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Emydoidea blandingii (Holbrook 1838) – Blanding's Turtle

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Summary. – In Canada and the United States, the Blanding's turtle, *Emydoidea blandingii* (Family Emydidae), is officially designated as endangered or threatened in several provinces and a number of states. In many areas, it has become a "poster species" for attracting public interest in issues common to conservation of freshwater turtles in general. Over the past three decades, knowledge of Blanding's turtle biology and ecology has increased dramatically, and among species with conservation concerns, it now ranks as one of the best known turtle species throughout much of its range. Blanding's turtles seldom occur in dense populations such as those of sympatric painted turtles, but two large populations exist in southeastern Minnesota, and in north-central Nebraska. Individuals delay maturity from 14–21 yrs, and can attain ages greater than 75 yrs and still reproduce successfully. Most populations of Blanding's turtles are threatened by collecting, road mortality, and the reduction and degradation of both aquatic and terrestrial portions of their core habitats. Adults of both sexes make extensive forays onto land to visit temporary wetlands, and adult females move overland on pre-nesting movements and to nest; both activities exposes adults to increased risk of mortality associated with roads, farm machinery, and terrestrial predators. Proposed conservation measures include: 1) methods to reduce road mortality (e.g., fencing and road passages); 2) elimination of commercial collecting; 3) protection of large resident wetlands and smaller ephemeral wetlands; 4) protection and management of adjacent terrestrial areas used for nesting and as corridors for movements among wetlands; 5) research on risks associated with the timing and duration of terrestrial movements of both sexes; and 6) where necessary, removal of nest predators. More extensive regional information can be found in Herman et al. (2003), COSEWIC (2005), and Congdon and Keinath (2006).

Distribution. – Canada, USA. Distributed disjunctly from southeastern Ontario, adjacent Quebec, and southern Nova Scotia, south into New England, and west through the Great Lakes to western Nebraska, Iowa, and extreme northeastern Missouri.

Synonymy. – *Testudo flava* Lacépède 1788 (name suppressed), *Testudo meleagris* Shaw 1793 (name suppressed), *Lutremys meleagris*, *Emys meleagris*, *Cistuda blandingii* Holbrook 1838, *Cistudo blandingii*, *Emys blandingii*, *Emydoidea blandingii*, *Neoemys blandingii*, *Emys twentei* Taylor 1943.

Subspecies. – None recognized, but three separate evolutionarily significant units have been identified: 1) the main populations west of the Appalachian Mountains, 2) the disjunct populations east of the Appalachians in southern New York and New England, and 3) the highly disjunct eastern population in southern Nova Scotia.

Status. – IUCN 2007 Red List: Near Threatened (LR/nt) (assessed 1996, needs updating); CITES: Not Listed; US ESA: Category 2 (Candidate for Listing); Canada Species at Risk Act: Endangered (Nova Scotia), Threatened (Great Lakes / St. Lawrence).

Taxonomy. — The Blanding's turtle was originally described by Holbrook (1838) and no subspecies are recognized. According to Pritchard (1979), this turtle used to be considered congeneric with the European pond turtle, *Emys orbicularis,* until clarified by Loveridge and Williams (1957). Whereas the etymology of *Emydoidea* refers to the similarity between it and the genus *Emys* (McCoy 1973), the skull is more similar to that of *Deirochelys* (McDowell 1964). Frair (1982) and Seidel and Adkins (1989) refuted kinship between *Emydoidea* and *Deirochelys* on the basis of serology and myoglobins, and Bramble (1974) claimed that *Emydoidea* was more closely related to *Emys* and *Terrapene* based on anatomical and functional similarities, e.g., plastral kinesis. He hypothesized that *Emydoidea* was

Figure 1. Adult *Emydoidea blandingii* from central Massachusetts. Photo by Terry E. Graham.

convergent with *Deirochelys* on the basis of similar feeding mechanisms.

Recent revisions to the taxonomy and phylogeny of Blanding's turtle are based on molecular studies (Bickham et al. 1996; Burke et al. 1996; Lenk et al. 1999; Feldman and Parham 2001, 2002; Spinks and Shaffer 2005) and recent discovery of fossils (Hutchison 1981; Holman 1987, 1995). As a result, Blanding's turtles and Western pond turtles (*Actinemys marmorata*) may be placed in the same genus (*Emys*) with the European pond turtle (*Emys orbicularis*). However, it was recently suggested that the recommendation to lump *Emydoidea* and *Actinemys* under the genus *Emys* was incorrect because the authors were unaware of the arguments of Holman and Fritz (2001). Crother et al. (2003) recommended the retention of separate genera for *Emys* and *Emydoidea*, and the Turtle Taxonomy Working Group (2007) listed both *Emydoidea* and *Emys* as available names for Blanding's turtles.

Though no subspecies have been described, Mockford et al. (2007) evaluated genetics of Blanding's turtles from throughout their range and identified three evolutionarily significant units: 1) the main populations west of the Appalachian Mountains, 2) the disjunct populations east of the Appalachians in southern New York and New England, and 3) the highly disjunct eastern population in southern Nova Scotia.

Figure 2. Adult *Emydoidea blandingii* from the E.S. George Reserve, Michigan, a ca. 72-yr old female, first marked as an adult in the mid 1950s and still alive and reproducing in 2007. Photo by Justin D. Congdon.

Description. — Blanding's turtles are dark brown to black with some yellow spotting on the carapace. The carapace is domed and elongate and the plastron is hinged at the

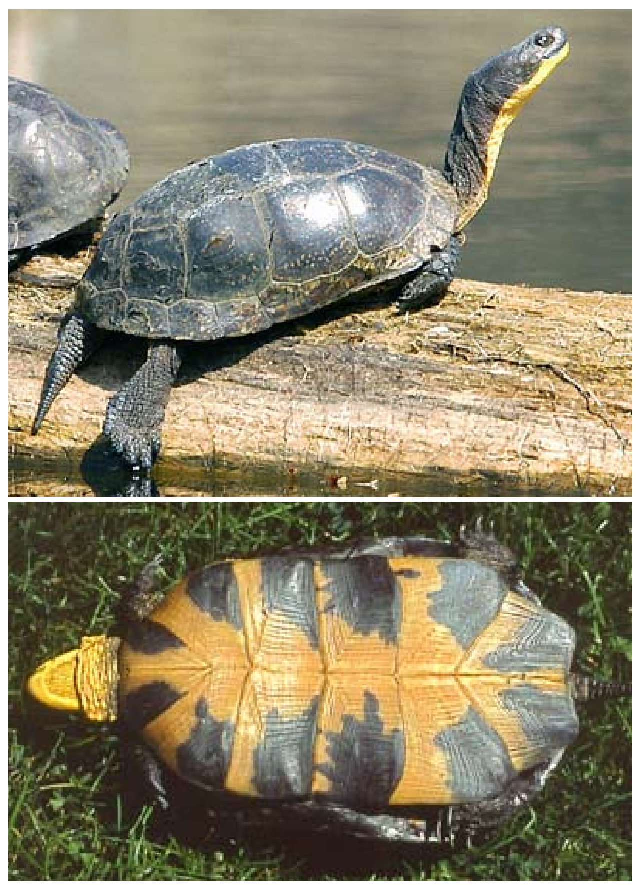

Figure 3. Adult *Emydoidea blandingii*. Top: Weaver Dunes, Minnesota, March 2003, showing the long neck. Photo by Janet Hostetter. Bottom: Plastron of female from Devens, Massachusetts. Photo by Terry E. Graham.

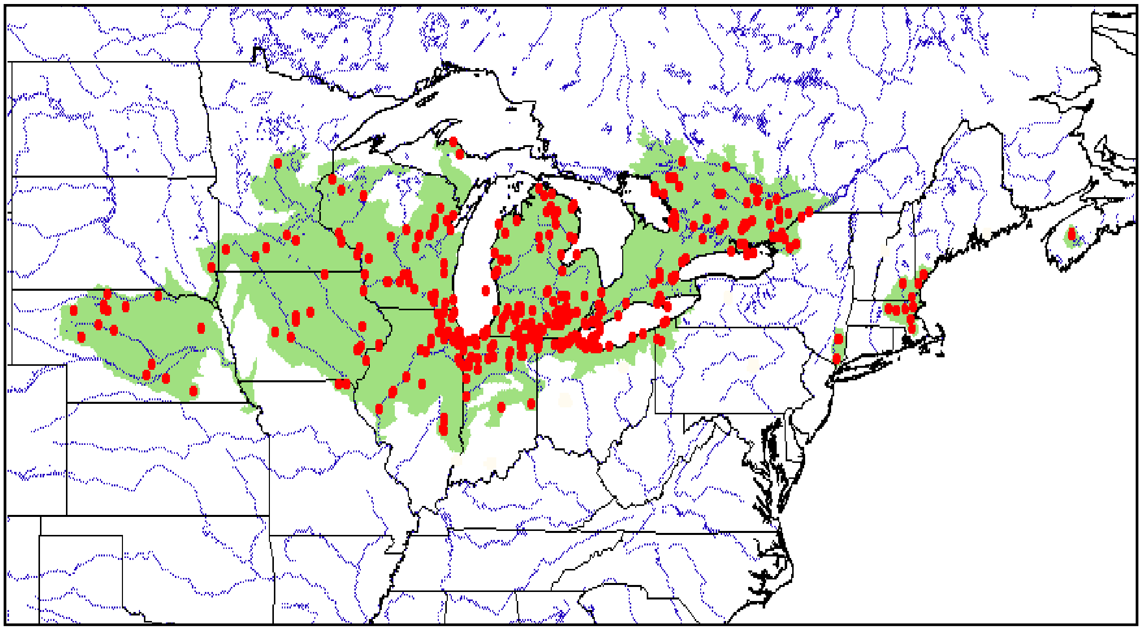

Figure 5. Distribution of *Emydoidea blandingii* in northern USA and Canada. Red points = museum and literature occurrence records based on published records plus more recent and authors' data; green shading = projected distribution based on GIS-defined hydrologic unit compartments (HUCs) constructed around verified localities and then adding HUCs that connect known point localities in the same watershed or physiographic region, and similar habitats and elevations as verified HUCs (Buhlmann et al., unpubl. data), and adjusted based on authors' data.

pectoral-abdominal seam. The characteristic that most easily separates them from other species within their range is the bright yellow color of the entire ventral portion of their throat and long neck. The vent is located posterior to the margin of the carapace and the plastron is slightly concave in males. The plastron hinge of juveniles becomes movable by ages two to three and the anterior of the plastron can completely close at five years of age and by 103 mm CL (Pappas et al. 2000). In adults, there is no apparent sexual size dimorphism, but intersexual shape differences may result from differences in morphology of the plastron (Congdon and van Loben Sels 1991; Pappas et al. 2000). Blanding's turtles are not aggressive, and seldom attempt to bite when handled.

Across most of their range, adults of both sexes range from approximately 150–240 mm in carapace length (CL), and from about 750–1400 g in body mass. Mean and maximum body sizes of adults from Grant and Arthur Counties, Nebraska (Rowe 1992b), and Valentine National Wildlife Refuge in Cherry County, Nebraska (Germano et al. 2000), were larger than those from more eastern populations (Ontario, MacCulloch and Weller 1988; Massachusetts, DePari et al. 1987; Michigan, Congdon and van Loben Sels 1991;

Figure 6. Adult *Emydoidea blandingii*. Photo by James H. Harding.

Figure 7. Hatchling *Emydoidea blandingii* from Devens, Massachusetts. Photos by Brian O. Butler.

Nova Scotia, McNeil 2002; and southeastern Minnesota, Pappas et al. 2000), except for populations in central and southwest Minnesota (Sajwaj et al. 1998; Piepgras and Lang 2000; Sajwaj and Lang 2000; Lang 2006) where adults were substantially larger in body size (> 250 mm CL) and body mass (> 2.0 kg) than those in Nebraska.

Distribution. — The main range extends disjunctly from southeastern Ontario, adjacent Quebec, and southern Nova Scotia, south into New England, and west through the Great Lakes to western Nebraska, Iowa, and extreme northeastern Missouri. The disappearance of Blanding's turtles from Illinois prairies was noted by Garman (1892). With the exception of two populations in the western portion of their range (Minnesota and Nebraska), populations are frequently small, discontinuous, and often isolated. In the eastern USA and Canada, small and disjunct populations occur in southeastern New York, Massachusetts, New Hampshire, and Nova Scotia. A major population center of this species includes southeastern Ontario, the lower peninsula of Michigan, Wisconsin, and Minnesota. Two populations of note are in southeastern Minnesota (> 5000 adults, Pappas et al. 2000) and in north central Nebraska (> 130,000 individuals, Lang 2004).

Habitat and Ecology. — In general, Blanding's turtles occupy a variety of eutrophic wetlands such as swamps, marshes, beaver dams, permanent and temporary ponds, and slow flowing streams (Kofron and Schreiber 1985; Petokas 1986; Rowe 1987; Ross and Anderson 1990; Rowe and Moll 1991; Pappas and Brecke 1992; Power et al. 1994; Herman et al. 1999; Joyal et al. 2001). Blanding's turtles frequently emerge from water to bask on logs and tussocks, or sedge clumps. During the summer in Wisconsin, adult *Emydoidea* were found more frequently in ponds than in marshes and occupied wetlands with water < 0.6 m deep and < 28.5ºC (Ross and Anderson 1990). In Nova Scotia, adults were associated with tannin rich acidic streams and beaver dams (Power et al. 1994; Caverhill 2003). Compared to adults, juvenile Blanding's turtles were most commonly found in shallow standing water between closely spaced hummocks of bottlebrush sedge and speckled alder (Pappas and Brecke 1992; Barlow 1999); in Nova Scotia they disproportionately inhabit dense sphagnum adjacent to sweet gale, leather leaf, and sedge (McMaster and Herman 2000). Such habitats are replete with cover for small turtles, and may afford them protection from predators and foraging areas where interactions with larger turtles are minimal.

Activity and Movements. — Blanding's turtles were considered to be primarily terrestrial in the early literature (Garman 1892; Surface 1908; Cahn 1937; Carr 1952); whereas, they have been considered to be primarily aquatic and secondarily terrestrial in more recent publications (Gibbons 1968; Graham and Doyle 1977; Congdon et al. 1983; Koffron and Schreiber 1985; Ross and Anderson 1990; Rowe 1987; Rowe and Moll 1991; Pappas et al. 2000). One explanation for the difference in perception is that the extensive terrestrial nesting activity was mistakenly viewed as indicative of the entire activity season. Another reason may be that a reduction in temporary wetlands and terrestrial movement corridors in human dominated landscapes has led to less overall terrestrial activity by Blanding's turtles.

Blanding's turtles make seasonal movements among aquatic areas that may be related to seasonally abundant resources (Calhoun et al. 2003) or access to mates (Congdon et al. 1983; Linck et al. 1989; Ross 1989; Kinney 1999; Joyal et al. 2001). Power (1989) noted occasional overland movements > 10 km by male Blanding's turtles in Nova Scotia, and that several females routinely traveled > 2 km overland, particularly in less productive habitats. Rowe and Moll (1991) reported that in a northeastern Illinois marsh-fen population, individuals were primarily aquatic, but daily excursions from a single pond, and long and short travels between ponds were common in the spring. In Illinois, both male and female Blanding's turtles have similar sized activity centers that are seldom greater than 2 ha in area. Movements in aquatic habitats ranged from 1–230 m/day, and average distances moved were greater for males than for females (Rowe and Moll 1991). In contrast, Ross and Anderson (1990) reported that females moved significantly greater distances each day than did males. Increased risk of death associated with movements of Blanding's turtles may lead to a reduced propensity for movements in the individuals remaining in populations (Dorff 1995, Rubin et al 2001a).

In most relatively small wetland areas, mean home ranges of Blanding's turtle females and males were from 0.6–7.9 and 0.8–7.8 ha, respectively (Ross and Anderson 1990; Rowe and Moll 1991; Piepgras and Lang 2000). In 10 suburban areas of Massachusetts, they averaged 22 ha (Grgurovic and Sievert 2005) and in a large open water area of Weaver Bottoms females and males occupied 18.9 and 56.9 ha, respectively (Hamernick 2001). In north-central Nebraska, home ranges of adults varied from 6 to 74 ha. Older females occupied larger areas and traveled greater distances than most males. During a two year telemetry study, three females each traveled distances that exceeded 10 km. Turtles living near larger lakes had smaller home ranges and smaller travel distances, relative to those using extensive seasonal wetlands. Some individual turtles can live in specific localities for a decade or more (pers. obs. in Michigan, J. Congdon; Minnesota, M. Pappas, and Nebraska, J. Lang).

In Illinois, diurnal activity was bimodal with morning and evening peaks that appeared to be related to feeding (Rowe and Moll 1991). Laboratory investigation of locomotor activity patterns in *Emydoidea* (Graham 1979) indicates that at 25ºC adults show a bimodal pattern to their activity; whereas, at 15ºC (constant) the pattern tends to be unimodal with movements concentrated around noon. As data have accumulated, it has become apparent that Blanding's turtles are more active at lower temperatures than previously suspected. Laboratory studies have indicated a critical thermal maximum of 39.55ºC (Hutchison et al. 1966) and a mean preferred temperature of 22.5ºC for male and 24.8ºC for female Blanding's turtles, respectively (Nutting and Graham 1993); values substantially lower than those reported for many other species. Rowe and Moll (1991) observed that individuals entered winter dormancy between mid-October and mid-November and the first turtle seen in the spring was in late March at a water temperature of 19ºC. Ross and Anderson (1990) found that Blanding's turtles entered hibernation when water temperatures ranged from 10–13ºC, seemed to prefer ponds for overwintering, and some apparently overwintered communally. Their observations have been corroborated by Graham and Butler (1993). However, on the E.S. George Reserve in Michigan, Blanding's turtles were active within wetlands until early December and emerged as early as 1 March, when body temperatures of captured turtles was less than 3°C (Sexton 1995). As ice melted in southeastern Minnesota in March, body temperatures of males were 2.3–5.2°C (n = 26) when emerging, 4.4–16.6°C (n = 23) during male searching activity for females, and 6.6–15.5° (n = 31) when exhibiting mounting behavior (M. Pappas, unpubl. data). Similar activity at low temperatures was recorded in Nova Scotia, where turtles occupy overwintering sites from mid-November to late March, moving beneath ice cover up to 7 m in water less than 1.5ºC (Newton 2007).

Diet. — Adult *Emydoidea* are thought to be primarily carnivorous (Lagler 1943; Penn 1950; Kofron and Schreiber 1985; Rowe 1992a) or omnivorous (Cahn 1937; Conant 1938, Carr 1952, Graham and Doyle 1977). In New England, 92 individuals had consumed 58% crayfish by volume (Penn 1950), and DeGraaf and Rudis (1986) reported that the diet consisted of 50% crayfish and other crustaceans, 25% insects, and 25% invertebrates and vegetable matter. Crayfish and insects were also the most important prey in Michigan (Lagler 1943), and in Missouri (Kofron and Schreiber 1985). In Nova Scotia where crayfish are absent, diets included aquatic insects, such as dragonfly nymphs, aquatic beetles, snails, fish (Bleakney 1963), and vegetation such as *Nuphar* (T. Herman, unpubl. data). In Illinois, diets were made up of snails (35.0% by volume) followed by crayfish (19.3%), earthworms (12.7%), and insects (10.3%; Rowe 1992a). Blanding's turtles also eat fish, fish eggs, and frogs (Kofron and Schreiber 1985).

Parasites. — Ernst and Barbour (1972) summarized the parasites known to affect *Emydoidea*. Their list included protozoans, trematodes, nematodes, acanthocephalans, leeches, and mosquitos, but levels of infestation and conservation concerns were not mentioned. Epizoic filamentous cyanobacterium, *Konivophoron sp*. and cladophoroid green alga *Basicladia chelonum* were recorded from Ontario and Nova Scotia (Colt et al. 1995; Garbary et al. 2007).

Growth. — Growth in *Emydoidea* has been examined at different sites across its range (Gibbons 1968; Graham and Doyle 1977; Petokas 1986; Ross 1989; Congdon and van Loben Sels 1991; Rowe 1992b; Germano et al. 2000; Pappas et al. 2000; McNeil 2002). In general, the annual rates of increase in carapace length, plastron length, and body mass are greatest in the first year and decrease more or less steadily as sexual maturity is approached; at that time growth declines abruptly. Variation in juvenile growth rates and ages at maturity may be a major cause of variation in adult body size within a population (Congdon and van Loben Sels 1993).

Pre-Nesting Movements. — In southeastern Minnesota, females may move up to 7.5 km prior to the nesting season (J. Lang and M. Pappas, unpubl. data), and > 1000 gravid females observed in 2000 were concentrated in wetlands adjacent to nesting sites just before and after they moved to nesting sites in nearby upland dunes. Movements made immediately prior to actual nesting can take longer than seven days and consist of visits to woodland pools, temporary marshes, previous nest sites, and finally to the area where the nest is constructed (Congdon et al. 1983, 2000; Ross and Anderson 1990; Piepgras 1998; Kinney 1999; Pappas et al. 2000; Piepgras and Lang 2000). Ruben et al. (2001) suggested that nesting migrations are less extensive in areas impacted by development and restricted by human disturbance. Some nests are constructed over a kilometer from the nearest water, and nests are frequently constructed in areas that are not adjacent to the marsh where females reside (Congdon et al. 1983, 2000; Linck et al. 1989).

Nesting. — In Michigan, nesting takes place from late May to early July with an average nesting season of approximately 23 days (Congdon et al. 1983, 2000); whereas, in Massachusetts it occurs from early to late June with an average duration of two weeks (Linck et al. 1989). Most of the actual nesting takes place from 1900–2100 hrs, with nest construction taking 2–2.5 hrs to complete (Congdon et al. 1983; Linck et al. 1989; Standing et al. 1999). Whereas some females apparently return to the same general nesting area over a number of years, some individuals had up to 2 km inter-nest distances between years (Congdon et al. 1983; 2000; McNeil 2002; B. Butler, pers. comm.).

Some general observations have been made on Blanding's turtle nesting (Snyder 1921; Brown 1927; Bleakney 1963). Exposure to sunlight, low vegetation cover, well-drained soils, and proximity to wetlands combine to determine the quality of a nesting area (Congdon et al. 1983, 2000; Linck et al. 1989; Butler 1997; Kiviat 1997; Sajwaj et al. 1998; Kinney 1999; Standing et al. 1999). In Maine and Nova Scotia, nests are sometimes excavated in soil-filled cracks in bedrock (Joyal et al. 2000; T. Herman, unpubl. data). Nests constructed in grassy areas or adjacent to some plants (e.g., wild grape) sometimes become "root bound," and hatchlings die because they are unable to dig out of the nest. Many nests are constructed in areas with disturbed soils, such as gardens, driveways, dirt roads, roadsides, railroad embankments, fire lanes, and agricultural fields. Some nests in disturbed areas are at risk of being destroyed by garden tools, farm machinery, road graders, and other motor vehicles. An additional 4% of observed nests on the E.S. George Reserve in Michigan were washed out or deeply buried during thunder storms, and others constructed in low lying areas were covered with standing water and developing embryos apparently drowned (Congdon et al. 2000).

Nest predation rates are highly variable in Michigan (Congdon et al. 1983, 2000) and averaged 74% (range = 37–100%). Most nest predation is due to raccoons and foxes and occurs within three days of nest construction. Minor nest predators in Michigan include skunks, opossums, and unknown burrowing mammals (see Standing and Herman 2000 for nest predation by short tailed shrews). Following the collapse of the local fur industry in Michigan in the early 1980s, nest survival on the E.S. George Reserve fell from 45% to 4% (Congdon et al. 1993). If there is a cause and effect relationship between reduced harvest of raccoons and foxes and reduced nest survival, then continued high population levels of nest predators will definitely result in serious reductions in recruitment into the juvenile age classes of some Blanding's turtle populations.

Hatchling Emergence and Dispersal. — From nest construction to hatchling emergence takes approximately 84 days and results in hatchlings emerging from late August through early October (Congdon et al. 1983; Pappas et al. 2000); at the northeastern limit of the range in Nova Scotia, incubation can take up to 128 days with emergence in late October (Standing et al. 1999). Although most hatchlings emerge from nests in the fall, some do not immediately move toward water (Standing et al. 1997; McNeil et al. 2000). As a result, a few hatchlings may successfully overwinter on land, but only if the surrounding area is moist enough to prevent desiccation (Pappas et al. 2000; Dinkelacker et al. 2004; Camaclang 2007). Hatchlings from Massachusetts (Graham and Doyle 1979), Nebraska (Gutzke and Packard 1987), Minnesota (Pappas et al. 2000), and Michigan (Congdon and van Loben Sels 1991) were similar in size (29–39 mm CL) and mass (6–10 g).

Butler and Graham (1995) found that hatchling Blanding's turtles sometimes entered wetlands distinct from those occupied by adults and older juveniles. They suggested that hatchlings orienting toward wetlands may use olfactory cues, and because some hatchlings followed the same trails, they may have been exhibiting scent-trailing behavior. Hatchlings moved most often during early and mid-morning and late afternoon. They sometimes stayed in cryptic forms for several hours to several days, presumably to avoid predators and temperature extremes. Hatchlings successfully tracked from the nest to wetlands reached their goal in from less than 12 hrs to 9 days (Butler and Graham 1995). In contrast, hatchlings emerging from nests on the beaches of large cold-water lakes in Nova Scotia did not go directly to closest water, but went inland to more distant sheltered and productive aquatic habitats (Standing et al. 1997) or saturated terrestrial ones (Camaclang 2007), and showed no evidence of scent-trailing (Smith 2004).

Population Structure. — Low numbers of yearlings and young juveniles has been reported in several studies (Gibbons 1968; Graham and Doyle 1977; Congdon et al. 1983; Congdon and van Loben Sels 1991), and may be real because of high nest failure (Congdon et al. 1983) or high juvenile mortality compared to that of adults (Frazer et al. 1990). However, demographic data from a relatively stable population of Blanding's turtles on the University of Michigan's E.S. George Reserve indicated high average annual survival between the ages of 1 and 17 (mean age at maturity) was required to maintain a stable population (Congdon et al. 1993). Low numbers of juveniles may also be a misperception because juveniles occupy habitats atypical of adults and are consequently not sampled as often by investigators (Pappas and Brecke 1992; McMaster and Herman 2000).

Biased adult sex ratios in Blanding's turtle populations may be due to environmental sex determination, differential mortality, or biased immigration or emigration rates of males and females. Two relatively large and well-studied populations of Blanding's turtles had female-biased adult sex ratios (1 male to 4 females in the population on the E.S. George Reserve in southeastern Michigan (Congdon and van Loben Sels 1991); and 1 male to 2.2 females at Weaver Dunes in southeastern Minnesota (Pappas et al. 2000). A relatively large population in Ontario (429 adults; S. Gillingwater, unpubl. data; cited in COSEWIC 2005) had an adult sex ratio that was 1:1 or slightly male-biased. Adult sex ratios of 1:1 also exist in the Nova Scotia population complex (T. Herman, unpubl. data). The sex ratio in a large Nebraska population was 1 male to 1.3 females (796 adults; Lang 2004). Blanding's turtles have temperature-dependant sex determination (Gutzke and Packard 1987), but relationships between hatchling and adult sex ratios are unknown for any population. Regardless of the cause, biased adult sex ratios reduce effective population size (Hartl 2000), which in turn can contribute to population instability and reduce the probability of population persistence (particularly for small populations).

Loss of genetic diversity has apparently occurred in small and isolated populations in the greater Chicago, Illinois, metropolitan area compared to larger populations in Michigan, Nova Scotia, and Wisconsin (Rubin et al. 2001b).

Life History Trait Values. — Demographic data from a relatively stable population of Blanding's turtles on the University of Michigan's E.S. George Reserve indicated that a 72% average annual survival between the ages of 1 and 17 (mean age at maturity) was required to maintain a stable population, a value only 22% lower than that found for adults (Congdon et al. 1993). As a result, threats that increase mortality of adults and older juveniles can have substantial impact on population stability.

In Michigan, females mature between ages 14 and 20 (mean = 17.5 yrs (Congdon and van Loben Sels 1991, 1993). Clutch sizes range from 3–19 eggs and means among populations range from 7.6–12.9 eggs (Carr 1952; Gibbons 1968; Graham and Doyle 1979; DePari et al. 1987; MacCulloch and Weller 1988; Standing et al. 1999; Pappas et al. 2000), and clutch size increases with body size. Eggs average approximately 23 mm in width, 38 mm in length, and weigh about 12 g. There are no data to suggest that females produce more than one clutch per year, and some adult females do not reproduce each year (Congdon and van Loben Sels 1991). As a result, average fecundity is low (clutch size / 2 [assuming an equal hatchling sex ratio] X 0.8 [reproductive frequency] = 4 female eggs). Both egg size and clutch frequency increase with age of females, but clutch size does not (Congdon et al. 2001).

Annual survival of adults exceeds 0.94 and life table analysis results in a mean cohort generation time of approximately 37 yrs (Congdon et al. 1993). Blanding's turtles are long-lived (known minimum ages > 75 yrs). A number of adult Blanding's turtles that were marked between 1953 and 1957 on the University of Michigan's E.S. George Reserve by Owen Sexton were still alive and reproductive in 2007 (Congdon, unpubl. data), and one individual in Minnesota was confirmed to be a minimum of 77 years old (Brecke and Moriarty 1989). Because of their extended longevity, long reproductive life-spans, and apparently lack of expression of actuarial senescence (Congdon et al. 2001), Blanding's turtles have become of interest to life historians researching the evolution of longevity and gerontologists working with non-human models of aging.

Population Status. — The largest population of Blanding's turtles presently known is on the Valentine National Wildlife Refuge, in north central Nebraska. A recent survey there indicated over 130,000 individuals (excluding hatchlings and yearlings) with densities ranging from 20–57 individuals per ha (Lang 2004). They occupy a mosaic of pothole lakes and shallow wetlands surrounded by sandhills. Road mortality is presently a concern for this population, but roadside fences and culverts have been effective in reducing highway mortality.

The next largest population of Blanding's turtles exists at Weaver Dunes in Wabasha County, southeastern Minnesota (Pappas et al. 2000). Weaver Dunes is an area of upland and sand prairie on a glacio-alluvial terrace within the upper Mississippi River flood plain. Of the aquatic habitat, 1200 ha (about 80%) is protected; however, less than 25% of the nesting areas are protected. In 1976, over 550 nesting females (moving to nest sites in June–July) and 500 hatchlings (moving from nests to wetlands in August–September) were captured crossing a 1.7 km stretch of highway (Pappas et al. 2000). Long-term observations at this locality from 1974–2007 indicate that nesting migrations of > 1000 females occur annually from late May until early July (Lang, unpubl. data). In contrast to most other populations studied, juveniles between hatching and age 11 were regularly captured (Pappas and Brecke 1992). Mortality of turtles crossing roads, residential development, and disruption of nesting habitats due to natural succession and invasion of non-native species are all cause for concern.

In Michigan, one stable population of approximately 200 adult Blanding's turtles (Congdon and Gibbons 1996) has been studied for 43 of the past 54 years (Congdon et al. 1993, 2001). The population is on a 650 ha protected site, the University of Michigan's research area (E.S. George Reserve, Livingston County) in the southeastern part of the state. It contains a number of marshes and swamps where Blanding's turtles reside permanently, and additional habitats adjacent to the George Reserve are protected from development because they are owned by the state of Michigan and administered as recreation areas. In the southwestern part of the state, a relatively stable population of 300–400 juveniles and adult Blanding's turtles exists at Sheriffs Marsh in Kalamazoo County (Gibbons 1968). Sheriffs Marsh is about 40 ha of wetlands (that includes 6 ha of open water) that has been privately owned and protected by a local hunting club for over 30 years.

In the northeastern portion of the range, Blanding's turtles are usually found in small isolated populations. In the Nashua River Valley of central Massachusetts B. Butler (pers. comm.) found 45% subadults (6–15 yrs) that may indicate a stable population. In Dutchess County, New York, M. Emrich and E. Kiviat (pers. comm.) project a probable decline in their small population of about 40 animals, and Petokas and Alexander (1981) reported their Ontario study population to be very small and potentially in need of active management.

Over the past two decades aspects of the ecology and status of Blanding's turtles in and adjacent to Kejimkujik National Park, Nova Scotia, Canada, have provided information on an isolated eastern population complex (Herman et al. 1999; Mockford et al. 1999, 2005, 2007; Standing et al. 1999, Standing and Herman 2000; McMaster and Herman 2000; McNeil et al. 2000; McNeil 2002; Caverhill 2003; Bourque 2006; Camaclang 2007; Howes et al., in press). Three spatially and genetically distinguishable populations, together estimated at fewer than 350 adults, occur in two adjacent watersheds; although separated by only 15–25 km the three populations show variable but limited recent and historical gene flow (Mockford et al. 2005; Mockford et al. 2007; Howes et al., in press), even at small spatial scales within populations (Toews 2005).

Threats to Survival. — Blanding's turtles are suffering from degradation of wetlands and the terrestrial portion of their core habitat. Reduction and alteration of nesting areas and wetland habitat, together with delayed maturation, less than annual reproductive frequency, and losses due to predation, collecting (Levell 2000), and automobiles (Ashley and Robinson 1996) are all serious problems. In many instances females either cross roads or due to nest site limitations, nest on road edges (both make females susceptible to collectors and being killed by cars). Negative impacts on their populations are exacerbated by life history traits associated with delayed sexual maturity, low annual fecundity, and extreme longevity.

A study of fragmented populations of Blanding's turtles in southwestern Minnesota, indicated that appropriate conservation measures should be tailored to the size and demographic status of each metapopulation, and the wetland and terrestrial habitats characteristic at each site. Roads, ownership and boundaries of terrestrial and wetland habitats, and land management practices vary for each population, which constitutes a major problem for conservation efforts to maintain the viability of populations (Lang 2006).

The apparent extirpation of the spotted turtle (*Clemmys guttata*) and changes in adult sex ratios and loss of smaller (apparently younger) Blanding's turtles in the protected habitats of Point Pelee National Park in Ontario, Canada, indicates that populations of freshwater turtles can be impacted by factors other than habitat loss (Browne and Hecnar 2007).

There are four issues raised by Blanding's turtle life history traits and population structure:

1) Head-starting programs that include protecting or moving nests to artificial nesting areas run the risk of producing highly biased hatchling sex ratios that will eventually contribute to biased adult sex ratios. Biased adult sex ratios in small populations will add to reductions in effective population sizes.

2) Blanding's turtles are long-lived (even compared to other turtles) and older females have higher survivorship and reproductive output than do younger females (Congdon et al. 2001). Increased mortality of adults will decrease reproductive output in the population because females of all ages are reproductive.

3) Annual fecundity of Blanding's turtle females is low; they do not begin to reproduce until they are between 14 and 20 years old, have small clutch sizes, and do not reproduce every year (combined = low annual fecundity). As a result, annual survivorship between ages 1 and maturity must average at least 60% to maintain population stability under most population scenarios (Congdon et al. 1993).

4) Because reproductive lifespans of females are longer than generation times, there is increased probability of inbreeding (mating with an offspring). Inbreeding probabilities will be higher in small and isolated populations and where nesting migrations of females (that usually place hatchlings in proximity to a wetland other than the resident wetland of the mother) are no longer possible due to degradation of terrestrial movement corridors, terrestrial habitats, and wetlands.

Conservation Measures Taken. — Blanding's turtles have the following conservation ratings: IUCN/SSC Specialist Group Action Plan Rating: 3 (TFTSG, 1989); U.S. Endangered Species Act of 1973: status category 2 (candidate for listing); IUCN 2007 Red List status: Lower Risk / Near Threatened; Canada Species at Risk Act: Endangered (Nova Scotia), Threatened (Great Lakes / St. Lawrence).

The Blanding's turtle is protected by statute in several states, but no federal protection exists. According to NatureServe, in the USA Blanding's turtle is listed as At Risk in 15 of 16 states. It is "Extirpated" (SX) from Rhode Island, "Critically Imperiled (S1) in Missouri, Pennsylvania, and South Dakota, "Imperiled" (S2) in Iowa, Massachusetts, Minnesota, New York, and Ohio, and "Vulnerable" (S3) in Illinois, Indiana, Michigan, New Hampshire, and Wisconsin. It is considered "Secure" (S4) only in Nebraska. In Canada, it is considered "Critically Imperiled" (S1) in Nova Scotia, Ontario, and Québec.

Turtle crossing signs were installed on a paved road that runs between Blanding's turtle nesting areas and wetlands in the Weaver Dunes area of southeastern Minnesota (Lang 2000). Recently the Nebraska Department of Roads also installed turtle crossing signs and chain link drift fences to guide Blanding's turtles through culverts (also called "eco-passages") under U.S. Highway 83 at the Valentine National Wildlife Refuge. A study to evaluate the effectiveness of fences and culverts at road crossings resulted in specific recommendations about the installation of more fencing at vulnerable sites, and additional sites were subsequently fenced to limit further road mortality (Lang 2004).

No captive breeding programs are known, but populations exist in protected natural reserves in several states, e.g., Massachusetts, Michigan, and Minnesota, as well as in the provinces, e.g., Ontario and Nova Scotia.

Since most observers have reported severe predation on Blanding's turtle nests, removal of the key predators should help to reduce nest mortality. Graham (unpubl. data.) employed a mammal trapping/removal strategy for one season to reduce redbelly turtle nest destruction. Because this protocol required considerable work, and yielded results that were less than satisfying, an alternative program of caging fresh nests with wire mesh was undertaken about ten years ago. Whereas this approach required the expenditure of much time and effort in locating nests initially, once properly caged they were essentially impregnable. A limited caging program for *Emydoidea* nest protection in Massachusetts has proven effective at improving hatchling recruitment (Butler and Graham 1995). In Nova Scotia, a caging program using volunteers has been in place for approximately 20 years; in recent years it has protected more than 30 nests annually in and around Kejimkujik National Park, and has become an important stewardship tool (Standing et al. 2000; Caverhill 2006).

Conservation Measures Proposed. — Increased road mortality (commercial or incidental collection of individuals from a population has the same effect as mortality) is a function of proximity to aquatic areas, movement corridors, and nesting areas. Small isolated populations can be severely impacted or extirpated by chronic increases of mortality due to roads. Road signs can be placed along roadways with high volumes of traffic of both Blanding's turtles and vehicles. In some areas, fencing and eco-passages (e.g., culverts, tunnels, or bridges) that encourage turtles to cross under the roadway should be installed. The cost of such structures should be less if they are incorporated into the design of new roads.

Long term studies of movements and habitat utilization would be helpful to future conservation efforts, and preservation of wetlands, upland corridors, and nesting sites, together with strict pollution control, will be vital to the survival and increase of *Emydoidea*. In some situations, enhancement of existing nesting areas by removal of invasive species or trees that shade the ground could increase hatchling recruitment or reduce risks associated with the duration and distance traveled by females (particularly where roads are an issue). Construction and maintenance of new nesting areas should be considered where necessary and the success of such efforts should be monitored. Although Blanding's turtles seek disturbed (often cultivated) areas for nesting, attempts to create artificial nesting sites or enhance existing sites by harrowing have not been especially fruitful (B. Butler, J. Congdon, and M. Emrich; pers. obs.). However, such efforts were not extensive or maintained over long periods of time.

Captive Husbandry. — Hatchling Blanding's turtles have been headstarted in captivity for subsequent release in the wild (Linck et al. 1989; Graham, unpubl. data). Headstarting protocols involved housing the young in a 10–20 gal aquarium holding not more than 10 cm of clean well water over 3–4 cm of coarse sand. The water temperature was maintained at 27–29ºC with a submersible heater, and filtration was provided by an aeration-driven foam bottom filter. A basking site (brick on edge) was provided at mid-tank and illumination (two 15W incandescent bulbs) was provided from a standard stainless aquarium reflector. The remainder of the tank top was covered with a plexiglas sheet to reduce heat loss and evaporation. Lighting was supplemented with a black light placed across the top of the tank with the plexiglas removed at least once a week for a full day (12 hr photoperiod). Young *Emydoidea* were fed live brine shrimp (*Artemia* sp.) initially, and then small strips of fresh scallop, shrimp, and fish for a couple of weeks while they were transferred over to a diet composed exclusively of Reptomin™ pellet food fed in a separate shallow (3 cm) warm water tray to avoid fouling their main tank. This protocol proved very effective in producing extremely robust yearlings for release. In Nova Scotia, a headstarting program has been in place since 1993 (Penny 2004), in an effort to raise hatchlings in captivity to a size at which they are less vulnerable to raccoon predation.

Current Research. — After 33 consecutive years, the E.S. George Reserve study was closed after the 2007 field season. During the past 10 years, research on Blanding's turtles at this site focused on taking blood samples from all adults and juveniles, and tissue samples from hatchlings (from protected nests) for determining sources of variation in the reproductive success of males. Initial orientation of hatchling Blanding's turtles dispersing from experimental nests in a variety of settings has been studied from 2001 to present at Weaver Dunes, Minnesota (Pappas, Congdon and Brecke, unpubl. data).

Research in Nova Scotia initiated in 1987 continues today, and has increasingly involved volunteers and local land owners. The most recent research has targeted terrestrial movements using GPS telemetry, habitat modeling and critical habitat designation, fine-scale population genetic structure, paternity analysis, hatchling overwintering, and long-term survival of headstarted juveniles.

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