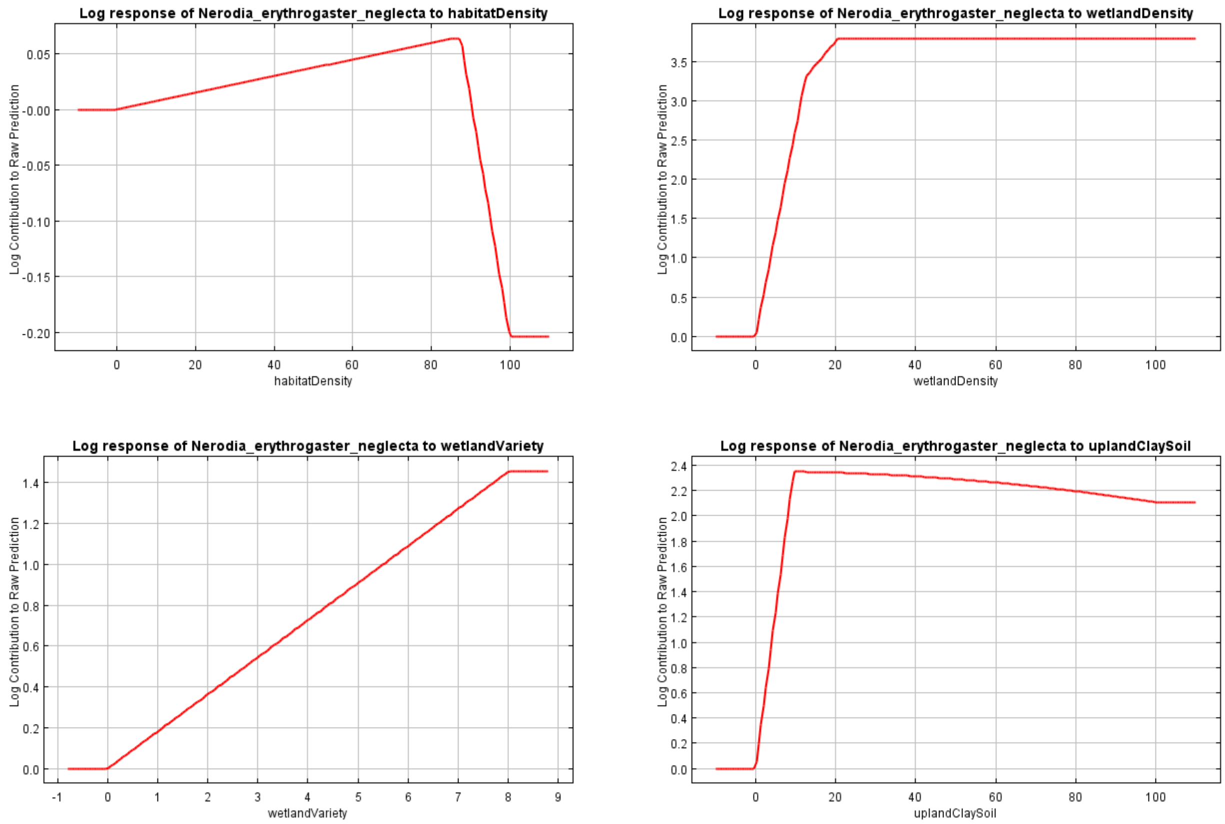


**Figure 6.** The variable response curves for model two, the "clay soil" model, indicated positive responses to wetland density, wetland variety, and upland clay soil for the Copperbelly Water Snake Maxent predictive distribution model in Hillsdale County, Michigan. The model also showed a mild positive response to habitat density and a strong positive response to percent clay soil in the upland until about 10%.

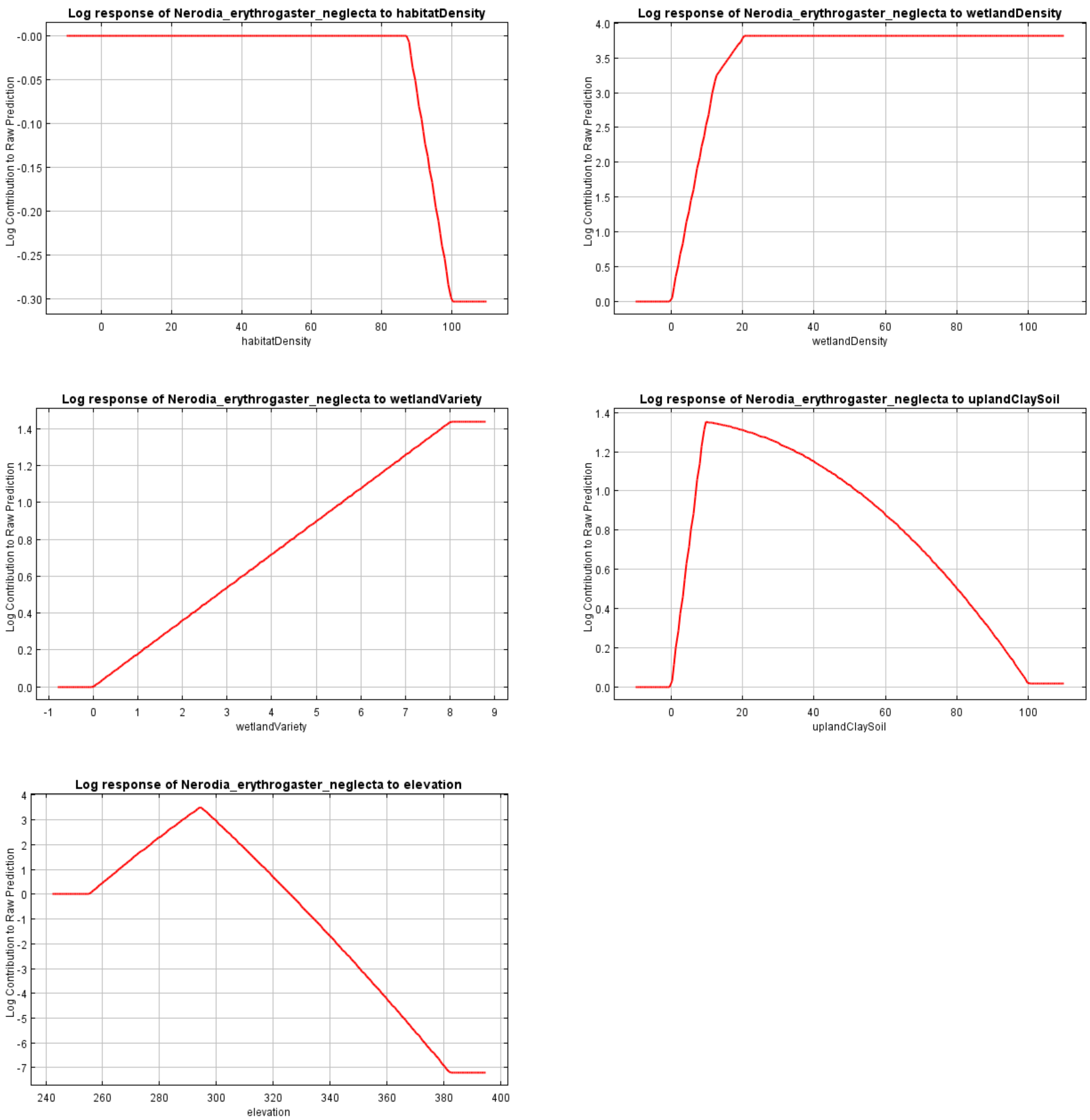


**Figure 7.** The variable response curves for model three, the "elevation/DEM" model, indicated positive responses to wetland density, wetland variety, and upland clay soil for the Copperbelly Water Snake Maxent predictive distribution model in Hillsdale County, Michigan. The model basically showed no response to habitat density and a strong positive response to percent clay soil in the upland until about 10%. The model also demonstrated a positive response to elevation until almost 300 m and a negative response to elevation above 300 m.

**Table 2.** Summary of fractional predicted areas and omission rates for each of the three Maxent models (1=heavy soil, 2=clay soil, and 3=elevation) using two threshold methods, the simple threshold method whereby the omission rate is set at zero and the optimum ROC curve threshold. The fractional predicted area and omission rate for the 2003 deductive model also are included. The three Maxent models were based on Copperbelly Water Snake occurrences in Hillsdale County, Michigan.

| Model | Threshold | Fractional predicted area | Omission rate |
|---|---|---|---|
| 1 | 2.589 | 0.354 | 0 |
| 1 | 25.916 | 0.127 | 5.90% |
| 2 | 3.917 | 0.32 | 0 |
| 2 | 25.582 | 0.11 | 5.90% |
| 3 | 12.169 | 0.11 | 0 |
| 3 | 12.169 | 0.11 | 0 |
| Deductive (2003) | 0 | 0.15 | 22% |

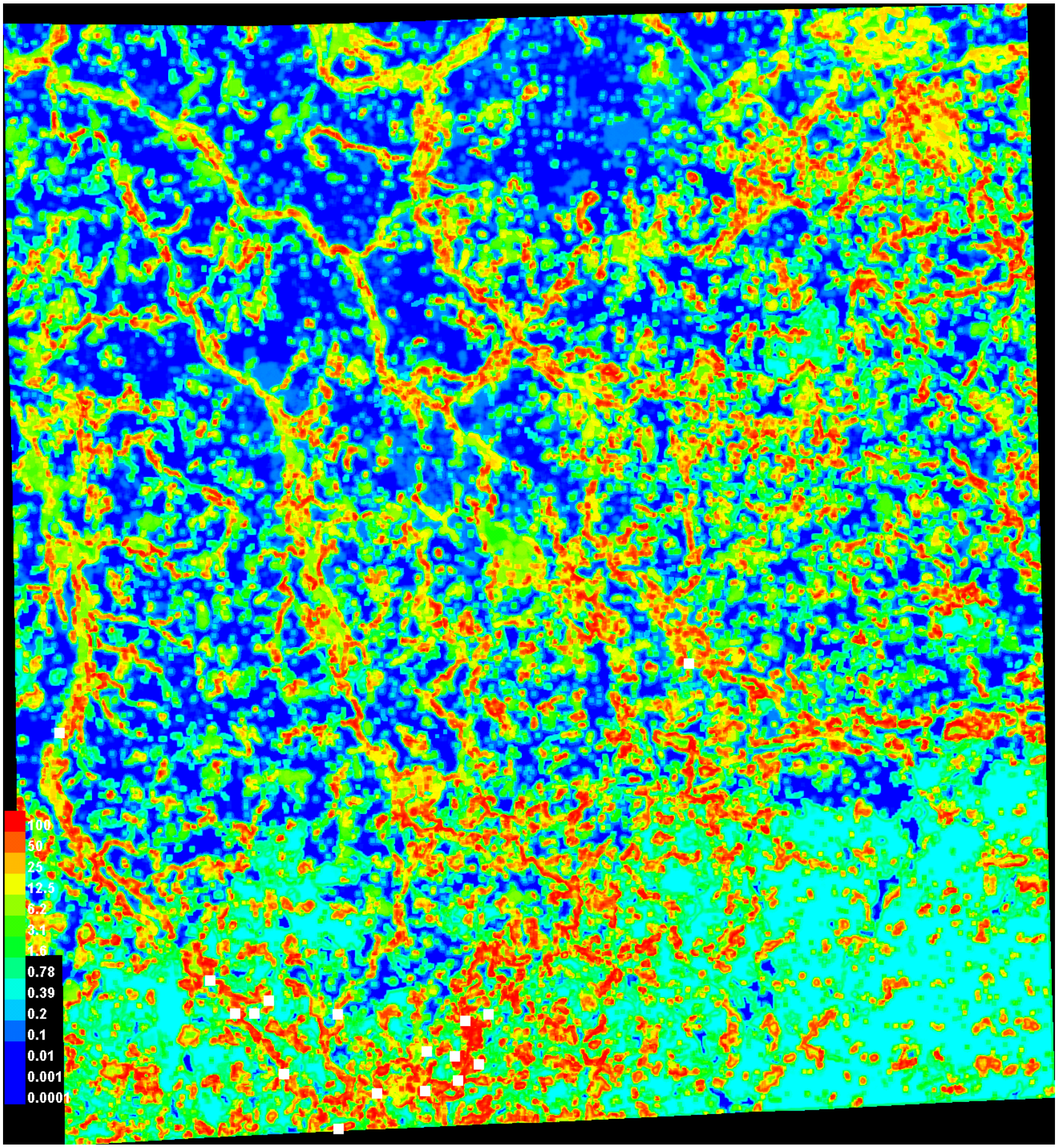


**Figure 8.** This figure depicts the continuous predicted output for Maxent model one, the "heavy soil" model, with warmer colors indicating more suitable conditions for the Copperbelly Water Snake in Hillsdale County, Michigan.

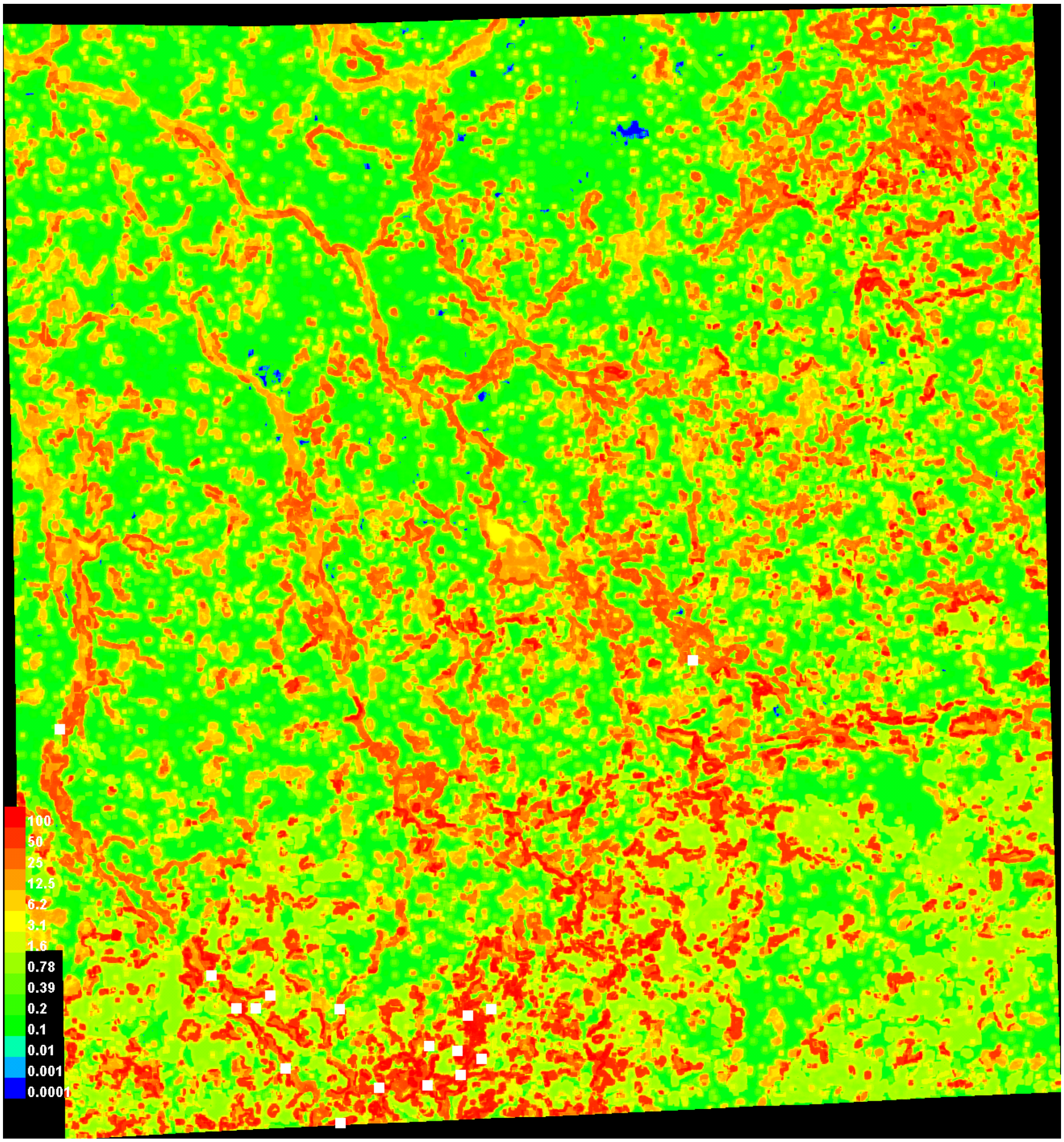


**Figure 9.** This figure depicts the continuous predicted output for Maxent model two, the "clay soil" model, with warmer colors indicating more suitable conditions for the Copperbelly Water Snake in Hillsdale County, Michigan.

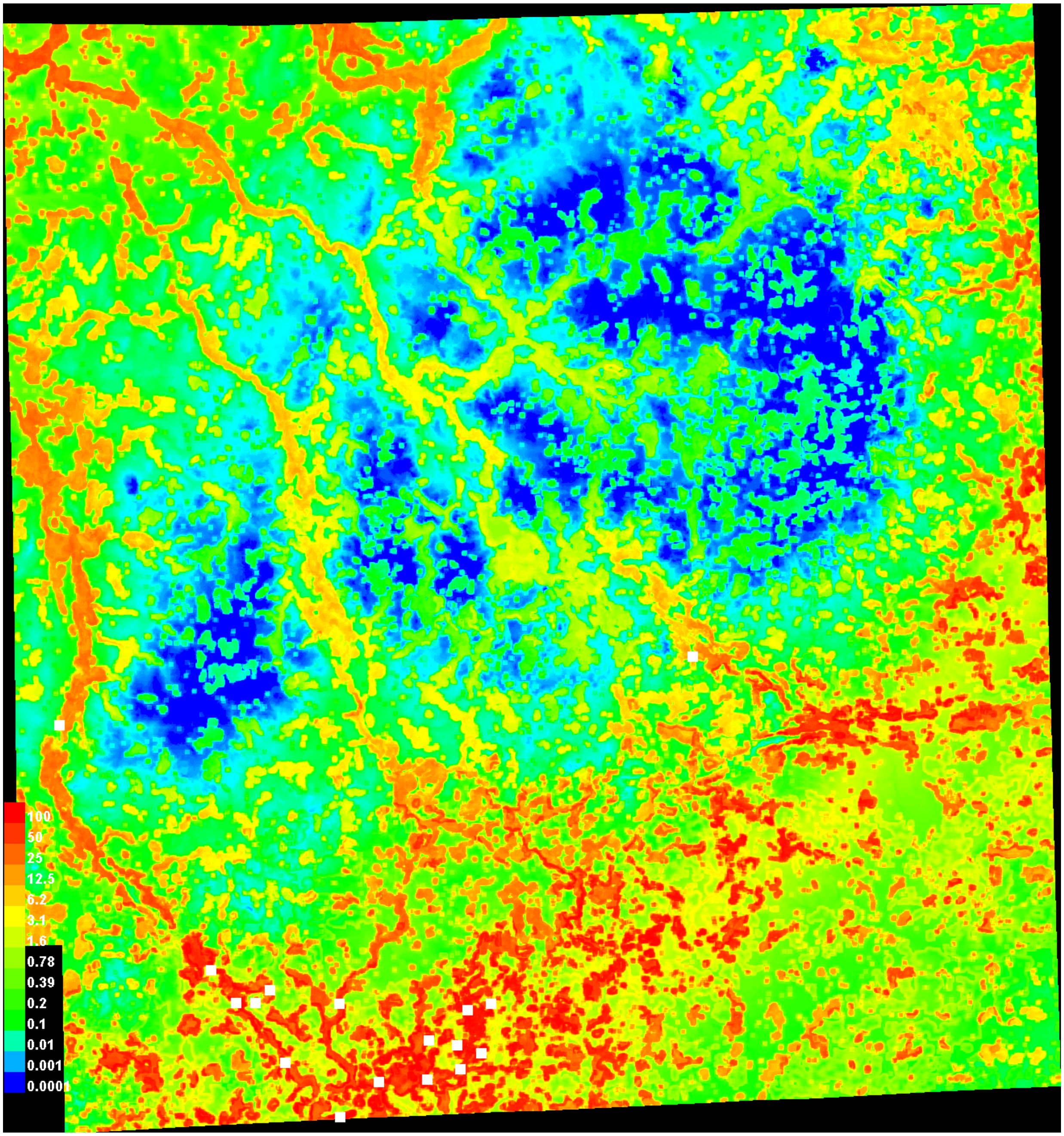


**Figure 10.** This figure depicts the continuous predicted output for Maxent model three, the "elevation" model, with warmer colors indicating more suitable conditions for the Copperbelly Water Snake in Hillsdale County, Michigan.

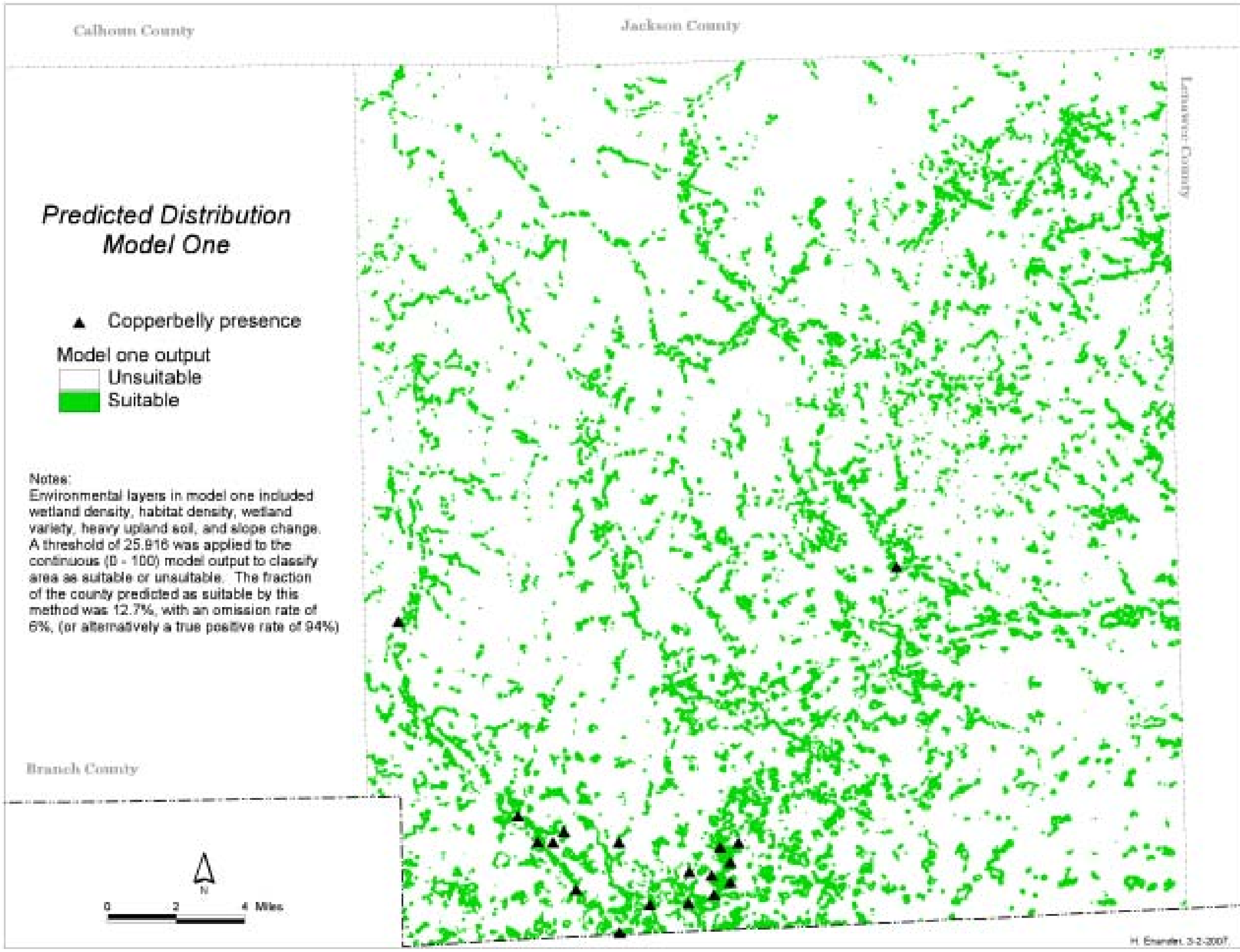


**Figure 11**. Map of predicted distribution of suitable areas (shown in green) for Copperbelly Water Snakes in Hillsdale County, Michigan based on results of Maxent model one, "heavy soils," with a threshold determined by the ROC (receiver operator characteristics) curve. This model predicted 12.7% of the study area as suitable, with an omission rate of 6%.

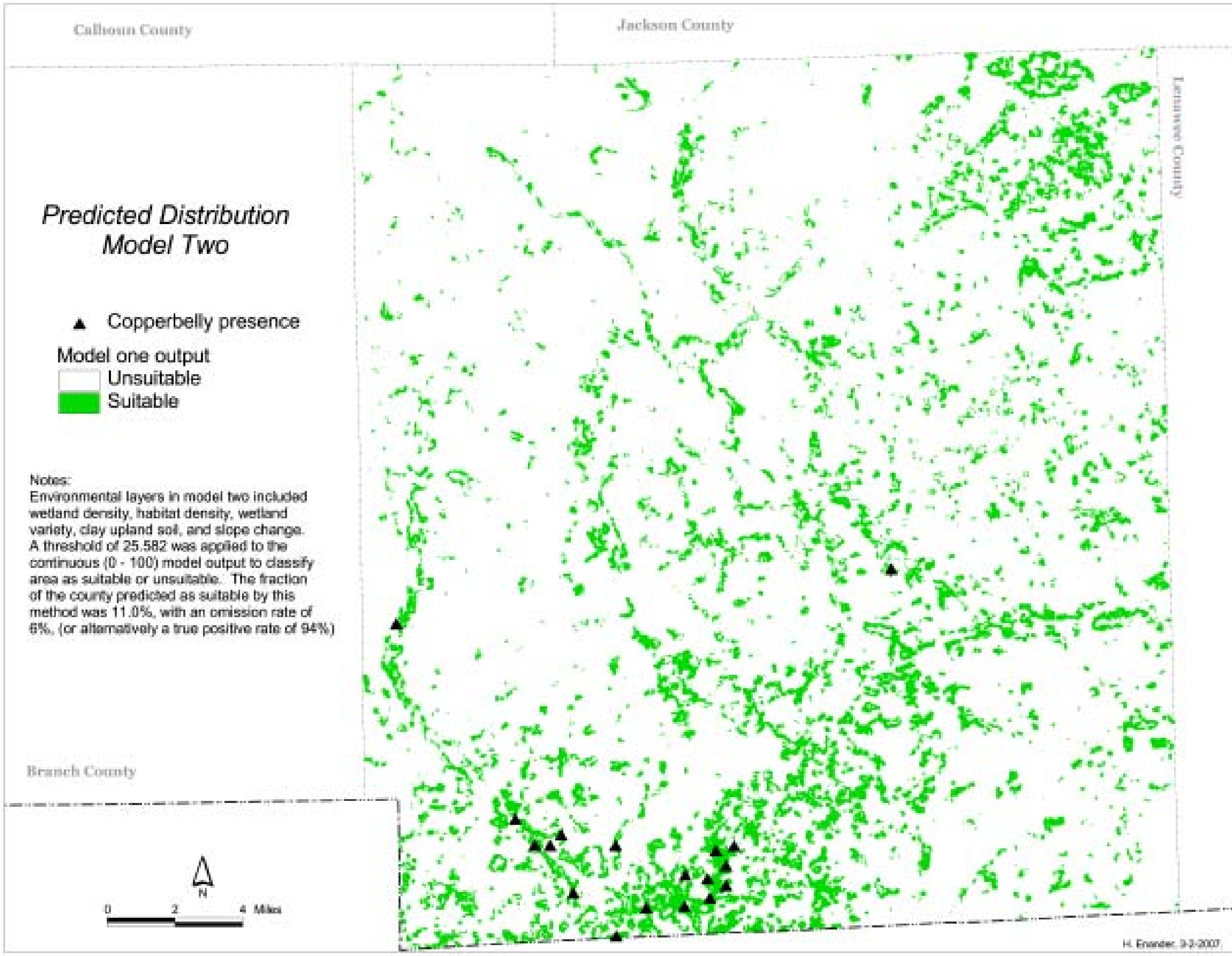


**Figure 12**. Map of predicted distribution of suitable areas (shown in greens) for Copperbelly Water Snakes in Hillsdale County, Michigan based on results of Maxent model two, “clay soils,” with a threshold determined by the ROC (receiver operator characteristics) curve. This model predicted 11% of the study area as suitable, with an omission rate of 6%.

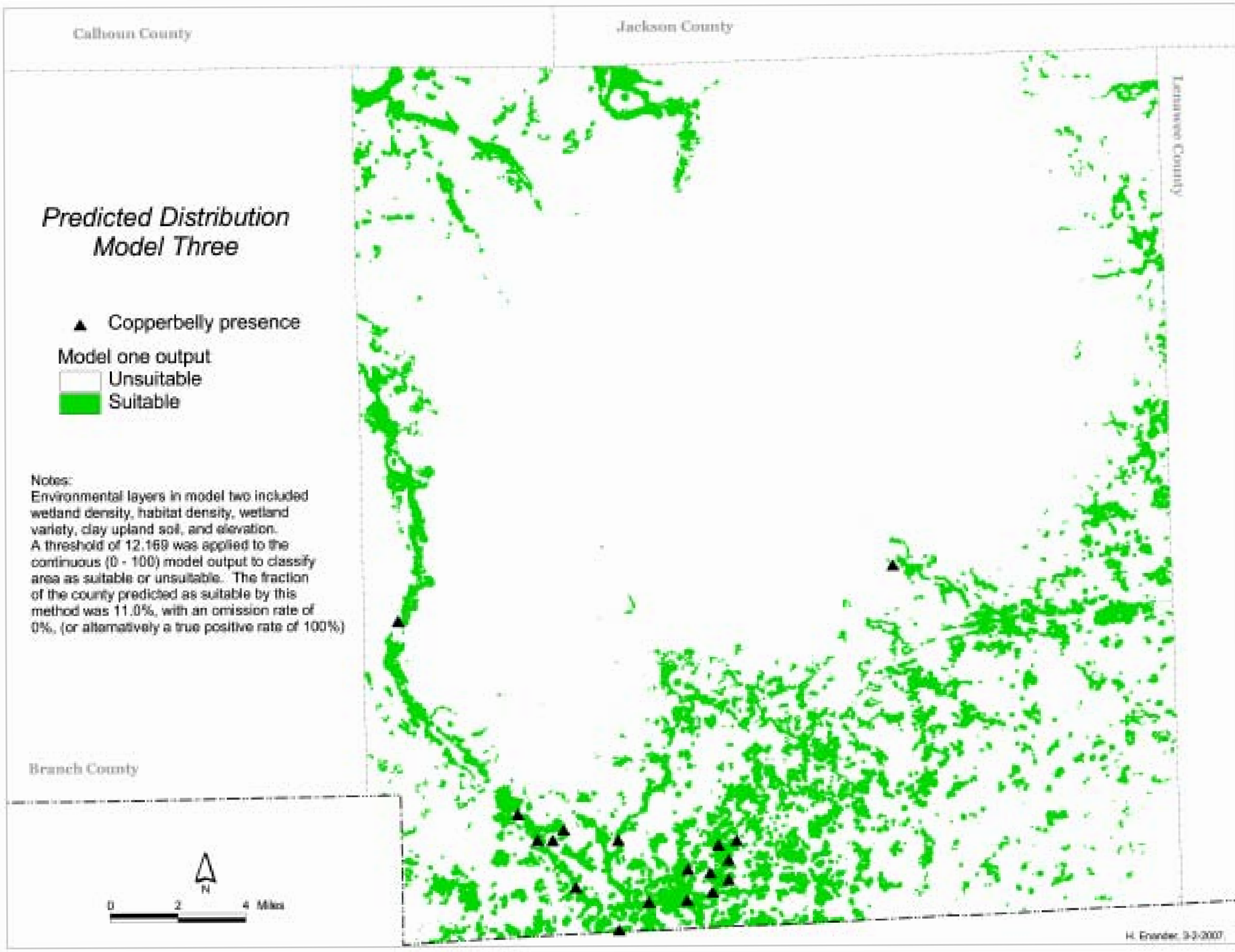


**Figure 13**. Map of predicted distribution of suitable areas (shown in green) for Copperbelly Water Snakes in Hillsdale County, Michigan based on results of Maxent model three, "elevation," with a threshold determined by the ROC (receiver operator characteristics) curve. This model predicted 11% of the study area as suitable, with an omission error of 0%.

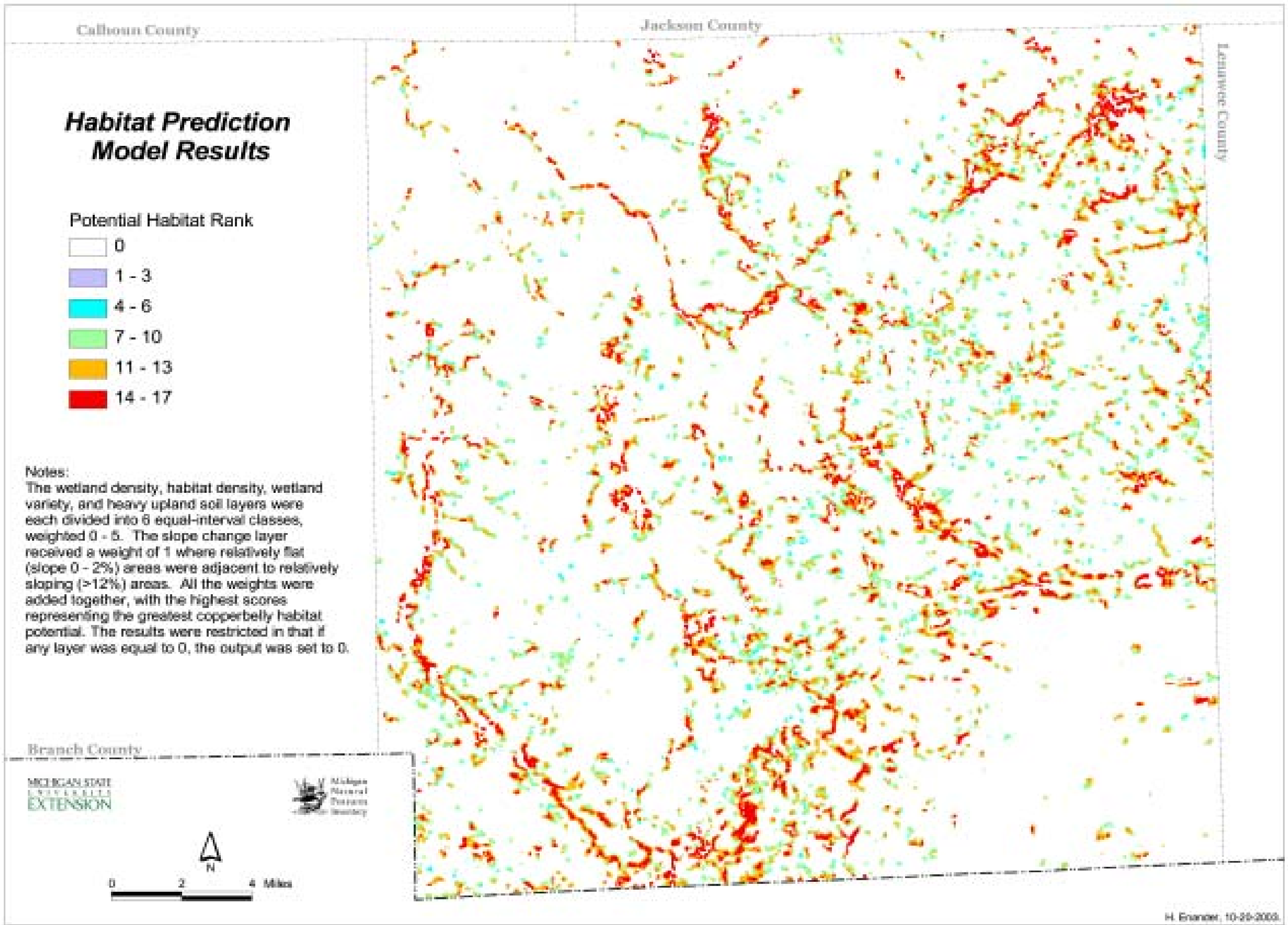


**Figure 14**. Map of results from the 2003 landscape-scale deductive habitat model developed by Michigan Natural Features Inventory for the Copperbelly Water Snake in Hillsdale County, Michigan. This model predicted 15% of Hillsdale County as suitable for Copperbelly Water Snakes, with an omission error of 22%.

Landscape Ecology and Distribution Analysis

The final logistic regression model for Copperbelly Water Snakes correctly predicted 82.0% of overall occurrence ($\chi^2$ = 10.80, df = 2, *P* = 0.005, AIC = 99.92), with copperbellies significantly more likely to occur in wetlands that were farther away from roads (Wald = 4.69, B = 0.82 ± SE 0.38, *P* = 0.030; Figure 15) and with more shoreline length (Wald = 4.67, B = 0.84 ± SE 0.33, *P* = 0.011; Figure 16). Copperbelly Water Snakes also were more likely to occurr in wetlands with more forest area within 30 m, 125 m, and 250 m buffer zones (Table 3, Figure 17).

Community/Macrohabitat-Scale Habitat Characterization

Results of the natural community habitat characterization and threats assessment are summarized in detail in Kost et al. (2006). Overall, natural communities that were characterized at nine known copperbelly sites in Michigan and adjacent Ohio (three extant sites and six historical sites) were comprised of 10 different types, including 6 wetland and 4 upland types (Kost et al. 2006). Wetland types included pond, emergent marsh, southern wet meadow, inundated shrub swamp, southern floodplain forest, and southern swamp (Kost et al. 2006). Upland types included mesic southern forest, dry-mesic southern forest, old field and pasture (Kost et al. 2006). All of the sites had communities that had undergone significant change since presettlement (Kost et al. 2006). All of the sites occurred within a landscape dominated by agriculture and rural housing (Kost et al. 2006). All of the sites contained invasive species (i.e., 37 species) and showed evidence of hydrologic alterations from either water level manipulation or increased surface flow (e.g., dredging, damming, flooding) (Kost et al. 2006).

Most of the Copperbelly Water Snake observations documented during surveys in 2005 and 2006 were associated with small, shallow water wetlands and open water ponds and small lakes. Using the NWI macrohabitat classifications, all the Copperbelly Water Snake observations documented at the two extant sites that occur exclusively in Michigan (Hillsdale County EO .008 and .010) were associated with palustrine scrub-shrub (20 of 36 observations/56%), palustrine scrub-shrub/palustrine forest (7 of 36 observations/ 19%), palustrine open water (6 of 36 observations/ 17%), palustrine emergent (2 of 36 observations/5%), and lacustrine open water (1 of 36 observations/ 3%).

Microhabitat Scale

At the two extant sites that occur in Michigan (Hillsdale County EO .008 and .010), most of the Copperbelly Water Snake observations documented during surveys in 2005 and 2006 were of snakes basking on logs or brush piles (15 of 36 observations/ 42%). A number of snakes also were observed basking in shrubs (7 of 36 observations/19%), in or on herbaceous vegetation (6 of 36 observations/17%), in or on grass or sedge (2 of 36 observations/5%), and on an island in the wetland (1 observation/3%). The remaining observations were of copperbellies traveling or foraging in the water (5 of 36 observations/14%). One mating pair also was observed on or in a brush pile in a shallow wetland.

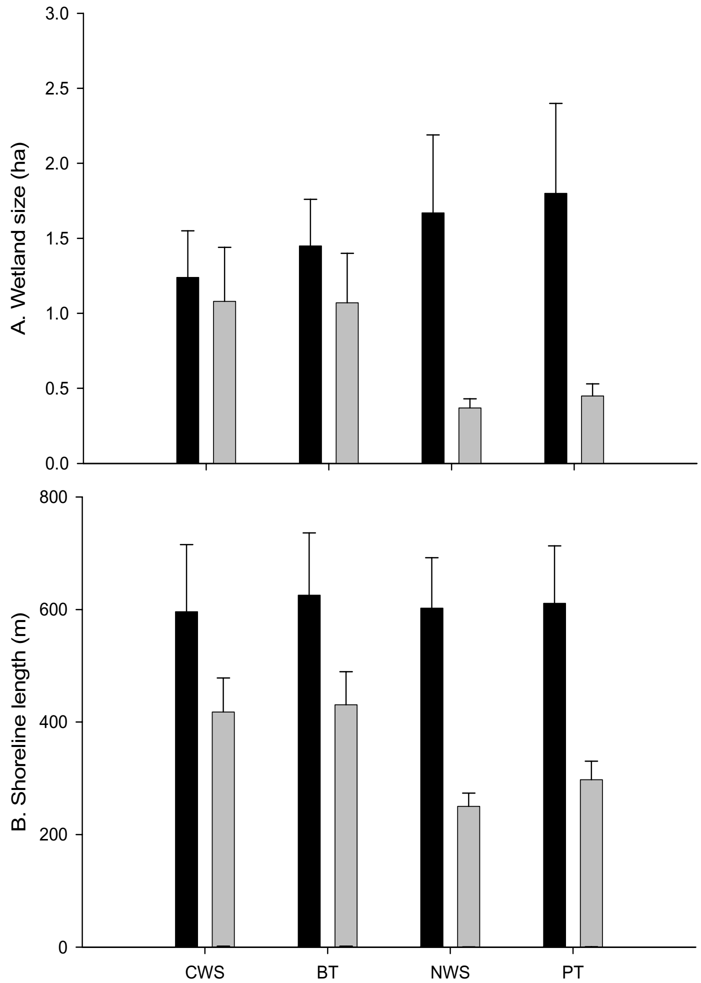


**Figure 15.** The mean size and shoreline length + SE of wetlands in which Copperbelly Water Snakes (CWS) were found or not found during surveys in 2005. Black bars represent wetlands in which a CWS was present. Gray bars represent wetlands where that species was not found. CopperbellyWater Snakes occurred in 20 of the 111 wetlands that were surveyed in 2005 in Hillsdale County, Michigan and Williams County, Ohio.

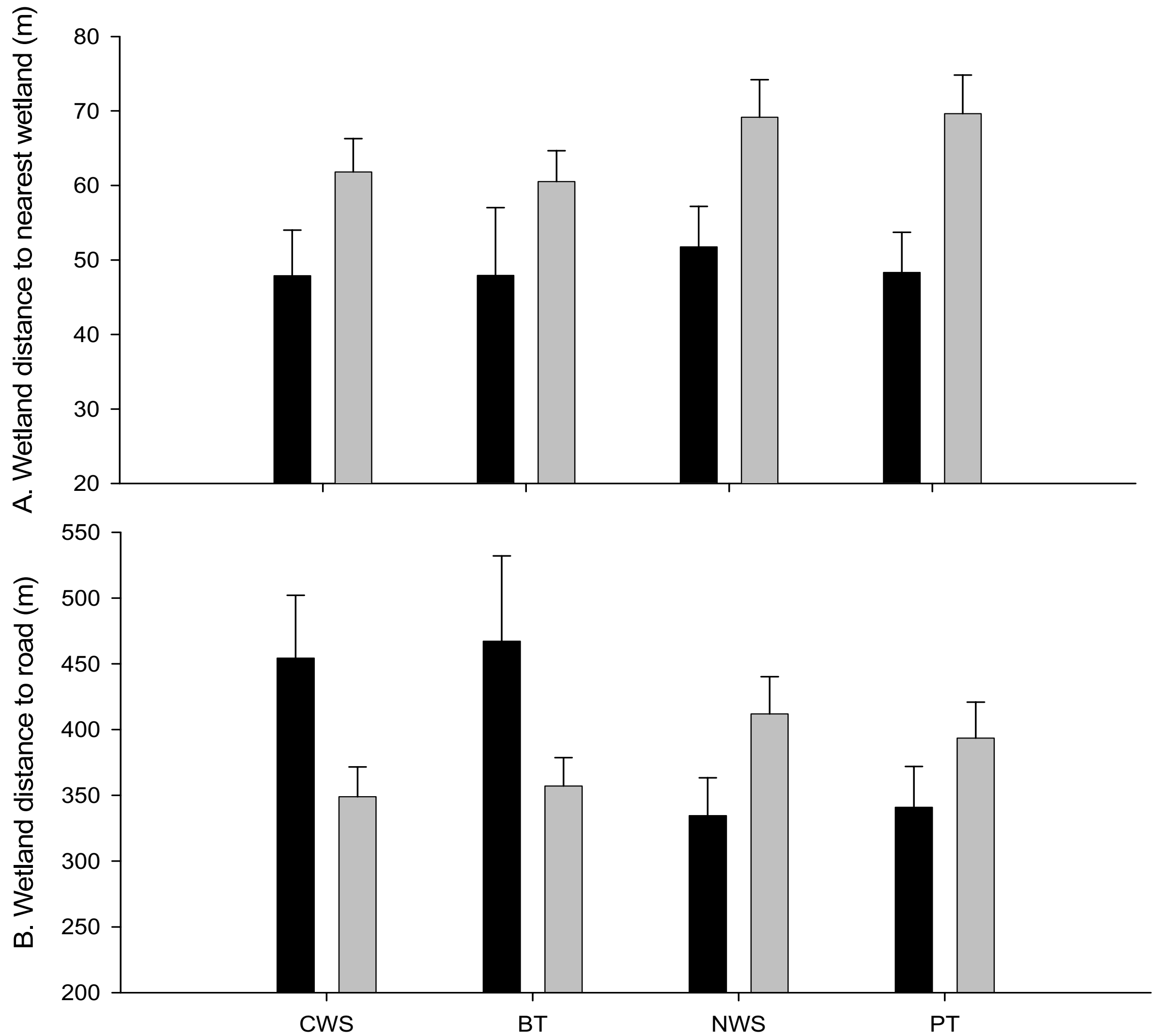


**Figure 16.** The effects of wetland distance to nearest wetland and wetland distance to road on Copperbelly Water Snake (CWS) distribution. A.Wetland distance to nearest wetland is the mean wetland distance (m) ± SE of used and unused wetlands. B. Wetland distance to roads is the mean wetland distance (m) ± SE of used and unused wetlands. Black bars represent wetlands in which a CWS was present. Gray bars represent wetlands where CWS were not found. Copperbelly Water Snakes occurred in 20 of 111 wetlands that were surveyed in 2005 in Hillsdale County, Michigan and Williams County, Ohio.

**Table 3**. Logistic regression results regarding the effects of forest area within differently sized buffer zones on Copperbelly Water Snake distribution at an extant site that occurs in both Hillsdale County, Michigan and Williams County, Ohio. P-values were corrected for multiple tests within each buffer zone size by the sequential Dunn-Sidak method. ^ Not Significant, $p > \alpha_{adj}$. ***** Significant, $p < \alpha_{adj}$. Df = 1 for all tests.

| **30 m** | **125 m** | **250 m** | **500 m** | **1000m** |
|---|---|---|---|---|
| $\chi^2$ = 6.88, *P* = 0.002* | $\chi^2$ = 6.98, *P* = 0.008* | $\chi^2$ = 6.91, *P* = 0.009* | $\chi^2$ = 1.86, *P* = 0.17 | $\chi^2$ = 1.54, *P* = 0.22 |
| B = 3.09 ± SE 1.09 | B = 1.76 ± SE 0.77 | B = 2.11 ± SE 0.93 | B = 1.22 ± SE 0.95 | B = - 1.26 ± SE 1.04 |

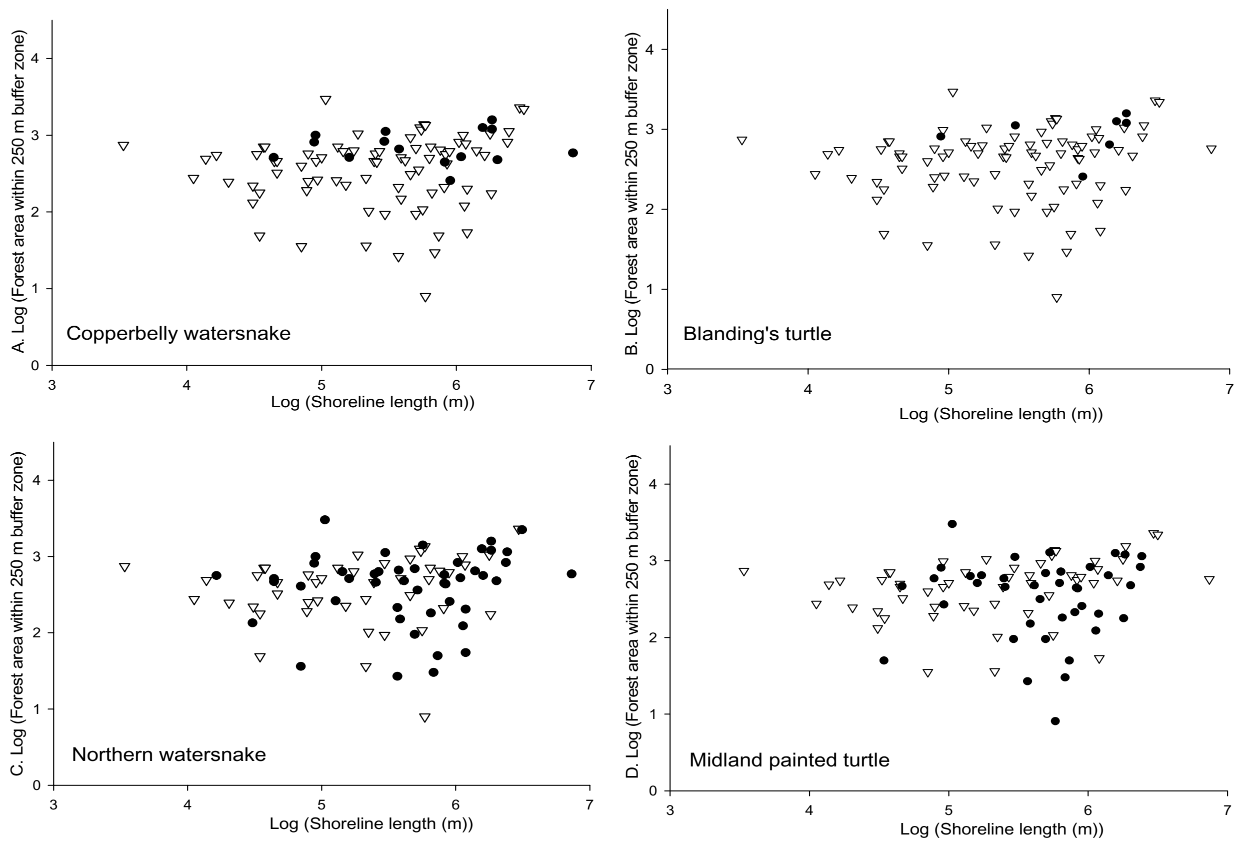


**Figure 17.** The relationship between forest area within a 250-m buffer zone and shoreline length on Copperbelly Water Snake (CWS) distribution. The black circles represent species' presence in a wetland, and the triangles represent wetlands in which the species was not documented during surveys in 2005 in Hillsdale County, Michigan and Williams County, Ohio. Copperbelly Water Snakes were documented in 20 of 111 wetlands that were surveyed in 2005.

## Maintenance and Enhancement of Copperbelly Information Base

For the copperbelly sites in Michigan, results from the field surveys and monitoring were transcribed and entered into MNFI's Natural Heritage Database, following heritage data standards and methodology as defined by NatureServe (www.natureserve.org). This information was used to update known Copperbelly Water Snake element occurrences in the MNFI database. In addition to updating the tabular information in the MNFI database, the Copperbelly Water Snake occurrences were updated spatially as well to represent the known geographic extent of each occurrence.

Study results and/or technical assistance were provided to federal, state, and local government agencies and conservation organizations including the U. S. Fish and Wildlife Service's (USFWS) field offices in Michigan, Indiana, and Ohio; Natural Resources Conservation Service; Michigan Department of Natural Resources (DNR); Ohio DNR; Indiana DNR; Soil and Water Conservation Districts; The Nature Conservancy (TNC); and Michigan Nature Association (MNA) during the project period. A copy of this report will be provided to these agencies and organizations as well as other interested and appropriate parties. Information from this study was provided to the USFWS in 2006 to assist with their review of the status of the northern population of the Copperbelly Water Snake. Information from this study on the Copperbelly Water Snake's current status, distribution, estimated population size, habitat conditions, and threats have been incorporated or used to help the USFWS develop a federal recovery plan for the northern population. We provided technical consultation to the USFWS with environmental review regarding activities related to emerald ash borer at or near known or potential Copperbelly Water Snake sites. We also provided technical consultation to MDNR LIP biologists in southwest and southeast Michigan regarding potential impacts of management activities at a previously documented copperbelly site in Calhoun County and potential opportunities or recommendations for habitat restoration at extant or historical copperbelly sites in Hillsdale County. We also have contacted the MNA and the MDNR regarding property immediately adjacent to an extant copperbelly site that may be available for purchase.

We (Bruce) assisted the USFWS East Lansing Field Office (ELFO) in Michigan with development of a Preventing Extinction grant proposal for the Copperbelly Water Snake which was funded. This grant provides funding for habitat management and restoration efforts on private lands by the USFWS' Private Lands programs in Michigan, Indiana, and Ohio; development of Copperbelly Water Snake site conservation plans for Michigan, Indiana, and Ohio; and research regarding potential copperbelly population augmentation efforts (e.g., translocation, reintroduction, headstarting, etc.). In 2006, in support of the Preventing Extinction grant project, we (Yu Man) met with USFWS' Private Lands program staff in Michigan to discuss Copperbelly Water Snake habitat needs and priority areas and actions for habitat management and restoration that would be most beneficial to copperbellies. In late 2006, we also organized and conducted a field trip for USFWS Private Lands and Endangered Species Program biologists in Michigan to visit extant copperbelly sites in Hillsdale County, Michigan and Williams County, Ohio to become more familiar with the species and its habitat. The training also provided an opportunity for researchers and managers to share information and discuss aspects of the Copperbelly Water Snake life history and ecology, implications for management and conservation, and appropriate habitat management and restoration strategies in the field. In addition to FWS staff, researchers, managers, or planners from MNFI Zoology and Conservation Planning programs, IPFW, the MDNR Landowner Incentive Program (LIP), the Michigan Chapter of TNC, and the Ohio DNR participated in the field trip.

In late 2006, we also participated in a copperbelly habitat management working group meeting convened by the USFWS. The purpose of this meeting was to discuss and coordinate copperbelly habitat management and restoration activities in Michigan, Ohio, and Indiana. Meeting participants were primarily land managers and biologists from the USFWS' Private Lands and Endangered Species programs in the three states, but also included land managers from the NRCS, local or county soil and water conservation districts (e.g., Hillsdale County), and TNC. We provided background information about Copperbelly

Water Snake ecology, habitat needs, status, and distribution, particularly status and extent of current and historical sites. We also provided recommendations for habitat management and restoration strategies and activities and priority areas for these efforts.

We also presented several talks at professional meetings or conferences and published or prepared two manuscripts on results of this study. Papers presented at professional meetings or conferences include the Midwest Fish and Wildlife Conference, Turtle Survival Alliance, International Wetlands Symposium, Annual Meeting of the Society for the Study of Reptiles and Amphibians, and Herpetology Weekend, Kentucky. One manuscript entitled "Upland-wetland linkages: relationship of upland and wetland characteristics with watersnake abundance" by Omar Attum, Yu Man Lee, John H. Roe, and Bruce A. Kingsbury was submitted and accepted in the Journal of Zoology in 2006 and published in 2007 (Attum et al. 2007). The second manuscript examines landscape effects on Copperbelly Water Snake distribution and is in review. A third manuscript on the population estimation component of the study has been prepared and will be submitted for publication in the near future.

## Public Education and Outreach

All property owners who owned parcels associated with the three extant Copperbelly Water Snake sites in Michigan were contacted either by phone or in person with an on-site visit in 2005 and 2006. Nine private property owners were contacted in 2005 and 2006, all of whom granted permission to survey their properties. We discussed survey results with all on-site landowners immediately after field surveys, if they were available, or sometime during the field season. Absentee landowners were contacted either by mail or phone informing them of survey results. We have interacted with most of these landowners for the last 4-6 years since our initial surveys in 2001. One of these landowners has expressed an interest in pursuing a conservation easement for his property and seeing if adjacent landowners are interested as well. We have provided some initial contacts to this landowner to assist in his efforts. We also have initiated discussions about the idea of a conservation easement and habitat restoration with an adjacent landowner in the same complex who also has copperbellies on his property.

# DISCUSSION

## Copperbelly Status and Distribution

<u>Surveys and Monitoring</u>

Overall, the numbers of Copperbelly Water Snakes that were observed in 2005 and 2006 at the three known extant sites were very small and appeared to be similar or slightly lower than the numbers observed during previous surveys at these sites from 2001-2004. The population cluster that occurs in both Michigan and Ohio (i.e., Hillsdale County EO .005 and Williams County-Ohio EO) is considered to be the largest population of the three currently known extant copperbelly sites that comprise the northern population. However, only 53 total Copperbelly Water Snake observations were documented at this site during surveys in 2005 and 2006. Surveys at the other two extant sites that occur exclusively in Michigan (Hillsdale County EO's .008 and .010) resulted in only 19 Copperbelly Water Snake observations total in 2005 and 17 observations total in 2006, with 13 and 12 observations, respectively, at one site (Hillsdale County EO .010) and 6 and 5 observations, respectively, at the other site (Hillsdale County EO .008). Similarly, surveys in 2004 at these two sites resulted in only 15 Copperbelly Water Snake observations overall, with 7 observations total at the Hillsdale County EO .010 site and 8 observations at the Hillsdale County EO .008 site.

Additionally, our results suggest that there has been a decrease in the number of Copperbelly Water Snake observations in five wetlands considered to be copperbelly hotspots at the Williams County-Ohio site since 2001. These wetlands were all surveyed between the months of April and June, using the same protocol described earlier. Between 2001 and 2003, these wetlands were surveyed one to three times. In 2005, each wetland was surveyed three times, and in 2006, wetlands were surveyed four times. The mean number of Copperbelly Water Snakes observed per survey in these five high-use wetlands decreased from approximately 1.7 to 1.8 snakes in 2001 to slightly less than 0.5 snakes per survey in 2006 (Figure 18).

Similarly, surveys appear to have documented fewer copperbelly observations at three wetlands on two different private parcels associated with the Hillsdale County EO .008 site from 2001 to 2006 (Figure 19). Copperbelly Water Snakes were observed in higher numbers and/or regularly observed (i.e., observed on almost every survey visit) at these three wetlands during surveys from 2001-2003. For example, in 2001, three copperbellies were found during a single survey of the two wetlands on one of the parcels (Parcel A), and four copperbellies were found during two survey visits to the wetland on the other parcel (Parcel B). These observations resulted in a mean of 3 copperbelly observations per survey for the two wetlands on Parcel A and a mean of 2 copperbelly observations per survey for the wetland on Parcel B in 2001. Also, repeated surveys or monitoring of the two wetlands associated with Parcel A in 2001 resulted in a total of 67 Copperbelly Water Snake observations on 31 of 36 survey visits. The mean numbers of Copperbelly Water Snake observations per survey for the two wetlands on Parcel A and the one wetland on Parcel B appeared to decrease from 2001 to 2006 with means generally greater than one copperbelly observation per survey for surveys from 2001-2003 but consistently less than one observation per survey from 2004-2006 (Figure 19). However, survey effort (i.e., time frame, number of surveys, and/or number of surveyors) varied slightly over the years, and may have contributed to differences in survey results Annual variations in weather or survey conditions also may contributed to differences in survey results over the years. For instance, the small number of Copperbelly Water Snakes observed in 2004 may have been due to relatively cool, rainy weather during the first half of the survey period and timing of the surveys. Other snake researchers in the region also reported fairly low numbers of observations of other snake species during surveys conducted in the spring of 2004 (Anton pers. comm.). Also, although the numbers of copperbellies observed at these wetlands appeared to decrease from 2001-2006, copperbellies were observed in other wetlands associated with this site.

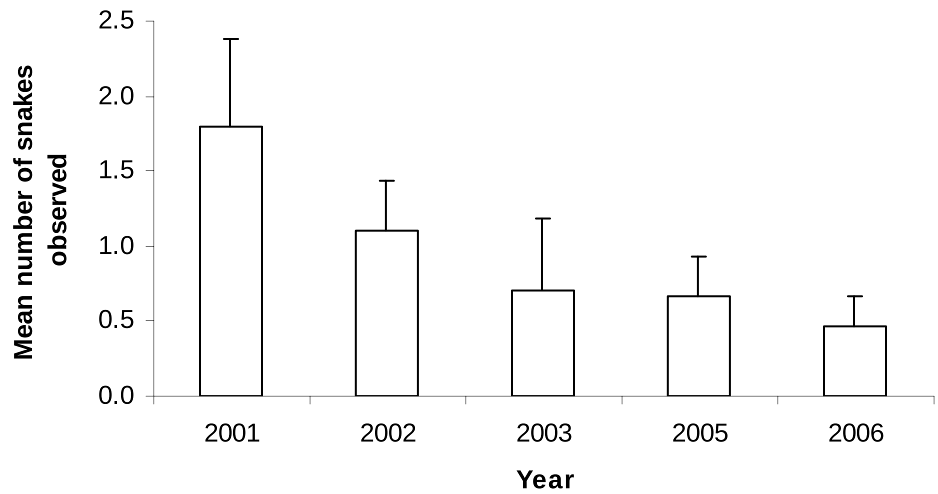


**Figure 18.** Mean number of Copperbelly Water Snakes observed per survey in five high use wetlands located within the extant site in Williams County, Ohio between 2001-2006. All wetlands were surveyed between April and June. In 2001, 2002, and 2003, wetlands were surveyed three times per year. In 2005, each wetland was surveyed three times, and in 2006, wetlands were surveyed four times.

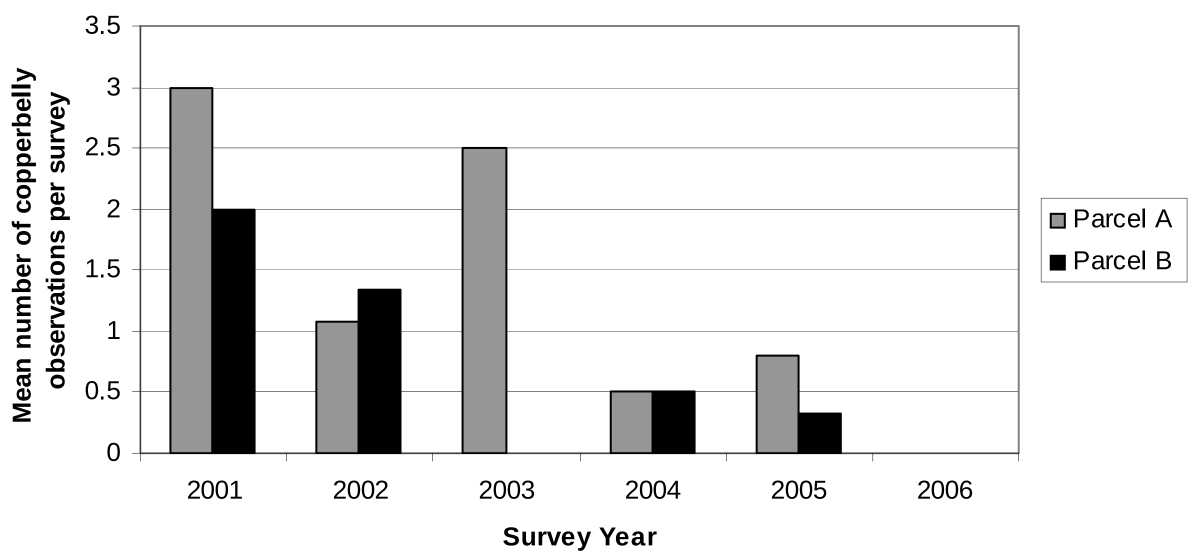


**Figure 19.** Mean number of Copperbelly Water Snakes observed per survey at three wetlands on two private parcels (two wetlands on Parcel A and one wetland on Parcel B) associated with the Hillsdale County EO .008 site in Michigan from 2001-2006. Copperbelly Water Snakes were regularly observed at these three wetlands during durveys from 2001-2003. Means were derived by dividing the total number of copperbellies observed by the total number of survey visits for the two wetlands on Parcel A and one wetland on Parcel B for each survey year. Limited surveys were conducted in 2003.

The frequency and potential impacts of blister disease (or condition that appears to be blister disease) in Copperbelly Water Snake populations should continue to be monitored and further investigated. Blister disease may be a fairly common and generally benign condition in copperbellies and other wild snakes. However, a Copperbelly Water Snake that was found and diagnosed with this condition in 2006 died unexpectedly while it was undergoing treatment at the Detroit Zoo. Also, several copperbellies have been found with blisters and potentially the same condition during recent surveys, and some snakes appear unable to recover from this condition or the condition appears to worsen and potentially negatively impact snakes (e.g., facial deformities especially around eyes and mouth could affect ability to forage). Also, an eastern fox snake with apparently similar hard bumps or nodules on the body was found by a researcher at a study site near Toledo, Ohio in 2006. This snake was diagnosed by a veterinarian at the Toledo Zoo as potentially having some kind of lymphoma or cancer that apparently occurred in captive snakes and would likely cause the snake to die within several weeks. Given the Copperbelly Water Snake's small population sizes and precarious status, any condition that potentially causes adverse impacts or loss of individuals should be reason for concern. The specific nature, causes, and impacts of this condition on individual snakes and remaining extant copperbelly populations warrant further investigation.

<u>Population Estimation</u>

Water snakes often have high population densities and can be locally abundant (Hebrard and Mushinsky 1978; Mills et al. 1995; Gibbons and Dorcas, 2004; Winne et al. 2005). The Northern Water Snake was more common than the Copperbelly Water Snake in our study area, although the densities of both species were lower than reported for other water snake species (Hebrard and Mushinsky 1978; Lacki et al. 1994; Mills et al. 1995). However, the northern population of the Copperbelly Water Snake is extremely small and characterized by a conspicuously lower density than reported for other populations of *N. erythrogaster*. For example, in southern Indiana, Lacki et al. (1994) reported densities of Copperbelly Water Snakes to be between 10-14 snakes/ha, depending upon locality, for prime Copperbelly Water Snake habitat. In addition, Hebrard and Mushinsky (1978) reported notably higher linear densities of 34.7 individuals/km of shoreline for the Yellowbelly Water Snake (*N. erythrogaster flavigaster*) in Louisiana. The linear density of the Copperbelly Water Snake was estimated at 3 individuals/km of shoreline based on observations during this study.

There are two sources of bias in our population and density estimates. First, the transects were not randomly placed but instead occurred on the wetland shoreline. Copperbelly Water Snakes are more likely to be found within the vicinity of the shoreline, especially in palustrine and lacustrine open wetlands (Laurent and Kingsbury, 2003; Herbert et al. unpublished data). Therefore, water snake abundance and density will be overestimated because of collecting data in the area of highest water snake density non-randomly and applying that density estimate to the entire wetland. The other potential source of overestimation bias is that the detection function may decrease more rapidly than expected. As distance from the transect increases, there is a decline in detectability from the transect which is accounted for by distance sampling. However, decreased detectability may also be due to snakes potentially being less common as perpendicular distance from the transect increases (Laurent and Kingsbury, 2003; Herbert et al. unpublished data). We believe that the overestimation biases would be less pronounced in Northern Water Snakes than Copperbelly Water Snakes, because the more aquatic Northern Water Snake use a larger proportion of the wetland surface area and are found further away from the shoreline (Herbert et al. unpublished data).

However, despite potential biases, and although other historical Copperbelly Water Snake locations within the range of the northern population were not surveyed, we believe our population size and density estimates are the most complete available for the entire northern population of copper-bellied watersnakes. The other unsurveyed localities are mostly historic records believed to consist of relic individuals versus populations, with no recent observations (Lee et al. 2002, Lee et al. 2003, Kingsbury, unpublished data). We believe that including these sites would only increase population size estimates by a few individuals and not by hundreds of individuals.

## Copperbelly Habitat Characterization

Landscape-Scale Habitat/Distribution Modeling

Generally, the preferred method for evaluating the accuracy of a predictive species distribution model is to test the model with independent occurrence data (i.e. those not used to build the model). Many measures of model evaluation can be calculated based on how well the model places independent occurrence data points in areas identified as suitable habitat and independent absence or non-occurrence data points in areas identified as unsuitable habitat (Fielding and Bell 1997). However, for studies of rare species, an independent data set is often not available, as is the case with this study. Omission rates (proportion of presence points predicted as unsuitable) were reported for each model in this study, but these are the same points used to build the model. The collection or inclusion of additional occurrence and non-occurrence data that can be used as independent sample points in the future will provide a better assessment of the model's ability to predict copperbelly presence. We are currently in the process of trying to expand the model to include copperbelly occurrence and habitat data from Ohio and Indiana. This would provide additional data for model development and evaluation.

It is interesting to note that although the Maxent model one, the heavy soil model, and the 2003 deductive model utilized the same habitat variables, the two models predicted common suitable areas but also predicted suitable areas that were not predicted by the other model. The models share a common predicted area equal to 55% of their combined total predicted suitablilty. Model one has 16% area exclusive to it, and the deductive model has 29 % area predicted suitable that was not predicted by model one. Additional occurrence data from future surveys could be used to test and compare these models.

Model three, the elevation model, contained the most information ("gain"), had the highest AUC, and predicted the least amount of area as suitable. These measures suggest it is the best model of the three Maxent models. However, we are not exactly certain as to why this model performed the best and what elevation is providing in the context of copperbelly suitability. One possible explanation is that the wetlands that are left on the landscape and provide suitable habitat for copperbellies occur at certain elevations. Elevation may serve as a surrogate for another environmental factor such as wetland hydroperiod and/or certain wetland types. Elevation also is fairly uniform across the county and within the range of the Copperbelly Water Snake. It also would be interesting to examine whether the elevation response shown in the Hillsdale County model extends to the full range of the species or even to a regional area. F. Graf et al. (2006) found that models built with data from single regions provide less certain predictions of species' distributions in other regions. The same elevation in a different region may experience a different environmental gradient.

The model evaluations using the jackknife procedure and the variable response curves all indicate the importance of wetland density, upland clay or heavy soil, and elevation in predicting suitable areas for copperbellies. All three models also demonstrated a consistent positive response to wetland variety. The overall importance of wetland density and wetland variety in the Maxent models correspond with similar research findings by Roe (2002) and Roe et al. (2003, 2004).

Finally, certain questions or comments remain regarding the Maxent models. For example, is the scale used to calculate wetland and habitat density (a 6 x 6 pixel block, or 180 meters on a side) appropriate, or should others (larger, smaller) be tested? Forest density should perhaps be included in the Maxent models instead of habitat density, as wetland density is already represented in the models. Finally, construction of these models is limited by the availability of digital spatial data layers that approximate the requirements for the species under study (Austin 2002).

Landscape Ecology and Distribution Analysis

Wetland connectivity is often dependent upon a species' vagility and landscape scale (Hokit et al. 1999, D'Eon et al. 2002). Wetland proximity, the distance between neighboring wetlands, was not a significant predictor of Copperbelly Water Snake, although there was a trend for Copperbelly Water Snakes to occur in wetlands that were closer to other wetlands (Figure 2). Copperbelly Water Snakes are a highly vagile species in our study area, frequently traveling long distances over land, greater than several hundred meters, to reach nearby wetlands (Hall and Cuthbert 2000, Joyal et al. 2001, Roe et al. 2003). Therefore, Copperbelly Water Snakes should be able to reach any of the wetlands in our study site, assuming there are no barriers and given that no wetland was further away than 197 m from a neighboring wetland.

Corridor quality is an important factor that can affect survival during dispersal. Dispersal through hostile habitat can be costly, with increased mortality risk in poor corridor habitat (Henein and Merriam 1990). Our results suggest that corridor quality between wetlands is important for Copperbelly Water Snakes. The Copperbelly Water Snakes were less likely to occur in wetlands near roads. Roads fragment habitat, act as barriers to movement, and cause mortality (Trombulak and Frissell, 2000), with vagile species, such as the Copperbelly Water Snake, being more susceptible than sedentary species to road effects (Gibbs, 1998, Bonnett et al. 1999; Carr and Fahrig 2001; Roe et al. 2006). The loss of adults from small populations could be devastating (Kramer-Schadt et al. 2004; Roe et al. 2006). In some situations, reducing unnatural sources of mortality (e.g., roads) is one of the most effective ways to expedite species recovery or stabilize declining populations (Heppell 1998).

Forest area within a buffer zone can be considered another characteristic of connectivity quality, especially if the forest matrix connects two wetlands. Our results show that forest area within buffer zones up to 250 m was a significant predictor of Copperbelly Water Snakes. A 250-m buffer zone would protect the connectivity between wetlands given the maximum distance between neighboring wetlands was 197 m. However, 250 m is double the minimum buffer zone size recommended for Copperbelly Water Snakes, corroborating past findings that suggest minimum buffer zones may not always be adequate for species protection (Houlahan and Findley 2003, Roe et al. 2003, Herrmann et al. 2005). Buffer zones represent a radius of upland habitat surrounding the wetland that protect core habitat for wetland species, based upon vital natural history activities outside of the wetland, such as hibernation, aestivation, nesting, or other terrestrial activities (Burke and Gibbons 1995, Semlitsch 1998, Joyal et al. 2001, Semlitsch and Bodie 2003). A critical component typically missing from buffer zone estimates is protection of connectivity between wetlands and edge effects, which increases with smaller forest patch size and also benefits generalist predators that prey upon wetland species (Dijak and Thompson 2000, Semlitsch and Bodie 2003). For example, a minimum buffer zone of 125 m would be needed to protect vital behaviors of Copperbelly Water Snakes, but a 250-m buffer zone would provide more protection from edge effects and increase protection for animals moving between wetlands by maintaining connectivity quality (Semlitsch and Bodie, 2003). When protecting extensive forest may not be practical because of financial, logistical, or political considerations, we suggest the prioritization of corridors to maintain connectivity between wetlands. Our finding highlights the importance of considering connectivity when estimating buffer zone sizes or using corridors for maintaining connectivity in wetland complexes.

Shoreline length was a better predictor than wetland size for Copperbelly Water Snakes because shoreline length is dependent upon size and shape, whereas wetland size is more dependent upon water surface area. For example, the shoreline length is highly correlated with size ($r = 0.87$, $P < 0.0001$), with larger wetlands having more shoreline. Wetlands with increased shoreline have more available wetland edge habitat, which is the most used habitat by both snake species and are also important feeding areas for turtles (Laurent and Kingsbury 2003). As shoreline increases, there is greater potential to have more structural vegetation diversity and areas of shallow water, which would be utilized by Copperbelly Water Snakes (Kofron and Schreiber 1985, Bury and Germano 2003, Laurent and Kingsbury 2003).

Community/Macrohabitat and Microhabitat Characterization

The community-level habitat characterization identified a number of different natural communities that comprise extant and historical Copperbelly Water Snake sites. A number of threats also were identified at these sites including significant habitat loss, degradation, and fragmentation, primarily due to agricultural and rural residential development, invasive plants, and hydrological alterations (Kost et al. 2006). Based on these results, conservation and recovery of the Copperbelly Water Snake will require maintaining large, diverse and functioning wetland-upland habitat complexes; restoring and maintaining hydrology; and controlling invasive plants (Kost et al. 2006).

Macrohabitat characterizations for Copperbelly Water Snake observations in 2005 and 2006, based on the NWI wetland classifications, were similar to results obtained in 2004. In 2004, most of the copperbelly observations were associated with palustrine open water, palustrine scrub-shrub/palustrine open water, and lacustrine open water (Lee et al. 2005). These observations were from all three extant sites in Michigan. Copperbelly Water Snake observations in 2005 and 2006 for two of the three extant sites in Michigan were documented primarily in palustrine scrub-shrub, palustrine scrub-shrub/palustrine forest, and palustrine open water. The association with lacustrine open water in 2004 was primarily due to copperbelly observations at the extant site that occurs both in Michigan and Ohio which was not included in the 2005 and 2006 macrohabitat analyses. The Copperbelly Water Snake use of shallow wetlands and small ponds and lakes during the spring and early summer documented during this study is consistent with findings from other studies (Roe 2002, Kingsbury et al. 2003, Roe et al. 2003). However, it is important to note that these results may be biased since these wetland types were targeted for surveys, and many were sites at which copperbellies had been documented previously. Additional analyses using macrohabitat availability and/or macrohabitat data from nearby survey sites at which copperbellies have not been documented may help clarify these habitat associations.

Microhabitat characterizations in 2005 and 2006 also were somewhat similar to results obtained in 2004. At the two extant sites that occur in Michigan (Hillsdale County EO .008 and .010), most of the Copperbelly Water Snake observations documented during surveys in 2005 and 2006 were of snakes basking on logs or brush piles as well as shrubs and herbaceous vegetation. In 2004, most of the copperbelly observations also were of snakes basking on logs or other downed woody debris followed by observations of snakes in grass, including mowed grass, and in water (Lee et al. 2005). Interestingly, copperbelly observations from surveys in 2002 and 2003 were primarily of snakes in grass followed by snakes basking on logs or other downed woody debris and at the base of woody shrubs or trees (Lee et al. 2003). Herbert (2003) found that copperbelly microhabitat associations varied somewhat in different macrohabitat types. In open wetlands, Copperbelly Water Snakes were most often found near or were strongly associated with shrubs, herbaceous emergent, or low-lying vegetation and logs/log cover when available. In palustrine forest/scrub-shrub habitats, Copperbelly Water Snakes were more likely found in areas with thick woody growth or dense shrub growth with log cover (Herbert 2003). In open canopy upland habitats, copperbellies were more likely found in areas with tall herbaceous growth and shrubs (Herbert 2003). In upland forest, copperbellies were often found in grassy patches of forest floor (i.e., areas with more insolation for thermoregulation, canopy gaps, and along forest margins) (Herbert 2003). These results as well as our study results indicate that logs and other downed woody debris and shrubs are essential within wetland habitats for providing cover and basking opportunities.

## Maintenance and Enhancement of Copperbelly Information Base

We will continue to work and share information and expertise with federal, state, and local partners and stakeholders to promote and facilitate conservation and recovery of the northern population of the Copperbelly Water Snake. To help implement the USFWS' Preventing Extinction grant for the Copperbelly Water Snake, we are currently developing site conservation plans centered around extant and historical copperbelly sites and habitat corridors connecting these sites within the range of the northern population in Michigan, Ohio, and Indiana. These plans will help the USFWS identify priority areas and activities for habitat management and restoration, and provide a long-term, strategic, landscape-level framework for copperbelly habitat conservation and restoration efforts. We also will be providing information about landowners in these areas and assisting with landowner contact as needed. We will continue to participate, share information, and collaborate with a tri-state copperbelly habitat working group comprised of state and federal land managers from Michigan, Ohio, and Indiana. We also will be assisting the MDNR's Landowner Incentive Program (LIP) in southeast and southwest Michigan by conducting surveys for the Copperbelly Water Snake and providing recommendations for habitat management and/or restoration on private lands. We also will investigate collaborating and training partners to assist with surveys and monitoring efforts.

Additionally, we have been working on trying to obtain additional funding to continue research, management, and/or public education and outreach efforts for the Copperbelly Water Snake. MNFI recently collaborated with TNC's Michigan Chapter and Fish Creek Office in Indiana to develop a grant proposal to conduct conservation planning and coordination, habitat management and restoration, and education and outreach in the St. Joseph of the Maumee Watershed in which the three known extant copperbelly sites occur. This proposal was not funded, but we will continue to pursue funding for these efforts. MNFI also has offered to assist the Hillsdale Conservation District with development of a watershed management plan for a sub-watershed of the St. Joseph of the Maumee Watershed if they awarded the funding for the plan.

## Public Education and Outreach

We will continue to conduct education and outreach and strengthen working relationships with private landowners at extant sites and additional landowners of known or new sites through survey and habitat management efforts such as the MDNR's LIP program, TNC's Michigan Chapter's Headwaters Project and the Fish Creek Office, and Hillsdale Conservation District's watershed management planning efforts. We also will pursue funding to continue and expand public education and outreach regarding the Copperbelly Water Snake including conducting educational workshops focused on wetlands and other rare species and opportunities for habitat management and restoration in the St. Joseph of the Maumee Watershed. We will continue to distribute and make educational materials on the Copperbelly Water Snake available to landowners and the public through mailings, workshops, meetings, and the Internet.

## CONCLUSIONS

According to the U. S. Endangered Species Act, a threatened species is one likely to become endangered in the foreseeable future, while an endangered species is “in danger of extinction within the foreseeable future throughout all or a significant portion of its range”. We believe that the northern population of the Copperbelly Water Snake is already endangered based on the small population size reported, the decrease in number of observations from 2001 to 2006, that extinction probability is extremely high for small populations, and in accordance with the definition of the Endangered Species Act.

The small population size and low density of the northern population is most likely the result of in adequate wetland habitat and negative landscape effects on existing habitat (Roe et al. 2003, 2004, 2006, Attum et al. unpublished data). The recovery of the Copperbelly Water Snake will require protecting and restoring large wetland complexes encompassed in a forest matrix versus individual wetlands (Roe et al. 2003, 2004). These complexes should contain a mosaic of wetland types, consisting of large open wetlands surrounding by multiple ephemeral and variable types of wetlands (Roe et al. 2003, 2004). Our results suggest that shoreline length is a better index of available wetland habitat than wetland area size when assessing habitat quality for the conservation and recovery of the Copperbelly Water Snake. Within wetland habitats, maintaining or providing adequate cover and basking platforms, such as shrubs, logs, and other downed woody debris, also is essential.

In order to maintain connectivity between wetlands in a complex, conservation efforts should focus on protecting small wetlands (less than 1 ha), the upland forest habitat between wetlands, and creating wetlands that are located within approximately 250 m of each other (Roe et al. 2003, 2004). When considering wetland connectivity for Copperbelly Water Snake, characterization of connectivity should not only consider distance between wetlands, but also corridor quality (Ricketts 2001, Fleishman et al. 2002, WallisDevries 2004). For example, two wetlands may at first appear well-connected due to their close proximity to one another, but if the habitat matrix between them prevents movement or increases mortality risk for animals that move between the patches such as in agricultural fields or roads, then the two wetlands are more isolated than simple distance would indicate (Ricketts 2001). The use of buffer zones to protect forest area near small wetlands would improve connectivity between wetlands and thus aid in the recovery efforts for Copperbelly Water Snakes, but forest restoration alone may not be enough to assist in their recovery without addressing the impacts of roads as a source of mortality and habitat fragmentation (Kramer-Schadt et al., 2004; Roe et al. 2006).

Monitoring of known extant Copperbelly Water Snake populations and surveys to identify additional extant populations should continue in Michigan, Ohio, and Indiana. Additional efforts to characterize copperbelly habitat at the landscape-scale such as including copperbelly occurrences in Ohio and Indiana in the habitat models are warranted. More research on copperbelly habitat management and restoration needs and impacts on copperbelly populations also is needed. Research investigating the potential for translocation and/or headstarting Copperbelly Water Snakes for introduction or reintroduction efforts in the future to maintain or augment populations has been initiated and should continue. Efforts to document and better understand genetic composition and genetic diversity of the northern population of the Copperbelly Water Snake also should continue. Finally, working with agencies, conservation organizations, private landowners, and a broad range of partners and stakeholders to maintain and restore adequate habitat complexes will be essential for conservation and recovery of the northern population of the Copperbelly Water Snake.

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# APPENDICES

**Appendix I.** Survey protocol for Copperbelly Water Snakes that was used and/or modified for copperbelly surveys at three known extant sites in Hillsdale County, Michigan and Williams County, Ohio in 2005 and 2006.

## A SURVEY PROTOCOL FOR COPPERBELLY WATER SNAKES (*NERODIA ERYTHROGASTER NEGLECTA*) FROM NORTHERN POPULATIONS

Bruce Kingsbury, Indiana-Purdue University

In order to increase the value and compatibility of surveys for the copperbelly water snake by different individuals, we suggest the following protocol and datasheet. If surveyors are consistent in their approach, we may be able to use the information they collect in more sophisticated ways than simply stating whether or not copperbellies were found. Adhering to such guidelines will also strengthen the implication of surveys where no copperbellies are observed.

To minimize the impact of environmental and seasonal conditions, surveys should only be conducted on partly sunny days of at least 20 C (68 F), or sunny days between about 18 and 30 C (65-86 F). Surveys should also only be conducted while the sunlight would be able to strike the ground in the survey area (roughly 9-5). These constraints will maximize the chances of seeing snakes out basking and traveling. Also, as the weather turns hot, surveys should be conducted in early morning and late afternoon to avoid hot temperatures that drive the snakes into cooler microhabitats. The best time to see copperbellies is mid-April through the end of May, when water temperatures are not too great and vegetation has not leafed out. Surveys conducted later in the season with negative results are inconclusive.

Copperbellies are very mobile and can be found in all sorts of habitat in and around wetlands, but they should be sought in specific habitats to maximize the chance of seeing them. Empirical evidence shows that copperbellies prefer 1) the edge habitat between open canopy areas, such as shrub-scrub wetlands, and forest, to bask and rest, and 2) extremely shallow waters (<10 cm (4”)), to forage. They do not spend much time in open, deep water (>30 cm), or moving water. However, they are often seen basking on platforms over deeper water, and will not hesitate to swim across open areas. They are not routinely seen in forest, but sometimes can be found at isolated pools of water. Surveyors are most likely to find stationary snakes basking on horizontal surfaces just above the water, such as on nearly sunken logs or branches, or a little higher on living branches of bushes such as buttonbush (*Cephalanthus occidentalis*). Foraging snakes may be seen cruising shorelines. Ripples on the water’s surface may also indicate the presence of a foraging or traveling snake, and should be investigated.

If the goal of the survey is simply to try to find copperbellies at a site, then a group of surveyors may be the most effective means of finding them. On the other hand, if the intent is also to quantify observations so that findings can be compared between sites, especially where the differences between them are relatively subtle, then methodology will have to be more strictly defined.

A quantifiable approach is to measure observations per survey effort. Surveys are conducted by traveling the survey path (transect) and counting the snakes seen over a known time and estimated distance. Surveyors should move slowly and cautiously with frequent stops (pauses) of one or more minutes to scan both sides of the transect for snakes. The duration of pauses is left to the discretion of the surveyor, but should be long enough to allow careful examination of the field of view before moving on. An initial suggestion for distance to move between pauses when surveying wetlands is 20 paces. On the other hand, searching in forest, which is not anticipated to be very productive and mostly transitional between wetlands, may just be a slow walk. Transect length will be approximated as accurately as possible using an aerial photograph or topographical map. The time will be recorded at the beginning and end of the transect, as well as each time the *Macrohabitat* type, as defined by the attached Habitat Classification, changes. Habitat shifts should be marked on the map as well.

Surveyors should always bring binoculars and use them. They are *vital* for examining complex habitats such as brush, and for properly identifying snakes to species. You *will* miss snakes if you do not use binoculars to scan ahead. A watch is needed for timing transects. Surveyors will also need to consider footwear. Hip or chest waders may keep you dry, but are tiring to wear for any length of time, and can get hot. Pull-on farm boots work okay unless there is any flooding. Once the water has warmed, I just go ahead and get wet, wearing "Army" boots to protect my feet. Use pencil to keep your notes- pen will smear and run if it gets wet, erasing your data. Ziplock bags are good for keeping things dry.

Copperbelly detectability is extremely variable, depending on the set of conditions at a particular time. Thus, while any discovery of copperbellies at a site implies that they are resident there, negative findings from surveys not adhering to the restrictions detailed in this document are inconclusive. If copperbellies are abundant in an area and are searched for as detailed here, then they should be found within several hours. On the other hand, if a wetland complex is examined by an experienced copperbelly surveyor as directed here for 10 or more hours spread out over three or more different days, and no copperbellies are observed, then it is reasonably certain that they do not occur in the area.

### Data Sheet Explanation

At the top of the data sheet, *Date*, *Site*, *Surveyors*, and *Weather Summary* are filled out prior to beginning the survey. *TimeBeg* is entered when the survey actually begins. *TimeEnd* is entered when the survey is suspended. Times should be recorded in military time (1200 is 12 noon, 1400 is 2PM).

*Weather Summary* comments include air temperature, cloud cover, wind, etc. Air temperature (*Tair*) is taken with the thermometer held at about waist height with the bulb shaded (by your hand is fine). Substantive changes in the weather during surveys should be indicated on data rows between observations. *TransectL* is an estimate of the total transect length. Length should be recorded in meters. Additionally, a line is provided to *summarize* your observations for numbers of selected snake species.

<u>Snake Observations and Habitat Shifts</u>

The codes for data entries are described in the survey code descriptions provided below. The last column is for brief or coded additional comments. In the field, comments can also be inserted on the data row(s) beneath the relevant observation. If habitat changes during the length of the transect, times and lengths of subtransects should be recorded by habitat. *Time* is when you start a new habitat classification, *elapsed time* is the number of minutes spent surveying the previous habitat. *Species* of snake is coded. Your comments should include mention of other species observed. This column is also used to measure the subtransect length (*TransectL*) if you switch macrohabitats. You can figure that out later. *AgeClass* is the apparent age class of the snake. Keep in mind that male copperbellies are often substantially smaller than the females. *Behav*ior is the activity of the snake at time of observation. If you have disturbed it and don't know, don't speculate.

*Shore* is the distance (in meters) the snake is from shore (distance to shore will be negative for terrestrial observations). *Depth* is the apparent depth (in meters) of the water at the snake's location. *Macro*habitat and *Micro*habitat are coded as indicated in the attached habitat classification (based on a simplification of Cowardin et al.'s wetland classification system). The code should be strictly adhered to, and deviation from the code should be well documented with comments.

*Comment Code* is space for symbol to link to comments made below. For example, "A" would relate to comments next to "A" in the comments area. Use the *Comments* section to make initial notes on any details about the survey site. Additional comments can be made there as you go or on data rows between observations. Surveyor comments will be used to help establish habitat extent and quality throughout the range of the snake, so surveyors are encouraged to make detailed notes of their surroundings (including apparent condition of water and abundance of prey).

A final note: pursuit of individual snakes may not only be illegal for some surveyors, it will also disrupt the continuity of the survey. Snakes should be approached only to the extent that species identification is certain. Which brings up another point: many individual northern water snakes may look quite a bit like copperbellies, especially along the border between Ohio and Michigan. Be careful in making your assignments to species. The most certain diagnostic on adults is the lack of any crescents on the belly. Very young northerns and copperbellies look very similar dorsally, but the presence/absence of crescents still holds.

**Appendix I.** Continued.

## SURVEY CODE DESCRIPTIONS

<u>Macrohabitat</u>

This classification was designed to be suitable for studying habitat use by the copperbelly in the northern populations. It is therefore not intended to be an exhaustive classification scheme. Wetland components are intended to be relatively compatible with the National Wetlands Inventory (NWI) classification developed by Cowardin et al. (1979). "Macrohabitat" as used here is a large-scale measure. Distinct areas less than about 10 meters in diameter should just be incorporated into the surrounding habitat type. A patch of a few buttonbush in the middle of a forest is still forest. Microhabitat will be used to indicate finer levels of selection.

**IMPORTANT:** For the purposes of these surveys, when working along the margin between habitat types, we default the habitat classification to the more open side of the macrohabitat. For example, if you are surveying along a PFO/PSS boundary, you mark that as PSS. If your route takes you into just PFO, then PFO is what you write down.

**PFO** Palustrine Forested Wetland: has standing water and tree canopy cover exceeding 30%.
**PSS** Palustrine Scrub-shrub: shrub cover exceeds 30%, but tree cover does not.
**PEM** Palustrine Emergent: vegetation present (cats, etc.) but not enough shrubs to be considered PSS.
**POW** Palustrine Open Water: shallow wetland systems with little or no vegetation present. *Note: moist soil units should be commented as such, but would be classified as PEM or POW.*
**LIM** Lacustrine Open Water: deep water (>2m) of lakes.
**LIT** Littoral (shoreline) zone of lakes.
**UFO** Upland Forest: greater than 30% canopy cover by trees, elevated above any potential flooding by sloping topography
**USS** Upland Scrub-Shrub: extensive areas of berry bushes, willows, crab apples and hawthorns.
**OLD** Oldfield: fallow fields well covered with herbaceous or grassy cover. CRP lands would often be included here
**FRM** Crops: farm fields, croplands
**GRZ** Grazed: grazed or mowed areas
**RES** Residential: all space used for living by people

<u>Microhabitat Classification</u>

Microhabitat classification is somewhat similar to habitat, but on a smaller scale. Its use as a category allows the specific position (substrate) of the animal to vary to some degree from its general surroundings.

**S**hrub -up in a bush
**T**ree -up in a tree
**G**rass -in a patch of grass
**R**ock -on a rock or rocks
**L**og -on a log
**H**erbaceous -in a patch of herbs
**W**ater -in the water
**B**are -on bare soil
**I**sland -on a small hummock
**D**etritus -on leafy debris

**Appendix I.** Continued.

<u>Behavioral Classification</u>

**B**asking -at rest in sunny location
**R**esting -resting in non-basking position
**C**ourting -male pursuing female, female, being pursued by male
**M**ating -actually copulating (much less likely than courting)
**F**oraging -moving slowly and methodically through shallow water or on shore
**T**raveling -moving continuously in linear path, with little investigative behavior along the way
**U**nknown -behavior ambiguous or snake disturbed before behavior observed: *something that happens all the time!*

<u>Miscellaneous</u>

**Species:** **CWS**- copperbelly (*N.e. neglecta*), **NOR**- northern water sake *(N. sipedon*), **EGS**- eastern garter snake (*T. sirtalis*), **UNK**-unknown. Other species can just be written out.

**Age class**: **Y** = yearling, only about 20 cm long with distinct, **S** = subadult, losing juvenile markings, but not more than about 2/3 meter in total length. **A** = adult.

### Sample data from a "survey":

| Time | New Macrohab | Elapsed Time | TransectL/ Species | AgeCl | Behav | Distance to Shore (m) | Depth (m) | Microhab | Comment Code |
|---|---|---|---|---|---|---|---|---|---|
| 1132 | PFO | | | | | | | | |
| 1156 | PSS | 24 | 120 | | | | | | |
| 1207 | | | CWS | S | B | 3 | 20 | L | 1 |
| 1212 | | | NOR | A | B | 5 | 30 | W | |
| | This is the biggest northern water snake I have ever seen in my entire life!!! | | | | | | | | |
| 1234 | PFO | 38 | | | | | | | |
| 1243 | END | 9 | | | | | | | |
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COMMENTS:
1) The buttonbush looks really old here, and not very extensive.

Questons or comments? Contact:

Bruce Kingsbury
Center for Reptile and Amphibian Conservation and Management
Science Building
Indiana-Purdue University, Fort Wayne, IN 46805-1499
(219) 481-5755, kingsbur@ipfw.edu, http://herpcenter.ipfw.edu

**Appendix I.** Continued.

## COPPERBELLY SURVEY SHEET

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Date: | | Site: | | | | | |
| TimeBeg: | | Surveyor: | | | | | |
| TimeEnd: | | | | Beg Tair: | | Sun? | |
| Duration: | | Weather Summary: | | End Tair: | | Sun? | |
| TransectL: | | | | | | | |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| SUMMARY: # of | CWS: | | NOR: | | EGS: | | |

| Time | New Macrohab | Elapsed Time | TransectL/ Species | AgeClass | Behav | Distance to Shore (m) | Depth (m) | Microhab | Comment Code |
|---|---|---|---|---|---|---|---|---|---|
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| | | | | | | | | | |
| | **Macros**: PFO, PSS, PEM, POW, LIM, LIT, UFO, USS, OLD, FRM, GRZ, RES | | | | B, R, C, M, F, T | meters | meters | **Micros:** S, H, T, W, G, B, R, I, L, D | |

**COMMENTS:**

**Appendix II.** Copperbelly Water Snake survey form developed and used by Michigan Natural Features Inventory during 2005-2006 surveys of known extant copperbelly sites in Hillsdale County, Michigan.



## Copperbelly Water Snake Survey Form

**Survey Date:** ____________ **County:** ____________ **Surveyors:** ____________

**Survey Start Time:** ____________ **Site:** ____________ **T, R, S:** ____________

**Survey End Time:** ____________ **Location:** ____________ **Landowner:** ____________

**Survey Duration (-proc):** ____________ **Managed area:** **New / Known CWS Site** (circle one) **If known, EO #** ________

| **Area/Distance:** ______ | **Summary of Species:** | CWS | NWS | NRS | EGS | | | |
|---|---|---|---|---|---|---|---|---|
| | **Number:** | | | | | | | |

**Beginning Weather:** **Air temp (°F):** ________ **Sky Code:** ________ **Wind Code:** ________ **First visit in '06?** Y N **If no, visit #:** ________

**Rel. humidity (%):** ________ **Precipitation Code:** ________ **Revisit needed?** Y N

| Time | Macrohab | Community Type/Habitat Description | Suitable-Y/N | Species/ # | M/F/GR/U | N/ R | GPS Waypt. | Photo # | PIT tag # & Comments |
|---|---|---|---|---|---|---|---|---|---|
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**Macros**: PFO, PSS, SDG, CAT, UFO, USS, OLD

**Community type:** emergent marsh, inundated shrub swamp, mesic southern forest, etc.

**Habitat Description:** species composition, dominant canopy, shrub, ground cover

**M/ F/ GR/ U**: Male, Female, Gravid Female, Unknown

**N / R:** New, Recapture

**GPS Waypt:** GPS waypoint name for survey location/route or EMR location

**Ending Weather:** **Air temp (°F):** ________ **Sky Code:** ________ **Wind Code:** ________ **Crayfish Burrows:** Present Not Observed

**Rel. humidity (%):** ________ **Precipitation Code:** ________ **If present, burrow density:** Few Many

**Threats:** Habitat loss/development Habitat fragmentation Altered hydrology Incompatible management (mowing, disking, burning etc.) ________

**(circle all** Invasive species: ________ Succession/woody encroachment - species? ________

**that apply)** Road mortality Human persecution Collection Hibernaculum loss/alteration Comments: ________

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Page ______ of ______

**Other Species Present:** List additional species observed at this site. Note especially listed species and potential predators. :

| Species: | Number observed | Notes, observations, etc. |
|---|---|---|
| | | |
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**Directions to survey site and location if first time to site/location and how to access survey site/location:**

**Attach map, air photo or drawing indicating survey area, survey routes and locations of massasaugas and/or suitable habitat.**

**Sky Codes:**
0 = Sunny/clear to few clouds (0-5% cloud cover)
1 = Mostly sunny (5-25% cloud cover)
2 = Partly cloudy, mixed or variable sky (25-50%)
3 = Mostly cloudy (50-75%)
4 = Overcast (75-100%)
5 = Fog or haze

**Precipitation Codes:**
0 = None
1 = Mist
2 = Light rain or drizzle
3 = Heavy rain
4 = Snow/hail

**Wind Codes (Beaufort wind scale):**
0 = Calm (< 1 mph) smoke rises vertically
1 = Light air (1-3 mph) smoke drifts, weather vane inactive
2 = Light breeze (4-7 mph) leaves rustle, can feel wind on face
3 = Gentle breeze (8-12 mph) leaves and twigs move, small flag extends
4 = Moderate breeze (13-18 mph) moves small tree branches, twigs & leaves, raises loose paper
5 = Strong breeze (19-24 mph) small trees sway, branches move, dust blows
6 = Windy (> 24 mph) larger tree branches move, whistling

**Macrohabitats:**
**PFO** = Palustrine Forested Wetland: standing water at least part of the year, tree canopy cover exceeds 30%.
**PSS** = Palustrine Scrub-Shrub Wetland: shrub cover exceeds 30%, but tree cover does not.
**SDG** = Palustrine Emergent Wetland dominated by sedges.
**CAT** = Palustrine Emergent Wetland dominated by cattails.
**UFO** = Upland Forest: >30% tree canopy cover, elevated above any potential flooding by sloping topography.
**USS** = Upland Scrub-Shrub: berry bushes, willows, crab apples and hawthorns, typically mid-succession.
**OLD** = Oldfield: fallow fields covered with herbaceous or grassy cover, includes CRP lands.

*MNFI, 03/27/2007*

**Appendix III.** Copperbelly Water Snake observation form developed and used by Michigan Natural Features Inventory during surveys in 2005-2006 of known extant copperbelly sites in Hillsdale County, Michigan.

**Copperbelly Water Snake Observation Data Sheet (attach to survey form)**

**Processing Start Time:** _________
**Processing End Time:** __________

**Date:** ________ **County:** ________ **Surveyors:** ________
**Capture Time:** ________ **Site:** ________ **T, R, S:** ________
**Snake / #:** ________ **Location:** ________ **Landowner:** ________

**PIT Tag #:** ________ **New/ Recapture** (circle one) **Previous capture date(s):** ________ **Scale Clipping** Yes No
**GPS Unit:** ________ **GPS Waypt.:** ________ **EPE:** ________ **Blood sample** Yes No
**Latitude:** ________ **Longitude:** ________ **Specimen** Yes No
**Weight (g):** ________ **SVL (cm):** ________ **Tail (cm):** ________ **Total (cm):** ________

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Sex:** | M | Non-gravid F | Gravid F | Unknown | **Age class:** | Adult | Subad | Juvenile | Young-of-yr **Litter size** ________ |
| **General Health:** | Healthy | Scars | Injuries | Markings | Deformities | Disease | ________ | | |
| **Behavior:** | Basking | Resting | Traveling | Courting | Mating | Foraging | Combat | Unknown | |
| **Detection Method:** | | Sight | Sound | Other | Comments: ________ | | | | |
| **Weather:** | **Air temp ($^{o}$F):** ________ | | **Sky Code:** ________ | | **Wind Code:** ________ | | | | |
| | **Rel. humidity (%):** ________ | | **Precipitation Code:** ________ | | | | **Photos Taken?** | Yes | No #'s _____ |

**Habitat description of location where snake was observed:** **Snake in shade/sun** (circle one)
**Macrohabitat** (natural community type, dominant canopy, understory, shrub and ground cover, species composition, moisture, etc.) :

________
________
________

**Microhabitat:** **Description** (location, plant species, etc.;e.g.,along edge under shrubby cinquefoil) ________

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Substrate:** | Shrub | Sedge/Grass | Cattail | Rock | Log | Herb/Moss | Detritus | Island | Bare Other/Unk |
| **Cover:** | None | Shrub | Sedge/Grass | Cattail | Rock | Log | Herb/Forb | Detritus | Hummock Other/Unk |

Other/Unknown & Comments: ________

| | | | | | | |
|---|---|---|---|---|---|---|
| **Soil Moisture:** | Inundated | Saturated | Moist (mesic) | Dry-mesic | Dry (xeric) | **Water Depth (cm):** ________ |
| **Soil Type:** | Sand | Loamy Sand | Sandy Loam | Loam | Silty Loam | Clay Loam |
| | Sandy Clay Loam | Silty Clay Loam | | Sandy Clay | Clay | Silty Clay **Hibernation/Gestation Site?** (circle one) |
| **Crayfish/other burrows:** | | Present | Few | Many | Not Observed | |

| **Distance (m) to closest cover objects:** | | **Light:** | **Position:** | **Slope:** | **Other Comments:** |
|---|---|---|---|---|---|
| Hummock | ________ | ___open | ___crest | ___flat | ________ |
| Log/Woody Debris | ________ | ___partial | ___upper slope | ___0-10 | ________ |
| Shrub | ________ | ___filtered | ___mid slope | ___10-35 | ________ |
| Tree | ________ | ___shade | ___lower slope | ___35+ | ________ |
| Other | ________ | | ___bottom | ___vertical | ________ |
| Water's edge | | | | | |

**Attach or draw on back a map or air photo indicating where snake was found**

*MNFI, 03/27/2007*

**Appendix IV.** Michigan Natural Features Inventory's Special Animal Survey Form was completed to document observations of Copperbelly Water Snakes and other rare species during 2005-2006 surveys at three known extant copperbelly sites in Hillsdale County, Michigan.

MICHIGAN STATE UNIVERSITY EXTENSION

## SPECIAL ANIMAL SURVEY FORM

Michigan Natural Features Inventory

### SURVEYOR INFORMATION

| Survey date: __ __ __ __ - __ __ - __ __ | Time from: ______ to: ______ am or pm (circle) | Sourcecode: F __ __ __ __ __ __ __ M I U S |
|---|---|---|

Surveyors (principal surveyor first, include first & last name): ____________________

____________________

Weather conditions: ____________________

Revisit to this EO needed? ___yes ___no Why?: ____________________

### ELEMENT INFORMATION

| Scientific name: Data sensitive? Y N | EOID: | Occ.# (if known): |
|---|---|---|

### FILING

| SURVEYSITE: | SITENAME: |
|---|---|
| QUADCODE: | QUADNAME: |

### LOCATIONAL INFORMATION

Was the Landowner contacted? Yes ______ No ______ Landowner Name: ____________________

Owner Type: ______________________________ Note:____________________

**DIRECTIONS**: Provide detailed directions to the observation (rather than the survey site). Include landmarks, roads, towns, distances, compass directions.

____________________

____________________

____________________

Township/Range/Section ____________________

County ____________________ Managed area ____________________

Was GPS used? Yes ______ No ______ Type of unit ______________________________ Unit number __________

Waypoint name/# (when using Garmin) ______________________________ File name (when using Trimble) ____________________

OPTIONAL: Latitude ____________________ Longitude ____________________

FEATURE INFORMATION (mandatory) Point: <12.5 m in both dimensions, Line: >12.5 m in one dimension, Polygon: >12.5m in both dimensions

Source Feature: Single Source EO _____ Multi-Source EO _____ Conceptual Feature Type: Point _____ Line _____ Polygon _____

**TOPOGRAPHIC MAP (mandatory, the website topozone.com can be used as a source for these maps)**

1. Attach a photocopy of the appropriate part of a USGS topographic map (1:24,000 scale if available) and write the map scale on the photocopy. Please do NOT enlarge or reduce the map.
2. Indicate on the map the exact location of the observation(s):
   a. When the observed area is ***no larger than a pen point*** on the map (i.e., only a small number of individuals or extremely small patches), place small points on the map indicating the location(s) of the individuals or patches, and label each point with an arrow so they are more easily seen.
   b. When the observed area is ***larger than a pen point*** on the map, (e.g., a population of plants, foraging birds):
      (1) Draw a thin solid boundary line showing the extent of the observed area occupied by the individuals.
      (2) Indicate disjunct patches (polygons) by drawing the boundary for each patch separately.
      (3) If the boundary follows the edge of a lake, stream, road, marsh or other feature, draw the boundary precisely on the edge of the feature.

(4) Where needed, add notes to the map with instructions on where the boundary line is located or if the boundary is shared with other observations.

3. A hand drawn sketch may be included for finer details.

LOCATIONAL CERTAINTY

Is your depiction of the observed area on the map within 6.25 **m (approximately 20ft)** of its actual location on the ground? Y N

If **N,** complete the following:

a. Estimate of uncertainty distance: based on landmarks, elevation, etc., the location of the observed area on the map is accurate to within __________ meters kilometers feet miles of its actual location on the ground.

b. Is the observed area known to be located within some feature(s) on the map (e.g., wetland boundary, lake, road, trail, highway, contour lines)? Y N

If Y, indicate the boundary within which the observed area is known to be located on the map line, and if applicable, identify the feature (e.g., marsh).

**Appendix IV.** Continued.

IDENTIFICATION
Photograph/slide taken? ___yes ___no If yes, will a copy be submitted to Heritage? ___yes ___no MNFI office: Added to collection?____ (check)

Specimen collected? ___yes ___no Collection # and repository: ______________________________

Identification problems? ___yes ___no If necessary, describe the important animal characteristics you used for identification: ______________________

______________________________

## SIZE OF ELEMENT OCCURRENCE

Size is a quantitative measure of the area and/or abundance of an occurrence. Components of this factor are 1) area of occupancy, 2) population abundance, 3) population density and 4) population fluctuation.

Type of observation: ___sight ___ song/vocalization ___ road kill ___ trapped ___ other (explain):______________________

Abundance (number of pairs, chicks, nests, adults, juveniles, hatchlings, behavior, sex, size of each individual, etc.):

Actual number observed:______________________________

______________________________

______________________________

Number estimated and basis for estimate:______________________________

______________________________

______________________________

______________________________

Population density (if practical): number:______________ per area unit:________________ (i.e., meters$^2$, kilometers$^2$, miles$^2$, etc.)
Does population fluctuate? (May be particularly relevant to invertebrates):
___ yes ___ no ___ unknown. Explain: ______________________________

Area of occupancy (fill in one):_______meters ________acres ________miles Type of measurement (check one): ___ Precise ___ Estimate

## ASSOCIATED SPECIES

List other species observed at this site. Note especially listed species and potential competitors, predators, and prey. Mark appropiate columns.

| Species | ID + | ID ? | Number Observed | Notes, observations, etc. |
|---|---|---|---|---|
| ______________________ | _____ | _____ | _________ | ______________________ |
| ______________________ | _____ | _____ | _________ | ______________________ |
| ______________________ | _____ | _____ | _________ | ______________________ |
| ______________________ | _____ | _____ | _________ | ______________________ |
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| ______________________ | _____ | _____ | _________ | ______________________ |
| ______________________ | _____ | _____ | _________ | ______________________ |
| ______________________ | _____ | _____ | _________ | ______________________ |
| ______________________ | _____ | _____ | _________ | ______________________ |
| ______________________ | _____ | _____ | _________ | ______________________ |

## CONDITION:

Condition is an integrated measure of the quality of biotic and abiotic factors, structures and processes within the occurrence, and the degree to which they affect the continued existence of the occurrence. Components of condition for species are: 1) reproduction and health, 2) ecological processes, 3) species composition and biological structure, 4) abiotic physical/chemical factors. Factors to consider: evidence of regular successful reproduction, habitat degradation, disturbance, presence of exotic species, the degree to which ecological processes are sustaining the habitat. Where possible include a comparison to other occurrences.

EVIDENCE OF REPRODUCTION:______________________________

______________________________

______________________________

EVIDENCE OF DISEASE/PREDATION:______________________________

## **Appendix IV.** Continued.

**CONDITION** (continued)

**HABITAT DESCRIPTION**: Describe the specific habitat or micro habitat where this animal occurs. Convey a mental image of the habitat and its features including: land forms, aquatic features, vegetation, slope, aspect, soils, associated plant and animal species, natural disturbances.

______________________________________________________________________

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LANDSCAPE CONDITION: Describe the condition of the landscape surrounding the elements habitat (i.e., farmland, residential area, pristine forest)

______________________________________________________________________

______________________________________________________________________

CURRENT THREATS to this occurrence (i.e., grazing, logging, mining, plantations, ATVs, dumping, etc.) Discuss exotics in the next section.

______________________________________________________________________

______________________________________________________________________

POTENTIAL THREATS to this occurrence:__________________________________________

______________________________________________________________________

EXOTICS PRESENT? ___yes ___no. If yes, describe their impacts to the occurrence.______________________

______________________________________________________________________

______________________________________________________________________

PAST IMPACTS to the occurrence (i.e., logging, , etc.):____________________________________

______________________________________________________________________

______________________________________________________________________

| **TOPOGRAPHY** | Aspect: | Slope: | Light: | Position: | Moisture: |
|---|---|---|---|---|---|
| Elevation:______________ft.<br><br>If elevation is a range:<br>Minimum: _____________ft.<br>Maximum:_____________ft. | ___N ___NE<br>___E ___NW<br>___S ___SE<br>___W ___SW | ___flat<br>___0-10<br>___10-35<br>___35+<br>___vertical | ___open<br>___partial<br>___filtered<br>___shade | ___crest<br>___upper slope<br>___mid slope<br>___lower slope<br>___bottom | ___Inundated<br>___saturated (wet-mesic)<br>___moist (mesic)<br>___dry-mesic<br>___dry (xeric) |

**MANAGEMENT AND PROTECTION**

MANAGEMENT, MONITORING AND RESEARCH NEEDS for this occurrence (e.g. burn periodically, open the canopy, ensure water quality, control exotics, keep out the ATV's, study effects of browsing)

______________________________________________________________________

______________________________________________________________________

______________________________________________________________________

AREAS IN NEED OF PROTECTION: (e.g. the entire marsh, the slope and crest of slope, the fen and upland, etc.) ________________________________

______________________________________________________________________

If you have any questions regarding this form and its methodology please contact MNFI at (517) 373-1552.
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