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Results of Bog Turtle (*Clemmys muhlenbergii*) Surveys in Various Watersheds in Monroe County, Pennsylvania during 2002 and 2003

A juvenile bog turtle from [redacted]

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to

The Nature Conservancy

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Notice: Certain portions of this document have been redacted in order to protect, and not divulge the exact locations of critical Bog Turtle habitat.

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Volunteers Jerry Keltz, Robert Papa, and Pete Mooney contributed their time and talents in the field assisting HA staff with various aspects of this research project.

INTRODUCTION

Herpetological Associates, Inc (HA) was commissioned by The Nature Conservancy (TNC) to conduct bog turtle (*Clemmys muhlenbergii)* presence/absence surveys, mark-recapture studies, and nesting studies in the [redacted] and [redacted] Creek watersheds in Monroe County, Pennsylvania. The focus of project was to determine the population size of confirmed bog turtle colonies [redacted] and to document unknown bog turtle populations in new areas. Special emphasis was placed on identifying areas of critical habitat including ideal microhabitats, hibernacula, and nesting sites. In order to improve hatching success and reduce mammalian predation, predator excluders were installed on all located nests.

Significant bog turtle habitats were identified and recorded by GPS, including each confirmed bog turtle site at the time of the first bog turtle capture (**Map 1**). Coordinates of wetland boundaries for confirmed sites, corridors between hydrologically connected sites, hibernaculum and nest locations were also recorded. HA evaluated corridor and buffer zones that may serve to connect metapopulations. Assessments of habitat, significant wetland plant communities, spatial distribution, movement patterns, and barriers to movement were examined. Population analyses, including population estimates and age structure, were conducted to determine the stability of individual populations. Other herpetofauna observed (especially *Clemmys* species) were recorded to determine the species composition within bog turtle habitats. Recommendations for habitat management, habitat restoration, corridor and buffer monitoring, predator control, and future studies have been included to assist TNC in protecting bog turtle populations.

TNC biologists assisted in locating potential habitat, developing management plans, and securing permission from landowners to enter private property. The United States Fish and Wildlife Service (USFWS) and the Pennsylvania Fish and Boat Commission (PFBC) encouraged the project and provided HA with the necessary endangered species scientific collecting permits.

MATERIALS AND METHODS

ABOUT HERPETOLOGICAL ASSOCIATES, INC. STAFF

Bog turtle habitat evaluations and presence/absence, mark-recapture, and nesting surveys were conducted in [redacted] and [redacted] watersheds by the following HA staff members: Raymond F. Farrell, Turtle Biologist and New York State Regional Manager; Robert T. Zappalorti, Senior Herpetologist and Executive Director; Michael E. Torocco, Pennsylvania Regional Manager; Tessa M. Bickhart, Staff Herpetologist; and Field Biologists Alex Figueroa, William Callaghan and Courtney Anderson. Seasonal assistants Catherine Eser and Stephanie Larkin also assisted HA staff. Matthew P. McCort was responsible for GPS processing and GIS analysis. Raymond Farrell and Robert Zappalorti supervised all fieldwork during this two-year project.

HA staff members are well qualified and highly trained in bog turtle study methods; all have previously conducted intensive field work on other bog turtle projects in Pennsylvania and New Jersey for TNC, Columbia Transcom, Natural Lands Trust, Wildlands Conservancy, and the New Jersey Department of Environmental Protection.

STUDY SITES

The study sites are primarily located in the [redacted] watershed, including [redacted] and [redacted] Townships ([redacted] Quadrangles); additional sites are located in the [redacted] Creek watershed, [redacted] Township ([redacted] Quadrangles), Monroe County, Pennsylvania. HA visited 30 properties within the [redacted] and [redacted] watersheds. The sites in [redacted] are located along an eight-mile stretch of [redacted]. One study site consisting of approximately 20 acres of wetland is located along [redacted]. All of the study sites are either previously confirmed bog turtle habitats or are potential habitats located near confirmed bog turtle locations. The sites included in the study varied between the two years due to the request of TNC to concentrate our efforts in 2003 on sites where little data was previously collected in order to determine population estimates. Landowner approval to enter private property was not granted for four of our known bog turtle sites in 2003.

HABITAT EVALUATION METHODS

On a broad scale, HA has three criteria for judging the value of the existing conditions and habitat available for bog turtles. These are:

*1. **Structure of Available Habitat:*** Both the biotic and abiotic components are considered. These are good indicators for the possible occurrence of bog turtles within a particular study area or ecosystem (Zappalorti, 1976; Ernst, Lovich, and Barbour, 1994).

*2. **Historic Evidence:*** The overall range of the bog turtle and historic records on or near a study site are examined. Historic records are important to the overall evaluation of a site (Conant and Collins, 1991).

*3. **Indicator Species:*** The presence of plant and animal species that are often found in association with bog turtles is highly informative when evaluating a site. Such species may include food/prey organisms, or species that typically occur in similar or identical habitats as the target species. The presence of indicator species will often increase the ranking of a study site (Zappalorti 1976; Ernst, Lovich, and Barbour, 1994).

These criteria are valuable for identifying habitats that could support bog turtles. Once potential habitats are found, it becomes necessary to rank the habitats as to their overall value for bog turtles. At this stage in the evaluation, specific aspects of the habitat are examined. Important characteristics of bog turtle habitat are derived from HA's research and publications as well as other published data on bog turtles. The incorporation of this information into HA's ranking system is described below.

CONDUCTING THE HABITAT EVALUATION

Vegetative types and communities, hydrological conditions, topography, soil characteristics, and surrounding terrestrial habitat were used to evaluate each wetland as potential bog turtle habitat. The presence of historic bog turtle records from adjacent sites were also important in the habitat evaluation.

Bog turtles inhabit unpolluted bogs, marshes, and wet meadows with shallow water and a soft, deep, muddy substrate. Their habitat is usually vegetated with various sedges (*Carex* spp.), sphagnum moss (*Sphagnum* spp.), cattail (*Typha* spp.), skunk cabbage (*Symplocarpus foetidus*), red maple (*Acer rubrum*), poison sumac (*Rhus vernix*), swamp magnolia (*Magnolia virginiana*), alder (*Alnus* spp.), Juneberry (*Amelanchier spicata*),

swamp honeysuckle (*Rhododendron viscosum*), swamp blueberry (*Vaccinium corymbosum*), sundew (*Drosera rotundifolia*), swamp orchids (*Arethusa bulbosa, Nymphaea tuberosa, Pogonia ophioglossoides*), and clubmosses (*Lycopodium* spp.; Ernst, Lovich, and Barbour, 1994, Kiviat, 1978; Zappalorti and Zanelli, 1978; Zappalorti et al., 1979; Herman 1994). The habitat characteristics can be grouped into three main features: hydrology, substrate, and vegetation. These are considered significant components of bog turtle habitat and are typically found in distinct combinations, forming a characteristic ecological community (Zappalorti, 1976; Chase et al.,1989). In order to standardize the results of bog turtle habitat evaluations, each wetland was given a numerical rank using HA's wetland ranking system for bog turtles (**Table 1**).

Table 1. HA's Standardized Habitat Ranking System for Bog Turtles.

Rank	Description
1	**Not suitable:** Site lacks all of the three main features of bog turtle habitat: hydrology, soil, and vegetation.
2	**Atypical:** Site contains two of the three habitat features, one of which must be vegetation.
3	**Marginal:** Site contains hydrology and soils, but does not contain the ideal vegetation.
4	**Typical:** Site contains all three features of bog turtle habitat, but contains only one core of habitat.
5	**Ideal:** Site has all three features of bog turtle habitat, and has numerous rivulets, seeps, and/or springs; area of perceived bog turtle habitat is large with multiple interconnected cores.

Certain sites may not fall perfectly into one of the five categories, however, each wetland was ranked to suitably represent the existing conditions of the area as bog turtle habitat. Of the three main features of bog turtle habitat (i.e., hydrology, soil, and vegetation), hydrology and soils are considered the most important by HA. Without the combination of these two features, it is highly unlikely that bog turtles can persist at a site. Vegetation, while an important feature of bog turtle habitat, is the most variable and therefore the least important. Situations where natural succession has turned a typical bog habitat into a shrub or hardwood dominated swamp are often encountered, but bog turtles may still persist. With management, these types of sites may become productive bog turtle habitats. Therefore, wetlands that lack vegetation but have suitable soils and hydrology are ranked higher than sites that have indicator plants but lack either soils or hydrology.

This ranking system is provided for the convenience of the PFBC, USFWS, and HA's clients. This system provides a standardized method for ranking bog turtle habitat based on HA's 30 years of bog turtle experience. The rankings closely follow the recommendations of the "Guidelines for Bog Turtle Surveys" (revised May 2001).

STANDARDIZED BOG TURTLE SITE-QUALITY ANALYSIS

Each of the confirmed bog turtles sites in [redacted] watershed were ranked using the Standardized Bog Turtle Site-Quality Analysis protocol developed by Michael Klemens (USFWS, 2001). This ranking system assesses the capacity of a study site to support a viable population of bog turtles by using both the quality of habitat (Matrix One) and the health of the population (Matrix Two). Matrix One ranks the quality of the site based on four factors, including (1) the habitat size and degree of fragmentation, (2) the abundance of invasive and later successional plant species, (3) immediate threats such as proximity to roads within the wetland grade, housing developments, wetland ditching, draining, filing or excavation, and (4) the type and extent of land use (e.g. urban, suburban, rural, agriculture, etc.). Matrix Two scores a population of bog turtles based upon the population size and amount recruitment. Both matrices are then combined to give an Overall Site Ranking ranging from good to poor. The sixteen confirmed sites (nineteen

properties) examined were ranked as individual "population analysis sites" (PAS) rather then as a larger unit (e.g. metapopulation).

VEGETATION ANALYSIS

In an effort to classify the wetland habitats of the confirmed bog turtle sites in [redacted] and [redacted] watersheds, HA complied a list of the vegetation observed at each site. The goal of this investigation was to provided a general representation of the plant community and stage of succession for each bog turtle study site. It is not intended to provide a complete plant inventory.

Each bog turtle study site was visited once in August of 2002 and again in June and/or September of 2003 (excluding those sites where permission to enter the property was revoked in 2003). The entire area of core bog turtle habitat was visually examined to determine the abundance of vegetation at each study site. Plants within each site were identified to genus and species using several field guides (Cobb 1984; Harlow 1946; Graves 1992; Knobel 1980; Magee 1981; Newcomb 1971; Rhodes 2000). Plants were identified only to genus when more than one species of the same genus was present or if the species was not identified. The top five dominant plant species were identified to assist in the habitat classification and to identify management needs for each site.

BOG TURTLE SURVEY METHODS

Searching for bog turtles is performed by a team of experienced herpetologists in a systematic fashion. This consists of walking through a wetland and carefully looking for basking turtles in shallow, muddy water; atop or amid tussock grasses; and in or on dead/decaying plant debris. Wooden sticks (broom handles) are used to move grass and other vegetation aside and to probe into soft mud in search of hidden turtles. Additionally, shallow water and the muddy substrate may be searched by muddling, or feeling around in the mud by hand (Ernst and Bury, 1977).

Two standard visual methods for reptiles and amphibians were used to survey the sites in this study: random opportunistic sampling (ROS), which examines an entire site, including both high and low potential areas; and time-constrained searching (TCS), which focuses on highly potential habitats within a site. ROS was used primarily during the initial surveys, enabling HA to observe all habitats on the site and determine the locations of highly potential habitats. TCS was used in later surveys, after highly productive bog turtle areas were found within a site.

ROS (*Random Opportunistic Sampling*): A relatively simple method for the trained herpetologist, ROS can be employed while other sampling techniques are being performed on the study site. It involves searching all areas of a site, whether they show potential habitat for the bog turtle or not. This allows for the identification of highly suitable habitat patches within a site. All herptiles encountered are recorded to supplement the species list generated by other field methods. This method is effective if there are no time constraints on the survey and more detailed follow-up surveys will be performed. Qualitative impressions can be developed as to the relative abundance and habitat use of certain species (Campbell and Christman, 1982; Karns, 1986).

TCS (*Time-constrained Searching*): In this method, a specific habitat (e.g., cattail swamp or spring-fed meadow) is selected and an experienced staff of 1 to 3 persons conducts an intensive timed search within it. Spatial boundaries for each search are limited to the selected habitat or a portion of a habitat.

The TCS method is effective when searching for very secretive forms of wildlife (e.g., bog turtles). During times of the year when target species are known to congregate in particular habits (e.g., hibernacula, nesting area, stream, spring) for some aspect of their life history (e.g.,egg laying, hibernating). TCS is highly productive and superior to other types of surveys. Time limits ensure that each habitat is adequately, but not excessively, examined (Campbell and Christman, 1982; Karns, 1986).

Trapping: To supplement the visual surveys at the [redacted] property, an array of 20 bog turtle traps were positioned throughout the open wetland. Trapping was initiated because of the difficulty of locating turtles due to the dense vegetation and the high water table at this site. Natural corridors created by spring rivulets and seeps, tree roots, hummocks, and other natural features were chosen for trap placement. The traps were set for 20 trapping days. A trapping day is defined as a 24 hour period in which the trap was in position and set to entrap turtles. Once in place, traps were visited daily. Vegetation was placed atop each trap to provide concealment and shade. Turtles were released within one-half meter of the trap location, in the direction the turtle was initially traveling (which was determined by footprints).

Figure 1. Bog turtle trap. Vegetation is placed atop to provide shade and concealment (not shown).

The traps are made of 1 inch x 1 inch, plastic-coated, galvanized steel wire mesh. Each measures 10 cm (4 in) H x 10 cm (4 in) W x 40 cm (16 in) L. Four 38 cm (15 in) adjustable "arms" are attached to the ends of each traps to direct turtles into the trap. Both ends are open and equipped with swinging doors which can be pushed open easily by a walking turtle.

DATA COLLECTED ON BOG TURTLES

Upon initial capture, turtles were assigned field numbers and marked by filing code notches in the marginal scutes (Ernst et al., 1974) in a manner consistent with the previous work performed [redacted]. In this study, as in previous HA studies, data collection on initially captured or recaptured turtles included date, time, weather conditions, relative humidity, location, cloacal temperature, along with ambient and surface temperatures. In addition, sex, weight, reproductive status, carapace length, plastron width, shell height, age (by counting the growth annuli on the shell or abdominal scutes) and overall health were recorded. Notes were also taken on the macro and microhabitat characteristics of the capture site. Refer to **Appendix 1** for conversion legend for numeric value assigned to each category.

POPULATION SIZE ESTIMATION

To gain meaningful information about population trends and relative abundance within individual bog turtle populations, the number of individual turtles captured and recaptured are used to estimate population size. The methods and formula HA used to arrive at a population size estimate for each site is provided below.

Individual Turtles. The number of initial captures at each site is considered a raw measure of population size.

Schumacher Eschemeyer Estimate. Bog turtle population estimates with 95% confidence intervals are based on mark-recapture sampling and were calculated by the Schumacher Eschemeyer method (Krebs, 1989). The estimates include mark-recapture sampling of adult, sub-adult, and juvenile turtles. Hatchlings (first season turtles) were excluded from the analysis.

NESTING STUDY METHODS

The bog turtle typically nests in an individual *Carex* sedge tussock or other small vegetated hummocks. The female turtles camouflage the eggs by covering them with vegetative material and humus (Zappalorti, 1976; Zappalorti. et al, 1995a). During and after the June-July nesting season, canopy-free *Carex* spp., *Sphagnum,* and grass hummocks in each study site were searched intensively for concealed eggs. While searching, great care was taken not to disturb or crush any unseen eggs in hidden nests. Each nest discovered was flagged with surveyor's tape. The information recorded included the nest location, surrounding vegetation, distance from surface substrate or water to top and bottom of the nest chamber, and the number and condition of eggs or shells.

Predator Excluders

To insure the protection of bog turtle eggs from predators, predator excluders were installed over all viable nests that were located in 2002 and 2003. The excluder is designed to completely surround a bog turtle nest, including the tussock or hummock in which the eggs are deposited (Zappalorti et al., 1998a: 1998b). Every attempt was made to allow the vegetation to stand naturally within the cage. Predator excluders are made of ¼ inch mesh hardware cloth. The height and width of each predator excluder varies depending on the height of vegetation at each nest, however each is approximately 61 cm (24 in) H x 38 cm (15 in) W. The bottom of the device is open, so that it may be placed over a nest. The base of each predator excluder is buried 10-15 cm to prevent a predator from accessing the nest. A cover is placed on the top and secured in position with wire. The top can easily be removed to allow access to the nest.

Figure 2. Predator excluder around nest at the [redacted] study site.

RESULTS

RESEARCH EFFORT

HA staff spent a total of 265 person-days in the [redacted] watersheds in 2002 and 2003. This effort exceeded the 174 person-days outlined in the contract by 91 additional person-days in the field (**Table 2**). It should be noted that these were 8 to 10 hour days with 2 to 6 consultants. When 3 or more consultants were used at a particular wetland, the duties among consultants were divided at different sections of the wetland. The initial habitat evaluations at new sites were conducted in late April, early May and June. The date of each site visit, number of consultants, time of arrival, hours of search effort, and weather conditions for each site are listed in **Appendix 2**.

Table 2. Total Effort Expended in 2002 and 2003.

Month	Actual Person-Days*		Contracted Person-Days		Variance	
	2002	2003	2002	2003	2002	2003
April	16	4	10	4	+6	0
May	49	31	38	24	+11	+7
June	32	61	38	24	-6	+37
July	21	23	8	4	+13	+21
August	10	6	8	4	+2	+2
September	4	8	8	4	-4	+4
Sub-Total	**132**	**133**	**110**	**64**	**+22**	**+69**
Total	**265**		**174**		**+91**	

***Person-day** is defined as an eight-hour period expended by one surveyor/biologist. Two persons in the field for an eight-hour period equates two person-days, and so on.

HABITAT EVALUATION

The following habitat evaluations are of confirmed bog turtle sites within the [redacted] watersheds. The areas described are the extent of core habitat used by bog turtles within individual private properties. The use of the terms "site" and "property" should be noted, since some wetlands cross property lines. A bog turtle "site" may therefore be composed of more than one property, which is indicated by separating property names with a slash (/).

The habitat at eleven unconfirmed properties was evaluated, but detailed descriptions are not included in this report since no bog turtles were captured. **Table 3** lists the eleven unconfirmed sites, their habitat rankings and wetland type. All of the evaluated study sites were ranked using HA's Standardized Habitat Ranking System (**Table 1**) and the USFWS's Standardized Bog Turtle Habitat Site-Quality Analysis (Klemens, 1993). **Appendix 3** lists herbaceous and woody plants species including the five dominant species for each confirmed bog turtles site. Latitude and longitude of each confirmed bog turtle site were recorded by GPS (**Appendix 4**).

[redacted] (Figures 3 and 4)

[redacted] is a shrub/scrub wetland with small open patches dominated by cattail and tussock sedge (*Carex stricta*). Dominant trees and shrubs include willows (*Salix* spp.), alders, and dogwoods (*Cornus* spp.). The substrate is 10 to 100 cm of muck. There is an excessive amount of water that feeds into the wetland from a man-made channel draining runoff from the adjacent tree farm. Seeps, small streams and runoff from surrounding hillsides also contribute to the large amount of water moving through this wetland. In 2003 the wetland was flooded on several occasions with water levels exceeding one meter. This site is ranked a **4** (**Typical**) because of current management practices of removing trees and shrubs.

[redacted] (Figures 5-9)

The [redacted] properties are both within one wetland area that has been separated by [redacted]. The [redacted] property is an open marsh dominated by purple loosestrife (*Lythrum salicaria*). Shrubs including dogwoods and multiflora rose (*Rosa multiflora*) are also rapidly becoming dominant. Other vegetation includes tussock sedge, cattail (*Typha latifolia*), and reed canary grass (*Phalaris arundinacea*). The substrate in this area is 10 to 40 cm of muck with rivulets of standing water throughout. [redacted] property is also an open marsh with areas dominated by tussock sedge, reed canary grass, purple loosestrife, and cattail. Shrubs including multiflora rose, buttonbush (*Cephalanthus occidentalis*), maples (*Acer* spp.), and poison sumac are dominant along the edge of the wetland. The substrate is 10 to 50 cm of muck. Standing water is up to 50 cm in depth, but tends to dry rapidly without consistent rainfall. This wetland is ranked a **4** (**Typical**), but the dominance of purple loosestrife is degrading the habitat.

[redacted] (Figures 10-12)

[redacted] property is characterized by areas of cattail marsh, wet meadows, shrub/scrub and riparian wetland. Dominant vegetation includes tussock sedge, reed canary grass, cattails, red willow (*Cornus amomum*), and jewelweed (*Impatiens capensis*). A dirt access road bisects a portion of the wetland. The substrate is 10 to 40 cm of muck with standing water depths up to 45 cm. A channel feeds into the site from the north and drains south towards [redacted]. Sheet flow from the upland to the north also contributes to this wetland area. A small, disjunct area of wetland on the other side of [redacted] under the power line is open and appears to contain ideal bog turtle habitat. This site is ranked a **4** (**Typical**) on HA's Standardized Habitat Ranking System.

[redacted] (Figures 13-15)

These three properties encompass one large wetland area within the PPL Powerline ROW. The majority of this wetland is open with borders of shrub/scrub due to the management of the ROW. A central channel originates from seeps and drains south towards the ROW. Dominant herbaceous vegetation includes tussock sedge, jewelweed, soft rush (*Juncus effusus*), *Polygonums*, and goldenrods (*Solidago* spp.). Common shrubs and trees include arrow-wood (*Viburnum recognitum*), silky dogwood (*Cornus amomum*), multiflora rose, eastern red cedar (*Juniperus virginiana*), and willow. The substrate is 10 to 40 cm of muck with pools of standing water. This site is ranked a **4** (**Typical**), but natural succession and the prior augmentation to the hydrology (e.g. ditching) is limiting the amount of suitable bog turtle habitat.

[redacted] (Figures 16 and 17)

[redacted] is a large open sedge/grass meadow and cattail marsh with numerous rivulets and shallow, surface water. Cattail, sedges, goldenrods, reed canary grass, sensitive fern (*Onoclea sensibilis*), and New York ironweed (*Vernonia noveboracensis*) are among the dominant vegetation. Silky dogwood and poison sumac are controlled by seasonal mowing, but saplings are abundant throughout the open meadow. The substrate is 10 to 40 cm of muck throughout the cattail dominated area, but is dry and hard-packed within the sedge/grass meadow. The open area is surrounded by trees and shrubs including willow and arrow-wood. This site is ranked a **5 (Ideal)**.

[redacted] (Figures 18-20)

The [redacted] site contains cattail marsh, wet meadow, and shrub/scrub wetlands. Cattail and reed canary grass are the dominant herbaceous species. Large tussock sedge colonies are located in the northern and southern portions of the site. Spikerushes (*Eleocharis* spp.), rushes (*Juncus* spp.), and *Polygonum* species are also present in large numbers. The marsh is bordered on all sides by shrubs and trees. Within the northern portion of the marsh silky dogwood, eastern red cedar, poison sumac, alders, red maple and other hardwoods trees are dominant. The substrate is 10 to 60 cm of muck with rivulets of shallow water throughout. Although two small streams feed into the marsh providing additional water to the area, the surface water decreases over the course of the season causing some areas to become completely dry. This site is ranked a **5 (Ideal)** because of its large size and the presence of many integrated wetland types.

[redacted] (Figures 21 and 22)

The [redacted] property is a forested swamp with three open-canopy seeps feeding into [redacted]. The substrate within the rivulets is 10 to 90 cm of muck and 10 to 30 cm of water. The dominant vegetation includes alders, poison sumac, red maple, eastern red cedar, skunk cabbage (*Symplocarpus foetidus*), and autumn olive (*Elaeagnus umbellata*). The presence of dead and dying tussock sedges indicate this wetland was once a more open habitat, but has since succumbed to natural succession. This site is ranked a **3 (Marginal)** because it contains suitable soils and hydrology but lacks an adequate amount of open-canopy habitat required by bog turtles.

[redacted] (Figure 23-25)

The [redacted] property contains three distinct areas of bog turtle habitat, and for ease of discussion are described separately. The first area encountered when entering the property is located in the front or southeastern portion of the property. It contains a swale dominated by cattail and sedges, which bisects a frequently mowed wet meadow. The water level fluctuates with seasonal rains, but typically maintains an ample amount of water which originates from an inlet pipe feeding into the swale from across [redacted]. The substrate is up to 60 cm of muck throughout the swale, but is shallow (10 to 20 cm of muck) along the edges. Willow and silky dogwood are also present in a small clump in the center of the swale. The second area of habitat is located northeast of the front meadow, in the eastern portion of the property. A small shrub-lined drainage ditch borders the area to the west. Sedges and grasses are dominant and the substrate is shallow muck (10 to 30 cm deep) with shallow standing water. The third and largest area of habitat is located in the back or western portion of the [redacted] property. Numerous seeps, sheet flow, and overflow from the pond contribute to the hydrology in this wet meadow and shrub/scrub wetland.

The substrate is 10 to 60 cm of muck with shallow standing water. There is a high level of plant diversity in this area, including several species of sedge, cattail, sweetflag (*Acorus calamus*), and spikerush. Autumn olive, willow, and alders are among the spreading shrub species. The Quindlen site is overall ranked a **5 (Ideal)** for its large size and numerous habitat cores.

[redacted] (Figures 26 and 27)

This site is unique in [redacted] due to its location on a hillside. The substrate is 10 to 60 cm of muck. Several seeps combine to form rivulets, which drain south into a channel that flows parallel to the road. Although this wet meadow is almost entirely free of tree canopy it does have numerous shrubs including willow, silky dogwood, meadow-sweet (*Spiraea* sp.), and multiflora rose. Dominant herbaceous vegetation includes sweetflag, sedges, cattail, and goldenrod. This site is ranked a **4 (Typical)** for the presence of numerous seep, deep, mucky substrate, and tussock-forming sedges and grasses.

[redacted] Figures 28 and 29)

This forested wetland is located in close proximity to an existing dwelling, which may have altered the wetland. A small open area adjacent to the property is dominated by cattail, sensitive fern, sedges, jewelweed, and skunk cabbage. The substrate in this area is 10 to 50 cm of muck. Several seeps form rivulets which drain this wetland south toward [redacted]. Silver maple (*Acer saccharinum*), willow, American elder (*Sambucus canadensis*), poison sumac, and multiflora rose create a dense canopy within the interior of this wetland. This site is ranked a **4 (Typical)**, but the close proximity of the existing dwelling to the wetland may affect this habitat.

[redacted] (Figures 30-32)

[redacted] is a shrub and tree dominated wetland, but has become much more open due to management practices. Numerous seeps form rivulets of shallow water and muck, 10 to 80 cm deep. Red maple is dominant, but poison sumac, alders, and multiflora rose are present in large numbers. Tussock sedge and other sedge species are persisting in this wetland, indicating that in the past [redacted] was likely ideal bog turtle habitat. In the winter of 2002/2003, TNC cleared a large portion of the shrubs and hardwood trees in order to expand open areas. This site is currently ranked a **4 (Typical)** because of the recent management practices, but without management this site would be considered marginal habitat due to the dominance of trees and shrubs.

[redacted] (Figures 33 and 34)

The site has been greatly impacted by the building of a man-made pond a number of years ago. A ditch, adjacent to the mowed berm of the pond's southeastern edge, has standing water fed by runoff, but the substrate is hard-packed with no appreciable muck. The ditch is dominated by stiltgrass (*Microstegium vimineum*) and goldenrods, and is shaded by eastern white pine (*Pinus strobus*). This site is ranked a **1 (Not Suitable)** due to the lack of seeps, deep muck, and tussock-forming vegetation.

[redacted] (Figures 35-37)

There are three distinct open areas where bog turtles have been located within a large wetland area on the [redacted] property. The area located in the southeastern portion of the property is open-canopied and dominated by tussock sedge, skunk cabbage, and jewelweed, and is surrounded by shrubs including poison sumac, alders, and red maple. Seeps feed rivulets with 10 to 40 cm of muck. Within the eastern portion of the site is a shrub/scrub wetland dominated by red maple, alders, spicebush, and poison sumac. Small open areas with tussock sedge, jewelweed, and sedges are interspersed among the shrubs and trees. The substrate is 10 to 80 cm of muck. Numerous seeps and rivulets flow north toward [redacted]. The third and western-most area is open-canopied and contains tussock sedge, arrowhead (*Sagittaria latifolia*), jewelweed, sphagnum moss, and marsh fern (*Thelyperis palustris*). This area is surrounded by shrubs including alders, poison sumac, spicebush, and red maple. The substrate is 10 to 100 cm of muck. Numerous seeps form rivulets with water levels ranging from 10 to 30 cm deep. This study site is ranked a **4 (Typical)** for the presence of numerous seeps, deep mucky substrate, and tussock-forming vegetation.

[redacted] (Figures 38 and 39)

[redacted] has open marsh and wet meadow areas dominated by tussock sedge, sphagnum moss, cattail, and spikerushes. A few trees and shrubs including red maple and poison sumac are beginning to encroach, increasing the amount of canopy. Numerous seeps and rivulets of shallow water with 10 to 100 cm of muck are present throughout the study site. This site is ranked a **4 (Typical)** on HA's Standardized Habitat Ranking System.

[redacted] (Figures 40-42)

[redacted] is a hardwood swamp with red maple, green ash (*Fraxinus pennsylvanica*), alders, and spicebush (*Lindera benzoin*) among the dominant trees and shrubs. Several seeps flow through the wetland draining into [redacted]. The substrate in these seeps ranges from muck to rock and gravel. Pockets of deeper muck ranging from 10 to 50 cm are present throughout the forested wetland. Small open-canopied areas are dispersed throughout the wetland, with the largest area adjacent to [redacted]. Vegetation in the open areas includes sedges, skunk cabbage, arrowhead, sphagnum moss, and jewelweed. This site is ranked a **4 (Typical)**, but ideal vegetation is limited due to the heavy shrub and tree canopy.

[redacted] (Figure 43):

[redacted] study site is located along the [redacted]. It includes approximately 8 ha (20 acres) of wetland comprised of forested and shrub/scrub wetland with the dominant trees and shrubs including red maple, black willow (*Salix nigra*), alders, autumn olive, meadow-sweet, multiflora rose, and silky dogwood. Black willow, tussock sedge, cattail, purple loosestrife, and goldenrods are dominant in the gas line ROW, which is the largest open canopy area on this property. The substrate is rocky with shrub stumps and debris throughout. Small areas of muck and water are present, but are under a dense shrub canopy. This site is ranked a **3 (Marginal)** due to the dominance of shrubs and trees.

Figure 43. Easterly view of [redacted] wetland from [redacted]

Table 3: Unconfirmed Study Sites Evaluated in 2002 and 2003.

Property/Site Name	Habitat Ranking	Wetland Type
[redacted] Watershed		
[redacted]	4 (Typical)	Shrub/Scrub
[redacted]	2 (Atypical)	Sedge Meadow
[redacted]	3 (Marginal)	Shrub/Scrub and Forested
[redacted]	2 (Atypical)	Forested and Sedge Meadow
[redacted]	1 (Not Suitable)	Forested
[redacted]	5 (Ideal)	Sedge Meadow and Shrub/Scrub
[redacted]	4 (Typical)	Sedge Meadow
[redacted]	2 (Atypical)	Shrub/Scrub
[redacted]	1 (Not Suitable)	Forested
[redacted]	4 (Typical)	Sedge Meadow
[redacted]		
[redacted]	5 (Ideal)	Sedge Meadow and Shrub/Scrub

Notice: Certain portions of this document have been redacted in order to protect, and not divulge the exact locations of critical Bog Turtle habitat.

POPULATION STRUCTURE

The presence of bog turtles was confirmed at eight new sites consisting of 11 properties in 2002 and 2003. A total of 216 bog turtles have been marked within the [redacted] watersheds from 1999 through 2003. Forty-six new turtles were marked in 2003, 82 in 2002, and 88 between 1999 and 2001. In total, 381 bog turtle captures were made from 1999 through 2003, of which 165 were recaptures (**Appendix 5**). Refer to **Table 4** for captures by site from 1999 to 2003.

Table 4. Bog Turtle Captures by Site 1999-2003.

Property/Site Name	Turtles Marked in Prior Years	New Turtles Marked in 2003	Total Turtles Marked	Turtles Recaptured in Prior Years	Turtles Recaptured in 2003	Total Turtle Recaptures	Total Turtle Captures
[redacted]							
[redacted]	50	0	50	37	1	38	88
[redacted]	1	0	1	0	2	2	3
[redacted]	7	0	7	1	3	4	11
[redacted]	2	2	4	0	2	2	6
[redacted]	3	14	17	0	9	9	26
[redacted]	2	1	3	0	0	0	3
[redacted]	6	8	14	2	12	14	28
[redacted]	4	0	4	2	0	2	6
[redacted]	1	0	1	0	0	0	1
[redacted]	8	4	12	5	9	14	26
[redacted]	3	0	3	0	1	1	4
[redacted]	62	2	64	30	2	32	96
[redacted]	12	0	12	3	0	3	15
[redacted]	5	8	13	5	29	34	47
[redacted]	3	7	10	1	9	10	20
[redacted]							
[redacted]	1	0	1	0	0	0	1
[redacted]	**170**	**46**	**216**	**86**	**79**	**165**	**381**

The bog turtles captured in [redacted] were categorized by age structure and sex according to site (**Table 5**). These 216 marked turtles consists of 90 males (42%), 104 females (48%), 15 juveniles (7%) and 7 yearlings (3%). The overall population structure represents a healthy and viable metapopulation in [redacted]. Although many of the sites have small populations, these are important to the metapopulation as a whole. Some of these populations may have been formed recently by migrating individuals, whereas other sites may serve as "stepping stones" between more suitable habitats. It is important to remember that bog turtles are long-lived animals and can produce offspring for 40 or more years. Juveniles and yearlings have been found at six of the sixteen sites indicating that recruitment is taking place.

FREQUENCY OF BOG TURTLE CAPTURES

The capture day and time of the 381 bog turtle captures was recorded in an attempt to determine daily and monthly activity patterns (**Table 6**). During the months of May and June, 344 (91%) bog turtle captures were made. Bog turtle activity was highest between 1000 and 1600 hours, when 329 (87%) captures were made. As July approached, turtles became more secretive and spent little time exposed. Increasing vegetation density also diminished bog turtle captures, but we believe that the impact of vegetation growth on finding bog turtles is minimized by using experienced surveyors.

Table 6. Frequency of Capture by Month and Hour for *Clemmys muhlenbergii* 1999-2003.

Hour	April	May	June	July	August	September	Total (%)
0700	0	0	1	0	0	0	1
0800	0	0	7	0	0	0	7 (2%)
0900	0	3	13	1	0	0	17 (4%)
1000	0	16	24	3	0	1	44 (12%)
1100	3	22	17	2	0	0	44 (12%)
1200	1	31	20	3	0	0	55 (14%)
1300	6	35	14	2	0	0	57 (15%)
1400	3	29	16	1	0	1	50 (13%)
1500	5	14	24	0	0	0	43 (11%)
1600	2	22	13	1	0	0	38 (10%)
1700	0	5	9	2	0	0	16 (4%)
1800	0	0	6	0	0	0	6 (2%)
1900	0	0	3	0	0	0	3 (1%)
Total (%)	**20 (5%)**	**177(46.5%)**	**167 (44%)**	**15 (4%)**	**0**	**2 (0.5%)**	**381(100%)**

POPULATION SIZE ESTIMATION

Population size estimates were calculated for sites with sufficient numbers of captures and recaptures. In 2003, the focus of the mark-recapture study was to increase the number of captures at sites where few turtles were found in previous years. Not all sites yielded an abundance of new turtles or a sufficient number of recaptures to estimate the population size.

Population size estimates for [redacted] are shown in **Table 7**. The [redacted] properties are treated as one site, as are the [redacted] properties.

Table 7. Population Size Estimate and Confidence Interval.

Property/Site Name	Year(s)	Number of Turtles marked	Population Estimate	95% Confidence Interval
[redacted]	1999-2002	50	66	55-82
[redacted]	2000-2003	17	23	19-31
[redacted]	2002-2003	14	17	13-24
[redacted]	2002-2003	12	12	9-16
[redacted]	2000-2002	64	110	83-162
[redacted]	2002-2003	13	12	11-14
[redacted]	2001-2003	10	11	8-19

SITE-QUALITY ANALYSIS

Using the USFWS's Standardized Bog Turtle Site-Quality Analysis Ranking System (USFWS, 2001) the consistency of the quality of habitat and the health of a population within a study site is determined. At this time each study site is treated as one "population analysis site (PAS)" although we recognize the connectivity of all the sites (except [redacted]). It is HA's opinion that further research is needed before these study sites can be combined into a larger systems.

The study sites with healthy populations and high quality habitat are ranked as "good", or "good or fair". Sites ranked as "poor" or "poor to fair" are where either the population and/or habitat has been compromised. The site-quality analysis rankings for each study site are listed in **Table 8**.

Table 8. USFWS Standardized Bog Turtle Site-Quality Analysis Ranks.

Property/Site Name	Habitat Rank-Matrix 1	Population Rank-Matrix 2	Overall Site Rank	Property/Site Name	Habitat Rank-Matrix 1	Population Rank-Matrix 2	Overall Site Rank
[redacted]	poor	poor	poor	[redacted]	poor	good	fair
[redacted]	poor	fair	poor	[redacted]	fair	poor	poor or fair
[redacted]	fair	poor	poor or fair	[redacted]	good	poor	fair
[redacted]	good	fair	good or fair	[redacted]	fair	poor	poor or fair
[redacted]	good	fair	good or fair	[redacted]	fair	good	good
[redacted]	fair	good	good	[redacted]	good	poor	fair
[redacted]	fair	fair	fair	[redacted]	poor	good	fair
[redacted]	fair	good	good	[redacted]	poor	poor	poor

NEST SURVEY

Searches for bog turtle nests were concentrated during the months of June and July in 2002 and 2003 at all sites with confirmed bog turtle populations. A total of 19 bog turtle nests were located during the two years.

Eleven bog turtle nests were found in 2002, as well as one spotted turtle nest (containing five eggs). The 11 nests contained 43 eggs. Four (36%) of these nests (containing 15 eggs) were predated. Predator excluders were placed around the remaining seven nests to protect the vulnerable eggs. Seventeen (40%) of the initial 43 eggs hatched. This low success rate was caused in part by predation of nests and the impact of the drought on the developing embryos.

In 2003, emphasis was placed on finding nests at sites with small populations of bog turtles. A total of eight nests containing 28 eggs were located. Predator excluders were installed the same day that any nest was found, and as a result none of these nests were lost to predators. Despite protecting these nests, only 9 (32%) of the eggs hatched. The low success rate is believed to be caused in part by the heavy rains in the spring and early summer, which inundated some of the nests with water and may have caused the developing embryos to drown.

In total there were 19 bog turtle nests containing 71 eggs found in 2002 and 2003. Four of the 19 nests (21%) were lost to predation, or 17 of the 71 eggs (24%). Twenty-six (37%) eggs hatched successfully.

The nest and hatching data in [redacted] for 2002 and 2003 was compared to the bog turtle nest data that was gathered in 2001 at the [redacted] in Lancaster County, Pennsylvania (Zappalorti et al., 2002). A total of 9 nests containing 26 eggs were located at the [redacted]. Three (33%) of the nests (containing 7 eggs) were lost to predation. The remaining six nests (containing 19 eggs) were protected with predator excluders. Twelve (46%) of the eggs hatched.

The hatching success rate of 46% at the [redacted] in 2001 was higher than the [redacted] success rate in both 2002 (40%) and 2003 (32%). It is possible that the environmental conditions at the [redacted] in the spring and summer of 2001 were more favorable for hatching success than was experienced in [redacted] in 2002 and 2003. Additionally, predation of nests before predator excluders were installed in [redacted] in 2002 was 36% as compared to 23% in 2001 for the [redacted]. Additional comparative data on nest site selection should be examined to determine the significance of these findings.

Figure 44. Predated bog turtle nest from th[redacted]site.

While searching for nests in 2002, two additional predated nests were found at the [redacted] site (**Figure 44**). In 2003, remnants of five nests from the previous year, one nest at [redacted], three at [redacted], and one at [redacted], were found. The nest locations were identified by remnants of entire egg cases or

egg fragments in the mud. These nests are not reflected in **Table 9**, but locations were recorded and are presented on the map of each site. A summary of the nesting survey and hatchling results are shown in **Table 9**.

Table 9. Individual Bog Turtle Nest Data by Site.

Site Name & Nest No.	Clutch Size	Height from Surface to Top of Nest (cm)	Height from Surface to Bottom of Nest (cm)	Dimensions of Nest Chamber (cm) (d x l x w)	Depth of Cover over Eggs (cm)	Distance to Nearest Surface Water (cm)	Number of Eggs Hatched	Description of Unhatched Eggs
Nest Data from 2002								
*[redacted]	3	6.8	2.0	4.0 x 6.0 x 4.5	0.8	30.0	3	All Hatched
*[redacted] #1	4	9.0	1.0	5.0 x 7.0 x 6.0	3.0	48.0	4	All Hatched
*[redacted]	3	12.6	6.2	4.4 x 4.0 x 4.1	2.0	10.0	1	2 - Died while hatching
*[redacted]	4	15.0	10.3	2.7 x 8.0 x 6.0	2.0	20.0	0	4 - Dehydrated due to drought
*[redacted]	5	12.5	5.3	5.2 x 4.8 x 3.7	2.0	41.0	3	1 - Not Viable 1-Embryo died
[redacted]	3	12.0	6.0	4.0 x 5.0 x 5.5	2.0	28.0	0	3 - Predated
[redacted]	4	10.0	2.0	5.0 x 5.5 x 4.2	3.0	7.0	0	4 - Predated
[redacted]	4	11.5	3.0	5.0 x 4.0 x 3.0	3.5	30.0	0	4 - Predated
*[redacted]	5	12.8	6.0	6.0 x 6.6 x 5.0	0.8	18.0	3	2 - Not Viable
*[redacted]	4	12.0	7.0	4.0 x 7.0 x 6.0	1.0	17.0	3	1 - Not Viable
[redacted]	4	6.2	1.2	2.5 x 3.0 x 2.5	2.5	23.0	0	4 - Predated
Total 2002	**43 eggs**	**Avg. 10.9**	**Avg. 4.5**	**Avg. 4.3 x 5.5 x 4.6**	**Avg 2.1**	**Avg. 24.7**	**17 hatchlings**	**40% hatched**
Nest Data from 2003								
*[redacted]	4	6.4	1.4	3.0 x 6.0 x 5.5	2.0	27.0	4	All Hatched
*[redacted]	3	6.9	0.9	4.0 x 6.0 x 5.0	2.0	23.0	0	Not Viable
*[redacted]	5	17.8	6.8	6.5 x 8.1 x 7.4	4.5	23.0	0	5 - Embryo's died
*[redacted]	3	13.0	8.0	3.0 x 5.5 x 4.0	2.0	13.0	2	1 - Not Viable
*[redacted]	4	11.0	5.0	4.0 x 7.0 x 5.0	2.0	12.0	1	3 - Not Viable
*[redacted]	2	14.0	9.0	4.0 x 7.0 x 5.0	1.0	22.0	2	All Hatched
*[redacted]	3	15.0	8.5	4.5 x 7.0 x 5.0	2.0	20.0	0	3 - Not Viable
*[redacted]	4	13.0	6.0	5.0 x 6.0 x 4.0	2.0	10.0	0	4 - Not Viable
Total 2003	**28 eggs**	**Avg. 12.1**	**Avg. 5.7**	**4.3 x 6.6 x 5.1**	**Avg. 2.2**	**Avg. 18.8**	**9 hatchlings**	**32% hatched**
Total (2002 & 2003)	**71 eggs**	**Avg. 11.4**	**Avg. 5.0**	**Avg. 4.3 x 6.0 x 4.8**	**Avg. 2.1**	**Avg. 22.2**	**26 hatchlings**	**37% Hatched**

*Nests that were enclosed with predator excluders.

SITE MAPS SHOWING SIGNIFICANT FINDINGS

The core-habitat within each of the sixteen study sites was delineated and mapped on arial photographs using GPS and Arcview GIS (ver 3.2) software (**Maps 2-11**). The bog turtle locations indicated on the site maps are representative of initial capture locations and do not include all bog turtle captures within a site. All nests are indicated within each study site. The one confirmed hibernaculum, located on the [redacted] property, is shown on the site map. The locations of [redacted] and [redacted] are identified on the appropriate site maps.

WILDLIFE OBSERVED

A host of wildlife were observed in [redacted] watersheds. A number of reptile and amphibian species were randomly observed on or near the study sites during searches for bog turtles, including six turtles (including the bog turtle), five snakes, and 12 amphibians (**Table 10**). Many tadpoles and metamorphs of several amphibian species were also found, but are not included in the species totals. Since accurate numbers of calling amphibians were not counted, their numbers were not recorded.

Table 10. Herpetofauna Observed during 2002 and 2003.

Common Name	Scientific Name	Number Observed		
		[redacted]	[redacted]	Total
Turtles: Testudines				
Common Snapping Turtle	*Chelydra s. serpentina*	38	17	55
E. Box Turtle	*Terrapene c. carolina*	4	1	5
E. Painted Turtle	*Chrysemys p. picta*	48	11	59
Spotted Turtle	*Clemmys guttata*	91	1	92
Wood Turtle	*Clemmys insculpta*	147	18	165
Bog Turtle	*Clemmys muhlenbergii*	266	1	267
Total Turtles	**6 Species**	**594**	**49**	**643**
Snakes: Serpentes				
E. Garter Snake	*Thamnophis s. sirtalis*	40	4	44
E. Ribbon Snake	*Thamnophis s. sauritus*	1	1	2
E. Milk Snake	*Lampropeltis t. triangulum*	1	0	1
N. Brown Snake	*Storeria d. dekayi*	3	0	3
N. Water Snake	*Nerodia s. sipedon*	10	0	10
Total Snakes	**5 Species**	**55**	**5**	**60**
Frogs and Toads: Anura				
American Toad	*Bufo americanus*	19	0	19
N. Spring Peeper	*Pseudacris c. crucifer*	1	0	1
Bullfrog	*Rana catesbeiana*	6	0	6
Green Frog	*Rana clamitans*	538	34	572
Pickerel Frog	*Rana palustris*	119	0	119
Wood Frog	*Rana sylvatica*	17	1	18
Total Frogs and Toads	**6 Species**	**700**	**35**	**735**
Salamanders: Caudata				
Red Spotted Newt	*Notophthalmus v. viridescens*	235	0	235
N. Dusky Salamander	*Desmognathus f. fuscus*	15	3	18
Redback Salamander	*Plethodon cinereus*	0	1	1
Longtail Salamander	*Eurycea l. longicauda*	3	0	3
N. Two-lined Salamander	*Eurycea bislineata*	1	0	1
N. Red Salamander	*Pseudotriton r. ruber*	5	0	5
Total Salamanders	**6 Species**	**259**	**4**	263
Total	**23 Species**	**1608**	**93**	**1701**

A total of 267 bog turtle, 91 spotted turtle (*Clemmys guttata*) and 147 wood turtle (*Clemmys insculpta*) captures were made during 2002 and 2003 (**Table 11**). A large number of spotted turtles were found on the

[redacted] and [redacted] sites. Wood turtles were found in large numbers on the [redacted] sites. The number of spotted and wood turtles recorded is not an accurate representation of their population size.

Table 11. Number of Turtle (*Clemmys*) Captures by Site in 2002 and 2003.

Property/Site Name	Bog Turtle (*Clemmys muhlenbergii*)	Spotted Turtle (*Clemmys guttata*)	Wood Turtle (*Clemmys insculpta*)
[redacted] Watershed			
[redacted]	0	1	5
[redacted]	0	1	1
[redacted]	36	3	16
[redacted]	0	0	2
[redacted]	2	2	2
[redacted]	11	35	39
[redacted]	5	0	5
[redacted]	23	0	12
[redacted]	3	0	0
[redacted]	28	33	7
[redacted]	4	0	0
[redacted]	0	0	6
[redacted]	1	0	0
[redacted]	0	0	1
[redacted]	26	0	0
[redacted]	3	5	3
[redacted]	0	0	0
[redacted]	44	2	10
[redacted]	15	0	4
[redacted]	47	7	3
[redacted]	0	0	0
[redacted]	0	0	2
[redacted]	0	0	0
[redacted]	0	0	0
[redacted]	18	1	11
[redacted] Watershed			
Scott	0	1	12
Seiler	1	0	6
Total	**267**	**91**	**147**

DISCUSSION

Herpetological Associates, Inc. performed bog turtle habitat evaluations, presence/absence surveys, mark

and recapture studies, and nest monitoring at sites in the [redacted] watersheds in Monroe County, Pennsylvania during 2002 and 2003. These two watersheds contain numerous wetlands that provide suitable bog turtle habitat. HA visited 30 properties with potential habitat (28 in [redacted] and two in the [redacted] watershed) during the two-year study. Bog turtles were found on 18 properties (or 15 study sites) along an eight mile stretch of [redacted]. One bog turtle was found at a property within the [redacted] watershed. A total of 216 turtles have been marked in these watersheds (215 in the [redacted] watershed and one in the [redacted] watershed). There has been a total of 165 recaptures, all in [redacted], yielding 381 turtle captures between 1999 and 2003.

POPULATION STUDIES

Prior to 2002, the presence of bog turtles had been confirmed at eight properties in the [redacted] watershed ([redacted]). Bog turtle populations had not been confirmed in the [redacted] watershed prior to this study.

HA has since confirmed the presence of bog turtles at 11 new properties (ten in the [redacted] watershed and one in the [redacted] watershed). Eight of these properties were confirmed in 2002 ([redacted]), and three in 2003 ([redacted]). These discoveries increased the number of properties where bog turtles were found to 18 (or a total of 15 study sites) in the [redacted] watershed and 1 (1 study site) in the [redacted] watershed. One of the new sites found in 2003 was the [redacted] property, which adjoins the [redacted] property, but is separated by [redacted]. It was suspected that the turtles were crossing [redacted], utilizing both habitats. We found a male from the [redacted] property on June 12, 10 feet from [redacted] heading toward the [redacted] property. In August Lynn Carroll, a TNC volunteer program coordinator found female L2-R1 from the [redacted] property crossing [redacted] heading towards [redacted]. In light of these observations, we are treating the turtles from both properties as one population. It is possible that an additional population was found based on the discovery of a dead bog turtle on [redacted], approximately 200 feet from [redacted]. This can not be confirmed as a new population until permission is obtained from the landowners to survey their properties. The location of the dead bog turtle was recorded via GPS and is included in this report (**Map 5 and Appendix 1**).

In 2002 mark and recapture studies were conducted at 16 properties ([redacted]). Presence/absence surveys were also conducted concurrently at ten additional unconfirmed properties. The data collected in 2002 was sufficient to generate population estimates for only the [redacted] and [redacted] sites. There were an insufficient number of captures and recaptures to produce population estimates for the remaining 14 properties, therefore the mark and recapture studies of these sites were planned to continue in 2003. Mark and recapture studies were discontinued at four of the properties ([redacted]) in 2003 because the landowners denied access. The May property was not visited in 2003 because of a lack of suitable habitat to support a viable population of bog turtles. Three additional properties ([redacted]) were confirmed in 2003. Mark-

Notice: Certain portions of this document have been redacted in order to protect, and not divulge the exact locations of critical Bog Turtle habitat.

recapture studies were performed at a total of 16 properties in 2002 and12 properties in 2003, including nine properties originally examined in 2002.

The mark and recapture studies have been instrumental in increasing our knowledge of the size and structure of individual bog turtle colonies and the metapopulation as a whole in [redacted]. Sufficient data was collected to calculate population size estimates for seven populations which inhabit 10 properties ([redacted]). As discussed earlier in this report, the [redacted] properties have been combined to produce one population estimate due to the close proximity of the wetlands. The [redacted] properties were also treated as one population since several marked turtles were found moving between these properties.

The [redacted] sites have the largest bog turtle populations, represented by all age categories. [redacted] has 50 marked turtles with an estimated population size of 66 turtles, and [redacted] has 64 marked turtles with an estimated population size of 110 turtles. These two sites are critical to the [redacted] metapopulation, since they have the potential to yield large numbers of offspring on an annual basis. Seven properties, or five sites ([redacted]), have a conservative number of bog turtles. Recruitment has been observed, indicating that the populations are remaining stable or increasing at these sites. Smaller populations were documented at sites such as [redacted], where population estimates could not be generated due to low numbers of recaptures. These sites may contain recent founder colonies, formed by migrant individuals from neighboring populations, or may be remnant populations from formerly productive habitats. Regardless, these small local populations are important to the genetic diversity and the stability of the metapopulation.

HABITAT USE

Delineating areas of critical habitat (e.g., hibernacula, nesting areas) is difficult without the aid of radiotelemetry. Detailed visual surveys, however, can generate important information on habitat partitioning and even critical habitat. One hibernaculum was identified with certainty during visual surveys at the [redacted] site (**Figure 45**). This hibernaculum is located under the roots of a willow shrub. Branching subterranean tunnels within the root system, soft mud, and relatively constant water characterize this overwintering site. The exterior of the root system is covered with vegetation which acts as an insulation layer. This is a typical bog turtle hibernaculum based on other bog turtle hibernacula observed by HA.

Figure 45. The [redacted] hibernaculum is located near the edge of the wetland on the top of the hillside.

Bog turtle nests were found at eight sites (nine properties) in [redacted]. A total of 19 nests containing 71 eggs were found during 2002-2003. Unfortunately, hatching success was relatively low, with only 26 of the 71 eggs producing hatchlings. Several

factors were noted which likely affected hatching success. One such factor was atypical nest site selections by bog turtles. Typically, nests are made in hummocks which are elevated, often greater than 20cm, so that the humus surrounding the eggs is only slightly damp. In [redacted], many of the nests were found in very low hummocks, extremely close to the water surface. In many situations this allowed the nest substrate and the eggs to become saturated with water, thus causing the embryos to drown. This circumstance was noted with at least five nests in 2002 and 2003. Another factor impacting hatching success is predation on eggs by mammals. In 2001, and in previous years, turtle nests were often found unearthed and the eggs destroyed with obvious tooth marks. The predators of bog turtle eggs are believed to be small mammals, which are abundant in bog turtle habitat. This is supported by the small size of the tooth marks and the lack of significant disturbance to the nest site (as would be expected from large mammalian predators).

General habitat use by bog turtles is consistent with HA's observations at other locations and with published literature (Arndt, 1977 and Carter et al., 1999). Habitats that were occupied by turtles occurred along a gradient from highly suitable to marginal. Excellent habitat exists at the [redacted] properties, and these sites have correspondingly large populations of bog turtles. [redacted] provide examples of especially closed-canopied areas. [redacted] does not appear to contain a productive population of bog turtles, but [redacted] has yielded a conservative number of turtles and evidence of recruitment. The population at [redacted] probably benefits from several small openings in the canopy at spring heads (including the nesting area). [redacted] also contains a conservative number of turtles, and is unusual because it is prone to flooding. The large influx of water is likely a result of the alterations associated with the adjacent tree farm, hillsides, and man-made channels. [redacted] is an unique study site in that the bog turtle habitat is located on a hillside.

Migratory movements are difficult to document without the aid of radiotelemetry. Opportunistic recaptures of turtles, however, can provide important insight into the movements of turtles. Most recaptures occur within the same wetland where an individual turtle was originally captured, and therefore provides useful information on movements and habitat use within that wetland. The frequency of recapturing a turtle on a different site than it was originally captured is low, but these observations are highly informative when they occur. One such migratory movement was documented in [redacted] when a male bog turtle (L12-R1) moved from the [redacted] property on July 1, 2002 to the [redacted] property on July 6, 2003. This turtle traveled a straight line distance of 1030 m between the sites. Although [redacted] does not provide ideal bog turtle habitat, it nevertheless supports a small number of turtles. It is unclear whether [redacted] was once a more suitable habitat, but the evidence suggests that the site provides a temporary habitat for turtles moving between more suitable habitats. This observation is the first documented record of a bog turtle in the [redacted] watershed migrating from one population to another, and is the first time a bog turtle was noted crossing [redacted]. It is important to note that this turtle did not have to cross roads in order to reach the [redacted] site. The migratory movements between local populations is important to the overall stability of the metapopulation and protection of natural upland and wetland corridors is critical to their survival. HA believes [redacted] and the surrounding wetlands is the primary movement corridor for local bog turtle populations.

PREDATORS

As adults, bog turtles have very few natural predators. Occasionally, some may fall to persistent, large predators such as racoon, fox, and dogs. This is evident through teeth marks, or crushed shells at fox dens. Raccoons may also chew limbs off turtles. This natural predation is unlikely to reduce healthy populations of bog turtles. Concern is warranted, however, if predator populations rise to unnatural levels due to human

influence (e.g., the presence of excess household garbage allowing raccoon or rodent populations to rise), which may result in unnaturally high predation levels. Predation from humans, in the form of illegal collecting, road mortality, and habitat disturbance, is an additional threat to bog turtles.

Even though predation on adult bog turtles is generally not considered a significant threat to a population, predation on eggs and hatchlings can have a strong influence on the viability of individual populations. Bog turtles are highly vulnerable to predation during their first several years due to their small size. Many types of avian, mammalian, and reptilian fauna will prey on immature bog turtles. Our research suggests that the greatest source of predation on bog turtles is from small mammals such as voles, shrews, and mice. These assiduous mammalian predators eat bog turtle eggs, and possibly hatchlings and juvenile turtles. This has a great impact on the number of hatchlings and their survival through the first few years, which bears a direct impact on the number of reproductive turtles in future years. This can have a profound impact on bog turtle populations, especially if they are already reduced by habitat degradation or other factors.

Although little can be done to protect individual bog turtles from predators, bog turtle nests may be defended relatively easily. The installation of predator excluders around nests has been shown to protect bog turtle eggs from predation. The results of our nest monitoring studies in 2001 at the [redacted] in Lancaster County showed 46% hatching success, but predator excluders were not installed immediately upon discovery of each nest resulting in some eggs being lost to predation (Zappalorti et al., 2002). However, a concurrent nesting study at the [redacted] where no predator excluders were used resulted in a 100% loss of eggs to predators. In [redacted] in 2002, predator excluders were not installed immediately, and hatching success was 40% with a considerable number of eggs taken by predators. Clearly, bog turtle eggs may fail to hatch for a variety of reasons, but their loss to predators is avoidable.

MANAGEMENT RECOMMENDATIONS

Habitat protection, management, and restoration are critical to the long-term survival of the bog turtle in the wild. Populations of bog turtles can not be sustained without suitable habitat in which to reside and sufficient corridors to ensure safe movement between populations. The fragmentation of bog turtle metapopulations into isolated colonies is one of the major threats to the survival of the species. Natural succession and the spread of invasive plant species further threatens to degrade habitats, eliminating local populations of bog turtles and limiting the opportunity to migrate to neighboring habitats. This is having a profound impact on the bog turtle populations throughout their range, and even threatens those within the pristine [redacted] watersheds. To insure the survival of the bog turtle, habitat protection and management techniques must be implemented.

SITE-SPECIFIC HABITAT RECOMMENDATIONS

Specific habitat recommendations for each site are provided below. Refer to **Appendix 7** for labeled, dated, and indexed digital photos of each site. A list of the most common plants, shrubs and trees at each site is presented in (**Appendix 3**).

[redacted]

Reed canary grass is spreading in the northern portion of the marsh and will become a problem unless it is controlled or eradicated. Woody shrubs are also advancing into the southern portion of the marsh and should be controlled as part of the habitat management plan. However caution needs to be taken until it is determined where bog turtles are hibernating.

The mortality of turtles on roads is an issue at this site. Although no dead bog turtles have been found, five adult female wood turtles and two snapping turtles were found dead along a section of [redacted] Road in early June (**Figure 46**). This portion of the road lies along the northern perimeter of the property. Located between the primary area of bog turtle habitat (to the south) and [redacted] Road is a large, open field with temporary pools. A small, mucky stream (ditch) immediately borders [redacted] Road. Bog turtles, wood turtles, and snapping turtles have been migrating in the spring and early summer from the primary area of habitat to utilize the temporary pools in this open, grassy area. These turtles were probably looking for nesting sites in drier portions of the field or foraging habitat due to the proximity to the more suitable habitat.

Figure 46. The small mucky stream (ditch) adjacent to [redacted] Road. Several DOR wood and snapping turtles have been found along this section of road. The core bog turtle habitat is located approximately 125 meters southeast of the road.

Serious consideration should be given to constructing a barrier along the road to prevent turtles from crossing the road, and direct them toward [redacted] (a safer movement corridor). This would provide turtles a safe passage under the road and allow them to migrate to the other wetlands on the north side of [redacted] Road. Another consideration is to create a berm in the field one meter high and three meters wide, paralleling [redacted] Road. This would benefit the wood turtles and other turtles by creating a dry, elevated area for nesting.

[redacted]

TNC has taken positive steps toward improving the habitat at [redacted] by clearing the wetland of shrubs and trees. There are still many shrubs and trees interspersed within the wetland that should be removed or girdled. Currently, it appears that [redacted] serves as either an intermediary point for transient bog turtles migrating to different wetlands or is a degraded habitat of a once productive bog turtle population. This is based on the fact that only four turtles have been found in the last four years, one of which was originally marked at the May property in 2002 (over 1030 meters away). With continued tree and shrub management, this site may support a stable population of bog turtles.

[redacted]

The [redacted] site contains a large wetland that is located a significant distance from roads and is connected to other wetlands by [redacted] The area is currently managed by cutting the vegetation at least once a year. The farmers that take care of this property indicated that the vegetation is usually cut in late August or September when surface water has receded. Given our knowledge of the movements of the turtles we recommend that the cutting be delayed until late October or November to minimize the possibility of turtles being killed by the equipment. To impede the spread of the cattail, it is recommended that the shrubs along the edge of the wetland should no longer be cut. Leaving the shrubs may also provide suitable areas for the turtles to hibernate.

[redacted]

In the winter of 2002 TNC removed a number of shrubs and trees in the marsh to provide more open habitat for bog turtles. This was a positive step in improving the habitat. We recommend that the removal of shrubs and trees continues so that an open corridor is created through the wetland, connecting the small, open wetland areas within the site. This will enable more detailed surveys to be conducted at this site by providing access to these areas, and allow important areas to be documented. Ultimately, 40-50% of the tree and shrub cover should be removed. In addition, consideration should be given to reducing the amount of runoff from the tree farm into the wetland.

[redacted]

This wetland is a much more productive bog turtle habitat than previously thought, despite the heavy tree and shrub cover. This population has probably survived the plant succession due to the presence of small, open areas that have remained around deep springs and mucky areas. Creating larger open areas is critical to the long-term survival of this population. Shrubs and trees should be removed where possible along the seeps and rivulets feeding into the wetland. In addition, plans must be developed to build a barrier along this section of [redacted] road to minimize road mortality (**Figure 47**). A reduced speed zone, turtle crossing signs, and/or speed bumps should be installed if barriers can not be placed immediately. The amount of traffic appears to have greatly increased on [redacted] Road over the last two years and is having a detrimental impact on the turtle populations.

Figure 47. Southeasterly view of [redacted] adjacent to the [redacted] wetland. Two wood turtles and one box turtle were found DOR on this section of the road. The largest area of open habitat is located just down slope from the shoulder of the road.

[redacted]

The [redacted] site has ideal habitat for bog turtles and does not require management at this time. However, the site should be monitored every couple of years to determine if natural succession is having a negative impact on the site.

[redacted]

On the [redacted] property, the presence of purple loosestrife is being addressed, but it must be controlled before it dominates the site. The purple loosestrife on [redacted] property is not currently being managed and is one of the dominant plant species. The shrubs in the northeast section of the [redacted] property, under the powerline right-of-way, also present a problem and should be removed.

One important management issue for these properties is the lack of a safe migratory corridor crossing [redacted] (**Figure 48**). Currently, bog turtle must cross over [redacted] to move between the wetlands, exposing them to vehicle traffic and other potential predators. A culvert should be installed under [redacted] and barriers should be placed on both sides of the road to safely guide the bog turtles under the road when they are moving between wetlands. Another concern is with the hydrology of wetland within these properties. In 2001 and 2002, the water table dropped to the point where there was no surface water and very little mud in the [redacted] wetland in August and September (when bog turtles are hatching). The creation of [redacted] may have affected the water flow between these properties. This should be evaluated by a qualified hydrologist.

Figure 48. Northerly view of [redacted] facing the intersection with [redacted]. [redacted] bisects this section of the [redacted] wetland.

[redacted]

The [redacted] property has been dramatically altered with the building of the pond and other impoundments. The pond and impoundments should be evaluated for the presence of springs. If springs are present, these areas may be converted to bog turtle habitat by draining the ponds. Regardless this area may be important for movement and should be managed to improve the bog turtle habitat.

[redacted]

The site needs to be monitored to insure that shrubs do not advance and reduce the amount of open area that is utilized by the bog turtles. The site also needs to be to monitored to insure that it is not overrun by invasive plant species that are currently present including reed canary grass, mint, honeysuckle, and multiflora rose.

[redacted]

A small area of potential bog turtle habitat exists across [redacted] (under the powerline right-of-way) from the [redacted] property. Permission was not obtained to survey this habitat, but the potential does exist for bog turtles to move between [redacted] and this wetland. Several painted, snapping, and wood turtles were found dead on the road between these wetlands. A culvert should be installed under the road along with barriers to provide safe passage for bog turtles and other species between these wetlands.

[redacted]

Woody vegetation and invasive species including autumn olive, multiflora rose, barberry, reed canary grass, and *Phragmites australis* are currently present in small areas, but are spreading in the study site. The spread of these plants should be evaluated every two to three years in order to identify any changes in the percent coverage. Presently the fields are mowed once or twice during the summer months, but HA recommends that mowing be limited to October through March.

[redacted]

The removal of trees and shrubs, such as red maple and alders, would be highly beneficial to increase the amount of open habitat. Also, the movement corridors between the three areas of core-habitat should be identified and opened.

[redacted]

Shrubs and trees are encroaching on the wetland and should be removed or girdled to maintain the open conditions. Currently, reed canary grass is a dominant species within the small area of open bog turtle habitat. Removal would be the most cost effective approach at managing the reed canary grass since it is within a limited area.

[redacted]

The shrubs and trees in the gas line ROW, where a bog turtle was found in 2003, were recently cut. This area and the surrounding area needs to be cleared to increase the amount of open habitat. Purple loosestrife is also currently invading the ROW and should be monitored.

[redacted]

The channel that was dug by the landowner to drain the wetland on the [redacted] property should be dammed. This should improve the hydrology in the surrounding area and create additional habitat for bog turtles. If effective, the channel along the [redacted] and [redacted] properties should also be dammed so that the water may flood the surrounding area, returning it to a wetland. The removal of additional shrubs beneath the powerline right-of-way and near the suspected hibernaculum will greatly benefit the turtles on this property. Invasives, which include multiflora rose, reed canary grass, and purple loosestrife, also need control and monitoring before they become dominant.

[redacted]

There are three interconnected seeps on the [redacted] property (see **Map 6**). The shrubs and trees have only been removed from the wetland surrounding the southernmost seep. However the wetlands surrounding the two primary seeps to the north are overgrown with shrubs and trees. These wetlands, as well as areas between the seeps, should be thinned of trees and shrubs to create more open habitat. In addition, the small streams that flow into the site should be dammed at points to allow the surrounding area to flood with water, thereby creating additional habitat.

REINTRODUCTION OF THE BEAVER (*CASTOR CANADENSIS*) INTO THE [redacted] WATERSHED

The natural succession of hardwoods and shrubs has negatively impacted the bog turtle habitat along [redacted]. As it has been indicated above, many of these wetlands require the removal of hardwoods and shrubs in order to maintain suitable habitat for bog turtles. This is a costly and time consuming effort that must continue from year to year to ensure that there will always be suitable bog turtle habitat in the wetlands [redacted]

HA suggests that consideration be given to the reintroduction of beaver into the [redacted] watershed. Beaver act as natural stewards of the habitat, alternately flooding areas and then allowing their return to natural hydrology (Somer et al., 2000). Although short-term losses of bog turtle habitat may occur, the long-term benefit is the natural management of plant succession and invasives. Our studies of the [redacted] Fens Complex indicate that beavers play a key role in keeping wetlands open by cutting trees and shrubs and by creating small bodies of water for short periods of time (Farrell et al., 2003). When the food supply is exhausted in an area, beavers will relocate, leaving behind an open wetland that contain the mucky soils, hydrology, and vegetation required by bog turtles.

The beaver has a unique influence on the landscape and has always had an association with the bog turtle. The reintroduction of beaver into [redacted] is the most cost effective way to control the natural succession of hardwoods and shrubs in the watershed. The long-term benefits of slowing the encroachment of hardwoods and shrubs is key to ensuring the continued presence of bog turtles [redacted]

REDUCING ROAD MORTALITY

Road mortality on turtles in [redacted] was noticeably high. Bog turtles, box turtles, painted turtles, spotted, snapping, and wood turtles were found crushed on roads throughout [redacted] (**Figures 49-51**). Aside from the direct loss of turtles from the population, the roads further serve to harm these species by reducing their ability to migrate. Maintaining existing movement corridors and restoring once suitable corridors is essential for the long-term viability of the bog turtle. The ability for bog turtles to migrate is vital to promoting gene flow between local populations, thereby preventing problems associated with inbreeding. A recent publication evaluated the impact of roads on the movements of three groups of turtles: land turtles, large pond turtles, and small pond turtles (Gibbs and Shriver, 2002). The study provides a compelling explanation for the bewildering decline of turtles in our environment, particularly the terrestrial and semi-aquatic species which include the bog, box, spotted and wood turtle. A copy of their paper is included in this report (**Appendix 6**).

The impact of roads on turtles is clearly evident in [redacted]. The increasing volume of traffic passing along [redacted] and [redacted] Roads has resulted in more and more turtles being found

crushed by vehicles. In 2002 and 2003, 26 turtles were found crushed in various locations on [redacted] and [redacted] Roads. The majority of these turtles were found in 2003 along [redacted] and [redacted] Roads. The dead turtles included 1 bog, 2 box, 7 painted, 1 spotted, 5 snapping, and 10 wood turtles. One additional wood turtle was found dead in a field on the [redacted] property, most likely killed by a tractor while mowing. It is probable that the number of road-killed turtles is much higher than observed, since predators quickly remove carcasses and HA biologists were only present in [redacted] for a portion of the active season.

The annual loss of turtles is likely to have a serious impact on the populations of these species in [redacted] especially since most of these turtles were gravid females likely searching for suitable nesting sites. HA suggests that road signs (e.g., "Turtle Crossing") be placed along roads, along with lower speed limits, and speed bumps where warranted to reduce road mortality in these areas.

The long-term solution, however, may require a more aggressive approach. At locations with high rates of road mortality or where wetlands are bisected by roads, crossings in the form of culverts or elevated roads should be designed to provide safe passage. Barriers along roadways, such as high curbs, would also help to guide turtles into the culverts, keeping them off the roads. Unfortunately, as development continues, the impact of roads on turtles will only worsen. Steps should be taken now to minimize current and future problems with road mortality.

Figure 49. DOR bog turtle found on [redacted] 70 m west from the intersection with [redacted] Road.

Figure 50. DOR wood turtle found on [redacted] Road adjacent to the [redacted] wetland.

Figure 51. DOR yearling box turtle found on [redacted] Road adjacent to the [redacted] wetland.

FUTURE STUDIES

The habitat evaluations and presence/absence surveys were successful in discovering new bog turtle habitat and confirming populations. Additional surveys should be conducted to locate other bog turtle populations within the [redacted] and [redacted] watersheds. Future surveys should examine wetland habitats between known bog turtle populations to determine if additional populations or suitable habitat are present, and to determine the suitability of these areas as migratory corridors. Key areas that need to be examined include the wetland corridor along [redacted] between the [redacted] and [redacted] sites, and between the [redacted] and [redacted] sites. Mark and recapture studies need to be performed at all new populations, and at known sites which have not yielded population estimates (such as [redacted]). Future studies should also focus on nesting and hatching success, with emphasis on protecting nests and identifying predators within specific wetlands. A small mammal mark and recapture study is the best approach at determining the abundance and type of small mammals present within the bog turtle study sites.

Radiotelemetry serves as the best technique to document the movements of turtles, their home range, and the location of critical hibernacula and nesting sites (Farrell et al., 2002). Radiotelemetry should be performed at all sites where the identification of critical foraging, nesting, and hibernating habitat is undetermined. The identification of critical habitat is especially important at sites where habitat management is required. Critical areas should be determined (if possible) before any management is performed. Monitoring the movements of bog turtles will also help to determine critical movement corridors within and between sites. In order to develop an effective management plan critical areas of habitat and movement corridors must be identified.

The long-term benefit of protecting bog turtle eggs from predators has not been shown (and would require years of study), but it seems intuitively clear that providing a head start to developing eggs can only be beneficial. It is recommended that predator excluders be installed at any site where an increase in the bog turtle population size is desired. The majority of the sites examined in this study would benefit from nest protection, but the largest sites (such as [redacted]) are probably stable and do not require the effort.

A second approach to protecting eggs from predation is to remove eggs from the field and artificially incubate them in the lab. HA has done this in the past with excellent success. In 1978 and 1979 HA was under contract with the New Jersey Division of Fish and Game's Nongame Endangered Species Project. Part of this project was to gather data on nest and hatchling success including measurements on nest size, egg, and hatchling. During the two-year study, eggs from 27 turtles (82 eggs) were incubated in the lab. Of the 82 eggs, 60 (73%) successfully hatched. This is a much higher hatching rate than has been observed in nature by HA, and may provide a significant boost to bog turtle populations. The eggs could be incubated at a designated location and be monitored by experienced personnel.

SUMMARY

Herpetological Associates, Inc. was contracted by The Nature Conservancy to study the ecology of the bog turtle (*Clemmys muhlenbergii*) in the [redacted] watersheds in 2002 and 2003. Since very little research had been performed on the bog turtle within these watersheds, a major focus of this study was to determine the locations of potential habitat and then to determine presence or absence. Much of the habitat along [redacted] is relatively pristine with little human development, which generated a strong likelihood that bog turtles would be found in many of the suitable wetlands.

Twenty-eight properties were evaluated in the [redacted] watershed and 2 properties were examined in the [redacted] watershed. Bog turtles were found on 18 properties in [redacted] and at one property along [redacted]. Since some of the wetlands span several properties, it may be more accurately stated that bog turtles were found at 15 separate study sites in [redacted] and at one study site along [redacted]. Because the majority of the study sites are connected by [redacted], it is suspected that the local populations are forming a metapopulation, with an exchange of individuals likely occurring throughout the valley.

Mark-recapture studies were initiated at each of the 16 study sites, where at least one bog turtle was found. Efforts were also continued to find bog turtles at sites which were identified as potential habitat. Sufficient data was gathered to calculate population estimates at seven sites (encompassing 10 properties). The [redacted] site produced the highest population estimate of 110 turtles, probably due to the large area of high quality habitat. Other sites yielded very low numbers of turtles, which did not allow population estimates to be calculated. One such site is [redacted], which only produced two bog turtles. In some cases, sites with few turtles may need to be managed to support viable populations, but further research is needed to determine the best management approach and the long-term effects of management. Management techniques and goals have been highlighted in this report, and generally focus on the removal of hardwood trees and invasive plants in emergent wetlands. Additional suggestions for management focus on removing movement barriers and reducing road mortality.

One of the key factors influencing bog turtle populations is the nesting and hatching success. The encroachment of hardwood trees and invasive plants into nesting areas can have disastrous results for hatching success, and in many cases may begin the demise of a population. As indicated above, habitat management may provide a significant boost to population stability and recruitment. In other cases, natural predation on eggs may prevent a population from gaining a foothold, especially if the site has been compromised by natural plant succession or invasives. Another portion of this study examined nesting success at individual sites, and the protection of some nests from predation by placing wire mesh cages ("predator excluders") around the entire hummock that contained a nest. The results of this portion of the study showed that predation could be eliminated by the use of predator excluders, but eggs were still impacted by environmental factors such as drought or innundation by water. Of 71 monitored eggs (19 nests), 56 eggs (15 nests) were protected with predator excluders. Of the 56 protected eggs, 26 (46%) hatched. It should be noted that none of the protected eggs were impacted by predators.

The [redacted] metapopulation is a stronghold for the bog turtle in Pennsylvania. Future research in this region will assist in the long-term survival of the bog turtle in [redacted], and throughout Pennsylvania. Future goals should include identifying additional areas of potential habitat, confirming new populations, and conducting detailed studies at new and previously studied sites. Study

techniques such as radiotelemetry should also be incorporated to appropriately direct management efforts.

LITERATURE CITED AND OTHER REFERENCES

*In addition to the literature cited, this list includes other publications concerned specifically with the bog turtle (*Clemmys muhlenbergii*) or with amphibians and reptiles in general. Those who wish to learn more about bog turtles in Pennsylvania, New Jersey, or throughout the eastern United States may find these publications or papers of interest.*

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Results of Bog Turtle (*Clemmys muhlenbergii*) Surveys in Various Watersheds in Monroe County, Pennsylvania during 2002 and 2003

A juvenile bog turtle from Cherry Valley

Submitted January 13, 2004

to

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