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Restoration of Wetland and Upland Habitat for the Blanding's Turtle, *Emydoidea blandingii*

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ABSTRACT. – **Constructed wetlands and upland nesting areas were completed in May 1997 to replace Blanding's turtle (*Emydoidea blandingii*) habitats lost to a school expansion in Dutchess County, New York. Organic sediments and vegetation were salvaged and moved 200–700 m to create 1.4 ha of deep-flooding, shrubby, groundwater-fed wetlands interspersed with dry, coarse-textured, sparsely vegetated, upland soils. Deep pools were created for drought refuge, and a 1.5 km fence with one-way turtle gates was built between the restoration area and the school. During the 1997 nesting season, 9 of 11 radiotracked females used the constructed wetlands and all 11 nested on the constructed nesting areas, producing 104 live hatchlings. One to 3 adult turtles used the newly-created wetlands simultaneously throughout summer and fall. Occupancy of the new wetlands was greater during the nesting season and subsequent summer of 1998 than in 1997, but there was no documented presence during winter or early spring. Because the long-term prognosis of constructed wetlands is uncertain, wetland construction should be used to increase habitat for Blanding's turtle rather than merely to compensate on an area-to-area basis for the planned destruction of wetlands.**

KEY WORDS. – **Reptilia; Testudines; Emydidae; *Emydoidea blandingii*; turtle; habitat; landscape; soils; wetland restoration; mitigation; nesting; New York; USA**

Blanding's turtle (*Emydoidea blandingii*) (Reptilia: Emydidae) is listed by the New York State Department of Environmental Conservation as "threatened" in the state. The species occurs in two disjunct regions of New York: Dutchess County in the southeast, and Jefferson and St. Lawrence counties in the north. Most Blanding's turtle wetlands in Dutchess County have been altered by drainage, channelization, dredging, impoundment, partial filling, dumping, clearing of peripheral vegetation, agriculture, water pollution, or the adjacent construction of homes, businesses, schools, and parking lots. Dutchess County has a rapidly growing human population and intensive development activities, in marked contrast to northern New York where habitats have not undergone severe alteration (PJP, *pers. obs.*) and much habitat is in nature reserves. The rapid land use change and fragmentation of habitats and land holdings in Dutchess County present a serious stress to a species that requires habitat complexes of at least one to several square kilometers (Kiviat, 1997).

Loss and degradation of wetlands threaten many turtle populations (Klemens, 1989; Ernst et al., 1994). In the coterminous United States, more than half of the pre-European wetland area has been lost in historical times (Mitsch and Gosselink, 1993). Thus, there is less total area of habitat for many species, and remaining wetlands may be farther apart or farther from suitable nesting areas. Yet in the past 50 years, many artificial wetlands have been created — for water bird habitat, waste treatment, flood storage, and recently for compensatory "mitigation" of wetland loss permitted under federal and state wetland protection laws. Managers can potentially construct wetlands for replacement, enhancement or increase of available habitat, and as experiments to probe the ecological function of habitats. This opportunity must be tempered with caution: wetland ecosystems are complex, as are turtle habitats, and artificial replication of all of their key characteristics may not be possible. Nevertheless, scientific studies conducted before and after habitat construction can provide information about the feasibility, effectiveness, efficiency, and costs of restoration for specific goals and target species.

This paper summarizes the design of a habitat construction project for the Blanding's turtle, and 27 months of pre- and post-construction monitoring of turtles at the site. We include information about design and construction of habitats because of widespread interest in restoring or enhancing habitats. We use "restoration" in the broadest sense to include construction or alteration of habitat intended to improve its quality or quantity.

SITE DESCRIPTION

The restoration site lies between a public school and a state park on land that was farmed until around 1950 (Fig. 1). There are approximately 6 ha of pre-existing wetlands suitable for Blanding's turtle use, and 1.4 ha of constructed wetlands built in 1996–97. A "donor" wetland (0.7 ha) provided much of the soils and vegetation for the constructed wetlands. All the wetlands are underlain by organic sedi-

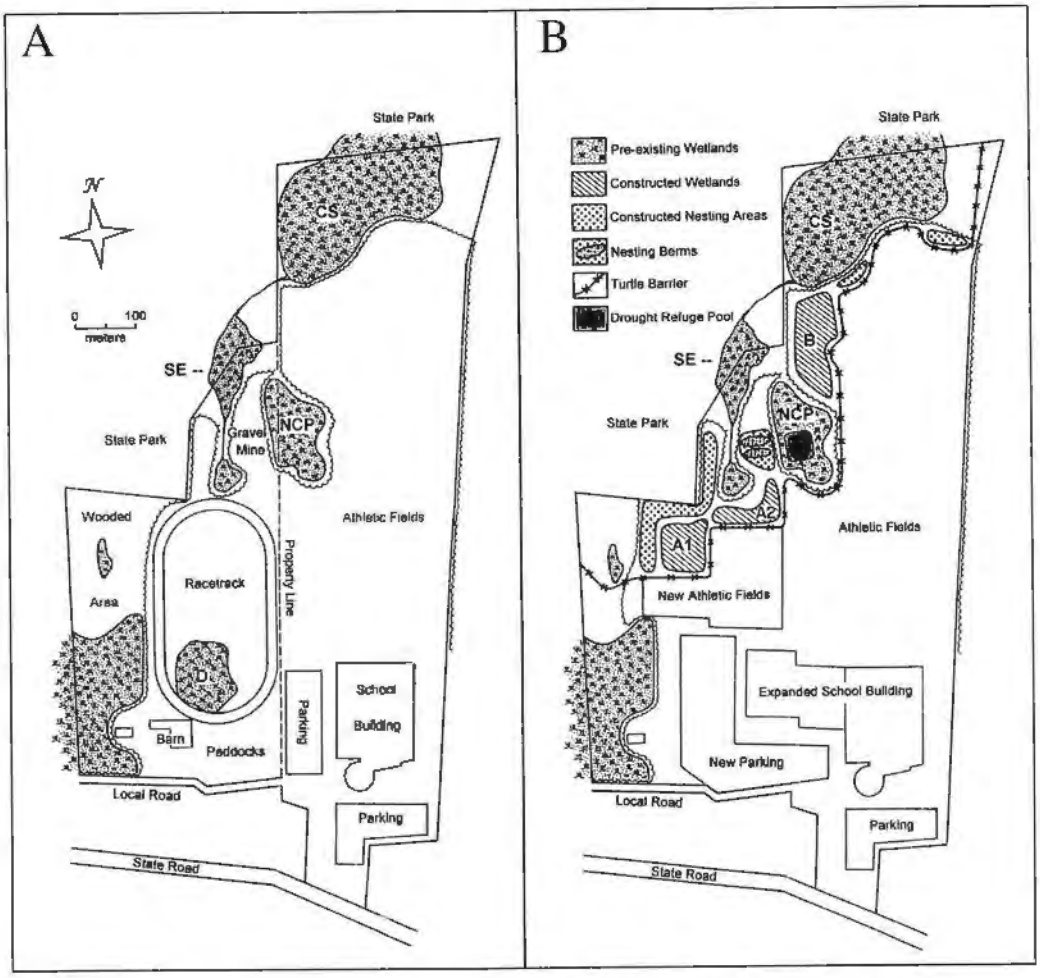

Figure 1. Maps of 1996 pre-restoration (**A**) and 1997 post-restoration (**B**) features. A1, A2, B = constructed wetlands; CS = Corner Swamp, NCP = North Campus Pond, SE = Southeast Swamp; D = donor wetland. (Drawn by Kathleen A. Schmidt).

ments. The two pre-existing wetlands favored by Blanding's turtles are: (1) Corner Swamp, 4.0 ha, with a central red maple (*Acer rubrum*) swamp and peripheral areas with buttonbush (*Cephalanthus occidentalis*), purple loosestrife (*Lythrum salicaria*), and a deeper moat; and (2) Southeast Swamp, 0.6 ha, dominated by purple loosestrife, tussock sedge (*Carex stricta*), and shrubs of several species. Southeast Swamp was a shallow red maple swamp not known to be used by Blanding's turtles prior to 1986 when it was permanently flooded due to accidentally blocked drainage (EK, *pers. obs.*). The turtles began using the wetland soon after this event.

The environment around the site is rural in transition to suburban, and there are two major highways nearby. Dutchess County lies east of the Hudson River between New York City and Albany. The western two-thirds of the county supports at least 11 small populations of Blanding's turtle in complexes of small wetlands with nearby uplands that have gravelly loam soils derived from glacial outwash. The vegetation of the wetlands used by the turtles includes a prominent shrub component, little tree canopy cover, and little cover by graminoid plants (Fig. 2). There are also organic sediments and fluctuating water levels (0–1.2 m deep). Environmental characteristics, from the landscape scale down to the microhabitat scale, appear to maximize warming in spring (Kiviat, 1997).

The spring and summer of 1996 were very wet. Most of the pre-existing wetlands retained water all year. In 1997, there was a severe drought, wetlands drew down rapidly in late spring, and by August water sufficient for adult Blanding's turtle use (>25 cm deep) remained only in constructed wetland A1, the dredged pool in North Campus Pond (Fig. 1B), and in artificial ponds in the park north of Corner Swamp. Spring and summer 1998 were much wetter than in 1997, and water levels in all wetlands remained high into July; water levels fell rapidly in late July and early August but all wetlands retained sufficient water for adult turtles through August. Turtles survived drying up of wetlands by migrating to permanent water, burrowing in the sediments of the dried-up wetland, or hiding in dense vegetation or leaf litter on uplands.

RESTORATION DESIGN AND IMPLEMENTATION

Restoration Plan. — The Arlington Central School District (ACSD) planned to expand its buildings, parking lots, and athletic fields. Neighboring land use limited op-

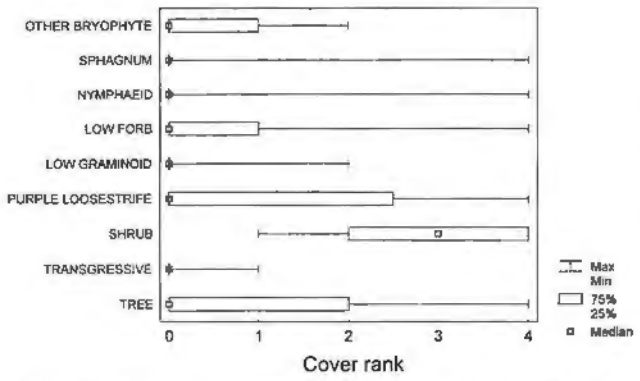

Figure 2. Vegetation of 25 Blanding's turtle wetlands in Dutchess County. In each wetland, each vegetation component (*y*-axis) was ranked from 0 to 4 (*x*-axis), according to proportion of the wetland covered: 0 = 0–6.25%, 1 = 6.25–12.5%, 2 = 12.5–25%, 3 = 25–50%, 4 = 50–100%. Nymphaeids are water-lilies and similar floating-leaved plants; graminoids are grass-like herbs, principally grasses, sedges, cattails, and rushes; forbs are broad-leaved herbs; purple loosestrife is *Lythrum salicaria*; transgressives are seedling and sapling-size trees. Medians and boxes farther to the right indicate greater importance in the vegetation. (Data from Kiviat, 1997.)

tions for expansion. An adjoining horse farm with barns, a racetrack, and a small gravel mine, had sufficient acreage for the school's needs, but also contained the 0.7 ha donor wetland that was part of a known Blanding's turtle habitat complex. This wetland was proposed to be filled for school expansion. Although the New York State Department of Environmental Conservation had never issued a permit to alter a known Blanding's turtle wetland, the agency agreed to consider the proposal if ACSD would design new wetlands equal to twice the area of the donor wetland and suitable for Blanding's turtles.

There has been a high incidence of functional failure of constructed wetlands (Larson and Neill, 1987; D'Avanzo, 1990). Thus, construction of wetlands to mitigate the loss of habitat for rare species is risky. We nonetheless agreed to design and monitor a habitat construction project because: (1) the donor wetland was in a hazardous location in relation to the racetrack, school parking lot, and roads with heavy traffic; (2) much prior loss and alteration of Blanding's turtle wetlands had occurred nearby; and (3) the project presented an unusual opportunity to study Blanding's turtles and their habitat, and to develop technology that could be adapted to expand and restore habitats elsewhere. We identified key elements in the creation of habitats for Blanding's turtle as: (1) groundwater discharge, (2) organic sediments, (3) shrubby wetland vegetation, and (4) upland nesting areas. Due to the requirements of the construction schedule, we had only five months (April–August 1996) to collect data and design the restoration project.

Restoration Targets. — Primary habitats of Blanding's turtle in Dutchess County are associated with groundwater discharge in depressional wetlands occupying "kettles" (hollows formed when sediments were deposited around residual ice blocks) in permeable glaciofluvial outwash deposits. The restoration goal was to create depressional wetlands fed primarily by groundwater discharge, with deep flooding in spring, drawdown in late summer, and shrub-dominated wetland vegetation (Fig. 2). Monitoring wells were drilled in locations of proposed wetland construction and in adjacent pre-existing wetlands, and staff gauges were installed in the wetlands. Wells and gauges were monitored for seasonal groundwater and surface water levels, and to establish recharge-discharge relationships. Grading plans for constructed wetlands were based on observed groundwater elevations. The grading plans were refined during construction by further observations of groundwater and soil indicators of the range of water table fluctuation.

Because of the local loss of habitat, we wanted to create new habitats that Blanding's turtles could use immediately, without the lag of decades or longer before a constructed wetland would develop mature shrubby vegetation and organic sediments. In 1996, we determined that the donor wetland was used by juvenile Blanding's turtles, as well as nesting females. We designed the constructed wetlands to provide shallow, shrubby, hummocky-tussocky wetland with small pools for juveniles, deeper and larger seasonal pools for adults, and three deep permanent pools. The new drought refuge pool, 1.5 m deep, in pre-existing North Campus Pond would also provide permanent standing water. All wetlands would have a surface organic sediment layer 15–40 cm deep. All new habitats were within the pre-existing habitat complex of the local Blanding's turtle population.

The banks of the constructed wetlands were designed to develop a wooded border for a visual and auditory buffer for the turtles and to moderate the wetland microclimate (Kiviat, 1997). Ground cover on the banks would prevent soil erosion but remain sparse enough that the banks could be used for nesting before a tree canopy developed. We specifically designed 0.57 ha of nesting habitat at four locations. Nesting habitats were built with a southern or southeastern exposure, on berms and flats with slopes of 0–20°, using local gravelly loam soil or sand salvaged from the racetrack. The nesting areas (Fig. 1B) were designed to develop sparse, tufted, low herbaceous vegetation interspersed with bare mineral soil. Nesting areas were to be mowed annually in fall or early spring when turtles are unlikely to be on land.

Implementation. — To create an immediately functional habitat, we used the "whole sod" salvage method developed by Munro (1994). We salvaged organic sediments and vegetation from the donor wetland including mature sedge (*C. stricta*) tussocks, woody hummocks (elevated root crowns), mature shrubs, and trees up to 12 cm dbh (diameter at breast height, measured 1.4 m from base) and 6 m tall, before the wetland was filled for school construction. Using a custom-made steel spatula mounted on an excavator, whole sods of 1.2 x 3 m, including all vegetation and a 38 cm deep layer of organic sediments, were cut from the donor wetland and transferred to newly excavated basins 200–700 m away (Fig. 3). All underlying organic material was also salvaged and used to fill gaps between sods and line pools with 20–40 cm of organic

Figure 3. Blanding's turtle habitat restoration, Dutchess County, New York. **(A)** Sod removal from the donor wetland, December 1996; **(B)** and **(C)** Sod placement in constructed wetlands, November and December 1996; **(D)** Completed constructed wetland, September 1997. (Photos by EK, Hudsonia, Ltd.)

sediment. Stumps and logs of larger trees were salvaged from the donor wetland and from upland construction areas, including a fence row and a wooded edge, to provide basking and shelter sites in the new wetlands.

Wetland banks were planted with nursery stock of native trees and shrubs. To inhibit weeds on potential turtle nesting areas and in the wetlands, no fertilizers were used. The soils in each planting hole, however, were mixed with compost and mycorrhizal inoculants. The soils between planted shrubs and trees were loosened and seeded with native grasses and forbs adapted to low nutrient conditions. The nesting areas were created by removing topsoil, grading, loosening to a depth of 15 cm, seeding with grasses and forbs, and mulching with blown straw. Four nesting berms (ca. 5 m wide x 25 m long x 1 m high) were built of gravelly loam topped with a 20 cm layer of sand. Berm slopes and summits were seeded similarly to the wetland banks.

A 1.5 km long fence was built along two sides of the restoration area (Fig. 1B) to reduce turtle movement from the restoration area towards the parking lots and highway, and to discourage human entry into the restoration area. The fence was composed of 1.2 m high chain link with 0.6 m high aluminum sheeting attached to the bottom on the restoration side and buried 0.3 m in the soil. The fence had one-way turtle gates at 30 m intervals, with earth ramps on the school side and 25 cm high curbs on the restoration side. Two curb designs alternated; quarter-round PVC (polyvinyl chloride) pipe (Fig. 4A), and recycled plastic lumber in an inverted L-shape with the top forming a 5 cm overhang (Fig. 4B). We had tested prototype curbs with a temporarily captive adult female Blanding's turtle and observed that the turtle could pass over the curb in one direction (down the curb) but not the other (up the curb).

Cost Analysis. — The costs associated with wetland construction are difficult to characterize, because each project has its own unique set of site-specific issues related to site preparation, excavation, placement of soil, landscaping, and drainage, as well as other factors (Kent, 1994). The costs of designing and implementing a conservation plan for Blanding's turtles affected by the expansion of a landfill operation in southern Wisconsin were estimated at $1.4 million over a 10-year period (G. Casper, *pers. comm.*). Extensive upland restoration, construction of experimental nesting mounds, installation of turtle exclusion fencing, habitat maintenance, and annual turtle assessment surveys were included in this cost estimate. These costs paralleled the cost of the ACSD construction project, which was $1.6 million over a 3-year period, excluding engineers', architects', and lawyers' fees. The ACSD costs covered the design and physical construction, including earth moving,

Figure 4. Two types of one-way gates in the turtle barrier (Photos by EK, Hudsonia, Ltd., and RB).

sod placement, plantings on banks, and fencing, as well as monitoring costs for a 2-year period (1996–97). This dollar figure is based on the original, contracted amount, and does not include modifications to the contract.

METHODS OF THE TURTLE STUDY

We trapped turtles for approximately 1 month in each year (1996–98) using commercial hoop nets (Nylon Net Co., Memphis, Tennessee). Individuals >149 mm carapace length (CL) were marked with serially-numbered 13 mm diameter plastic disks epoxied to the rear portion of the carapace, and individuals 75–149 mm CL were file-notched in marginal scutes. We radiotracked approximately 10 females and 5 males with transmitters in the range of 150.8–151.7 MHz (Johnson Telemetry, Eldorado Springs, Missouri) epoxied to the rear portion of the carapace, and CE-12 receivers with 3-element directional Yagi antennas (Custom Electronics, Urbana, Illinois). Turtles were radio-located daily in May–June, every 3–5 days in July and August, and at 1–4 week intervals in September–April. We were unable to maintain continuous records for each individual due to signal attenuation in the wetlands, transmitter failure, and excursions of turtles out of the local area.

During the nesting season, females were radiotracked daily and followed visually to locate nests. We covered nests with hardware cloth (13 mm mesh) cages with the bases buried in the soil. Cages were visited each morning beginning 15 August 1997 and 3 August 1998. Hatchlings were measured and released in shallow, densely-vegetated portions of nearby wetlands. On 28 September 1997, we excavated all nests, released live hatchlings, and counted all unhatched eggs and dead hatchlings remaining in the soil.

RESULTS OF THE TURTLE STUDY

In 1996 (before wetland construction), adult Blanding's turtles concentrated their activities in Corner Swamp and Southeast Swamp (Figs. 1, 5). We located two Blanding's nests on the edges of the racetrack. A third nest of either Blanding's turtle or wood turtle (*Clemmys insculpta*) discovered at the end of the summer had been dug in a compost pile near the racetrack and apparently produced no live hatchlings. Five additional radiotracked females did not develop palpable, shelled eggs, probably due to the very cold, late spring.

A temporary exclusion fence was removed in late May 1997, allowing turtles into the newly constructed habitats. In the remainder of 1997, 10 of 16 radiotracked turtles (9 females and 1 male) used the constructed wetlands (Fig. 5). Fifty-six percent of radio-locations in these wetlands were associated with the nesting season 3–21 June. Females used constructed wetlands while migrating to nesting areas and between nesting excursions, and all but one female returned to the pre-existing wetland in which each had been resident before the nesting season.

All 11 radiotracked females nested on the restoration area in 1997. Nests were dug on the constructed nesting habitats and in disturbed soils of the banks of wetlands A1, A2, and B (Fig. 1B). No female nested on top of a nesting berm, perhaps because the sandy elevated soil was too dry during the drought. Most females walked back and forth along the turtle barrier, then nested near the barrier (median distance from the barrier was 5.5 m and maximum distance was 36 m). The 1997 nests produced 104 live hatchlings (mean = 9.45 per nest).

Two females and 1 male used the constructed wetlands in summer and fall 1997 (Fig. 5). Many of these radio-locations were in wetland A1 (Fig. 1B) which held standing water throughout the drought. One female used the newly dredged pool in North Campus Pond during the drought. In winter 1997–98, 6 radiotracked adults overwintered in Corner Swamp and Southeast Swamp (Fig. 1B). Other adults overwintered in a small water-supply pond in the park north of the restoration area where they had spent much of the 1997 drought (these turtles moved into a small intermittent woodland pool during unusually warm weather in February 1998, then back to Corner Swamp and Southeast Swamp). No Blanding's turtle used the constructed wetlands in 1998 until the nesting season began on 25 May.

In 1998, we located 7 nests on the restoration area, including one on top of a nesting berm. Four additional

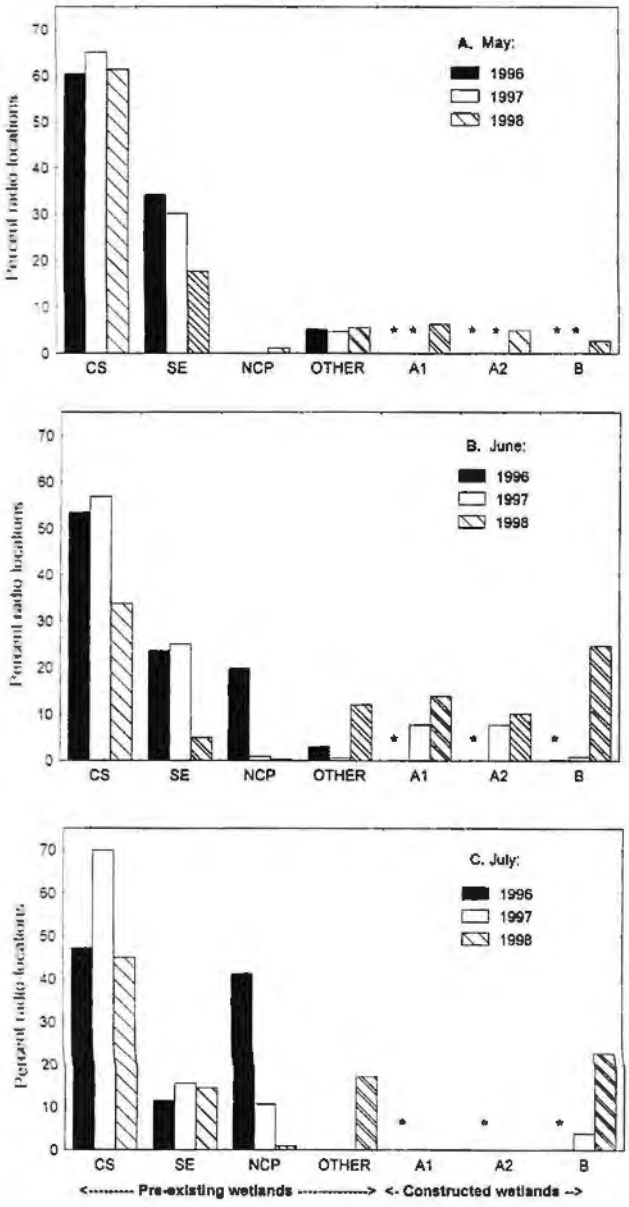

Figure 5. Radio-locations of adult Blanding's turtles in pre-existing wetlands and constructed wetlands 1996–98. Numbers on the y-axis are percentages of total radio-locations for a month-year-wetland combination. CS = Corner Swamp, SE = Southeast Swamp, NCP = North Campus Pond. * indicates wetland did not exist or was not accessible to turtles.

radiotracked females nested but escaped detection due to malfunctioning transmitters and a severe thunderstorm. Two females circumvented the barrier, twice each, and were brought back to the restoration area where they eventually nested. A different female was found on the school side of the barrier during the 1997 nesting season and was released on the restoration area where she then nested. She overwintered in Corner Swamp, bypassed the barrier in spring 1998 and moved to a woodland pool 750 m east of constructed wetland A2. During the 1998 nesting season she returned through a turtle gate onto the restoration area, nested, and once again bypassed the barrier and returned to the woodland pool. Ten females used the constructed wetlands during the nesting season. Five females and 2 males used the constructed wetlands after the nesting season (July, Fig. 5), with 2–7 radiotracked adults in the constructed wetlands on any one date.

DISCUSSION

Habitat restoration for rare species is increasingly proposed either to expand existing habitats, or as mitigation for planned destruction of habitat (e.g., Zedler, 1996). The habitat restoration project we describe was conducted to mitigate the filling of a wetland for expansion of a public facility. Blanding's turtles require habitats for residence, nesting, drought refuge, and overwintering (Kiviat, 1997). The constructed wetlands, drought refuge pools, constructed nesting areas, and one-way barrier fence at our study site served their intended functions reasonably well during the first two growing seasons after construction. This project, however, raises crucial questions about manipulative management of habitats for rare freshwater turtles: (1) what kinds of habitat restoration projects are feasible and effective?; (2) how can restoration projects be designed and carried out with maximal benefit to the target species, and minimal negative impacts on other components of the landscape?; and (3) in which land use situations are habitat restoration projects for turtles ecologically justified?

Blanding's turtles are known to use human-disturbed areas for nesting, including residential yards and parking areas (Emrich, 1991; Herman et al., 1995), plowed fields (Linck et al., 1989), and vegetable gardens (Petokas, 1986). There have been other attempts to manipulate nesting habitat for Blanding's turtles. A project at another Dutchess County site included removal of forest vegetation and tilling or bulldozing soils. After several years of experimentation, Blanding's turtles used a constructed habitat for two years, but not in 1998 (Emrich, 1991; C. Harmon and A. Breisch, *pers. comm.*). A Blanding's turtle nesting area was created inadvertently in Massachusetts by bulldozing in 1941; recently, burning and disking have been used experimentally to manage encroaching vegetation at this site (B.O. Butler, *pers. comm.*). Nesting mounds were built to mitigate the impacts of a landfill expansion in Wisconsin, but Blanding's turtles did not nest on them (Casper, 1999).

Observations by us and others (Emrich, 1991; C. Harmon and A. Breisch, *pers. comm.*), indicate that female Blanding's turtles may try to return to traditional nesting areas and are likely to circumvent fences. In our study, all females we were able to track eventually nested on the constructed habitats. However, some of these females tried to walk around the fence for 2–3 days before nesting, and we returned two errant females twice each before they nested on the restoration area. In some situations it may be desirable to fence in an entire habitat complex despite the high cost. The best measure of the success of our constructed nesting habitats is the substantial production of live hatchlings in 1997.

Blanding's turtles used wetlands and pools built for trout culture or waterfowl in Minnesota (Dorff, 1995). Blanding's turtles have also used wetlands impounded acci-

dentally or for waterfowl management in Dutchess County (EK, *pers. obs.*). Former wetland habitat for Blanding's turtle has been restored in Nova Scotia by removing the dam of a large lake (T. Herman, *pers. comm.*). Wetland habitat in Minnesota was restored for Blanding's turtles by deepening existing wetlands or breaking drainage tiles (M. Linck and J.J. Moriarty, *pers. comm.*). In Illinois, gray dogwood (*Cornus racemosa*) and non-native shrubs (*Rhamnus*) were cleared to improve wetland habitat for Blanding's turtles; some turtles also used ornamental ponds dredged by landowners in wetland edges (D.R. Ludwig, *pers. comm.*). Some of these phenomena provided precedents for our experiments in wetland and upland habitat construction. We know of no other instance, however, of wetlands designed and constructed specifically to serve as Blanding's turtle habitat.

During the nesting season, female Blanding's turtles use a wide variety of aquatic and terrestrial habitats for cover between nesting excursions. In New York, we have seen females use wetland pools, artificial ponds, and upland brush piles. At the restoration site, females occasionally used wetlands during the nesting migration that were rarely used otherwise. The behavioral plasticity of nesting females, and their semi-confinement by the fence, may explain their adoption of the constructed wetland habitats in our study. Their nest site selection, however, apparently reflects a behavioral compromise between fidelity to traditional nesting areas and the ability to switch nesting areas under changed conditions.

Adult Blanding's turtles take refuge in natural and artificial pools and ponds during summer droughts. In our study, during the 1997 drought adults of both sexes used the deep pools in constructed wetland A1 as well as the constructed drought refuge pool in North Campus Pond (Fig. 1B). More encouraging is the moderate use of the constructed wetlands by adults of both sexes during non-drought periods in summer 1998. In winter 1997–98 and spring 1998 (pre-nesting season), however, the radiotracked turtles only used the pre-existing wetlands. Possibly the constructed wetlands were thermally unsuitable in winter and spring or had insufficient prey in spring. Blanding's turtles may be more selective during these apparently more critical seasons.

We encountered problems likely to occur in other habitat construction projects. Unanticipated subsurface conditions (e.g., marl beneath organic wetland sediments, fine materials beneath upland gravelly loams) complicated habitat construction. It is difficult to achieve substrate contours and a water level regime suitable for the desired plants and animals, because 10–15 cm vertical difference can make a wetland suitable or unsuitable for some species. The donor wetland contributed plants and seeds of an invasive species (purple loosestrife) to the constructed wetlands. It is unclear whether purple loosestrife is harmful or beneficial to Blanding's turtles; nonetheless, to avoid loosestrife competition with plantings we avoided salvaging the densest concentrations of loosestrife, hand-pulled loosestrife seedlings in selected peripheral areas of the constructed wetlands, and introduced leaf-feeding beetles (*Galerucella* spp.) from the Cornell University loosestrife biocontrol program (Malecki et al., 1993). Ramps and curbs of the fence were challenging to design and build; post-construction erosion and settling of soil has created crevices around the curbs that could entrap hatchling turtles. Hydrological data collected in a very wet pre-construction year were atypical of the site. Furthermore, a single season of study of the environment and turtles was insufficient to represent the system. This problem was partly offset by the existence of limited data on the turtles and wetland vegetation collected by us in previous, unrelated studies. More extensive and detailed pre-design data on hydrology, soils, and turtles would have improved the project. We were also unable to find and track small juvenile turtles, and thus we could do little to design for, or monitor, this population component.

Wetland habitats of Blanding's turtles are composed of soil, water, microbes, living and dead plant material, and other animals. We cannot precisely predict the trajectory of development of constructed wetland ecosystems and their capability to support the hydrologic, thermal, dietary, and other requirements of Blanding's turtles. Information on the long-term development of the constructed habitats and their use by turtles will help ecologists and managers who are constructing or manipulating habitats for this species elsewhere in its range. Much remains to be learned about how Blanding's turtles (and other species of freshwater turtles) will respond to intentional restoration of habitats.

We therefore recommend that: (1) restoration be conducted to provide additional habitat rather than to mitigate intentional destruction of habitat; (2) habitat construction projects be located within or adjoining existing Blanding's turtle habitat complexes; and (3) habitat construction use areas with soils and hydrology locally known to be suitable for Blanding's turtle habitats. Different constructed habitat types appear differentially acceptable to Blanding's turtles. Pools or ponds for drought refuge and wetlands for use by females during the nesting season may be the simplest and most acceptable habitats. Wetlands for summer use may be expensive to build but moderately acceptable to the turtles. We cannot yet rate the acceptability of wetlands for use in winter or early spring, or for juvenile turtles. Although to date there have been several experiments with the creation of nesting areas, the responses of Blanding's turtles to these habitats have been unpredictable.

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