HABITAT SELECTION OF BLANDING’S TURTLE (*EMYDOIDEA BLANDINGII*): A
RANGE-WIDE REVIEW AND MICROHABITAT STUDY

A Thesis
Submitted to the Faculty of the
Graduate School of Environmental Studies

by
Tanessa Suzan Hartwig

in Partial Fulfillment of the
Requirements for the Degree of

MASTER OF SCIENCE IN ENVIRONMENTAL STUDIES

Bard College
Annandale-on-Hudson, New York
May 2004
We, the Thesis Committee for the above candidate for the Master’s Degree, hereby recommend acceptance of the thesis.

Erik Kiviat, Advisor
Bard College

Charles D. Canham
Institute of Ecosystem Studies

Jeffrey W. Lang
University of North Dakota (Emeritus)

K. Lorraine Standing
Environment Canada

The thesis is accepted by the College

Michele Dominy
Dean of the College

Robert Martin
Vice President for Academic Affairs and Dean of Graduate Studies

May 2004
Abstract of the thesis

Habitat selection of Blanding’s turtle (Emydoidea blandingii):

a range-wide review and microhabitat study

by

Tanessa Suzan Hartwig

Master of Science in Environmental Studies

Graduate School of Environmental Studies

Bard College

May 2004

The Blanding’s turtle is rare throughout most of its range. Habitat loss is considered a key factor in population declines. To conserve a species, habitat selection at all levels of scale must be considered. Much is known about Blanding’s turtle habitat at the landscape scale; however, little is known about range-wide or microhabitat requirements. Therefore, this study consisted of an extensive literature review to determine range-wide habitat characteristics and a field study to determine microhabitat characteristics at a site in Dutchess County, New York.

I conducted a literature review of Blanding’s turtle habitat throughout its range to determine similarities and differences in habitats at the range-wide, landscape, and microhabitat scales. Throughout their range, Blanding’s turtles select wetland complexes with shallow (< 2.5 m) water depths, organic substrates, areas of open water, and abundant vegetation. Wetland complexes consist of deeper wetlands for overwintering or drought refuge and a variety of shallow wetlands for feeding and thermoregulation. In the
Great Lakes region Blanding’s turtles tend to use ponds with abundant vegetation or herbaceous wetlands while in the Northeast turtles often use shrub swamps. Nova Scotia turtles use bays and floodplain wetlands with a mix of herbaceous and shrubby vegetation. Juvenile turtles tend to use shallower areas than adult turtles - either in the same wetlands that adults use or different wetlands. Water quality and seasonal movements vary by site, although long distances (> 1000 m) are traveled for nesting and other reasons range-wide. Because Blanding’s turtles are very mobile and use a variety of wetlands during an individual’s lifetime, they are susceptible to loss of individual wetlands and landscape connectivity. Management recommendations include conservation of wetlands in groups, 1 km buffer zones around a Blanding’s turtle wetland complex, and corridors between complexes or known habitats beyond the 1 km zone.

I studied Blanding’s turtle microhabitat in wetlands constructed for the turtles and reference (pre-existing) wetlands to assess Blanding’s turtle microhabitat selection and the suitability of the constructed wetlands as habitat for the turtles. Microhabitat was determined by radio-tracking individuals to their exact location and recording habitat variables. Blanding’s turtles selected shallow water depths ($\bar{x} = 30$ cm), muck substrates, and areas of abundant vegetation (total cover $\bar{x} = 87\%$). Buttonbush (Cephalanthus occidentalis) was most important, with mean cover 29%. In the constructed wetlands, Blanding’s turtles selected significantly less cover and warmer water than they did in the reference wetlands. Blanding’s turtles appeared to be using the constructed wetlands to bask and forage in the spring and early summer, but they moved to deeper wetlands in late summer, when the constructed wetlands dried up or became too warm. The turtles also overwintered in the reference wetlands. Habitat constructed for Blanding’s turtles
should contain abundant emergent vegetation (including buttonbush in Dutchess County and other areas where the turtles are known to use buttonbush swamps), muck substrates, deep pools and shallow water areas, floating plant material, and submerged aquatic vegetation. Because the constructed wetlands do not provide core habitat for the turtles, destruction or damage to essential habitat for Blanding’s turtles should be avoided. Construction of new habitat near essential habitat should, however, be considered, particularly where habitat has already been fragmented or destroyed. Many other wetland animals use multiple wetlands to fulfill their life history requirements and similar management considerations may apply.
EXPLANATION OF ALTERNATE THESIS FORMAT

This thesis follows Bard College’s alternate thesis format, in which the thesis is written as one or more articles to be submitted to scholarly journals. The thesis consists of two chapters: a literature review to determine range-wide habitat characteristics and a field study to determine microhabitat characteristics at a site in Dutchess County, New York. Each chapter will be submitted as a separate article to a scholarly journal. The literature review, “A Review of Habitat Use by Blanding’s Turtle (Emydoidea blandingii) and Implications for Management,” will be submitted to the journal Chelonian Conservation and Biology. The field study, “Microhabitat Selection by Blanding’s Turtles in Natural and Constructed Wetlands in Southeastern New York,” will be submitted to the Journal of Wildlife Management. Although the work is my own, both papers are co-authored with my advisor, Erik Kiviat.
# TABLE OF CONTENTS

Abstract of the Thesis ........................................ iii  
Explanation of Alternate Format .......................... vi  
Table of Contents ........................................ vii  
List of Tables ........................................ viii  
List of Figures ........................................ ix  

Literature Review: A Review of Habitat Use by Blanding’s Turtle  
(Emydoidea blandingii) and Implications for Management  
Abstract ........................................ 1  
Introduction ........................................ 2  
Literature ........................................ 4  
Discussion ........................................ 21  
Conclusions ........................................ 36  
Acknowledgements ..................................... 44  
Literature Cited ....................................... 45  

Field Study: Microhabitat Selection by Blanding’s Turtles in  
Constructed and Natural Wetlands in Southeastern New York  
Abstract ........................................ 77  
Introduction ........................................ 78  
Methods ........................................ 82  
Results ........................................ 88  
Discussion ........................................ 93  
Conservation and Management Implications ............ 101  
Acknowledgements ..................................... 103  
Literature Cited ....................................... 104  

vii
LIST OF TABLES

Literature Review: A Review of Habitat Use by Blanding’s Turtle (Emydoidea blandingii) and Implications for Management

Table 1. Blanding’s turtle status in states and provinces throughout its range  65
Table 2. Blanding’s turtle habitat use in the Great Lakes region  66
Table 3. Blanding’s turtle habitat use in the Northern United States and Nova Scotia  69
Table 4. Acreage of wetlands used by Blanding’s turtles and home ranges and activity centers of Blanding’s turtle  70
Table 5. Water quality and characteristics in Blanding’s turtle wetlands  72
Table 6. Long distance movements not related to nesting  74
Table 7. Blanding’s turtle hibernation patterns  75

Field Study: Microhabitat Use by Blanding’s turtle in Constructed and Natural Wetlands in Southeastern New York

Table 1. T-test results comparing reference and constructed plots for Blanding’s turtle-centered plots and random plots separately for each year, Dutchess County, New York, USA, 2000 – 2002  111
Table 2. Number of female, male and subadult Blanding’s turtle observations in constructed and reference (natural) wetlands in Dutchess County, New York, USA, 2001 – 2002  113
Table 3. Shrub and buttonbush cover in constructed wetland plots, Dutchess County, New York, USA, 2000 – 2002  114
LIST OF FIGURES

Literature Review: A Review of Habitat Use by Blanding’s Turtle (*Emydoidea blandingii*) and Implications for Management

Figure 1. Patterns of habitat use

Field Study: Microhabitat Use by Blanding’s turtle in Constructed and Natural Wetlands in Southeastern New York

Figure 1. Scatterplots of habitat variables in turtle-centered plots versus Julian date for Blanding’s turtles in Dutchess County, New York, USA, years 2001 and 2002

Figure 2. Scatterplots of habitat variables in turtle-centered plots versus time of day for Blanding’s turtles in Dutchess County, New York, USA, years 2000 – 2002

Figure 3. Confidence intervals on the differences in means for variables that did not overlap in 2002, plus buttonbush confidence intervals that overlapped slightly, for constructed and reference wetlands in Dutchess County, New York, USA
Abstract - We conducted a literature review of Blanding’s turtle habitat throughout its range to determine similarities and differences in habitats at the range-wide, landscape, and microhabitat scales. Throughout their range, Blanding’s turtles select wetland complexes with shallow (up to 2.5 m) water depths, organic substrates, areas of open water, and abundant vegetation. Habitat complexes consist of deeper wetlands for overwintering or drought refuge and a variety of shallow wetlands for feeding and thermoregulation. Although there are exceptions, in the Great Lakes region Blanding’s turtles tend to use ponds with abundant vegetation or herbaceous wetlands while in the Northeast turtles often use shrub swamps. Nova Scotia turtles use bays and floodplain meadows with a mixture of herbaceous and shrubby vegetation. Juvenile turtles tend to use shallower areas than adult turtles - either in the same wetlands that adults use or in different wetlands. In the Great Lakes, upland areas are generally sand, while in the Northeast they are gravelly or sandy loam. Water quality and seasonal movements varied by site, although long distances (> 1000 m) are traveled for nesting and other reasons
range-wide. Difference in wetland type and upland soils are probably related to climatic differences. Because Blanding’s turtles are very mobile and use a variety of wetlands during an individual’s lifetime, they are susceptible to loss of individual wetlands and landscape connectivity. Global warming may also put these north-temperate turtles at risk. Management recommendations include conservation of wetlands in groups, 1 km buffer zones around a Blanding’s turtle habitat complex, and corridors between complexes or known habitats beyond the 1 km zone.

**Key Words** – Reptilia; Testudines; Emydidae; *Emydoidea blandingii*; turtle; conservation; habitat fragmentation; habitat selection; landscape; management; microhabitat; range-wide; rare species; threatened species; endangered species; Canada; USA.

The Blanding’s turtle (*Emydoidea blandingii*) is listed as threatened or endangered in most of the states and provinces within its range (Table 1), which is centered on the Great Lakes region in North America (Ernst et al., 1994). Isolated relict populations exist in eastern New York, eastern Massachusetts, southern New Hampshire, southern Maine, and southern Nova Scotia (Ernst et al., 1994; A. Breisch, *pers.comm*). The Blanding’s turtle is also listed in the United States of America as a federal species of concern and is considered federally threatened in Nova Scotia (Farrar, 2003; NatureServe, 2003; Wilder, 2003). It has been extirpated from several states (Table 1). Habitat loss is considered a major threat to the Blanding’s turtle and appears to be a key factor in population declines (Kofron and Schreiber, 1985; Congdon and Gibbons, 1996; Kiviat, 1997; Piepgras and Lang, 2000; Standing, 2000; Blanding’s Turtle Recovery Team, 2003).
Habitat selection at all scales, from habitat range-wide to habitat use within wetlands, must be understood to conserve a species. Storch (1997) demonstrated this concept for a large game bird, the capercaillie *Tetrao urogallus*. As the capercaillie declined, conservation efforts focused on microhabitat features—areas within the home range that the capercaillie depended on for reproductive, sheltering, or feeding purposes. Storch showed, however, that while the capercaillie had specialized microhabitat needs, it also required large areas of rather undeveloped land. Fragmentation in the region led to increased predation and larger home range size, which probably increased energy demands (Storch, 1997). Habitat features at the landscape scale, such as fragmentation, must also be considered in order to prevent the decline of this species.

Blanding’s turtle habitat can also be evaluated on several scales: microhabitat, landscape, and range-wide (similar to Johnson, 1980). Microhabitat selection describes the habitat the turtles use within a wetland, for example feeding and basking areas or hibernation sites. Landscape selection denotes the wetland ecosystems and surrounding areas that a population of turtles uses throughout the individual turtles’ lives. Range-wide selection is defined as the geographical range of the species and describes features such as climate or surficial geology associated with habitats throughout the range.

Blanding’s turtle habitat has been studied on a landscape scale in some areas, but little is known about microhabitat or range-wide requirements. The Blanding’s turtle is a very mobile and fragmentation-sensitive turtle species (Ernst et al., 1994; Power et al., 1994; Dorff, 1995; Sexton, 1995; Kiviat, 1997; Linck and Moriarty, 1997; Piepgras and Lang, 2000; Standing, 2000; Joyal, 2001; Rubin et al., 2001). As development encroaches upon wetlands and other habitats used by Blanding’s turtles, it is essential to understand
spatial, temporal, and wetland characteristics needed to maintain viable populations. The purpose of this review is to analyze available habitat information at the microhabitat, landscape, and range-wide scale for adult and juvenile Blanding’s turtles throughout their range. We synthesize available habitat information and provide management recommendations so that researchers and managers can better protect, restore, and create habitat for Blanding’s turtles. This paper is organized in 6 categories: habitat types, vegetation characteristics, upland and wetland soils, water characteristics, juvenile and hatchling habitat, and patterns of habitat use.

LITERATURE

Habitat Types

At the landscape scale, Blanding’s turtles selected a complex of wetland and upland habitats throughout their range (Power, 1989; Ross and Anderson, 1990; Rowe and Moll, 1991; Sexton, 1995; Butler, 1997; Kiviat, 1997; Linck and Moriarty, 1997; Kingsbury, 1999; Hall and Cuthbert, 2000; Piepgras and Lang, 2000; Joyal, 2001; Rubin et al., 2001; Lang, 2003; Wilder, 2003; Hamernick and Lang, in prep). Wetlands used included: lakes, ponds, marshes, creeks, wet prairies, “sloughs,” shrub swamps, intermittent woodland pools, forested wetlands, bogs, and sluggish streams (Tables 2 and 3). “Slough” is interpreted differently in various regions of the United States. Mitsch and Gosselink (2000) defined “slough” as “an elongated swamp or shallow lake system, often adjacent to a river or stream…” Johnson (1981), Vogt (1981), Butler (1992), and Ernst
et al. (1994), cited in this paper, appeared to be referring to similar habitat. The number of wetlands used by an individual turtle varied; in Maine and Minnesota, individuals used from 1 to 6 wetlands annually (Piepgras and Lang, 2000; Joyal, 2001). This appears to be similar to other studies; however most studies did not specify the number of wetlands used by individual turtles. Size of individual wetlands ranged from 0.1 to 327 ha (Table 4). Home ranges and home range lengths also varied among sites and among individual turtles, from 0.1 to 292 ha and 90 to 5183 m, respectively (Table 4). Different methods of calculating home range size yield different results from the same data (Piepgras and Lang, 2000; Hamernick and Lang, in prep). Therefore, the home range acres cited above are approximate. Each turtle also occupied its own activity center - from 0.15 to 2.7 hectares - defined as an area of concentrated movement in a wetland, which changed through the year and sometimes overlapped with other turtles’ centers (Table 4).

Great Lakes Region. — In the Great Lakes region (including midwestern states, northwestern New York, Ontario, and Québec), Blanding’s turtle wetlands were often open marshes, ponds, or lakes containing herbaceous emergent vegetation. Of 42 references from the Great Lakes region, 38 mentioned lakes, ponds, or marshes (herbaceous wetlands) as Blanding’s turtle habitat (Table 2). Cahn (1937) and Dancik (1974) referred to “swampy floodplains.” Due to the lack of vegetation data, it is unclear whether these papers described herbaceous or wooded wetlands. Several references depicted shrub swamps as habitat. Other Blanding’s turtle habitat in the Great Lakes region included streams and ditches, temporary pools, bogs and swamps, “backwater sloughs,” and shallow, slow-moving rivers (Table 2).
Because the Blanding’s turtle is a very mobile species, the landscape surrounding the wetlands is an important aspect of its ecology, providing nesting habitat, corridors for travel, and cool or warm upland areas to escape unfavorable water temperatures. In the Great Lakes region, the upland landscape varied from forested and prairie to bare sand, often constituting a mixture of landscape features (Table 2). Many sites were associated with wetlands along shores of the Great Lakes or with river floodplains.

Northeast and Nova Scotia. — In the northeastern United States (Maine, Massachusetts, New Hampshire, and eastern New York; hereafter referred to as the Northeast), Blanding’s turtle wetlands were often shrub swamps with moats or ponded areas (Table 3). Turtles in Nova Scotia were associated with the bogs and vegetated coves of large lakes and tributary streams and rivers (Table 3). In Dutchess and Saratoga Counties (eastern New York), Maine, and Massachusetts many of the shrubby wetlands contained buttonbush (*Cephalanthus occidentalis*; scientific names of plants follow Gleason and Cronquist, 1991).

In Massachusetts, one population primarily used a riverine marsh (Graham and Doyle, 1977). Other habitats used in the Northeast were “sloughs” and oxbow marshes, temporary pools, bogs, flooded or forested swamps, floodplain ponds and wetlands, and farm ponds (Table 3). In Dutchess County, New York (hereafter referred to as Dutchess County) Blanding’s turtles also occasionally used slow-moving woodland streams (Hudsonia Ltd, unpubl. data). Upland habitat always included forested land, but could also include bare sand, shrubby areas, and meadows or meadow-like areas (Table 3). Several sites were on floodplains or very close to rivers.
Vegetation

Great Lakes Region. — The flora of the marsh habitats in the Great Lakes region included algae, stonewort (*Chara*), bladderworts (*Utricularia* spp.), common coontail (*Ceratophyllum demersum*), water scorpion-grass (*Myosotis scorpioides*), jewel-weed (*Impatiens*), water-willow (*Decodon verticillatus*), water-lilies (*Nymphaea* and *Nuphar*), water-cress (*Rorippa nasturtium-aquaticum*), white water-crowfoot (*Ranunculus longirostris*), arrow-arum (*Peltandra virginica*), common arrow-head (*Sagittaria latifolia*), cat-tails (*Typha* spp.), lesser and greater duckweeds (*Lemna minor* and *Spirodea polyrhiza*), grasses (Poaceae), pickerel-weed (*Pontederia cordata*), pondweeds (*Potamogeton* spp.), rushes (*Juncus* spp.), sedges (*Carex* spp.), soft-stem bulrush (*Scirpus tabernaemontani*), northern water-nymph (*Najas flexilis*), and water-weed (*Elodea*) (Gibbons, 1968b; Wilbur, 1975; Ballinger et al., 1979; Petokas, 1979; Kofron and Schreiber, 1985; Ross, 1987; Ross and Anderson, 1990; Rowe and Moll, 1991; Kingsbury, 1999; Hall and Cuthbert, 2000; Pappas et al., 2000). All 11 references mentioned coontail or cat-tail, with coontail often a dominant species and cat-tail sometimes dominant. Submerged vegetation was mentioned in 8 references. One that did not mention it (Ballinger et al., 1979) was not detailed enough to exclude the possibility that those wetlands also contained submerged vegetation. Shrub wetlands in the Great Lakes region contained floating liverworts (*Ricciocarpus natans* [reported as *Riccia lutescens*]), cat-tails, sedges, alder (*Alnus*), buttonbush, various-leaved swamp-cottonwood (*Populus heterophylla*), water-parsnip (*Sium suave*), willow (*Salix*), and

**Northeast and Nova Scotia.** — Eastern New York shrub swamp habitats were often dominated by buttonbush (Kiviat, 1993) or contained buttonbush in sections (Eckler and Breisch, 1988; Klemens, 1992; A. Breisch, *pers. comm*). Other shrub species in Dutchess County were: arrow-wood (*Viburnum dentatum*), highbush-blueberry (*Vaccinium corymbosum*), silky dogwood (*Cornus amomum*), and winterberry (*Ilex verticillata*) (Kiviat, 1997). Herbaceous species included filamentous algae, floating liverworts (*Riccia fluitans* and *Ricciocarpus natans*), beggar-ticks (*Bidens* spp.), bladderworts, purple loosestrife (*Lythrum salicaria*), spiny coontail (*Ceratophyllum echinatum*), water-lilies (*Nymphaea* and *Nuphar*), yellow water-crowfoot, duckweeds (*Lemna minor,* *Spirodela polyrhiza,* *Wolffia*), grasses, and pondweeds (Eckler and Breisch, 1988; Klemens, 1992; Kiviat, 1997). Cat-tail, common reed (*Phragmites australis*), sedges, and willows were sometimes present but rarely covered large areas (Kiviat, 1997).

Less information has been reported on vegetation in other parts of the Northeast. The marsh used as habitat in Massachusetts contained pondweed, free-flowered waterweed (*Elodea nuttallii*), and common coontail (Graham and Doyle, 1977). Turtles in Maine used wetland pools surrounded by shrub borders, sphagnum mats, or herbaceous emergent borders (Joyal, 1996). Common species included *Sphagnum*, sedge and three way sedge (*Carex* spp. and *Dulichium arundinaceum*), yellow water-lily (*Nuphar* sp.), buttonbush, highbush-blueberry, and winterberry (Joyal et al., 2000).

In Nova Scotia, vegetation in the floodplain meadows and bays inhabited by Blanding’s turtle included *Sphagnum*, blue-joint grass (*Calamagrostis canadensis*),

**Upland and Wetland Soils**

Throughout their range, Blanding’s turtles occupied wetlands with organic substrates, often relatively firm (Gibbons, 1968b; Graham and Doyle, 1977; Petokas, 1979; Ross, 1990; Klemens et al., 1992; Power et al., 1994; Kiviat, 1997; J. Moriarty, *pers. comm.*). Some wetlands in Nova Scotia also contained sandy substrates (Power, 1989).

Most of the Blanding’s turtle range lies north of the glacial maximum; populations in Nebraska, Iowa, central Illinois, and central Indiana are south of the maximum. In the Great Lakes region, upland soils were almost always sands (Evermann and Clark, 1920; Cahn, 1937; Schmidt, 1938a; Breckinridge, 1944; Adams and Clark, 1958; Ballinger et al., 1979; Kofron and Schreiber, 1985; Ross, 1989; Kingsbury, 1999; Pappas et al., 2000; Piepgras and Lang, 2000; Hamernick and Lang, in prep). One Indiana account described part of the upland area as gravelly sand (Evermann and Clark, 1920).
1920). In Minnesota the largest populations occurred in wetlands associated with “sandy outwash or alluvium deposits” (Dorff, 1995). In the Northeast, turtles were found in areas with upland gravelly loam soils (Kiviat et al., 1998), sandy soils (Butler, 1995), coarse sandy loam, or mixed sand and clay (Butler and Graham, 1995). In Nova Scotia, upland soils were sandy loam (Power, 1989).

**Water Characteristics**

There was no apparent difference in water quality and characteristics of Blanding’s turtle wetlands between the Great Lakes, Northeast, and Nova Scotia regions (Table 5). Blanding’s turtles were found in eutrophic water in some areas, but oligotrophic water in other areas. Wetland acidity also varied throughout their range, from alkaline to acidic. Blanding’s turtles occupied wetlands with shallow water depths, generally up to 2.5 m throughout their range. There was also no characteristic water color that prevailed throughout the turtle’s range; at some sites the water was clear, while at others it was dark or tea-colored.

**Juvenile and Hatchling Habitat**

Hatchlings and juveniles preferred shallower, more densely vegetated areas than adults at most sites. In Massachusetts, hatchlings sought hibernacula in wetlands that were more densely vegetated than those adults were usually found in, and the entry points were moderately to heavily shaded and contained *Sphagnum* and muck (Butler and
Graham, 1995). In a Nova Scotia study, however, hatchling movements were random with respect to water and no single habitat feature was sought (Standing et al., 1997), even during manipulative experiments that placed hatchlings near or far from water (McNeil et al., 2000). Hatchlings in Nova Scotia may use a random dispersal strategy for survival reasons and may overwinter in terrestrial as well as aquatic hibernacula (Standing et al., 1997), although in the laboratory Blanding’s turtle hatchlings could not withstand temperatures below –6.0 ºC (Packard et al., 2000). In addition, the open lake habitat at the Nova Scotia nest site may have been less preferred by hatchlings than the vegetated wetlands near the Massachusetts nest site (McNeil et al., 2000).

Hatchlings used a variety of forms to rest in after emergence. Forms were in: haircap moss (Polytrichum), Sphagnum, royal fern (Osmunda regalis) root clumps, little bluestem (Schizachyrium scoparium) tussocks, basal rosettes of spotted knapweed (Centaurea maculosa), leaf litter beneath sweetfern (Comptonia peregrina), brambles (Rubus sp.), leaf litter, beach cobble, roots and logs, and short-tailed shrew (Blarina brevicauda) burrows (Butler and Graham, 1995; Standing et al., 1997). Sphagnum was a preferred form substrate for hatchlings in Massachusetts (Butler and Graham, 1995). Vegetation in an emergent wetland and calcareous fen used by hatchlings in Indiana included large areas of Sphagnum, a robust forb community, dense shrubs (Salix spp. and Cornus spp.), poison-sumac (Toxicodendron vernix), red-osier dogwood (Cornus sericea), rushes (Juncus spp.), sedges (Carex spp.), shrubby cinquefoil (Potentilla fruticosa), swamp-rose (Rosa palustris), and water-lilies (Nuphar) (Kingsbury, 1999). Two yearlings in the fen spent most of their time in dense mats of bladderwort.
(Kingsbury, 1999). Several yearlings in Nova Scotia were found in dense *Sphagnum*, and several in shallow, muddy, unvegetated aquatic habitat (Standing et al., 2000).

Juveniles in Nova Scotia were found in riparian wetlands with *Sphagnum*, sweet gale, and leatherleaf (McMaster and Herman, 2000) and in certain areas within a lacustrine bog used by adult turtles (McNeil, 2002). In southeast Michigan, small juveniles used a wetland with bottlebrush sedge (*Carex comosa*) and speckled alder hummocks, while larger juveniles used sedge and open water edges, and the largest were in open water dominated by sago-pondweed (*Potamogeton pectinatus*) and duckweed (Pappas and Brecke, 1992). At a site in Dutchess County, juveniles were often captured near tussock sedge (*Carex stricta*), purple loosestrife, and young red maple (K. Munger, *pers. comm.*). Joyal et al. (2000) suggested that in Maine juveniles may be located in forested wetlands or shrub swamps, which were more heavily vegetated than the open water pools with a vegetated fringe where adults were found. In Indiana, juveniles were more likely to be in forested and shrub areas or sedge and cat-tail-sedge areas, while adults were found more often in sedge, water-lily, and floating mat areas (Kingsbury, 1999). In Nebraska, Bury and Germano (2003) found that while both adults and juveniles used small ponds and marshes, only adults used larger lakes. In Minnesota, wetlands that supported juveniles had relatively small proportions of open water compared to emergent vegetation (Dorff, 1995). At another site in Minnesota, juveniles were found in the same habitats as adults but had fewer and larger activity centers than adults and were less likely to move between wetlands (Piepgras and Lang, 2000). Piepgras and Lang (2000) did not find a difference between adult and juvenile habitat; however, turtles were considered juvenile if their carapace length was < 210 mm. Juvenile turtles in studies that noted a
difference in adult and juvenile habitat had carapace lengths of less than 155 mm (Pappas and Brecke, 1992; Kingsbury, 1999; Joyal, 2000).

With one exception (McMaster and Herman, 2000) water depth tended to increase as the turtle became older. In Indiana, yearling and hatchling turtles were typically found in shallow water less than 20 cm deep, juveniles were found in areas with 20 - 40 cm water, and adults used even deeper waters (Kingsbury, 1999). In Minnesota, juveniles occurred in water depths of 5 - 50 cm, compared with 30 - 210 cm for adults (Pappas and Brecke, 1992). At a site in Dutchess County, small juveniles were often found in shallow waters 30 – 50 cm deep, while larger juveniles were found in waters up to 80 cm deep (K. Munger, pers. comm.). Congdon et al. (2000) noted that Blanding’s juveniles captured during a study on the E.S. George Reserve in southeastern Michigan were caught in shallow areas of wetlands occupied by adults. Butler (1992) also noted that Blanding’s juveniles used shallower water than adults. McMaster and Herman (2000) attributed lack of body size - water depth correlation in Nova Scotia to lack of water depth heterogeneity in juvenile habitat at their study site.

**Patterns of Habitat Use**

**Wetland complex use**

Blanding’s turtles used wetland complexes in several ways at different sites: as a core - seasonal pattern, winter - summer pattern, or a mixture of the two. At several sites, wetland complexes consisted of core wetlands and seasonal wetlands (Ross and Anderson, 1990; Rowe and Moll, 1991; Kiviat, 1997; Barlow, 1999; Joyal, 2001; Wilder,
Core wetlands were a set of regularly used wetlands of similar habitat typically occupied during the winter, spring, early summer, and fall. They were deep enough to remain unfrozen at their bottoms, contained abundant aquatic vegetation, and ranged from ponds to emergent marshes or flooded shrub swamps with areas of deep water. Core wetlands functioned as overwintering, foraging, and thermoregulation habitat. Seasonal wetlands were used from early spring through late summer. Seasonal wetlands usually contained at least some standing water, and included deep ponds or lakes, forested wetlands, streams, ditches, and woodland pools. They apparently provided food during times of scarcity in core wetlands or peak productivity in seasonal wetlands, reduced competition, refuge from undesirable water temperatures or levels, and shelter for nesting females and traveling males.

At other sites, the majority of Blanding’s turtles exhibited a winter - summer pattern of habitat use (Power, 1989; Sexton, 1995; Lang, 2001, 2002, 2003; McNeil, 2002; J. Lang, pers. comm.). Turtles moved into overwintering wetlands in the late fall, and then quickly left them in the spring and spent the rest of the year in summer habitats. Overwintering wetlands included shrub swamps, streams, and lakes while summer wetlands included streams or stream mouths, marshes, swamps, and ponds. Overwintering wetlands provided unfrozen bottom areas, while summer wetlands provided foraging and thermoregulation habitat.

In other studies, the turtles showed a mixed pattern of habitat use, with some turtles exhibiting a core - seasonal pattern and some exhibiting a winter - summer pattern (Linck and Moriarty, 1997; Piepgras and Lang, 2000; C. Hall, pers. comm.; J. Lang, pers. comm.). In either the core - seasonal or winter - summer model, some individual turtles
may exhibit the alternate pattern. In studies lasting more than one year, individuals
sometimes switched between habitat use patterns (Hudsonia Ltd, unpubl. data; J. Lang,
pers. comm.). In addition, Blanding’s turtles are flexible and will use wetlands differently
as the wetlands change through the years. In Dutchess County, for instance, a seasonal
wetland’s hydrology was altered so that it was flooded more deeply and for a longer
period. Within a year, the turtles began using the wetland as core habitat (Hudsonia Ltd,
unpubl. data). At the Weaver Dunes in Minnesota, turtles quickly took advantage of a
rare flooding event to occupy wetlands in flooded fields (J. Lang, 2002).

**Movement Patterns**

Throughout their range, Blanding’s turtles engaged in two different types of
movement: annual home range movement and long distance sojourns (Power et al.,
1994; Butler, 1995; Kiviat, 1997; Sajwaj et al., 1998; Hall and Cuthbert, 2000; Rubin et
al., 2001; Hamernick and Lang, in prep). Annual home range movement included
movements that occurred regularly on a yearly basis, such as travel within and between
wetlands and nesting migrations by females. It was related to seasonal selection of
habitats, such as finding suitable water temperatures or levels, foraging areas,
reproductive strategies, overwintering sites, and possibly seeking refuge from
competition, and could include long distance movements, particularly by females during
nesting season. In fact, movements exceeding 1000 m were common in a Massachusetts
population (Butler, 1997). Long distance sojourns occurred on a less - than - annual basis,
were typically greater than 1000 m, and appeared to be associated with reproductive
strategies or habitat complexes becoming unsuitable for an individual. Although we have
distinguished between these two movement patterns for ease of discussion, a population
of turtles may exhibit a continuum of movement patterns from normal annual movement to long distance movements.

**Long Distance Sojourns**

Blanding’s turtles are capable of traveling long distances, which allows them to select suitable habitats within a landscape as habitats or social dynamics change. Whereas long distance movements by females were common during the nesting season, both male and female Blanding’s turtles often traveled long distances unrelated to nesting activity (Table 6). Mobile Blanding’s turtles established residency in new wetlands (Rowe and Moll, 1991; Power et al., 1994; Butler, 1995; Hall and Cuthbert, 2000; Hudsonia Ltd., unpubl. data), mated (Joyal et al., 2000), or eventually returned to their previous home ranges (Rowe and Moll, 1991).

**Annual Home Range Movement**

**Spring.** — In the spring, Blanding’s turtles emerge from hibernation and require habitats with plentiful food and opportunities for thermoregulation, such as basking sites and maximum periods of sunlight. Throughout their range, Blanding’s turtles generally become active mid-March to mid-April (Vogt, 1981; Herman et al., 1989; Rowe and Moll, 1991; Kiviat, 1993; Pappas et al., 2000; Piepgras and Lang, 2000; McNeil, 2002). Depending on the opportunities for thermoregulation and foraging or water temperatures, Blanding’s turtles spend most of their time in core wetlands, shallow seasonal wetlands, or on land. In southwestern Minnesota, Weaver Dunes, Minnesota, and Valentine National Refuge, Nebraska, turtles spent most warm days on land, sometimes in leafless woods greater than 100 m from water (Lang, 2001; J. Lang, pers. comm.). In Dutchess County, the turtles spent much of the spring in leafless buttonbush pools (Kiviat, 1997).
In Illinois, turtles at the Fox River site inhabited small ponds with sparse vegetation in May and June (Rowe and Moll, 1991; J. Rowe, pers. comm.). On the St. Lawrence River in northern New York, turtles occupied shallow water habitat from early spring to late June (Petokas, 1985). Blanding’s turtles often visited intermittent woodland pools in the springtime or early summer, probably to take advantage of abundant macroinvertebrates and amphibian larvae in a relatively small area or to bask in shallow, warm waters (Herman et al., 1989; Butler, 1995; Kiviat, 1997; Linck and Moriarty, 1997). In Dutchess County, some turtles spent time in an acidic bog (Kiviat, 1997). At Kejimkujik Lake in Nova Scotia, turtles moved downstream from their hibernation sites, probably to benefit from the warmer waters at lake margins (Power, 1989; Herman et al., 1989).

Basking is a significant component of thermoregulation for many species of turtles, including Blanding’s turtles, which bask often during the spring and summer. Basking sites are an important component of springtime habitats because water and air temperatures are cooler than in summer. In Minnesota, for example, many turtles basked in April and May while fewer basked through the remainder of the season, based on daily internal body temperatures and water temperatures (Sajwaj and Lang, 2000). In Nova Scotia, turtles were observed basking as early as March 20 (McNeil, 2002). Blanding’s turtles bask in or out of the water. Basking perches tend to be plentiful in Blanding’s turtle habitat, although their actual composition varies. Throughout their range, Blanding’s turtles basked on land, on shore within 2 m of water, steep banks of dikes and ditches, stumps, logs, piles of driftwood, matted stick piles, cat-tail debris, floating vegetation mats, sedge tussocks, *Sphagnum* hummocks, muskrat lodges, and even turtle traps (Conant, 1938; Dobson, 1971; Froom, 1976; Gilhen, 1984; Kofron and Schreiber,
1985; Rowe and Moll, 1991; Butler, 1992; Kiviat, 1993; Ernst et al., 1994; Joyal, 1996; Linck and Moriarty, 1997; Sajwaj and Lang, 2000; McNeil, 2002; Wilder, 2003; Hartwig and Kiviat, unpubl. obs.). Blanding’s turtles also rested under leaf litter or vegetation on land to escape cool waters (Rowe and Moll, 1991; Joyal, 2001), sometimes up to 40 m from the nearest wetland (Joyal, 2001). When basking in the water, the turtles remained partially submerged in neuston -- the floating layer of living and dead plant material on the water’s surface (Kofron and Schreiber, 1985; Butler, 1992; Kiviat, 1993). Blanding’s turtles at Camp Ripley preferred sheltered basking sites; for example, sedge mats or protected openings (Sajwaj and Lang, 2000).

**Nesting Season.** — In May and June (and sometimes early July), female Blanding’s turtles travel long distances to lay their eggs, often using wetlands or terrestrial sites as staging, or resting, areas. The females nested in a variety of soils, but generally chose well-drained sunny soils (Petokas, 1986; Kiviat, 1997; Linck et al., 1999; Standing et al., 1999; Lang, 2001; Blanding’s Turtle Recovery Team, 2003; Lang, 2003). Blanding’s turtles traveled between 100 m and 2900 m to lay their eggs (Linck et al., 1989; Ross and Anderson, 1990; Rowe and Moll, 1991; Herman et al., 1994; Butler, 1997; Kiviat, 1997; Joyal, 2000; Piepgras and Lang, 2000; McNeil, 2002; Farrar, 2003). Nesting females used dense vegetation or leaf litter on land, intermittent woodland pools, wooded swamps, shallow marshes, deep marshes, ornamental ponds, and open water areas as staging or rehydrating areas before and after nesting (Eckler and Breisch, 1988; Rowe and Moll, 1991; Kiviat, 1997; Sajwaj et al., 1998; Standing et al., 1999; Congdon et al., 2000; Piepgras and Lang, 2000; McNeil, 2002; Hudsonia Ltd., unpubl. data).
Summer. — During the summer, Blanding’s turtles move between wetlands while searching for food, and often travel to drought refuge habitat that provides escape from the heat or falling water levels. Drought refuges were usually ponds or lakes, or deeper portions of core wetlands (Petokas, 1985; Ross, 1987; Kingsbury, 1999; Rubin et al., 2001; J. Rowe, *pers. comm.*). In Dutchess County, these refuges were 250-900 m from the nearest springtime habitats (Kiviat, 1997). In Nova Scotia, turtles on smaller streams moved to the stream mouths on Kejimkujik Lake and spent most of their summer in the mouths, while turtles on larger rivers rarely used the lake (Herman et al., 1994); probably the smaller streams became too warm or too shallow. Another population in Nova Scotia moved upstream to an unvegetated pool and remained in channels under the bank; at this site the cove at the stream mouth dried up (McNeil, 2002).

Blanding’s turtles may increase inter-wetland movements during the summer to search for suitable foraging areas (Ross and Anderson, 1990). Turtles at a Minnesota site left their overwintering wetland, Beckman Lake, by mid-June and moved to shallower wetlands (Hall and Cuthbert, 2000), probably to feed on tadpoles and invertebrates (C. Hall, *pers. comm.*). Movement and foraging activity may also decrease or cease during hot periods (Kofron and Schreiber, 1985), as the turtles become inactive to escape warm waters or drought conditions. Blanding’s turtles remained inactive for periods of 6 hours to 21 days under herbaceous vegetation, shrub thickets, fallen logs, or leaf litter on land; or in the sediments of dry wetlands, in the silt substrate of a creek, under matted cattails, in deep pools, and in the water in red maple swamps (Ross and Anderson, 1990; Rowe and Moll, 1991; Joyal, 1996, 2001; Linck and Moriarty, 1997; Hudsonia Ltd, unpubl. data).
**Hibernation and Winter.** — In the fall, the turtles moved to suitable overwintering sites, although in Dutchess County some late-fall overland movement occurred during warm spells (Hudsonia Ltd., unpubl. data). Date of hibernation, water temperature, and water depth at hibernacula were quite variable through the geographic range (Table 7).

Blanding’s turtles often hibernated in deeper areas of a core wetland or in large ponds (Ross and Anderson, 1990; Rowe and Moll, 1991; Kiviat, 1993; Sajwaj and Lang, 2000; Kingsbury, 1999; Hall and Cuthbert, 2000). Streams were used in Nova Scotia, southwest Minnesota, and Wisconsin (Herman et al., 1989, 1994; Ross and Anderson, 1990; Lang, 2003; Wilder, 2003). In Nova Scotia, seasonally isolated pools or backwaters were also used (Power, 1989). In addition, turtles in Wisconsin hibernated in a beaver flowage at the mouth of a creek and in borrow pits (Wilder, 2003), some turtles in Massachusetts hibernated in intermittent woodland pools (B. Butler, pers. comm.), and at McGowan Lake in Nova Scotia turtles overwintered in a wooded swamp and in certain areas of their summer bog (McNeil, 2002). At some sites, Blanding’s turtles chose the deepest water available (Ross and Anderson, 1990) while at other sites the turtles chose hibernacula in shallower water than was available (Kofron and Schreiber, 1985; Rowe, 1987; Sajwaj et al., 1998).

During hibernation, Blanding’s turtles lay exposed on the substrate, sometimes under shrubs or undercut stream banks, or buried themselves in sediment, vegetation, or debris (Cahn, 1937; Carr, 1952; Kofron and Schreiber, 1985; Herman et al., 1989; Ross and Anderson, 1990; New York State Department of Environmental Conservation, 1991; Rowe and Moll, 1991; Kingsbury, 1999; McNeil, 2002). Turtles also occasionally used muskrat burrows (Cahn, 1937; Ross, 1985). Graham and Butler (1993) reported that the
turtles buried in sediment in marshes but maintained a more exposed position in ponds. They suggested that this behavior could be related to water depth; in deeper waters burrowing to avoid freezing or predation may not be necessary. In Missouri, for instance, sediment cover was up to 15 cm in 9.5 – 21 cm of water (Kofron and Schreiber, 1985). This behavior was not universal, however; in Dutchess County turtles hibernated exposed in 30-60 cm of water (Hudsonia Ltd., unpubl. data).

**DISCUSSION**

**Habitat Types**

At the landscape scale, there was a strong preference for herbaceous, marshy wetlands in the Great Lakes region and wetlands with shrub components in the Northeast and Nova Scotia. Several authors have presented evidence that Blanding’s turtles inhabited prairie regions in pre- and post-Wisconsin eras and relict populations are remnants of a prairie fauna that survived glaciation in a southwestern refuge and then migrated eastward via a “Prairie Peninsula” that formed during an arid, warm (Xerothermic) climatic period (Schmidt, 1938b; Smith, 1957; Preston and McCoy, 1971). Relict populations in Nebraska prairies and western fossil records also suggest that Blanding’s turtle was originally a prairie marsh-pond species (J. Harding, *pers. comm.*). In addition, a late Pleistocene record from southern Ontario is described as marsh-pond habitat (Churcher et al., 1990). Current distribution records suggest that the largest population of Blanding’s turtles may be in the prairie wetlands of the Valentine National
Wildlife Refuge in Nebraska (Farrar, 2003), suggesting that this may be favorable habitat.

However, an alternate hypothesis postulated that Blanding’s turtles had a pre-Wisconsin distribution in eastern North America and survived glaciation in an Atlantic coastal plain refuge (Bleakney, 1958). Recently discovered Pleistocene records from the southeastern states supported this view (Jackson and Kaye, 1974; Parris and Daeschler, 1995). Evidence that Blanding’s turtle populations in the Northeast and Nova Scotia are closer genetically to each other than to populations in the Great Lakes region (S. Mockford, *pers. comm*) may also support this hypothesis, because genetic differentiation in turtles appears to occur slowly (Starkey et al., 2003). The *dorsalis-picta* split in *Chrysemys*, for instance, may have occurred 3.5 to 2.7 million years ago; the last ice sheets retreated less than 20,000 years ago (Starkey et al., 2003).

If prairie marshes were the ancestral habitat of Blanding’s turtles and they migrated to eastern North America via a prairie peninsula, the northeastern turtles are relicts of a previous climate and vegetation. As the climate cooled and the Northeast and Nova Scotia was reforested, the turtles probably declined in number or shifted their distribution towards the Great Lakes region, isolating eastern populations. Blanding’s turtles may have then adjusted their habitat use to shrub swamps due to thermal strategies described below. An analysis of United States wetland maps indicated that Blanding’s turtles did not simply adapt to shrub swamps because they were more prominent in the Northeast; shrub swamps cover more surface area than emergent wetlands in both the Northeast and the Midwestern states (Wilen and Tiner, 1993). Comparable information for Canadian wetlands was not available. If Blanding’s turtles inhabited northeastern
North America before the Wisconsin glaciation, it is possible that they either have occupied shrub swamps in the Northeast and Nova Scotia since pre-Wisconsin times or that the Northeast’s climate and vegetation were significantly different than today, encouraging use of marshy habitats. Unfortunately, we could not find information on pre-Wisconsin Blanding’s turtle habitat or flora in the Northeast. Although the fact that the largest population in the Great Lakes region uses prairie wetlands may be indicative that these wetlands are Blanding’s turtle’s ancestral habitat, there many factors are involved in the health of a population and more paleoecological evidence is needed for this hypothesis to be conclusive.

Thermoregulation factors determined by climatic differences may strongly influence which wetland type Blanding’s turtles occupy. The Northeast receives fewer hours of sunlight than the United States portion of the Great Lakes region in May, although during other times of the year the Northeast receives the same or more sunlight than the Great Lakes region (NCDC, 2000). May, however, was an important time of the year for active thermoregulation at Camp Ripley, Minnesota (Sajwaj and Lang 2000). In areas that do not receive high amounts of sunshine or that are cooler in the spring, Blanding’s turtles may prefer wetlands that warm quickly. In the shrub ponds of Maine, Joyal (1996) found that Blanding’s turtle wetlands received more hours of sunlight than other wetlands. In Dutchess County, restricted or no surface water flow into wetlands, leafless buttonbush and tree fringe, abundant neuston, and upland gravelly soil may contribute to rapid warming of the water surface in the spring (Kiviat, 1997). Buttonbush and other shrub swamps also provide protected basking areas in shallower waters than herbaceous marshes or ponds before the shrubs leaf out.
In the Great Lakes region, Blanding’s turtles also used shrub swamps as an important component of habitat in portions of the St. Lawrence River valley, at Camp Ripley, Minnesota, and in portions of Ontario (Petokas, 1985; Piepgras and Lang, 2000; Sajwaj and Lang, 2000; F. Schueler, pers. comm.). In Ontario, many of these swamps were also buttonbush-dominated (F. Schueler, pers. comm.). While studying the thermal ecology of Blanding’s turtles, Sajwaj and Lang (2000) determined that shrub swamps, important habitat in Camp Ripley, provided significant diversity of thermal environments for the turtles. These areas are all at the northern periphery of the Blanding’s turtle range at approximately the same latitude, and presumably have cool spring climates compared to more southerly populations; climate maps indicate a general cooling trend in the spring as latitude increases (Thomas, 1953; NCDC, 2000). In addition, Ontario also appears to receive fewer hours of sunlight in May than the rest of the Great Lakes region (Thomas, 1953; NCDC, 2000). However, interpretation of sunshine hours in Canada versus the United States is difficult due to different methodologies: Canada uses a sunshine recorder to record “bright sunshine,” while the U.S. computes the “hours of sunshine observed.” Blanding’s turtles in the interior of Ontario also occupied more open, marshy wetlands (M. Oldham, pers. comm.) as well as shrub swamps. Analysis of microclimate at sites where Blanding’s turtles primarily use shrub swamps versus sites where marshes are mostly occupied would be useful.

Blanding’s turtles were found in prairie or grassland, forested, or mixed landscapes. About half of the references to landscape (Tables 2 and 3) described a mixed landscape containing forested areas and bare soil or grassland conditions. Blanding’s turtles require areas of sparse vegetation for nesting, such as prairies, grasslands,
disturbed areas, maintained lands, or agricultural fields. Forested areas, however, may provide important corridors for movement; adults and hatchlings traveled through forested areas to and from nest sites or wetlands (Butler, 1995; Standing et al., 1997; Hudsonia Ltd., unpubl. data). Forested areas also provide turtles with cool, shaded, and moist terrestrial sites in which to remain inactive during drought or high water temperatures, and warm areas to bask or escape cool waters in spring. Leaf litter from trees is an important component of detritus, the base of the food web in wetlands (Mitsch and Gosselink, 2000), and also an important food resource for the aquatic insects that may comprise 10 to 20% total volume of the turtles’ diet (Lagler, 1943; Rowe, 1992). A mixed landscape of disturbed or open, and forested, upland, therefore, may provide optimal Blanding’s turtle habitat in some regions.

Many Blanding’s turtle sites were in the floodplains or within travel distance of large rivers or lakes (Tables 2 and 3). In Illinois, Blanding’s turtle populations were often closely associated with the Mississippi and Illinois Rivers, in Indiana – the Pigeon River, in Iowa – the Des Moines River, in Minnesota – the Mississippi River, in northern New York – the St. Lawrence River, in Nova Scotia – Kejimkujik and other lakes, in Ohio – Lake Erie, and in Ontario – the Great Lakes. In New England, the turtles were generally found in association with the Merrimack River and its major tributaries (Butler, 1997). River valleys and lake basins provide aquatic travel corridors, and are also potentially locations of milder climates and more wetlands. Blanding’s turtles may use these aquatic systems as travel corridors when establishing new habitat complexes or moving to and from activity centers. Cahn (1937) mentioned that Blanding’s turtles spent time in the Illinois River. Sajwaj et al. (1998) suggested that the Crow Wing and Mississippi rivers
may be travel corridors at Camp Ripley, Minnesota, noting a sighting of a basking turtle on the Mississippi. At the Weaver Dunes in Minnesota, turtles often traveled along the edges of the Mississippi River (Lang, 2002). Movement across the Nashua River by breeding females was commonplace (Butler, 1995). Blanding’s turtle populations in Ohio were mostly associated with the marshes of Lake Erie; however, the turtles (including a hatchling) were found on islands in the lake as far as 13,500 m from the mainland (Conant, 1938; Langlois, 1964; Cormack and Cormack, 1975; King, 1988).

River and lake corridors are also less likely to have human-created barriers and are probably less dangerous than upland corridors, which often contain roads, fences, and other barriers. Therefore, Blanding’s turtle populations may be surviving near major waterbodies whereas they have been extirpated in many areas without aquatic corridors. In addition, low topography, as is generally present in river valleys and lake basins, favors formation of wetlands and their contiguity (Weakley and Schafale, 1994; Tiner, 1998). Finally, Bleakney (1958) indicated that Kejimkujik Lake provided a thermal buffer at night, providing extra warmth to Blanding’s turtle eggs at the northern periphery of their range. Numerous wetlands, easily accessible travel corridors, and moderated nighttime temperatures should provide favorable habitat for Blanding’s turtles in any part of their range.

Vegetation

Common genera or species found in Blanding’s turtle habitat in the Great Lakes region and the Northeast includes cat-tails, duckweeds, grasses, sedges, smartweeds,
bladderworts, coontails, and water-lilies. Nova Scotia shares bladderworts, sedges, and water-lilies with the Great Lakes region and the Northeast. In all regions, submerged vegetation seems to be prominent in wetlands occupied by turtles. Sexton (1995) noted that Blanding’s turtles were often located in areas of submerged vegetation. He speculated that plants such as common coontail, leafy pondweed (*Potamogeton foliosus*), stoneworts, and water-crowfoots provided mats strong enough to support the turtles (Sexton, 1995). In particular, coontail may be a preferred shelter for Blanding’s turtles, or support and shelter invertebrates or other prey. It was a dominant plant in the Great Lakes region habitats, and was also found in some of the northeastern habitats. Several studies have noted a preference for coontail by Blanding’s turtles. In Illinois, the turtles were seen foraging within coontail mats and stayed in coontail mats from July or August until dormancy (Rowe, 1987; Rowe and Moll, 1991). In Indiana, the turtles also exhibited a preference for large coontail mats, especially in the fall (Kingsbury, 1999). At the Weaver Dunes in Minnesota, rooted submerged aquatics (species not noted) and emergent vegetation were selected for (Hamernick and Lang, in prep). However, coontail was not present in turtle habitat in Nova Scotia, but other submerged aquatics were abundant (Power, 1989; McMaster and Herman, 2000) and in Dutchess County, turtles showed no affinity for coontail over other submerged vegetation (Hartwig, 2004). Throughout the Blanding’s turtle’s range, abundant submerged aquatic vegetation is selected for; species may vary between sites or regions although coontail appears to be important in the center of the Blanding’s turtle range.
Organic soils are found in wetlands used by the Blanding’s turtle throughout its range. Organic soils probably provide greater food resources for turtles than sandy wetland soils. Organic materials, especially fine particulate matter, are an important food and habitat resource for invertebrates (Evans et al., 1999). Turtles in ponds with organic substrates grew faster than those in ponds with sandy bottoms, possibly due to increased production of certain aquatic insects (Quinn and Christiansen, 1972; Moll, 1976). Organic wetland soils may also provide more stable and warmer environmental temperatures.

In the Great Lakes region, Blanding’s turtles were found mainly in areas with sandy upland soils, while in the Northeast upland soils were often sandy loam or gravelly loam. For instance, in Dutchess County Blanding’s turtle populations are associated with till-outwash soils (Kiviat, 1997). This difference may be an artifact of availability; glacial deposits of sand and silt are more prevalent in the Great Lakes region, while glacial till is more prevalent in the Northeast (Hunt, 1986). In the Great Lakes region, Blanding’s turtle populations were mostly located in sand and alluvial silt areas rather than loess, a wind deposited silt, or other surficial deposits. Loess is very fine grained, and may not have favorable thermal, moisture, or structural characteristics for turtle nests. Loess is also very productive farmland; turtle habitat may have declined in loess regions due to agricultural drainage.

The characteristics of upland soils may be an important component of Blanding’s turtle habitat. Maternal selection of nest site was an important factor in the survival and
fitness of turtle hatchlings (Wilson, 1998; Kolbe and Janzen, 2001), and was more important than physical characteristics - such as egg size or carapace length - of snapping turtle (Chelydra serpentina) hatchling survival (Kolbe and Janzen, 2001). Blanding’s turtles discontinued using a nesting site in Nova Scotia when the substrate size was reduced for human recreation (Blanding’s Turtle Recovery Team, 2003); they appear to avoid sandy sites in Nova Scotia (Power, 1989).

One of the key characteristics of sandy and gravelly soils is that they make a poor growing medium for plants (Miller and Donahue, 1995), creating sparsely vegetated potential nesting sites. Sandy and gravelly soils also warm rapidly (Miller and Donahue, 1995), presumably warming the eggs in the nest. Warm eggs develop and hatch faster (Sajwaj et al., 1998), giving hatchlings more time to find overwintering areas and to acclimatize to their new surroundings before winter. Blanding’s turtles in Nova Scotia, which often nested in cobble beaches, were probably choosing their nest sites to maximize warming at the northern periphery of their range (Standing et al., 2000).

Blanding’s turtles may also prefer cobble, gravel, or mixed sand areas in the Northeast and Nova Scotia for hydrologic reasons; the substrate may allow water to percolate more quickly than sand due to its larger pore sizes (Miller and Donahue, 1995), not drowning the eggs. Mean annual precipitation in the Great Lakes region is 51 to 76 cm, while in the Northeast it is 102 cm and in Nova Scotia it is 116 cm (Visher, 1954; GreenLane, 2004). Herman et al. (1989) also hypothesized that Blanding’s turtles may choose gravel or cobble substrate in Nova Scotia due to its greater stability, making nest construction easier. Nests constructed in sand in Nova Scotia collapsed before the turtle could deposit her eggs (L. Standing, pers. comm.). However, in at least some areas of
Massachusetts Blanding’s turtles chose “sandy” soil (but not fine sand) for nesting substrate (Linck et al., 1989; Butler and Graham, 1995; Butler, 1997).

**Water Quality**

Blanding’s turtles are often found in eutrophic water, sometimes in organic-polluted situations. For example, a Blanding’s turtle marsh in Massachusetts received most of its water from a sewage treatment plant; algal blooms were typical and indicated cultural eutrophication (Graham and Doyle, 1977). Although there was a less polluted pool in the same marsh, Blanding’s turtles were typically found in the pool receiving the effluent (Graham and Doyle, 1977). In some areas, Blanding’s turtle wetland complexes were surrounded by farmland or suburban land uses and included farm ponds (Dancik, 1974; Kofron and Schreiber, 1985; Rowe and Moll, 1991; Kiviat, 1997; Linck, 1997). These land uses were probably adding excess nutrients and other pollutants to the system. Blanding’s turtles may be able to tolerate certain types of pollution, especially organic pollution from sewage or livestock, but not the extreme amount that is associated with urbanization. Habitat fragmentation associated with residential development has been shown to adversely affect Blanding’s turtles (Dorff, 1995; Linck and Moriarty, 1997; Rubin et al., 2004). Urban and suburban situations provide more opportunities for collectors, increased exposure to automobiles, and greater habitat fragmentation. These may be more important factors than water quality in the decline of Blanding’s turtles in urban and suburban situations.
Juvenile Habitat

In much of the literature, an apparent scarcity of juvenile Blanding’s turtles has been noted (Gibbons, 1968a; Graham and Doyle, 1977; Kofron and Schreiber, 1985; Ross, 1989). Juvenile Blanding’s turtle habitats were often wetlands not occupied by adults or shallow, vegetated sections of occupied wetlands that adults did not frequent. Juvenile turtles of other species used shallower waters than adults of their species, possibly due to distribution of appropriate or abundant food resources, avoidance of fish and adult turtle predators, swimming abilities, difference in thermal preferences, and social interactions (Congdon et al., 1992; Bodie and Semlitsch, 2000). Fish, however, may not be as important predators of hatchling turtles as has previously been thought; a few studies have indicated that largemouth bass do not prey substantially on hatchling turtles (Semlitsch and Gibbons, 1989; Britson and Gutzke, 1993). Because smaller turtles are subject to higher mortality rates (Iverson, 1991), natural selection may favor young turtles that take advantage of shallow vegetated waters with abundant food resources to grow quickly (Bodie and Semlitsch, 2000). Juveniles may stay in shallow waters until body size decreases their ability to hide or vegetation density impairs their ability to escape predators (Congdon et al., 1992). Juvenile Blanding’s turtles probably have life history requirements similar to other juvenile turtles. As an example, Pappas and Brecke (1992) attributed Blanding’s juveniles’ use of shallow water and complex vegetation habitats to reduced competition with larger turtles and protection from predators. Care should be taken to include nearby shallow, vegetated wetlands or wetland sections not
associated with adult habitat when searching for juveniles or determining the impacts of development on Blanding’s turtle populations.

We found few references to *Sphagnum* in the literature on adult habitat, yet it may be a crucial plant for juveniles, at least in the Northeast and Nova Scotia. McMaster and Herman (2000) considered *Sphagnum* along with overhead vegetation cover optimal habitat for juveniles in Nova Scotia, while Butler and Graham (1995) found that hatchlings only entered wetlands in areas that contained *Sphagnum*. *Sphagnum* was also the preferred form substrate for hatchlings in Massachusetts (Butler and Graham, 1995). Because it can cover large areas, is flexible enough for a small turtle to move through but dense enough to provide cover, and stays moist, *Sphagnum* can provide optimal habitat for a young Blanding’s turtle. An exception to juvenile affinity for *Sphagnum* was in Indiana, where two yearlings were associated with dense mats of bladderworts (Kingsbury, 1999). *Sphagnum* was only available in small patches at this site, and the hatchlings may have preferred the larger area covered by the bladderwort. Younger turtles may be selecting for large areas of dense, flexible submerged vegetation in shallow water rather than a particular species.

**Patterns of Habitat Use**

**Wetland Use**

Core-seasonal and winter-summer patterns were not related to any pattern in climate or surficial geology at the coarse scale available to us on maps (Hunt, 1986; NCDC, 2000). Nor did we detect differences in wetland complexes or habitat use in the literature that explained these different habitat use patterns. Blanding’s turtles were
probably responding to differences at a finer scale than can be discerned from the literature. One possibility is that in core-seasonal scenarios, core wetlands warmed quickly in the spring, allowing the majority of the turtles to make use of these wetlands for a longer period of time. At sites that exhibit winter-summer patterns, the overwintering wetlands probably did not warm as quickly, and the turtles promptly moved to warmer waters or spent time on land. Other possible explanations include food resources or social behavior.

Movement Patterns

Long Distance Sojourns

Figure 1 is a representation of Blanding’s turtle seasonal and long-term movement patterns. Long distance movements, either non-annual sojourns or annual nesting movements, allow Blanding’s turtles to leave unsuitable or overcrowded habitat, find mates, and increase genetic diversity. While wetland complexes may originally meet food and shelter requirements, they can eventually become overcrowded or environmentally unsuitable, causing a few turtles to disperse long distances to other wetland complexes. Plummer and Shirer (1975), for instance, suggested that the softshell turtle (Trionyx muticus) explored new habitats when its home range became unsuitable. Female Blanding’s turtles traveled long distances when nesting or sometimes mating, possibly to avoid overcrowding their home range, to establish new habitat, or to effect gene flow. While many females returned to familiar nesting grounds, others occasionally pioneered new areas. For example, Congdon et al. (1983) observed that while 8 turtles remained faithful to previous nest sites, 3 turtles nested as far as 1300 m from their previous nest
sites. In Nova Scotia, certain females nested as far as 1800 m and 2000 m from their previous nesting site (Standing et al., 2000; McNeil, 2002).

These movement patterns link local populations of Blanding’s turtles, creating a metapopulation structure. In a Massachusetts study, Butler (1995) found that the “frequency of movement between wetlands ... suggest(s) that Blanding’s turtles ... comprise a single, more or less freely interbreeding meta-population as opposed to several distinct population units.” Genetic analysis of two populations in Nova Scotia also suggested a metapopulation structure; movements between the populations were common enough to maintain genetic variation but were sufficiently rare to make the two populations genetically distinguishable (Blanding’s Turtle Recovery Team, 2003). In Dutchess County, adults from several populations mingled in drought refuges or used the same nesting areas (Hudsonia Ltd, unpubl. data). The random movement of hatchlings exhibited in Nova Scotia may also be related to metapopulation maintenance. This has implications for conservation, emphasizing landscape scale features such as land use patterns and habitat fragmentation.

*Annual Home Range Movement*

Annual home range movement is also important to the conservation of this species. Inhibiting movement between habitats within a complex may be as harmful to an animal as actually destroying a wetland (Harris, 1988). Animals that require heterogeneous habitats, such as Blanding’s turtles, are particularly sensitive to loss of connectivity in the landscape (Lehtinen et al., 1999; Pope et al., 2000). In fact, wetlands surrounded by barriers (e.g., major roads, railroads, solid fences) often became unsuitable for Blanding’s turtles (Dorff, 1995). Aquatic corridors providing connectivity may
include streams and ditches (Hall and Cuthbert, 2000; Lang, 2002), and culverts under roads (Lang, 2000; Rubin et al., 2001; T. Hartwig, pers. obs). Terrestrial corridors include undeveloped, or at least roadless, forested or open areas. To allow access to resources and nesting sites and maintain contact between local populations, terrestrial and aquatic travel corridors must be intact.

Mobile animals may increase their home range size in response to development or fragmentation to meet nutritional and shelter needs (Storch, 1997). It is not clear whether this is the case for Blanding’s turtles. Development increases exposure to risks or creates barriers such as roads, curbs, solid fences, or walls. A study of turtles in two suburban preserves in the Chicago metropolitan area found that home range sizes were significantly less in the smaller preserve in late summer, probably due to a lack of natural wetland habitats as the turtles were moving longer distances to inhabit drought refuges (Rubin et al., 2001). Blanding’s turtles at the Valentine National Wildlife Refuge in Nebraska had larger home ranges than those in more populated areas (Farrar, 2003). In addition, maximum distances (not related to nesting or home range change) from the literature showed Blanding’s turtles moving longer distances at less developed sites (e.g., 1500 m at Kejimkujik National Park in Nova Scotia [T. Power, pers. comm.]; 2900 m at Camp Ripley [Sajwaj et al., 1998]; 2050 m in Maine [Joyal et al., 2001]) than they did at more developed sites (900 m in Dutchess County [Kiviat, 1997]; 722 to 1000 m in DuPage County, Illinois [Rubin et al., 2001]).

The maximum distances traveled, however, were also from the northern periphery of the range, where soils and waters may be less fertile and food less concentrated. Longer distances may be traveled in order to fulfill nutritional requirements in these
northern areas (e.g., Piepgras and Lang, 2000). In addition, a study of habitat in Weaver Dunes, Minnesota, found that Blanding’s turtles had larger home ranges in a fragmented section of the Dunes than in an unfragmented section (Hamernick and Lang, in prep). In this case, however, fragmentation of habitat was caused by a lock and dam system, which decreased vegetation productivity and therefore fragmented good habitat, rather than roads and suburban development. Blanding’s turtle home ranges in Camp Ripley, Minnesota, where habitats are widely dispersed, were larger than in other parts of their range, but were not different from a nearby population in a rapidly developing area (Piepgras and Lang, 2000 and references cited therein). Blanding’s turtle home ranges are probably larger in areas where widely spaced resources are equivalent to habitat fragmentation, but it is not clear whether suburban development increases or decreases home range size yet. Larger home ranges may require the turtles to expend more energy to meet nutritional or habitat requirements and risk road mortality, while smaller home ranges may decrease nutritional and shelter opportunities or reduce gene pool size and genetic diversity.

CONCLUSIONS

Although Blanding’s turtle habitat complexes are different in the Great Lakes region, Northeast, and Nova Scotia, they perform similar functions. Deep pools (>1 m) provide hibernacula and cool water during summer heat. Shallow waters with abundant emergent and submerged vegetation offer shelter from predators and nutrition for food resources. Organic wetland soils supply nutrients to the wetland system and may warm
the waters quickly in spring, while infertile, coarse-textured upland soils provide nesting sites. Open areas (moats, ponds, leafless shrubs, herbaceous wetlands) provide basking sites, and basking perches are supplied by emergent or submerged vegetation or fallen trees from the woody fringe. Undeveloped upland areas provide estivation sites and travel corridors between wetlands.

Conservation of the Blanding’s turtle must be considered at all habitat scales if the species is to persist amid human-induced pressures. At the microhabitat scale, Blanding’s turtles require feeding areas, basking sites, refuge sites for periods of inactivity (deep pools, dried wetlands, terrestrial sites), and overwintering sites. Juveniles and yearlings require shallow vegetated areas. Drainage or altered hydrology (through, for example, agricultural practices or residential development) may eliminate deep pools and change the chemical characteristics of the wetland. Removal of a surrounding fringe of trees may reduce basking sites or allow water temperatures to reach intolerable levels. Any human activities that affect the chemical, vegetation, or hydrologic conditions in Blanding’s turtle wetlands should be avoided.

At the landscape scale, landscape complementation effects as well as conservation of landscape corridors must be considered for species showing metapopulation dynamics and requiring the use of several habitat types (Pope et al., 2000). Landscape complementation is a measure of the availability of all critical habitats needed for a species to complete its life cycle (Dunning et al., 1992; see also Taylor et al., 1993). Critical habitat for Blanding’s turtles constitutes overwintering habitat (which varies by site), a diversity of nearby wetlands available for seasonal use, and upland areas for nesting and other life history requirements. Blanding’s turtles require wetlands with
organic substrates and abundant vegetation, generally marshes or ponds in the Great Lakes region, shrub swamps in the Northeast, and the lower reaches of rivers and bays of lakes in Nova Scotia. These habitats cannot exist in isolation; rather they must be part of a wetland complex with habitats that provide drought refuge, seasonal food resources, juvenile habitat, and thermoregulation opportunities. Upland areas surrounding the wetland complex must provide nesting sites, travel corridors between wetlands and to nest sites, cool sites for periods of inactivity when wetlands are dry or too warm, and warm sites for basking when waters are cold.

Residential development in or near Blanding’s turtle habitat complexes alters chemical and hydrologic wetland regimes, increases road mortality, exposes turtles to collectors, isolates populations, and degrades or eliminates upland habitat. Development also “subsidizes” many predators of turtle eggs and hatchlings, increasing predator densities and predation rates (Mitchell and Klemens, 2000). Raccoons are known to be a major predator of eggs in Nova Scotia (Power, 1989). Although it is thought that many of these predators - including skunks (Mephitis mephitis, Spilogale putorius), crows (Corvus spp.), opossum (Didelphis virginiana), and foxes (Vulpes vulpes, Urocyon cinereoargenteus) - have detrimental effects on turtle populations, only ravens (Corvus spp.) and raccoon (Procyon lotor) have been studied to date (Mitchell and Klemens, 2000).

Several studies have documented detrimental effects of development on Blanding’s turtle populations (Dorff, 1995; Linck and Moriarty, 1997; Rubin et al., 2001, 2004). Roads kill turtles, create barriers to gene flow, provide collectors and vandals easy access to wildlife, and increase development density (Boarman et al., 1997; Wood and
Herlands, 1997; Findlay and Bourdages, 2000; Trombulak and Frissell, 2000). (See Trombulak and Frissell (2000) for a detailed description of these and other affects.) Development and road construction near known Blanding’s turtle habitat should be restricted or avoided, or at least planned with the turtles in mind. Where development has already encroached upon Blanding’s turtle habitat, management or mitigation may be required (Joyal, 2001), with the goal of increasing or maintaining both adult survival (Congdon et al., 1993; Rubin et al., 2004) and juvenile survival (Iverson, 1991; Rubin et al., 2004). While juveniles of long-lived species are often considered less important for conservation than adults (Congdon et al., 1993), Rubin et al. (2004) argued that in threatened populations in suburban Chicago, where adult mortality was extremely low and apparently natural but populations were small, conservation of juveniles was also important.

Joyal (2001) suggested that an upland matrix surrounding a complex of wetlands is required to protect Blanding’s turtle populations. Buffer zones of at least 100 m are recommended for general wildlife and water quality protection (Environmental Law Institute, 2003); however, for a wide-ranging species like the Blanding’s turtle 100 m is clearly insufficient. For the Blanding’s turtle, a 1000 m buffer zone surrounding a wetland complex of regularly-used wetlands, rather than individual wetlands, would encompass the average home range length in most populations (Table 4). A 1000 m buffer will include most or all of the habitats used by an adult even if that individual’s home range only slightly overlaps the known habitats of the complex. We advise implementing a 1000 m buffer zone for unstudied populations throughout the geographic range. If a population can be radio-tracked for at least 2 years, this buffer zone can then
be adjusted to the actual activity areas, and aquatic and terrestrial connections to other known populations or occupied wetlands can be incorporated. If long-term studies are not possible, a 1000 m zone may represent the best compromise between scientific conservation and economic activities. Current wetland regulations do not adequately protect Blanding’s turtles. Buffer zones are not required for federally regulated wetlands in the United States, and buffer zones for state regulated wetlands in many states, including New York and Massachusetts, do not usually exceed 31 m (Montella, 1991; Riexinger, 1991; Butler, 1997; Schneider et al., 2002). In suburban areas where wetlands have been destroyed, additional wetland construction may be necessary to satisfy the turtles’ life history requirements (e.g., Kiviat et al., 2000).

Within a buffer zone, development should be avoided or planned carefully and mitigated for, and landowners should be educated about Blanding’s turtle ecology and conservation. Buffer zones need not necessarily be free of human influence; however, erring on the side of caution is appropriate. Allowing even low-impact human recreation (hiking and fishing) within the area occupied by a wood turtle population was clearly shown to detrimentally affect the turtles (Garber and Burger, 1995). New development (including road construction), for example, should be avoided within the buffer zone. If this is not possible, development should be avoided within 200 meters of a wetland complex to prevent destruction of upland habitats used for basking and summer inactivity periods. Development should also be avoided between regularly-used wetlands and between regularly-used wetlands and other habitats, including nesting areas and drought refuges. Development in other areas within the buffer zone should be planned carefully. New and existing roads should be fenced and have wide culverts so that the turtles can
cross the road safely (e.g., Lang, 2000; Farrar, 2003). In addition, “Rare Turtle Crossing”
signs can be erected during nesting season, when adult females are most at risk (e.g.,
Lang, 2000; Farrar, 2003), curbs can be angled at 45° so that turtles, including hatchlings,
can climb them rather than following them to certain death in storm drains (Piepgras et
al., 1998), storm drains can be screened to keep hatchling out, and planners can consider
gravel roads, lower speed limits, or speed bumps to slow down traffic. Females, however,
may be at risk if they attempt to nest on gravel road surfaces. Developments should be
planned to create as little increased pavement area as possible and to avoid destruction or
alteration of wetlands regardless of their size. Homeowners or public agencies should
refrain from using herbicides or weed harvesting in ponds or wetlands, because aquatic
vegetation is an important component of Blanding’s turtle habitat. Public education, in
the form of a poster campaign or a mailing, should also be implemented within the buffer
zone (e.g., Herman et al., 1998; McNeil, 2002). A poster or packet could include
information on actions homeowners can take to protect Blanding’s turtles (e.g., looking
under cars during nesting season, fencing swimming pools, covering pitfalls such as
window wells, watching carefully when mowing, leaving brush piles or creating shrub
thickets for resting turtles). Posters and mailings are also an efficient way to collect
additional information on Blanding’s turtle habitats (Herman et al., 1998; McNeil, 2002).

Certain military activities and small-scale agricultural practices within a
Blanding’s turtle buffer zone may be more compatible with turtle conservation than
suburban developments, creating disturbed land for nesting females and preserving
undeveloped land (e.g., Petokas, 1986; Linck et al., 1989; Butler, 1995, 1997; Piepgras
and Lang, 2000; Lang, 2003). Farm ponds may also provide habitat for Blanding’s turtles
(Linck, 1988) if not overly polluted. Farm or military machinery, however, may crush eggs or turtles, pesticides may damage embryos, wetlands may be drained for agricultural purposes, and agricultural or military activities may increase erosion, adding mineral sediments to the wetlands. These land uses can be either a sink or a source for Blanding’s turtle populations, depending on how they are managed. Wildlife managers should work with farmers and military bases to minimize risk to eggs or turtles during critical times of the year, generally June – September, and to avoid siltation or other damage to the wetlands. Purchase of Development Rights (PDR) programs in many states buy development rights to agricultural lands, ensuring that they remain open space. Because farms have the potential to both damage and sustain turtle and other animal populations, PDR and similar programs should take into greater consideration the affect of specific farming practices on local wildlife when accepting applications.

The Blanding’s turtle range lies generally within the 4.4ºC – 10ºC normal annual mean temperature range (Thomas, 1953; Visher, 1954). Reptiles and amphibians tend to have low dispersal rates and high sensitivity to moisture and temperature fluctuations, and may be particularly at risk of extinction under global warming conditions (Hall and Cuthbert, 2000). As the climate warms, Blanding’s turtles may be unable to tolerate temperature fluctuations beyond their current temperature range. In areas where mean annual temperature is expected to increase, Blanding’s turtles may be particularly at risk due to their low critical thermal maximum (Hutchison, 1966). Blanding’s turtle as a species is at least 5.5 million years old (Lang, 2001); and has survived global climate changes in the past. The current warming trend, however, is occurring rapidly and temperatures may increase even more quickly in the future (Cox and Moore, 1993).
Turtles may not be able to adapt or migrate quickly enough, considering current landscape fragmentation in North America (see Williams et al., 1998). Because development leads to fewer and more isolated wetlands and more roads, it decreases an animal’s ability to migrate from unfavorable environments (Findlay and Bourdages, 2000; Gibbs, 2000; Trombulak and Frissell, 2000). Large-scale corridors should be incorporated into land use planning now in order to prevent the need for more drastic measures, such as transporting populations to better habitat or keeping individuals in zoos, in the future.

It has been argued that habitat selection at coarser scales (i.e. range-wide) reflects the most important factors for an animal’s survival (Rettie and Messier, 2000). Selection at finer scales (i.e., landscape, microhabitat) will continue to reflect these factors until the next most important factors become more relevant (Rettie and Messier, 2000). If we compare Blanding’s turtle habitat range-wide, we find certain features appear in all populations studied: wetland complexes that include a variety of wetlands and open or disturbed upland areas, and sandy or gravelly soils. Wetland complexes contain: open deep pools (≥ 1 m) or ponds; shallow vegetated areas (at least 0.1 m) within wetlands, basking sites (which vary by location), and organic wetland soils. In addition, to remain viable, populations require minimum habitat fragmentation and road construction, or possibly mitigation measures such as culverts to compensate for prior development. Blanding’s turtle complexes that are unable to meet these requirements will require the turtles to expend more energy at finer scales to compensate, leading to decreased fitness and exposing individuals to higher risks (e.g., Rettie and Messier, 2000). As an example, if organic soils become silted in a Blanding’s turtle wetland, food resources may decrease
and the turtles will spend more time searching for food or may need to leave the wetland to search for more suitable habitat.

At the landscape scale, wetland complexes vary by region, and by site, to meet range-wide needs on a local basis. Wetland type, landscape, preferred vegetation, upland soils, water quality and characteristics, and patterns of habitat use all vary by region or by site. While certain wetland types or soils tend to dominate in each region, there is enough variability to justify caution in generalizing these habitat patterns to specific populations without prior research. At the microhabitat scale, basking, inactivity, drought refuge, nesting, feeding, and overwintering sites vary by location and by season or year. Therefore, temporal as well as spatial scales must be considered when studying the ecology of this species. Protection of a specific population ideally requires long-term study of that population or nearby populations judged by local experts to be using similar habitat. Two years of research, one during a dry year and one during a wet year, are probably the minimum required to gain an understanding of any population of Blanding’s turtles.

ACKNOWLEDGEMENTS

Our work was funded in part by the Geoffrey C. Hughes Foundation. This paper is part of the senior author’s thesis for the Master of Science in Environmental Studies degree at Bard College. Charlie Canham, Jeff Lang and Lorraine Standing were members of the thesis committee and provided editorial review. We thank Krista Munger, Raymond Saumure, and Lorraine Standing for earlier reviews. We also thank Jaime Hazard for editorial assistance. Finally, we thank Al Breisch, Brian Butler, Carol Hall, James
Harding, Tom Herman, Jeff Lang, Steve Mockford, James Moriarty, Krista Munger, Mike Oldham, Terry Power, James Rowe, Cory Rubin, Lorraine Standing, and Fred Schueler for their communications and insights. This is Bard College Field Station-Hudsonia Contribution 94.

LITERATURE CITED


Barlow, C.E. 1999. Habitat use and spatial ecology of Blanding’s turtles (Emydoidea blandingii) and spotted turtles (Clemmys guttata) in northeast Indiana. M.S. thesis, Purdue University, West Lafayette, Indiana.


Boarman, W.I., Sazaki, M., and Jenning, W.B. 1997. The effect of roads, barrier fences, and culverts on


68


Milwaukee Public Museum, 208 pp.


Table 1. Blanding’s turtle status in states and provinces throughout its range. State or Province

Status: E = Endangered, T = Threatened, SC= Special Concern or in need of conservation. National Heritage Status: S = Subnational; 1 = critically imperiled, 2 = imperiled, 3 = vulnerable to extirpation or extinction, 4 = apparently secure. National Heritage status is from NatureServe (2003).

<table>
<thead>
<tr>
<th>State or Province</th>
<th>Province Status</th>
<th>National Heritage Status</th>
<th>Reference for State or Province Listing</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>USA</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Illinois</td>
<td>T</td>
<td>S3</td>
<td>Center for Reptile and Amphibian Research, 2004</td>
</tr>
<tr>
<td>Indiana</td>
<td>E</td>
<td>S2</td>
<td>Center for Reptile and Amphibian Research, 2004</td>
</tr>
<tr>
<td>Iowa</td>
<td>T</td>
<td>S3</td>
<td>Center for Reptile and Amphibian Research, 2004</td>
</tr>
<tr>
<td>Maine</td>
<td>E</td>
<td>S2</td>
<td>Maine Department of Inland Fisheries and Wildlife, 2004</td>
</tr>
<tr>
<td>Massachusetts</td>
<td>T</td>
<td>S2</td>
<td>Natural Heritage and Endangered Species Program, 2004</td>
</tr>
<tr>
<td>Michigan</td>
<td>SC</td>
<td>S3</td>
<td>Center for Reptile and Amphibian Research, 2004</td>
</tr>
<tr>
<td>Minnesota</td>
<td>T</td>
<td>S2</td>
<td>Center for Reptile and Amphibian Research, 2004</td>
</tr>
<tr>
<td>Missouri</td>
<td>E</td>
<td>S1</td>
<td>Center for Reptile and Amphibian Research, 2004</td>
</tr>
<tr>
<td>Nebraska</td>
<td>SC</td>
<td>S4</td>
<td>Farrar, 2003</td>
</tr>
<tr>
<td>New Hampshire</td>
<td>SC</td>
<td>S3</td>
<td>New Hampshire Department of Environmental Services, 2004</td>
</tr>
<tr>
<td>New York</td>
<td>T</td>
<td>S2, S3</td>
<td>New York State Department of Environmental Conservation, 1991</td>
</tr>
<tr>
<td>Ohio</td>
<td>SC</td>
<td>S2</td>
<td>Center for Reptile and Amphibian Research, 2004</td>
</tr>
<tr>
<td>Pennsylvania</td>
<td>extirpated</td>
<td>S1</td>
<td>Pennsylvania Department of Conservation and Natural Resources, 2004</td>
</tr>
<tr>
<td>Rhode Island</td>
<td>extirpated</td>
<td></td>
<td>Standing, 2000 and pers. comm. cited therein</td>
</tr>
<tr>
<td>South Dakota</td>
<td>T</td>
<td>S1</td>
<td>Natural Source, 2004</td>
</tr>
<tr>
<td>Wisconsin</td>
<td>T</td>
<td>S3</td>
<td>Center for Reptile and Amphibian Research, 2004</td>
</tr>
<tr>
<td>Nova Scotia</td>
<td>E</td>
<td>S1</td>
<td>Standing, 2000 and pers. comm. cited therein</td>
</tr>
<tr>
<td>Ontario</td>
<td>No status;</td>
<td>S3?</td>
<td>Ontario Ministry of Natural Resources, 2004; Standing, 2000</td>
</tr>
<tr>
<td>Québece</td>
<td>No status;</td>
<td>S1</td>
<td>Herman et al., 1994; L. Standing, pers. comm.</td>
</tr>
</tbody>
</table>

74
<table>
<thead>
<tr>
<th>Location</th>
<th>Aquatic Habitat</th>
<th>Upland Landscape</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Illinois</td>
<td>Illinois River, tributary streams or adjacent swampy areas</td>
<td>Fields, woods, prairies, sandy areas</td>
<td>Cahn, 1937</td>
</tr>
<tr>
<td>Illinois, Des Plaines River</td>
<td>Overflow swamps, mudflats</td>
<td>Forested</td>
<td>Dancik, 1974</td>
</tr>
<tr>
<td>Illinois, Fox River, Chain O’ Lakes State Park</td>
<td>Man-made ponds, lowland marsh areas</td>
<td>Deciduous forest, prairie, farmland</td>
<td>Rowe, 1987</td>
</tr>
<tr>
<td>Illinois, Pratts Wayne Woods and West Chicago Prairie</td>
<td>Marshes, flooded timber, sedge meadows, wet prairies, ponds, and lakes</td>
<td>Suburban, agricultural</td>
<td>Rubin et al., 2001</td>
</tr>
<tr>
<td>Indiana</td>
<td>Drainage ditches, swampy ground, shallow grassy pond</td>
<td>--</td>
<td>Grant, 1936</td>
</tr>
<tr>
<td>Indiana, Jasper-Pulaski and Willow Slough Fish and Wildlife Areas</td>
<td>Wet prairie and sedge meadow</td>
<td>Oak forest, savannah, and sand prairie</td>
<td>Brodman et al., 2002</td>
</tr>
<tr>
<td>Indiana, Lake Maxinkuckee</td>
<td>Small shallow ponds, marshes, and ditches. Temporary woodland ponds</td>
<td>Deciduous woodlands</td>
<td>Evermann and Clark, 1920</td>
</tr>
<tr>
<td>Indiana (northeast), Pigeon River Fish and Wildlife Area</td>
<td>Cat-tail-sedge wetland, forested and shrub wetlands</td>
<td>Deciduous forests, Managed prairies, agricultural fields</td>
<td>Kingsbury, 1999</td>
</tr>
<tr>
<td>Michigan</td>
<td>Marshes, ponds, and river backwaters</td>
<td>--</td>
<td>Harding, 1990</td>
</tr>
<tr>
<td>Michigan (southwest), Sherriff’s Marsh and Wintergreen Lake</td>
<td>Grass-sedge marsh, eutrophic lake</td>
<td>--</td>
<td>Gibbons, 1968b</td>
</tr>
<tr>
<td>Minnesota</td>
<td>Small streams, drainage ditches, marshy places</td>
<td>--</td>
<td>Breckenridge, 1944</td>
</tr>
<tr>
<td>Minnesota, Crow-Hassan Reserve</td>
<td>Shallow emergent marshes</td>
<td>Grasslands</td>
<td>Dorff, 1995</td>
</tr>
<tr>
<td>Minnesota, Crow-Hassan Reserve</td>
<td>Wetlands with floating sedge mats and peat bottoms, mesotrophic lakes</td>
<td>Old fields, planted prairies, mesic woodlands</td>
<td>J. Moriarty, pers.comm..</td>
</tr>
<tr>
<td>Minnesota, Camp Ripley</td>
<td>Shrub swamps, deep and shallow marshes, ponds</td>
<td>Mixed hardwood and conifer forest, fields, training ranges</td>
<td>Sajwaj et al., 1998; Piepgras and Lang, 2000</td>
</tr>
<tr>
<td>Minnesota, Marget Lake Wildlife Management Area and Cedar Creek Natural History Area</td>
<td>Vegetated lakes</td>
<td>Old field, farmland, woodlots on sand plains</td>
<td>Hall and Cuthbert, 2000</td>
</tr>
<tr>
<td>Minnesota, Meadowvale</td>
<td>Ditches, restored wetlands, wetlands around ponds and lakes</td>
<td>--</td>
<td>Lang, 2002</td>
</tr>
<tr>
<td>Location</td>
<td>Aquatic Habitat Type</td>
<td>Upland Landscape</td>
<td>Reference</td>
</tr>
<tr>
<td>----------</td>
<td>----------------------</td>
<td>------------------</td>
<td>-----------</td>
</tr>
<tr>
<td>Minnesota, southwestern</td>
<td>Prairie potholes, ephemeral wetlands, streams</td>
<td>Dry terraces, cropland, dairy pasture</td>
<td>Lang, 2003</td>
</tr>
<tr>
<td>Minnesota, Weaver Dunes</td>
<td>Side channels of Mississippi River, eutrophic ponds, marshes, backwater areas, flooded deciduous woods</td>
<td>Sand terrace, agricultural crops, prairie, oak savanna</td>
<td>Pappas et al., 2000; Hamernick and Lang, in prep</td>
</tr>
<tr>
<td>Missouri</td>
<td>Preferred: natural marshes, river sloughs. Also ponds and drainage ditches</td>
<td>--</td>
<td>Johnson, 1981</td>
</tr>
<tr>
<td>Missouri, Mississippi River floodplain</td>
<td>Marsh</td>
<td>Grassland, pasture</td>
<td>Kofron and Schreiber, 1985</td>
</tr>
<tr>
<td>Nebraska</td>
<td>Lakes</td>
<td>Sandhills</td>
<td>Hudson, 1942</td>
</tr>
<tr>
<td>Nebraska</td>
<td>Lakes and marshes</td>
<td>Prairie</td>
<td>Ballinger et al., 1979</td>
</tr>
<tr>
<td>New York (northern), St. Lawrence River</td>
<td>Shrub wetlands, beaver-created wetlands and ponds, emergent-shrub marsh</td>
<td>Dairy farm pasture, forested</td>
<td>Petokas, 1979, 1985</td>
</tr>
<tr>
<td>New York, St. Lawrence River</td>
<td>Isolated coves, weedy bays, shallow, marshy waters and ponds</td>
<td>--</td>
<td>Department of Environmental Conservation, 1991</td>
</tr>
<tr>
<td>Ohio</td>
<td>Ditches, bogs, swamps, marshes associated with lakes</td>
<td>Lake plains and till plains</td>
<td>Conant, 1938</td>
</tr>
<tr>
<td>Ohio, Lake Erie</td>
<td>Marshes of Sandusky Bay, shoreline</td>
<td>--</td>
<td>Cormack and Cormack, 1975</td>
</tr>
<tr>
<td>Wisconsin</td>
<td>Open grassy marshes, backwater sloughs, prairie potholes, shallow slow-moving rivers and shallow lakes</td>
<td>Mesic prairie</td>
<td>Vogt, 1981</td>
</tr>
<tr>
<td>Wisconsin</td>
<td>Stream, marsh</td>
<td>Prairie, oak forest</td>
<td>Temple, 1987</td>
</tr>
<tr>
<td>Wisconsin, Crex Meadows Wildlife Area</td>
<td>Deep, large, permanent marshes</td>
<td>Brush prairie, pine barrens</td>
<td>Evrard and Canfield, 2000</td>
</tr>
<tr>
<td>Wisconsin, Fort McCoy</td>
<td>Ponds, borrow pits, streams, lakes, ditches, marshes</td>
<td>--</td>
<td>Wilder, 2003</td>
</tr>
<tr>
<td>Wisconsin, Pentenwell Wildlife Area</td>
<td>Ponds with abundant vegetation, ditches, streams</td>
<td>Grasslands, forested</td>
<td>Ross and Anderson, 1990</td>
</tr>
<tr>
<td>Canada</td>
<td>Shallow, marshy waters and ponds</td>
<td>--</td>
<td>Froom, 1976</td>
</tr>
<tr>
<td>Location</td>
<td>Aquatic Habitat Type</td>
<td>Upland Landscape</td>
<td>Reference</td>
</tr>
<tr>
<td>----------------------------------</td>
<td>---------------------------------------------------------------------------------------</td>
<td>------------------------------------------</td>
<td>--------------------------------------------</td>
</tr>
<tr>
<td>Ontario, Peterborough region</td>
<td>Beaver ponds, marshes or open swamps, ponds, small lakes, bays of larger lakes</td>
<td></td>
<td>M. Oldham, pers. comm</td>
</tr>
<tr>
<td>Ontario, Arden, Big Clear Lake</td>
<td>Wide, shallow, densely vegetated tributary stream</td>
<td>--</td>
<td>Saumure, 1990</td>
</tr>
<tr>
<td>Ontario, Byron Bog</td>
<td>Pond within floating bog</td>
<td>Deciduous forest</td>
<td>Judd, 1965</td>
</tr>
<tr>
<td>Ontario, Long Point</td>
<td>Marshy ponds, shallow marsh areas</td>
<td>--</td>
<td>Snyder, 1931</td>
</tr>
<tr>
<td>Ontario, Long Point, Big Creek National Wildlife Area</td>
<td>Grass-sedge wetland</td>
<td>--</td>
<td>Ashley and Robinson, 1996</td>
</tr>
<tr>
<td>Ontario, Point Pelee</td>
<td>Temporary rain pools</td>
<td>--</td>
<td>Snyder, 1921</td>
</tr>
<tr>
<td>Ontario, St. Lawrence River, Grenadier Island</td>
<td>Sedge meadow</td>
<td>Deciduous forests, abandoned farm fields</td>
<td>Petokas, 1986</td>
</tr>
<tr>
<td>Location</td>
<td>Aquatic Habitat</td>
<td>Upland Landscape</td>
<td>Reference</td>
</tr>
<tr>
<td>----------</td>
<td>----------------</td>
<td>-----------------</td>
<td>-----------</td>
</tr>
<tr>
<td>Maine</td>
<td>Marshes, shrub swamps, slow-moving rivers and streams, farm ponds, vernal pools</td>
<td>--</td>
<td>Graham, 1992</td>
</tr>
<tr>
<td>Maine, York County</td>
<td>Pools with scrub-shrub border (core), fen complex (core), scrub-shrub swamps, forested wetlands, seasonal pools</td>
<td>Deciduous – coniferous forest</td>
<td>Joyal, 1996; Joyal, 2001</td>
</tr>
<tr>
<td>Massachusetts</td>
<td>Marshes, sloughs, buttonbush swamps, temporary pools</td>
<td>Woodlands</td>
<td>Butler, 1992</td>
</tr>
<tr>
<td>Massachusetts, Concord and Sudbury Rivers, Great Meadows National Wildlife Refuge</td>
<td>Riverine marsh</td>
<td>--</td>
<td>Graham and Doyle, 1977</td>
</tr>
<tr>
<td>Massachusetts, Nashua River Valley, Fort Devens,</td>
<td>Marsh-shrub (buttonbush) swamp, floodplain buttonbush ponds, vernal pools, forested wetlands, borrow pits</td>
<td>Woodlands, bare disturbed sand, sparse herbaceous vegetation, scrub-shrub vegetation</td>
<td>Butler 1995, 1997; Butler and Graham, 1995</td>
</tr>
<tr>
<td>New York, Dutchess County</td>
<td>Shallow water-lily and buttonbush pond (core)</td>
<td>Hay and corn fields, woodlots, residential</td>
<td>Eckler and Breisch, 1988</td>
</tr>
<tr>
<td>New York, Dutchess County</td>
<td>Woodland pond (core), shrub swamp, buttonbush pond</td>
<td>Forest, meadow, maintained land</td>
<td>Klemens et al., 1992</td>
</tr>
<tr>
<td>New York, Dutchess County</td>
<td>Buttonbush swamps, intermittent woodland pools, acidic bogs</td>
<td>Hardwood forests, shrubby abandoned fields, hay, maize, cattle pasture, “waste grounds,” maintained land</td>
<td>Kiviat, 1997</td>
</tr>
<tr>
<td>New York, Saratoga County</td>
<td>Shallow ponds with buttonbush</td>
<td>Sand plains</td>
<td>A. Breisch, pers. comm</td>
</tr>
<tr>
<td>Nova Scotia, Kejimkujik National Park</td>
<td>Vegetated coves, bogs and vegetated inlets of Kejimkujik Lake, boggy marshlands associated with tributary rivers</td>
<td>Forested</td>
<td>Gilhen, 1984; Herman et al., 1989, Power, 1989; Power et al., 1994; McMaster and Herman, 2000</td>
</tr>
<tr>
<td>Nova Scotia, McGowan Lake</td>
<td>beaver-maintained vegetated bogs and coves of McGowan Lake, riverine sedge-shrub meadow</td>
<td>cottage development, forest, harvested woodlots</td>
<td>McNeil, 2002</td>
</tr>
<tr>
<td>Nova Scotia, Pleasant River</td>
<td>open and forested tributary streams, beaver-maintained riparian wetlands</td>
<td>--</td>
<td>Blanding’s Turtle Recovery Team, 2003</td>
</tr>
</tbody>
</table>
Table 4. Acreage of wetlands used by Blanding’s turtles and home ranges and activity centers of Blanding’s turtle. Mean home range lengths are in parenthesis except where mean length was the only data reported.

<table>
<thead>
<tr>
<th>Location</th>
<th>Wetland Acreage (ha)</th>
<th>Home Range (ha)</th>
<th>Home Range Length (m)</th>
<th>Activity Center (ha)</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Illinois, Chain of Lakes State Park</td>
<td>--</td>
<td>--</td>
<td>480 to 870*</td>
<td>0.4 to 2.3</td>
<td>Rowe and Moll, 1991</td>
</tr>
<tr>
<td>Illinois, Pratts Wayne Woods and West Chicago Prairie</td>
<td>--</td>
<td>0.1 to 9.8*</td>
<td>--</td>
<td>--</td>
<td>Rubin et al., 2001</td>
</tr>
<tr>
<td>Indiana, Pigeon River Fish and Wildlife Area</td>
<td>4.3 to 10.9</td>
<td>0.18 to 16.7</td>
<td>--</td>
<td>0.15 to 2.7</td>
<td>Kingsbury, 1999</td>
</tr>
<tr>
<td>Maine, York County</td>
<td>&gt; 0.4</td>
<td>--</td>
<td>90 to 2050 (680)**</td>
<td>--</td>
<td>Joyal, 2001</td>
</tr>
<tr>
<td>Massachusetts, Nashua River Valley</td>
<td>25</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>Butler and Graham, 1995</td>
</tr>
<tr>
<td>Michigan, E.S. George Reserve</td>
<td>0.4 to 0.6, 5, 7.3</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>Congdon and Gibbons, 1996</td>
</tr>
<tr>
<td>Michigan, Sheriff’s Marsh and Wintergreen Lake</td>
<td>8, 35.6</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>Gibbons, 1968b</td>
</tr>
<tr>
<td>Minnesota, Camp Ripley</td>
<td>&gt; 6, 18, 371</td>
<td>5.9 to 7.8</td>
<td>208 to 2700 (835)</td>
<td>1.5 to 2.6</td>
<td>Piepgras and Lang, 2000</td>
</tr>
<tr>
<td>Minnesota, Crow-Hassan Park Reserve</td>
<td>&lt; 0.4, 2, 8.4</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>Linck and Moriarty, 1997</td>
</tr>
<tr>
<td>Minnesota, Marget Lake and Beckman Lake</td>
<td>0.5 to 4, 8, 40</td>
<td>--</td>
<td>300 to 1000 (700)</td>
<td>--</td>
<td>Hall and Cuthbert, 2000</td>
</tr>
<tr>
<td>Minnesota, southwestern</td>
<td>28</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>Lang, 2003</td>
</tr>
<tr>
<td>Minnesota, Weaver Dunes</td>
<td>750, 1620</td>
<td>2.2 to 292</td>
<td>370 to 5183 (~1633)</td>
<td>--</td>
<td>Pappas et al., 2000; Hamernick and Lang, in prep</td>
</tr>
<tr>
<td>Nebraska, Valentine National Wildlife Refuge</td>
<td>0 to 327</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>Bury and Germano, 2003</td>
</tr>
<tr>
<td>New York, Dutchess County</td>
<td>0.1 to 7.2</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>Kiviat, 1997</td>
</tr>
<tr>
<td>New York, Dutchess County</td>
<td>6.8</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>Eckler and Breisch, 1988</td>
</tr>
<tr>
<td>New York, Dutchess County</td>
<td>0.6 to 4</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>Kiviat et al., 2000</td>
</tr>
<tr>
<td>New York, St. Lawrence River</td>
<td>40.7</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>Petokas, 1979</td>
</tr>
<tr>
<td>Location</td>
<td>Wetland Acreage (ha)</td>
<td>Home Range (ha)</td>
<td>Home Range Lenth (m)</td>
<td>Activity Center (ha)</td>
<td>Reference</td>
</tr>
<tr>
<td>----------</td>
<td>----------------------</td>
<td>-----------------</td>
<td>----------------------</td>
<td>----------------------</td>
<td>-------------------------</td>
</tr>
<tr>
<td>Nova Scotia, McGowan Lake</td>
<td>11</td>
<td>0.03 to 3.1</td>
<td>--</td>
<td>--</td>
<td>McNeil, 2002</td>
</tr>
<tr>
<td>Ontario, St. Lawrence River, Thousand Islands region</td>
<td>70</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>Petokas, 1986</td>
</tr>
<tr>
<td>Wisconsin, Fort McCoy</td>
<td>--</td>
<td>1.5 to 278</td>
<td>--</td>
<td>--</td>
<td>Wilder, 2003</td>
</tr>
<tr>
<td>Wisconsin, Pentenwell Wildlife Area</td>
<td>&lt; 0.2; ponds</td>
<td>--</td>
<td>260 to 635 (489)</td>
<td>0.56 to 0.94</td>
<td>Ross and Anderson, 1990</td>
</tr>
</tbody>
</table>

*mean distance or acreage, **distance between wetlands
Table 5. Water quality and characteristics in Blanding’s turtle wetlands.

<table>
<thead>
<tr>
<th>Location</th>
<th>Nutrient levels</th>
<th>Acidity</th>
<th>Water depth (m)</th>
<th>Water color</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Illinois, Chain of Lakes State Park</td>
<td>--</td>
<td>--</td>
<td>1.5, 2.5</td>
<td>--</td>
<td>Rowe and Moll, 1991</td>
</tr>
<tr>
<td>Indiana, Pigeon River Fish and Wildlife Area</td>
<td>--</td>
<td>--</td>
<td>1.5</td>
<td>--</td>
<td>Kingsbury, 1999</td>
</tr>
<tr>
<td>Indiana, Lake Maxinkuckee</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>Tea-colored</td>
<td>Evermann and Clark, 1920</td>
</tr>
<tr>
<td>Maine</td>
<td>--</td>
<td>--</td>
<td>&gt; 0.5</td>
<td>Dark</td>
<td>Graham, 1992; Joyal, 1996</td>
</tr>
<tr>
<td>Massachusetts, Great Meadows Refuge</td>
<td>Eutrophic</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>Graham and Doyle, 1977</td>
</tr>
<tr>
<td>Massachusetts, Nashua River Valley</td>
<td>--</td>
<td>--</td>
<td>1 to 2</td>
<td>--</td>
<td>Butler and Graham, 1995</td>
</tr>
<tr>
<td>Michigan, Sheriff’s Marsh and Wintergreen Lake</td>
<td>Eutrophic</td>
<td>Calcareous</td>
<td>--</td>
<td>--</td>
<td>Gibbons, 1968b</td>
</tr>
<tr>
<td>Michigan, E.S. George Reserve</td>
<td>--</td>
<td>--</td>
<td>1.3</td>
<td>--</td>
<td>Sexton, 1995</td>
</tr>
<tr>
<td>Minnesota, Camp Ripley</td>
<td>--</td>
<td>--</td>
<td>0.1-2; up to 4</td>
<td>Discolored</td>
<td>Sajwaj et al., 1998; Piepgras and Lang, 2000</td>
</tr>
<tr>
<td>Minnesota, Marget Lake and Beckman Lake</td>
<td>--</td>
<td>--</td>
<td>1 to 2</td>
<td>--</td>
<td>Hall and Cuthbert, 2000</td>
</tr>
<tr>
<td>Minnesota, Weaver Dunes</td>
<td>Eutrophic</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>Pappas et al., 2000</td>
</tr>
<tr>
<td>Minnesota, southwestern</td>
<td>--</td>
<td>Calcareous</td>
<td>0.25 to 0.5 (stream)</td>
<td>--</td>
<td>Lang, 2003; J. Moriarty, pers. comm.</td>
</tr>
<tr>
<td>Missouri, northeastern</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>Clear</td>
<td>Kofron and Schreiber, 1985</td>
</tr>
<tr>
<td>New York, Dutchess County</td>
<td>Oligotrophic</td>
<td>Calcareous</td>
<td>0.5 to 1.2</td>
<td>--</td>
<td>Kiviat, 1993; Kiviat, 1997; C. Galik, unpubl. data</td>
</tr>
<tr>
<td>New York, Dutchess County</td>
<td>Eutrophic</td>
<td>--</td>
<td>1; up to 4</td>
<td>--</td>
<td>Eckler and Breisch 1988</td>
</tr>
<tr>
<td>New York, St. Lawrence River region</td>
<td>--</td>
<td>--</td>
<td>2.5*</td>
<td>--</td>
<td>Petokas, 1979</td>
</tr>
<tr>
<td>Location</td>
<td>Nutrient levels</td>
<td>Acidity</td>
<td>Water depth (m)</td>
<td>Water color</td>
<td>Reference</td>
</tr>
<tr>
<td>----------</td>
<td>------------------</td>
<td>----------</td>
<td>-----------------</td>
<td>---------------</td>
<td>---------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Nova Scotia, Kejimkujik National Park</td>
<td>Oligotrophic</td>
<td>Acidic</td>
<td>0.2 to 3</td>
<td>Highly colored</td>
<td>Kerekes, 1975; Power et al., 1994; Herman, 1997; McMaster and Herman, 2000</td>
</tr>
<tr>
<td>Ontario, St. Lawrence River, Thousand Islands</td>
<td>--</td>
<td>--</td>
<td>.75</td>
<td>--</td>
<td>Petokas, 1986</td>
</tr>
<tr>
<td>Wisconsin, Pentenwell Wildlife Area</td>
<td>Eutrophic</td>
<td>Slightly acidic (pH=6.9)</td>
<td>&lt; 3 (ponds); ≤ 0.3 (marshes)</td>
<td>Highly colored</td>
<td>Ross, 1985; Ross and Anderson, 1990</td>
</tr>
</tbody>
</table>

*mean depth of creek running through marsh
### Table 6. Long distance movements not related to nesting

<table>
<thead>
<tr>
<th>Location</th>
<th>Distance (m)</th>
<th>Sex</th>
<th>Date</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Illinois</td>
<td>895 – 1400</td>
<td>Female, male</td>
<td>Late May to July</td>
<td>Rowe and Moll, 1991*</td>
</tr>
<tr>
<td>Illinois</td>
<td>722 – 1000</td>
<td>Female, male</td>
<td>--</td>
<td>Rubin et al., 2001</td>
</tr>
<tr>
<td>Maine</td>
<td>1330</td>
<td>Female</td>
<td>June or July</td>
<td>Joyal, 2000</td>
</tr>
<tr>
<td>Massachusetts</td>
<td>1000 – 1600</td>
<td>Female, male</td>
<td>--</td>
<td>Butler, 1995</td>
</tr>
<tr>
<td>Minnesota</td>
<td>2200</td>
<td>Male</td>
<td>July</td>
<td>Hall and Cuthbert, 2000*</td>
</tr>
<tr>
<td>Minnesota, Weaver Dunes</td>
<td>5632</td>
<td>Male</td>
<td>Mid-May</td>
<td>Lang, 2001*</td>
</tr>
<tr>
<td>Nebraska, Sandhills</td>
<td>~3200</td>
<td>Male</td>
<td>Late April to early June</td>
<td>Farrar, 2003*</td>
</tr>
<tr>
<td>New York, Dutchess County</td>
<td>2600</td>
<td>Female</td>
<td>--</td>
<td>Hudsonia Ltd, unpubl. data</td>
</tr>
<tr>
<td>Nova Scotia</td>
<td>5000 – 11,500</td>
<td>Male</td>
<td>--</td>
<td>Power et al., 1994</td>
</tr>
<tr>
<td>Wisconsin</td>
<td>900, 1240</td>
<td>Male</td>
<td>July</td>
<td>Wilder, 2003*</td>
</tr>
</tbody>
</table>

*Data for these turtles was only available for one year or the duration of the study was unknown; therefore we cannot be certain these were not annual movements.*
<table>
<thead>
<tr>
<th>Location</th>
<th>Water Depth, cm</th>
<th>Water Temperature, °C</th>
<th>Date</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Illinois</td>
<td>--</td>
<td>5</td>
<td>19 October to 22 November</td>
<td>Rowe and Moll, 1991</td>
</tr>
<tr>
<td>Indiana</td>
<td>30 – 50</td>
<td>--</td>
<td>--</td>
<td>Kingsbury, 1999</td>
</tr>
<tr>
<td>Massachusetts</td>
<td>3 – 110</td>
<td>9</td>
<td>October</td>
<td>Graham and Butler, 1993</td>
</tr>
<tr>
<td>Minnesota</td>
<td>40-170</td>
<td>--</td>
<td>15 November</td>
<td>Sajwaj et al., 1998</td>
</tr>
<tr>
<td>Missouri</td>
<td>10, 20</td>
<td>6.2, 7.5</td>
<td>31 October, 15 November</td>
<td>Kofron and Schreiber, 1985</td>
</tr>
<tr>
<td>New York, Dutchess Cty</td>
<td>--</td>
<td>--</td>
<td>Mid-fall</td>
<td>Kiviat, 1993</td>
</tr>
<tr>
<td>Nova Scotia</td>
<td>50 – 200</td>
<td>--</td>
<td>Mid-November or later</td>
<td>Herman et al., 1989, 1994</td>
</tr>
<tr>
<td>Ontario</td>
<td>~100</td>
<td>--</td>
<td>--</td>
<td>Schueler, 1981</td>
</tr>
<tr>
<td>Wisconsin</td>
<td>90</td>
<td>10-13</td>
<td>20 September to 22 October</td>
<td>Ross and Anderson, 1990</td>
</tr>
</tbody>
</table>
Streams
Core or Winter Nesting Habitat
Staging Upland Habitat
Wetland Habitat
Juvenile Habitat
Foraging Habitat
Intermittent Woodland Pools
Bogs
Streams
Deep Pools
Upland Habitat
Dry Wetlands
Overwintering Habitat
Deep or Shallow Water
Streams

Key:
- regular movement
- occasional movement
- core or winter wetlands
- seasonal or summer wetlands
- upland
MICROHABITAT ASSOCIATION OF BLANDING’S TURTLES IN NATURAL AND CONSTRUCTED WETLANDS IN SOUTHEASTERN NEW YORK

Tanessa Suzan Hartwig¹, Hudsonia Ltd. and Bard College Graduate School of Environmental Studies, P.O. Box 5000, Annandale on Hudson, NY, 12504, USA
Erik Kiviat, Hudsonia Ltd., P.O. Box 5000, Annandale on Hudson, New York, 12504, USA

Abstract: We studied Blanding’s turtle (Emydoidea blandingii) microhabitat in wetlands constructed for the turtles and natural wetlands in Dutchess County, New York, USA. We intended to determine Blanding’s turtle microhabitat association and the suitability of the constructed wetlands as habitat for the turtles. Microhabitat was determined by radiotracking individuals to their exact locations and recording habitat variables.

Blanding’s turtles were associated with shallow water depths (\( \bar{x} = 30 \) cm), muck substrates, and areas of abundant vegetation (total cover \( \bar{x} = 87\% \)). Buttonbush (Cephalanthus occidentalis) had the greatest mean total cover (29\%). In the constructed wetlands, Blanding’s turtles were associated with significantly less cover and warmer water than in the reference (natural) wetlands. Blanding’s turtles appear to be using the constructed wetlands to bask and forage in the spring and early summer, but move to deeper wetlands in late summer, when the constructed wetlands dry up or become too
warm, and in the winter to overwinter. For Blanding’s turtles, new habitat should contain abundant emergent vegetation (including buttonbush in Dutchess County and other areas where the turtles are known to use buttonbush swamps), deep pools and shallow water areas, neuston, and submerged aquatic vegetation. Because the constructed wetlands do not provide core habitat for the turtles, destruction or damage to core habitat for Blanding’s turtles should be avoided. Construction of new habitat near core habitat should, however, be considered, particularly where habitat has already been degraded, fragmented, or destroyed. Many other wetland animals use multiple wetland types to fulfill their life history requirements; these comments probably apply to them as well.

**Key Words:** Blanding’s turtle, conservation, constructed wetlands, *Emydoidea blandingii*, habitat, microhabitat, mitigation, New York, radiotelemetry, threatened species, wetlands.

Blanding’s turtle is listed by the New York State Department of Environmental Conservation as threatened in the state, where it occurs only in Dutchess County (southeastern New York, USA), Saratoga County (one known population; east-central New York), the eastern Ontario Lake Plain (one known population), and the St. Lawrence River Valley (northeastern New York). The disjunct Dutchess and Saratoga County populations are considered relict populations. In eastern North America, other relict populations exist in eastern Massachusetts, southern New Hampshire, southern Maine, and southern Nova Scotia (Ernst et al. 1994:240). The turtle’s range centers on the Great

---

1 hartwig@bard.edu
Hartwig

Lakes in the USA and Canada (Ernst et al. 1994:240). Habitat loss is a major threat to the Blanding’s turtle and appears to be a key factor in population declines (Kofron and Schreiber 1985, Congdon and Gibbons 1996, Kiviat 1997, Standing 2000).

Much is known about Blanding’s turtle habitat selection at the landscape scale - the wetland ecosystems and surrounding areas that the turtles use during their lives (Hartwig 2004.). Throughout their range, Blanding’s turtles tend to use a habitat complex made up of several wetlands and adjacent or non-adjacent upland areas (Hartwig 2004). In Dutchess County and in some other parts of their range, wetland complexes used by this species consist of core wetlands and seasonal wetlands (Ross and Anderson 1990; Rowe and Moll 1991; Kiviat 1997; Barlow 1999; Joyal 2001; B. O. Butler, Oxbow Wetlands Associates, personal communication). Core wetlands are regularly used by adult turtles, particularly during the winter, spring, early summer, and fall. Many of the core wetlands in the Northeast have been described as shrub swamps or ponds, often composed largely of buttonbush with areas of open water, and function as overwintering, feeding, and thermoregulation habitat (Hartwig 2004).

In contrast, seasonal wetlands are used during early spring through late summer. Seasonal wetland types are more variable than core wetlands and in Dutchess County they include intermittent woodland pools, riparian wetlands, emergent marshes, wooded swamps, acidic bogs, lakes, and ponds (J. Eckler and A. Breisch. 1988. The Blanding’s turtle (Emydoidea blandingii) in a Dutchess County Nature Conservancy Preserve, New York Field Office of the Nature Conservancy; Kiviat 1997; Hudsonia Ltd., unpublished data). Seasonal wetlands have many functions. They serve as rehydration or staging areas during nesting migrations, or drought refuges, thermoregulation areas, or feeding areas -
particularly when the core wetlands become unsuitable. Core wetlands may, for example, dry up or become overcrowded. Sluggish streams are also occasionally used as refugia from warm waters and as movement corridors (Hudsonia Ltd, unpublished data).

In many areas, Blanding’s turtle habitat is becoming increasingly fragmented, and wetlands are being degraded or destroyed. Opportunities to increase extent of Blanding’s turtle habitat, or improve its quality, should be considered, and where possible integrated into conservation and restoration programs for this species at risk. Wetland restoration, however, often ignores key ecological principles (Zedler 2000), resulting in a success rate of less than 50% and a net loss of wetlands (Mitsch and Wilson 1996, Mitsch and Gosselink 2000:680-684). Reasons for failure are many, and include improper water levels and hydroperiod (Mitsch and Gosselink 2000:681-684) and habitats dissimilar to those being replaced or inappropriate for the target species (Zedler 2000). Therefore, special attention and caution are required when restoring wetlands for a rare species such as the Blanding’s turtle.

Few published studies have monitored the success of wetland restoration in arresting the decline of rare animal species. Most research has monitored rare birds in restored salt marsh habitats, where results have indicated success (Shuwen et al. 2001), partial success (Haltiner et al. 1997, Boyer and Zedler 1998), or partial failure (Powell and Collier 2000, Darnell and Smith 2001). One study discussed the success of a restored salt marsh in increasing habitat for endangered salmon species (Tanner et al. 2002). Our study investigates the effects of a freshwater wetland restoration project on Blanding’s turtles and their habitat use and association over 3 years.
As part of a plan to expand its buildings, parking lots, and athletic fields, the Arlington Central School District in Dutchess County proposed to fill a 0.7-ha wetland used by Blanding’s turtles. The New York State Department of Environmental Conservation issued a permit to fill the wetland with the condition that 1.4 ha of suitable wetland habitat be created. In 1996, Hudsonia Ltd. (Annandale, NY) designed the wetland mitigation project as habitat for Blanding’s turtles. Part of the rationale behind Hudsonia’s participation was the opportunity to protect and study Blanding’s turtles and their habitat, and the chance to develop methods that could be used elsewhere to expand and restore habitats for this species (Kiviat et al. 2000). Construction of the new wetlands was completed in May 1997. Hudsonia has monitored the success of the mitigation project for 8 years.

Beginning in 1996, turtles were live-trapped each May in the natural (reference) and the newly created wetlands. Radio transmitters were attached to adult and subadult turtles (minimum carapace length = 174 mm), and turtles were then tracked daily through the nesting season and less frequently afterwards. Vegetation plots in the constructed and reference wetlands were surveyed each fall in 1997 and 1999. Turtle microhabitat was sampled beginning in 1999.

This paper evaluates the success of the mitigation project in creating Blanding’s turtle habitat, describes Blanding’s turtle microhabitat at the Dutchess County site, and compares microhabitat plots in reference and constructed wetlands. Previous observations have led to the development of the following 5 hypotheses: (1) Turtles in southeastern New York have an affinity for organic substrate, dense vegetation (shrubby or submerged), warm water or sunny exposed areas if water is cold, and shallow water; (2)
The constructed wetlands provide suitable aquatic habitat throughout the active season; (3) Microhabitats in constructed and natural wetlands differ in vegetation composition (due to vegetation differences between the wetlands), but are similar in vegetation structure, water temperature and water depth; (4) Purple loosestrife (*Lythrum salicaria*) is acting as a surrogate for buttonbush in the habitat structure of the constructed wetlands; and (5) Microhabitat requirements change through the year, and turtles respond by occupying different wetlands throughout the year.

**METHODS**

**Study site**

The study site consists of approximately 6 ha of pre-existing reference wetlands used as core habitat by Blanding’s turtles and 1.4 ha of constructed wetlands. The 3 pre-existing wetlands are shrub wetlands, dominated by buttonbush. Corner Swamp has a central red maple (*Acer rubrum*) swamp surrounded by buttonbush and a deep moat (maximum water depth 1 m). Southeast Swamp contains buttonbush, purple loosestrife, and other shrubs interspersed with areas of deep water (maximum 0.9 m). North Campus Pond is a little less than half buttonbush-covered with a dredged pool in its southern end. Small pools and channels are scattered among the buttonbush. Maximum depth in the dredged pool is 2.7 m; in the non-dredged section water levels can exceed 1.5 m. The three constructed wetlands (A1, A2, and B) contain wetland trees and shrubs salvaged from the filled wetland as well as planted buttonbush. Purple loosestrife is very common. Maximum water depths in the constructed wetlands are 1.0 to 1.2 m. Constructed wetlands were designed to contain both core habitat for adults and shallow areas for
juveniles. Kiviat et al. (2000) provided a detailed description of the study site and restoration project.

**Data collection**

Blanding’s turtles were collected under New York State Department of Environmental Conservation Endangered/Threatened Species License ESP03-0167. Turtles were livetrapped in hoop traps (May) or were hand captured (May and June). Radio transmitters (Advanced Telemetry Systems, Isanti, Minnesota, USA and Sirtrack, Havelock North, New Zealand) were attached to the carapace using a fast-drying epoxy, and the turtles were released. Turtles were radio-tracked to their exact location using a CE-12 receiver (Custom Electronics, Urbana, Illinois, USA) in 2000, and 2 R-1000 receivers (Communications Specialists, Orange, California, USA) in 2001 and 2002, with a hand-held Yagi antenna. A turtle’s general location was established by triangulation or occasionally by sight without the aid of telemetry. The researcher then entered the swamp and moved towards the signal if using telemetry. When the signal was strong (the turtle was close), the researcher circled the area, using the receiver to determine direction, until the turtle was seen or located. If a turtle appeared to be avoiding the researcher (e.g., signal continuously moved away from researcher) data were not collected. This occurred rarely; typically, the turtle either did not appear to be disturbed by the research activities or dropped down to the bottom sediments when the researcher approached and then swam away after a few minutes. Other researchers have noted this “drop and hide” behavior in Blanding’s turtle (Carr 1952, Gibbons 1968, Dobson 1971, Graham and Doyle 1977, Vogt 1981, Barlow 1999).
Once the turtle was located, a 3 x 3 m\(^2\) plot was sampled with the turtle at its center to determine microhabitat use. This plot size made turtle-centered plots comparable to previously established random plots in the study area. Vegetation composition was documented, and plants were identified to the species level when possible. Scientific names of plants follow Gleason and Cronquist (1991). Aerial cover of each plant species was visually estimated, and the species nearest to the turtle was recorded. Because structural and physical components of habitat may be more important to turtles than flora (Carter et al. 1999; Hamernick and Lang, in preparation), we also measured water depth to the nearest centimeter, recorded substrate type, estimated exposed soil cover, estimated cover of coarse woody debris (downed wood greater than 10 cm x 100 cm) cover, and measured water temperature to the nearest degree Celsius (2001 and 2002 only). Water depth was measured using a meter stick and water temperature was measured mid-column with a red liquid thermometer. Because we did not know where in the water column the turtle was before we disturbed it, we felt that mid-column temperature was most representative. These wetlands are generally ≤ 1 m deep, and do not appear to exhibit vertical thermal gradients apart from the neuston layer which may be warmer than the water below. Substrate type was determined visually and categorized as either muck—organic hydric soil; mud—mineral hydric soil; hummocks—usually sedge tussocks; mineral soil—sand or gravel; dead leaves; roots; logs; or a plant identified to species. Turtle-centered plots were sampled in constructed and reference wetlands from May to August in 2000, May to September in 2001, and April to October in 2002. Plots were not sampled if they overlapped with a previous plot within a season. Nesting season (June) was often underrepresented; we did not sample turtle-centered
plots due to time constraints and concern about disturbance of the females. We attempted to standardize the number of plots sampled each week; however, plot sampling was limited by the demands of the field season and the movements of the turtles into inaccessible areas, seasonal wetlands, or terrestrial habitats. Although we surveyed microhabitat in seasonal and terrestrial habitats, we did not include these samples in our analysis because our primary interest was to compare the constructed wetlands to core Blanding’s turtle habitat.

Random plots were also sampled each September in the constructed and natural wetlands to describe the wetlands used by the turtles. The plots were located in a stratified random design based on an analysis of plant communities using the plans for the constructed wetlands or aerial photographs of the reference wetlands. Comparable data collected included coarse woody debris cover and vegetation composition and aerial cover. Random plots were 3 x 3 m$^2$. Our plot sizes are comparable to those used to sample vegetation (e.g., 2 x 2 m for shrubs and 0.5 x 0.5 m for herbs [Dunn and Sharitz 1987] and turtle microhabitat (e.g., 3 m diameter circle [Carter et al. 1999]). Turtle-centered plots did not duplicate random plots.

**Data analysis**

We used Spearman rank correlations to compare variables in turtle-centered plots with time of year (2002 data only). Differences in mean microhabitat attributes of turtle-centered plots in constructed and reference wetlands were compared using Student’s t-tests with separate variance estimates and a Bonferroni adjusted significance level of $\alpha = 0.003$. Random plots in constructed and reference wetlands were also compared using t-
tests with separate variance estimates and the adjusted significance level. Data for many of the variables did not meet the t-test’s assumptions of normality or homogeneity of variances. T-tests, however, are fairly robust to non-normal distributions (McBean and Rovers 1998:179) and separate variance estimates were used to account for heterogeneity of variances. Adjusting the significance level also helped to correct for effects of non-normality. Because transformations did not improve data distributions, raw data were analyzed.

Another possible problem was the potential lack of independence of our sample units, which increases the probability of rejecting the null hypothesis when there is no difference (Type 1 error). Between individuals, we believe dependency is a negligible problem because Blanding’s turtles are not known to exhibit territoriality or parent-offspring relations. Within individuals, we reduced autocorrelation by requiring a minimum of two days before re-sampling an individual turtle. Other microhabitat studies of turtles have considered 1 or 3 days between samples adequate to reduce autocorrelation (Nieuwolt 1996, Carter et al. 1999). In addition, lack of independence typically results in underestimating the true variance (Erickson et al. 2001). Our variances are quite large, ranging from 21 to 2087 (Hudsonia Ltd., unpublished data). Our conservative $\alpha$ also helped to prevent Type 1 errors.

We also examined whether microhabitat use differed within reference versus constructed wetlands. We used the difference in a habitat variable between random plots in the reference vs. constructed wetlands to establish the null pattern. When the difference in a habitat variable between turtle-centered plots in the reference vs. constructed wetlands mirrored the null pattern found in the random plots, we concluded
that there was no evidence of difference in microhabitat association between reference and constructed wetlands (i.e., that the turtles were simply using the habitats in proportion to their abundance in the wetlands as a whole). Because turtle-centered plots and random plots were surveyed at different times of the year, we could not compare the variables with t-tests directly; instead, we computed bootstrapped 90% confidence intervals on the differences in turtle-centered plots between reference and constructed wetlands. We did the same for the differences in the random plots from reference and constructed wetlands for each variable. When the bootstrapped confidence intervals for the differences between reference and constructed wetlands for the turtle-centered versus random plots did not overlap, we considered this evidence of significant differences in turtle association with habitat in the two types of wetlands, and not a reflection of background habitat differences between constructed and reference wetlands. We used confidence intervals of 90% because lack of overlap in confidence intervals is considered a conservative method to test for differences. Bootstrapping was performed using Systat (Version 9 [1998], SPSS Corp., Chicago, Illinois, USA). All other statistical analyses were performed using Statistica (Version 6 [2003], Statsoft, Inc., Tulsa, Oklahoma, USA).

To determine whether the turtles are associated with microhabitat in relation to vegetation structure we combined species into 8 cover types: (1) total (all plant species, vascular and non-vascular), (2) graminoids (grass-like species, including grasses [Poaceae], sedges [Cyperaceae], and rushes [Juncaceae]), (3) herbs (forbs and graminoids), (4) shrubs, (5) woody vegetation (trees, shrubs, and woody vines), (6) shrubs and purple loosestrife combined, (7) neuston (the floating layer of plant material,
including dead material and algae, on the water’s surface) and (8) submerged aquatic vegetation (submerged rooted vegetation). Shrubs and trees included any species taxonomically considered a tree or a shrub by Gleason and Cronquist (1991). Shrub and purple loosestrife cover was combined to facilitate testing of the hypothesis that loosestrife is acting as a surrogate for buttonbush in the constructed wetlands. Vegetation structure may be more influential than specific plant species in predicting habitat selection for many animals; however, flora may also play an important role (Morrison et al. 1998). Therefore we also analyzed buttonbush, purple loosestrife, floating filamentous algae, watercelery (*Vallisneria americana*), and the floating liverwort (*Riccia fluitans*) because examination of nearest species and means of percent cover, and comparison of constructed and reference plots, indicated possible microhabitat association by the turtles for these taxa. Purple loosestrife is also considered an invasive wetland plant in the USA and therefore warrants attention wherever it is present at a research site.

**RESULTS**

Twelve turtles (1 subadult, 8 females, and 3 males) were studied in 2000, 14 (2 subadults, 9 females, and 3 males) in 2001, and 17 (1 subadult, 8 females, and 8 males) in 2002; a total of 21 turtles were studied over the three years. Seven females and 2 males were studied in all 3 years. Forty-nine turtle-centered plots were sampled in 2000 (4 subadult plots, 39 female plots, and 6 male plots), 71 in 2001 (11 subadult plots, 43 female plots, and 18 male plots), and 102 in 2002 (11 subadult plots, 56 female plots, and 35 male plots). The number of plots in a single month varies from 3 to 35. Because the greatest numbers of plots and individual turtles were sampled in 2002, we have
Hartwig emphasized the interpretation of 2002 results, particularly for the statistical and seasonal analyses.

Ninety-two species of plants were found in turtle-centered plots. Buttonbush was the dominant species with a mean percent cover of 29%. Other individual species represented less than 9% each of the mean cover in turtle centered plots. Most (80%) represented less than 1% of the total vegetation cover within each plot.

T-tests indicate that although water depth differed in 1 of 3 years between the reference and constructed wetlands, turtles used areas of similar depth in the reference and constructed wetlands in all years (Table 1). The water in random plots in the reference wetlands was deeper than in the constructed wetlands in 2002, but was non-significantly different in 2000 and 2001 (Table 1). Mean depth in all turtle-centered plots for the 3 years was 30 cm ($n = 223$, min = 0 cm, max = 110 cm, SD = 22 cm). Mean depth in reference turtle-centered plots was 28 cm ($n = 146$, min = 0 cm, max = 100 cm, SD = 20 cm) and mean depth in the constructed turtle-centered plots was 34 cm ($n = 77$, min = 0 cm, max = 110 cm, SD = 25 cm).

Although turtles occupied areas of similar depth in the reference and constructed wetlands, we noted differences in microclimate association between the turtle-centered plots in the constructed and reference wetlands. Water temperature was higher in constructed wetlands than in reference wetlands from late June through early August 2002 (Figure 1). In 2002, water in turtle-centered plots was significantly warmer in the constructed wetlands than in the reference wetlands (Table 1; $n = 29$ constructed wetland plots and 60 reference wetland plots). Mean water temperature in turtle-centered plots for both wetland types was 22°C ($n = 134$, min. = 8°C, max. = 35°C, SD = 5°C; data collected
Hartwig

in 2001 and 2002 only). Mean water temperature in reference turtle-centered plots was
21°C (n = 97, min = 8°C, max = 35°C, SD = 5°C). Mean water temperature in constructed
turtle-centered plots was 23°C (n = 37, min = 13°C, max = 30°C, SD = 5°C).

Muck was the most commonly observed substrate type in both reference and
constructed wetlands. In the reference wetlands, muck was the substrate type for 78%
(113 of 146) of observations. In August and September, the turtles were sometimes found
half buried to completely buried under 2 to 10 cm of muck in the reference wetlands and
once in a constructed wetland. Other substrate types in reference wetlands were:
hummocks (10%), mud (5%), dead leaves (5%), roots (2%), and spike-rush (*Eleocharis*
*acicularis*, 1%). In the constructed wetlands, substrate type was muck for 49% (37 of 76)
of observations. In late summer, a turtle was found buried in muck once in a constructed
wetland. Other substrate types in constructed wetlands were: mud (30%), hummocks
(9%), mineral soil (7%), logs (3%), dead leaves (1%), and roots (1%).

In the reference wetlands, turtles were found most often in association with
buttonbush (38% of observations) or *Riccia fluitans* (10% of observations; n =147). In
the constructed wetlands, turtles were found most often in close association with purple
loosestrife (51% of observations) or watercelery (10% of observations; n = 72). Average
total cover of plants in both constructed and reference wetlands for all 3 years in turtle-
centered plots was 87%.

There was a difference in habitat association by females, males, and subadults at
the wetland complex scale but no consistent difference at the microhabitat scale. In 2001,
buttonbush cover was greater at the locations of 9 females compared to those of 3 males
(n = 43 observations of females and 18 observations of males, t = 4.04, P ≤ 0.001). In
2002, filamentous algae cover was greater at the locations of 8 males compared to those of 8 females ($n = 56$ observations of females and 35 observations of males, $t = 3.45, P = 0.001$). These patterns did not occur in other years. At the wetland complex scale, females were more likely to use the constructed wetlands than males. In both 2001 and 2002, the ratio of female to male microhabitat observations was higher in the constructed wetlands than in the reference wetlands (Table 2). Total female to male observations was similar to female to male observations in the reference wetlands, indicating that both sexes spent equal amounts of time in the reference wetlands (Table 2). Year 2000 data were not considered because there were only 6 microhabitat observations of males. Also, because we only had data for two subadults (one individual in 2000 and another individual in 2001 and 2002), we could not compare subadult microhabitat use to adult use. The subadult (CL ≈ 182 mm) we tracked in 2001 and 2002 spent more time in the constructed wetlands than in the reference wetlands (Table 2); we only recorded 4 observations (all in reference wetlands) for the subadult (CL = 174 mm) tracked in 2000.

Although most habitat variables were not significantly correlated with time of year, several variables showed interesting seasonal peaks (Figure 1). Turtle use of submerged vegetation peaked in late July and August in 2001 and 2002 (Figure 1). In 2001, 14 turtles (9 females, 3 males, 2 subadults) were in the reference wetlands during these months; however, in 2002, 14 turtles (7 females, 6 males, and 1 subadult) spent time in the reference wetlands and 5 turtles (4 females, 1 male) spent time in the constructed wetlands (Figure 1). In the constructed wetlands, most of the submerged vegetation was water celery (Figure 1); from 23 July to 31 July 2002, 3 females were
located in areas of high cover consisting mainly of water celery. In the reference wetlands, most of the submerged vegetation was filamentous algae (Figure 1).

Graminoid use also peaked during the summer (Figure 1). In the reference wetlands, turtles used graminoid cover most often in late July to early August 2001 and in August 2002. During this time, radioed turtles were not in the constructed wetlands, even though the availability of graminoid cover did not differ significantly between the constructed and reference wetlands (Table 1). Graminoids in turtle-centered plots in the reference wetlands were primarily spike-rush in 2001 and spike-rush and grasses (Poaceae) in 2002.

For most of the time the turtles were in the constructed wetlands, herb cover was greater than in the reference wetlands (Figure 1). Turtles were associated with neuston, in particular *Riccia fluitans*, between approximately 1130 h and 1600 h, while coarse woody debris use peaked at approximately 1100 h and then gradually decreased to zero by 1650 h (Figure 2). This pattern occurred throughout the season, but was not as apparent in August and September. Water depth in turtle-centered plots showed a non-significant decrease throughout the day (Figure 2).

In all 3 years, the turtles in the constructed wetlands consistently used total cover, shrub cover, and buttonbush cover less than turtles in the reference wetlands (Table 1). However, if buttonbush cover is removed from the shrub cover, shrub cover is no longer significantly different (Table 1); it appears that the turtles were favoring buttonbush, rather than other shrub species. In addition, in 2002, the turtles in the constructed wetlands used neuston, woody vegetation, and shrub-loosestrife cover significantly less than turtles in reference wetlands (Table 1). Woody vegetation, however, is also no
longer significantly different when buttonbush is removed (Table 1), again indicating an association with buttonbush by the turtles. Based on the random plots, reference wetlands were significantly higher in buttonbush cover for all three years than the constructed wetlands (Table 1).

By comparing confidence intervals and means (Figure 3), we determined that turtle locations:

1. were positively associated with algae and buttonbush in the reference wetlands
2. were negatively associated with herb cover and purple loosestrife cover in the constructed wetlands
3. were negatively associated with herb cover in the reference wetlands and neither negatively or positively associated with purple loosestrife in the reference wetlands
4. were positively associated with high total cover and high shrub-loosestrife cover in reference wetlands but were negatively associated with these variables in constructed wetlands, and
5. were positively associated with water celery in the constructed wetlands.

Although the confidence intervals did overlap slightly for buttonbush cover, indicating no association, we believe the turtles are favoring buttonbush because analyses discussed above also indicated association.

**DISCUSSION**

In Dutchess County, New York, Blanding’s turtles generally are associated with waters between 0 and 110 cm in depth with muck substrates and dense vegetation cover during the active season. Turtles often are associated with vegetation cover consisting of
buttonbush, submerged vegetation, or neuston. This supports our original hypothesis that Blanding’s turtles in southeastern New York are found in areas with organic substrates, dense submerged or shrubby vegetation cover, and shallow waters. Turtles were found in similar water depths in the constructed and reference wetlands and microhabitat association changed through the season, as we hypothesized.

We also hypothesized that the turtles seek warm water or sunny exposed areas in cold water. This idea is supported by our data, although lack of random water temperature data requires the use of circumstantial evidence. Use of neuston increased at about the same time during the day that use of coarse woody debris decreased. The turtles bask on logs in the early morning and then use neuston by late morning as the sun warms the pool surface. Turtles in Minnesota exhibited a similar pattern; on sunny days the turtles basked on land during mid-morning, quickly raising their body temperatures, and then switched from land to water later in the day to maintain a body temperature of 32.5°C (Sajwaj and Lang 2000). In Dutchess County, this pattern was not as strong in August and September, probably because the turtles were seeking refuge from the heat in cool waters or burying in the muck. Similarly, in Minnesota most turtles did not bask in late summer and early fall (Sajwaj and Lang 2000). The neuston, most of which in this study area is the duckweed-like *Riccia fluitans*, may provide good camouflage for the turtles, similar to the camouflage effect noted for duckweeds (family Lemnaceae; Ross and Lovich 1992). Duckweeds are an important habitat for macroinvertebrates (Gaston 1999), and this might also be true of *Riccia*. By spending time in neuston, which also includes algae and detritus, Blanding’s turtles may be able to conserve energy by basking and foraging simultaneously (Kiviat, personal observation).
Piepgras et al. (1998) and Barlow (1999) described Blanding’s turtle habitat association at the microhabitat scale in the Great Lakes region. In Indiana, floating mats of sedges (*Carex* spp.), rushes (*Juncus* spp.), and water-willow (*Decodon verticillatus*) had the greatest relative use by Blanding’s turtles, followed by sedge and waterlily (*Nuphar* spp. and *Nymphaea* spp.) areas (Barlow 1999). In Minnesota, shallow water depths (about 55 cm) and dense vegetation (in particular narrow-leaved cat-tails [*Typha angustifolia*] and sedges [*Carex* spp.]) were more abundant in turtle microhabitats than in random plots (Piepgras et al. 1998). The water depth associated with turtles in Duchess County was shallower for all three years combined (\( \bar{x} = 30 \text{ cm} \)) than in Minnesota; however turtles at our study site were found in varying water depths (53 cm in 2000, 20 cm in 2001, and 27 cm in 2002) and may partly depend on year-to-year water level variation in the wetlands. In Dutchess County, Blanding’s turtles also appear to prefer dense vegetation cover, usually provided by buttonbush rather than sedges or cat-tails. In late summer 2001 and 2002, graminoid cover as well as buttonbush cover was high in turtle-centered plots (Figure 1). Possibly, water levels were decreasing in the shrubby sections of the wetlands and some turtles moved to the deeper emergent areas, where water may have been cooler and invertebrate densities may have been higher (Voigts 1976, Sharitz and Batzer 1999, Hamernick and Lang in preparation).

Blanding’s turtles may be found in association with certain plants because they provide support and structure, or feeding and thermoregulation opportunities. In Michigan, for example, Blanding’s turtles remained in areas of submerged vegetation in a shallow pond (maximum water depth 1.3 m) and avoided filamentous algae (Sexton 1995). Sexton speculated that the association between turtles and plants such as coontail
(Ceratophyllum), leafy pondweed (Potamogeton foliosus), stoneworts (Chara), and white water-crowfoot (Ranunculus longirostris) was because these plants, unlike the filamentous algae, provide mats strong enough to support the turtles (Sexton 1995).

Turtles in Duchess County (this study) do not appear to use these plants as frequently as the turtles in Michigan even though coontail and pondweeds are widely available in wetlands at the study site. The turtles in Dutchess County were associated with filamentous algae in the reference wetlands (Figure 3) and possibly watercelery in the constructed wetlands. The turtles were associated with algae and water celery in shallower areas (mean water depth in plots with algae = 0.32 m, \( n = 59 \); mean water depth in plots with watercelery = 0.34 m, \( n = 26 \)) than may have been available in most of the Michigan pond. In the Dutchess County wetlands, coontail, pondweeds, and stoneworts are often found in deeper water than algae and watercelery (T. Hartwig, personal observation).

In shallow water depths, filamentous algae may offer other benefits for the turtles, such as more food resources, a warmer microclimate, or cover from predators. Submerged aquatic vegetation is known to harbor high densities of macroinvertebrates (Yozzo and Diaz 1999, Gaston 1999); snail and other macroinvertebrate densities are also high in filamentous algae (Elwood et al. 1981, Euliss et al. 1999, Evans et al. 1999). Snails and other macroinvertebrates are a primary food source for Blanding’s turtles (Lagler 1943, Rowe 1992, Blanding’s Turtle Recovery Team 2003), although snails were not a large source in Michigan (Lagler 1943). At our site, turtles in reference wetlands were often found in beds of algae at the edge of buttonbush patches (mean buttonbush cover in turtle-centered plots with algae = 33% \( n = 47 \), min. = 0%, max. = 90%, SD =
Hartwig

32]; plus T. Hartwig, personal observation). Constructed wetlands in which the turtles used water-celery did not support large beds of coontail, pondweeds, or stoneworts. Many of the water-celery beds were also near large pieces of coarse woody debris, although they were not always in the turtle-centered plots (T. Hartwig, personal observation). These areas probably provided nearby cover and abundant food resources in shallow warm waters. In both reference and constructed wetlands, the turtles were apparently favoring shallow, warm waters, abundant aquatic vegetation with its associated macroinvertebrates, and nearby cover; association of structure was probably more important to the turtles than association with particular species of submerged vegetation.

In our study, turtles were associated with areas with less vegetation cover and warmer water temperatures in the constructed wetlands. This is contrary to our original hypothesis, which stated that the turtles would be found in areas of similar vegetation structure and water temperature. Blanding’s turtles used the constructed wetlands as basking areas, particularly in the spring and early summer. Other studies (e.g. Sajwaj and Lang 2000) have also reported Blanding’s turtles basking more in spring and early summer. In our study, turtles were found in areas with less total cover and less shrub-loosestrife cover in the constructed plots (Figure 3). Areas with less total cover and less tall vegetation cover (e.g. shrubs or loosestrife) potentially receive more sunlight and provide basking opportunities for the turtles, as indicated by the fact that turtles in the constructed wetlands were found in areas with warmer water temperatures than turtles in the reference wetlands (Table 1).
Females basked in the constructed wetlands more often than males, and females moved into these wetlands before and after nesting. Constructed wetlands were near (~10 m) many nest sites. We frequently observed females basking in the spring. Females at our site may bask more often in the spring to facilitate egg development before nesting, as they also apparently do in Nova Scotia (Standing et al., 1999; Blanding’s Turtle Recovery Team, 2003). Power (1989) also noted that females may move to warm waters in the spring to complete egg development. Although in Figure 1 a clear difference in water temperature is only seen after Julian date 170 (late June) we feel that this pattern also probably exists in early spring. The reproductive cycles of Blanding’s turtles, however, are not well studied (Ernst et al. 1994) and the timing of egg production is unknown. A Minnesota study found no difference in basking behavior between females and males in the spring but found that females basked more than males in the fall, indicating that egg production may occur then (Sajwaj and Lang 2000).

Blanding’s turtles in the Northeast may prefer buttonbush to other shrubs because its late leaf-out provides protected basking areas in the early spring and its dense, low cover provides shade and shelter in the summer. Blanding’s turtles were associated with buttonbush cover in the reference wetlands, as determined by the confidence intervals on the differences in means, which overlapped only slightly (Figure 3). Conversely, the greater overlap in the confidence intervals for the total shrub cover indicates no association with shrub cover by the turtles in the reference or constructed wetlands. In the constructed wetlands, shrub cover has increased over the years (Table 3) and by 2002 there was no difference in shrub cover between reference and constructed wetlands (Table 1). Buttonbush, which grows slowly, did not show such a large increase in the
constructed wetlands (Table 3). Interestingly, turtle use of shrubs actually decreased in constructed wetlands but turtle use of buttonbush in constructed wetlands increased slightly in 2002 compared to previous years (Table 3).

We hypothesized that purple loosestrife in the constructed wetlands plays the role that buttonbush does in the reference wetlands because we often saw turtles beneath lodged (fallen-over) loosestrife stems. Although our field observations suggest that the turtles do not entirely avoid loosestrife (turtles were seen under dead loosestrife 7 – 9 times each year), the confidence intervals on the means did not overlap in 2002 (Figure 3), indicating that turtles were not associated with loosestrife in either constructed or reference wetlands. Turtles were often found under overhanging plants, including marsh fern (*Thelypteris palustris*), purple loosestrife, tussock sedge (*Carex stricta*), buttonbush, marsh swamp-rose (*Rosa palustris*), and northern swamp-dogwood (*Cornus racemosa*). The turtles may select for cover, either from predators or prey, rather than a particular plant species.

We believed that loosestrife may provide habitat structure similar to buttonbush because both plants develop late in the growing season. Loosestrife also has some shrub-like characteristics, such as robust stems that persist through the winter. These ideas, however, were not supported by our data. As loosestrife reaches a high level of dominance, it becomes very dense. The turtles may not be able to maneuver in dense stands of loosestrife, or they may prefer more open areas for thermoregulation purposes. In seasonal wetlands, loosestrife may not be detrimental to the turtles as long as it does not reach high densities. In core habitats, however, invasion by loosestrife may signal
declining habitat quality because the turtles are not associated with it, while they are associated with buttonbush.

We hypothesized that the constructed wetlands are providing appropriate habitat for the turtles throughout most of the active season, but not in winter. Our data indicate that the constructed wetlands provide good habitat during the spring and early summer by providing warm basking areas due to shallower water, less tree fringe cover, and basking logs. This type of habitat is important for thermoregulation, which is an essential part of the species’ life history requirements (Sajwaj and Lang 2000). The constructed wetlands also provide staging or rehydrating areas for nesting females (Hudsonia Ltd., unpublished data) but in most years they become too warm or too shallow by August, and the turtles move to deeper waters elsewhere (Hudsonia Ltd., unpublished data).

The constructed wetlands also do not appear to provide suitable winter habitat. Only one turtle (a subadult) has been observed overwintering in the constructed wetlands since they were built 7 years ago and this turtle did not return to overwinter in the following years (Hudsonia Ltd., unpublished data). Analysis of substrate types in the turtle-centered plots indicates that the constructed wetlands have a discontinuous muck substrate throughout the wetlands, which Blanding’s turtles appear to prefer to mineral soil throughout their range (Hartwig 2004). If buttonbush cover continues to increase in the constructed wetlands, they may become more similar to the reference wetlands, but the difference in hydrology may preclude them from becoming suitable core habitat.

Constructed wetlands were also built to provide habitat for juvenile Blanding’s turtles; unfortunately we do not have enough data on young turtles to determine whether the constructed wetlands are providing juvenile habitat. Juvenile turtles tend to prefer
shallow, well-vegetated wetlands compared to adults throughout their range (Hartwig 2004). Previous studies that have noted this difference in habitat use have studied young turtles with carapace lengths of less than 155 mm (Hartwig 2004). Because we studied only two young turtles, and their carapace length was \( \sim 182 \) mm, we cannot make any statements about juvenile habitat at our study site.

CONSERVATION AND MANAGEMENT IMPLICATIONS

Destruction or damage to core Blanding’s turtle wetlands should be avoided. Mitigation costs are high (Kiviat et al. 2000) and it is difficult (or impossible) to replace organic soils and shrubby vegetation. Lack of suitable soils and vegetation and our limited understanding of the ecology of the Blanding’s turtle and its habitats limited the success of our project; these factors have also limited success of restoration projects for rare birds (Haltiner et al. 1997, Boyer and Zedler 1998, Powell and Collier 2000, Darnell and Smith 2001). The lag involved before constructed wetlands may become suitable as core habitat or may be considered successful is also an important consideration, as are other uncertainties in creating core habitat (e.g. habitat requirements of different age classes and hydrologic conditions). At our study site, although the turtles began using the constructed wetlands soon after they were built, it will require many more years of monitoring to determine whether these wetlands will function as core habitat. In addition, their success in increasing or maintaining the population may not be known until we can develop life tables and determine demographic changes in the population. This will require at least 15-20 years of post-construction monitoring because Blanding’s turtles generally mature at 14-20 years of age (Congdon and van Loben Sels 1993).
Constructed wetlands can provide good supplements to the habitat complex used by Blanding’s turtle, but they should not be considered core habitat unless they meet the needs of the turtles throughout their life cycle and at all seasons. Altering the design of the constructed wetlands and deliberately planning for the different seasonal needs of the turtles could improve the quality and range of habitat provided by constructed wetlands. Creating more and deeper pools could provide cool, wet areas throughout the summer and encourage the growth of submerged vegetation and neuston, providing cover and foraging areas. Unfortunately, the muck soils the turtles often bury themselves in during the summer are difficult to create or obtain during wetland restoration. We salvaged muck soils from the filled wetland; however, construction constraints limited our success. We also do not know how much muck is optimal for the turtles. At this site, reference wetland plots contained an average of 68 cm of muck (2002 data only; \( n = 27, \min = 7 \) cm, \( \max \geq 100 \) cm, \( \text{SD} = 31 \) cm). Until more is known about the specific role that organic soils play in turtle ecology, wetlands constructed for Blanding’s turtles in the Northeast should probably attempt to imitate these depths. In addition, upland areas surrounding the complex should also be examined to determine if they provide essential habitat such as nesting sites or refugia from hot or cold waters. In our study, nesting sites in the surrounding area were limited and therefore nesting berms were also constructed. While the data are still being analyzed, the results indicate that nesting areas are also difficult to reproduce. Although some turtles have used the nesting berms, most use areas cleared during construction of the wetlands or outside the study site.

Wetland complexes constituting diverse wetland types are required to sustain a Blanding’s turtle population (Hartwig 2004). Because they are currently providing good
thermoregulation habitat and because good core habitat exists nearby, it may be desirable for the constructed wetlands to continue to function as seasonal habitat. Blanding’s turtles use a diversity of wetlands in habitat complexes rather than single isolated wetlands (see also Joyal 2001), and new wetlands, even if they do not function as core wetlands, can increase the capacity of the landscape to support Blanding’s turtles by providing high quality seasonal habitat. Construction of wetlands, both core and seasonal, should be considered where Blanding’s turtle wetlands have already been fragmented or destroyed, and is a useful tool for conservation. Construction of terrestrial habitats, such as clearing nesting areas or planting trees and shrubs as refuges from cool or warm waters, and the integration of upland and aquatic habitats, should also be considered. For example, because our constructed wetlands were near nest sites, they served as staging areas for nesting females. Many aquatic animals require multiple wetlands or water bodies, either to sustain metapopulations or individuals (Schneider et al. 2002); these comments probably apply to any species that requires specialized habitat and uses a variety of aquatic systems during its life cycle.

ACKNOWLEDGEMENTS
We are grateful to many individuals for field assistance, editing, and data management, especially H. Bock, D. Goodfriend, J. Hazard, and K. Munger. Our work was funded in part by AmeriCorps; Arlington Central School District; Guinness Water of Life; Geoffrey C. Hughes Foundation; New York State Office of Parks, Recreation, and Historic Preservation; the Society for Ecological Restoration Project Facilitation Award (underwritten by Monsanto); United States Environmental Protection Agency (grant CD992776-01-0 to New York State Office of Parks, Recreation, and Historic
Hartwig

Preservation); and individual donors. All opinions and conclusions are those of the authors. This paper is part of the senior author’s thesis for the Master of Science in Environmental Studies degree at Bard College. We thank C. D. Canham, J. W. Lang, and K. L. Standing for sitting on the thesis committee and providing editorial review. We are especially grateful to C. D. Canham for providing extensive assistance with the statistical procedures, particularly the bootstrapping technique. This is Bard College Field Station-Hudsonia Contribution 95.

LITERATURE CITED
Barlow, C. E. 1999. Habitat use and spatial ecology of Blanding’s turtles (Emydoidea blandingii) and spotted turtles (Clemmys guttata) in northeast Indiana. Thesis, Purdue University, West Lafayette, Indiana, USA.


Congdon, J. D., and R. C. van Loben Sels. 1993. Relationships of reproductive traits and body size with attainment of sexual maturity and age in Blanding’s turtles (Emydoidea blandingii). Journal of
Hartwig

Evolutionary Biology 6:317-327.

Congdon, J. D., and J. W. Gibbons. 1996. Structure and dynamics of a turtle community over two
decades. Pages 137-59 in M. L. Cody and J. A. Smallwood, editors. Long-term studies of
vertebrate communities. Academic Press, San Diego, California, USA.

Darnell, T. M. and E. H. Smith 2001. Recommended design for more accurate duplication of natural

Canadian Field-Naturalist 85:255-256.


woodland stream ecosystem: effects of P enrichment on leaf decomposition and primary

resource selection studies with radio-marked animals. Pages 209-242 in Millsapugh, J. J. and J. M.
Marzluff, editors. Radio Tracking and Animal Populations. Academic Press, San Diego,
California, USA.

Smithsonian Institution Press, Washington, D.C., USA.

Hartwig


Hartwig

(Emydoidea blandingii) at the Weaver Dunes, Minnesota. Chelonian Conservation Biology.


Hartwig, York, USA.


Hartwig


Shuwen, W., Q. Pei, L. Yang, and L. Xi-Ping. 2001. Wetland creation for rare waterfowl conservation: a project designed according to the principals of ecological succession. Ecological Engineering 18:115-120.


Hartwig

Ontario, Canada.


Table 1. T-test results comparing reference and constructed plots for Blanding’s turtle-centered plots and random plots separately for each year, Dutchess County, New York, USA, 2000 - 2002. Turtle-centered plots were surveyed during the active season each year; random plots were surveyed in September. Significant results ($P<0.003$) are in bold type. Random plots: reference $n=28$, constructed $n=12$. Turtle-centered plots: reference $n=26$, constructed $n=23$ (year 2000); reference $n=53$, constructed $n=19$ (year 2001); reference $n=67$, constructed $n=35$ (year 2002).

<table>
<thead>
<tr>
<th>Variable</th>
<th>Reference Plot Mean</th>
<th>Min</th>
<th>Max</th>
<th>SD</th>
<th>Constructed Plot Mean</th>
<th>Min</th>
<th>Max</th>
<th>SD</th>
<th>$t$-value</th>
<th>2-sided $P$</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Year 2000</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Turtle-centered plots</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total cover</td>
<td>102%</td>
<td>9%</td>
<td>175%</td>
<td>36%</td>
<td>57%</td>
<td>6%</td>
<td>92%</td>
<td>26%</td>
<td>5.07</td>
<td>$\leq 0.001$</td>
</tr>
<tr>
<td>Shrub cover</td>
<td>49%</td>
<td>0%</td>
<td>99%</td>
<td>31%</td>
<td>17%</td>
<td>0%</td>
<td>65%</td>
<td>21%</td>
<td>4.37</td>
<td>$\leq 0.001$</td>
</tr>
<tr>
<td>Button-bush cover</td>
<td>39%</td>
<td>0%</td>
<td>99%</td>
<td>33%</td>
<td>0%</td>
<td>0%</td>
<td>5%</td>
<td>1%</td>
<td>5.98</td>
<td>$\leq 0.001$</td>
</tr>
<tr>
<td>Shrub cover without buttonbush</td>
<td>17%</td>
<td>0%</td>
<td>71%</td>
<td>21%</td>
<td>11%</td>
<td>0%</td>
<td>65%</td>
<td>22%</td>
<td>0.99</td>
<td>0.329</td>
</tr>
<tr>
<td>Water depth</td>
<td>53 cm</td>
<td>10 cm</td>
<td>90 cm</td>
<td>14 cm</td>
<td>53 cm</td>
<td>18 cm</td>
<td>110 cm</td>
<td>29 cm</td>
<td>0.11</td>
<td>0.911</td>
</tr>
<tr>
<td>Shrub cover</td>
<td>41%</td>
<td>0%</td>
<td>120%</td>
<td>42%</td>
<td>2%</td>
<td>0%</td>
<td>7%</td>
<td>2%</td>
<td>5.06</td>
<td>$\leq 0.001$</td>
</tr>
<tr>
<td>Button-bush cover</td>
<td>30%</td>
<td>0%</td>
<td>95%</td>
<td>36%</td>
<td>1%</td>
<td>0%</td>
<td>5%</td>
<td>2%</td>
<td>4.25</td>
<td>$\leq 0.001$</td>
</tr>
<tr>
<td>Water depth</td>
<td>32 cm</td>
<td>4 cm</td>
<td>100 cm</td>
<td>21 cm</td>
<td>24 cm</td>
<td>0 cm</td>
<td>71 cm</td>
<td>28 cm</td>
<td>0.93</td>
<td>0.366</td>
</tr>
<tr>
<td><strong>Year 2001</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Turtle-centered plots</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total cover</td>
<td>117%</td>
<td>38%</td>
<td>267%</td>
<td>46%</td>
<td>75%</td>
<td>4%</td>
<td>159%</td>
<td>49%</td>
<td>3.27</td>
<td>0.003</td>
</tr>
<tr>
<td>Shrub cover</td>
<td>46%</td>
<td>0%</td>
<td>111%</td>
<td>36%</td>
<td>13%</td>
<td>0%</td>
<td>65%</td>
<td>22%</td>
<td>4.68</td>
<td>$\leq 0.001$</td>
</tr>
<tr>
<td>Button-bush cover</td>
<td>43%</td>
<td>0%</td>
<td>100%</td>
<td>36%</td>
<td>0%</td>
<td>0%</td>
<td>5%</td>
<td>1%</td>
<td>8.65</td>
<td>$\leq 0.001$</td>
</tr>
<tr>
<td>Shrub cover without buttonbush</td>
<td>13%</td>
<td>0%</td>
<td>80%</td>
<td>22%</td>
<td>3%</td>
<td>0%</td>
<td>65%</td>
<td>12%</td>
<td>1.84</td>
<td>0.079</td>
</tr>
<tr>
<td>Water depth</td>
<td>18 cm</td>
<td>0 cm</td>
<td>100 cm</td>
<td>16 cm</td>
<td>23 cm</td>
<td>0 cm</td>
<td>60 cm</td>
<td>17 cm</td>
<td>1.15</td>
<td>0.259</td>
</tr>
</tbody>
</table>
Table 1 cont.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Reference Plot Mean</th>
<th>Min</th>
<th>Max</th>
<th>SD</th>
<th>Constructed Plot Mean</th>
<th>Min</th>
<th>Max</th>
<th>SD</th>
<th>t-value</th>
<th>2-sided P</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Random plots</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shrub cover</td>
<td>45%</td>
<td>0%</td>
<td>110%</td>
<td>43%</td>
<td>13%</td>
<td>0%</td>
<td>56%</td>
<td>18%</td>
<td>3.33</td>
<td>0.002</td>
</tr>
<tr>
<td>Buttonbush cover</td>
<td>33%</td>
<td>0%</td>
<td>99%</td>
<td>40%</td>
<td>3%</td>
<td>0%</td>
<td>25%</td>
<td>7%</td>
<td>3.78</td>
<td>0.001</td>
</tr>
<tr>
<td>Graminoid cover</td>
<td>16%</td>
<td>0%</td>
<td>91%</td>
<td>26%</td>
<td>3%</td>
<td>1%</td>
<td>7%</td>
<td>2%</td>
<td>2.59</td>
<td>0.015</td>
</tr>
<tr>
<td>Water depth</td>
<td>4 cm</td>
<td>0 cm</td>
<td>76 cm</td>
<td>15 cm</td>
<td>2 cm</td>
<td>0 cm</td>
<td>27 cm</td>
<td>8 cm</td>
<td>0.47</td>
<td>0.643</td>
</tr>
<tr>
<td><strong>Year 2002</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Turtle-centered plots</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total cover</td>
<td>90%</td>
<td>9%</td>
<td>196%</td>
<td>34%</td>
<td>54%</td>
<td>5%</td>
<td>141%</td>
<td>37%</td>
<td>4.79</td>
<td>≤ 0.001</td>
</tr>
<tr>
<td>Shrub cover</td>
<td>47%</td>
<td>0%</td>
<td>98%</td>
<td>34%</td>
<td>11%</td>
<td>0%</td>
<td>96%</td>
<td>21%</td>
<td>6.55</td>
<td>≤ 0.001</td>
</tr>
<tr>
<td>Buttonbush cover</td>
<td>45%</td>
<td>0%</td>
<td>98%</td>
<td>35%</td>
<td>3%</td>
<td>0%</td>
<td>25%</td>
<td>6%</td>
<td>9.76</td>
<td>≤ 0.001</td>
</tr>
<tr>
<td>Shrub cover without buttonbush</td>
<td>1%</td>
<td>0%</td>
<td>65%</td>
<td>8%</td>
<td>8%</td>
<td>0%</td>
<td>96%</td>
<td>21%</td>
<td>1.81</td>
<td>0.079</td>
</tr>
<tr>
<td>Neuston cover</td>
<td>6%</td>
<td>0%</td>
<td>51%</td>
<td>10%</td>
<td>1%</td>
<td>0%</td>
<td>20%</td>
<td>4%</td>
<td>3.60</td>
<td>0.001</td>
</tr>
<tr>
<td>Woody cover</td>
<td>48%</td>
<td>0%</td>
<td>102%</td>
<td>34%</td>
<td>12%</td>
<td>0%</td>
<td>115%</td>
<td>23%</td>
<td>6.28</td>
<td>≤ 0.001</td>
</tr>
<tr>
<td>Woody cover without buttonbush</td>
<td>3%</td>
<td>0%</td>
<td>78%</td>
<td>11%</td>
<td>9%</td>
<td>0%</td>
<td>115%</td>
<td>23%</td>
<td>1.64</td>
<td>0.109</td>
</tr>
<tr>
<td>Shrub-loosestrife cover</td>
<td>49%</td>
<td>0%</td>
<td>98%</td>
<td>33%</td>
<td>19%</td>
<td>0%</td>
<td>100%</td>
<td>23%</td>
<td>5.39</td>
<td>≤ 0.001</td>
</tr>
<tr>
<td>Water temperature</td>
<td>20°C</td>
<td>8°C</td>
<td>27°C</td>
<td>4°C</td>
<td>24°C</td>
<td>14°C</td>
<td>30°C</td>
<td>4°C</td>
<td>3.76</td>
<td>≤ 0.001</td>
</tr>
<tr>
<td>Water depth</td>
<td>26 cm</td>
<td>0 cm</td>
<td>100 cm</td>
<td>17 cm</td>
<td>27 cm</td>
<td>0 cm</td>
<td>90 cm</td>
<td>18 cm</td>
<td>0.23</td>
<td>0.820</td>
</tr>
<tr>
<td>Shrub cover</td>
<td>47%</td>
<td>0%</td>
<td>133%</td>
<td>45%</td>
<td>20%</td>
<td>0%</td>
<td>87%</td>
<td>26%</td>
<td>2.35</td>
<td>0.025</td>
</tr>
<tr>
<td>Buttonbush cover</td>
<td>35%</td>
<td>0%</td>
<td>99%</td>
<td>40%</td>
<td>6%</td>
<td>0%</td>
<td>50%</td>
<td>15%</td>
<td>3.32</td>
<td>0.002</td>
</tr>
<tr>
<td>Graminoid cover</td>
<td>21%</td>
<td>0%</td>
<td>111%</td>
<td>33%</td>
<td>7%</td>
<td>2%</td>
<td>23%</td>
<td>6%</td>
<td>2.21</td>
<td>0.035</td>
</tr>
<tr>
<td>Water depth</td>
<td>10 cm</td>
<td>0 cm</td>
<td>51 cm</td>
<td>14 cm</td>
<td>1 cm</td>
<td>0 cm</td>
<td>4 cm</td>
<td>2 cm</td>
<td>3.32</td>
<td>0.002</td>
</tr>
</tbody>
</table>
Table 2. Number of female, male and subadult Blanding’s turtle observations in constructed and reference (natural) wetlands in Dutchess County, New York, USA, 2001 – 2002. Subadult observations were based on 1 turtle and therefore were not included as a ratio.

<table>
<thead>
<tr>
<th>Year</th>
<th>Number of female observations</th>
<th>Number of male observations</th>
<th>Number of subadult observations</th>
<th>Ratio (female : male)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2001</td>
<td>Total</td>
<td>43</td>
<td>18</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>Reference wetlands</td>
<td>35</td>
<td>14</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Constructed wetlands</td>
<td>13</td>
<td>4</td>
<td>12</td>
</tr>
<tr>
<td>2002</td>
<td>Total</td>
<td>57</td>
<td>24</td>
<td>11</td>
</tr>
<tr>
<td></td>
<td>Reference wetlands</td>
<td>32</td>
<td>31</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>Constructed wetlands</td>
<td>24</td>
<td>4</td>
<td>7</td>
</tr>
</tbody>
</table>
Table 3. Mean shrub and buttonbush cover in constructed wetland plots, Dutchess County, New York, USA, 2000 – 2002.

<table>
<thead>
<tr>
<th></th>
<th>Mean percent cover in constructed wetlands</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2000</td>
</tr>
<tr>
<td>Shrubs in random plots</td>
<td>2</td>
</tr>
<tr>
<td>Buttonbush in random plots</td>
<td>1</td>
</tr>
<tr>
<td>Shrubs in turtle-centered plots</td>
<td>17</td>
</tr>
<tr>
<td>Buttonbush in turtle-centered plots</td>
<td>0</td>
</tr>
</tbody>
</table>
Figure 1. Scatterplots of habitat variables in turtle-centered plots versus Julian date for Blanding’s turtles in Dutchess County, New York, USA, years 2001 and 2002
Figure 2. Scatterplots of habitat variables in turtle-centered plots versus time of day for Blanding’s turtles in Dutchess County, New York, USA, years 2000 - 2002.
Figure 3. Confidence intervals on the differences in means for variables that did not overlap in 2002, plus buttonbush confidence intervals that overlapped slightly, for constructed and reference wetlands in Dutchess County, New York, USA. Columns represent the difference between the constructed and reference plot means for either random or turtle-centered plots. Error bars represent the bootstrapped confidence intervals for the difference in means. If the confidence intervals did not overlap, the difference between wetland types for turtle-centered plots is considered significant due to habitat association rather than habitat differences. Positive values indicate that reference plot means were greater than constructed plot means; negative values indicate that constructed plot means were greater than reference plot means. Means for each plot type are on the right of each graph. Ref = random reference plots, Con = constructed reference plots, TRef = turtle-centered reference plots, TCon = turtle-centered constructed plots.