

# JNAH

ISSN 1094-2246

THE JOURNAL OF NORTH AMERICAN HERPETOLOGY

Volume 2016, Number 1

5 July 2016

[jnah.cnah.org](http://jnah.cnah.org)

## EFFECT OF RACCOON (*PROCYON LOTOR*) REDUCTION ON BLANDING'S TURTLE (*EMYDOIDEA BLANDINGII*) NEST SUCCESS

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**ABSTRACT:** The Lake County Forest Preserve District has monitored a state-endangered Blanding's Turtle (*Emydoidea blandingii*) population at two adjoining nature preserves along the Illinois–Wisconsin border since 2004. Prior to predator management, 92.3% of documented and unprotected natural Blanding's Turtle nests (12 of 13) and 88% of monitored artificial nests have been at least partially depredated. The goal of this study was to determine the efficacy of subsidized Raccoon (*Procyon lotor*) removal efforts in increasing the nest success of Blanding's Turtles. During April–May 2013 and 2014, we captured and euthanized 78 Raccoons from our 2 km<sup>2</sup> study area. We estimated pre-removal abundance estimates using the Leslie depletion method; it appeared that we removed 83–89% of the Raccoons from the study area each year and pre-removal density estimates were 37.5% lower in 2014 than 2013. During the study period, we monitored 22 Blanding's Turtle *in situ* unprotected nests. In 2013, one of seven (14%) Blanding's Turtle nests was partially depredated and no nests were completely depredated, indicative of a successful impact of Raccoon removal on Blanding's Turtle nest success. However in 2014, nine of 15 (60%) Blanding's Turtle nests were depredated. Our results provide some evidence that removal of Raccoons may have increased Blanding's Turtle nest success but other factors, such as a functional response of surviving Raccoons or depredation by other subsidized predators may be contributing to decreased nest success.

### INTRODUCTION

The Blanding's Turtle (*Emydoidea blandingii*) is a long-lived, semi-aquatic turtle in decline throughout much of its range (COSEWIC 2005, USFWS 2011) and was designated as Endangered in Illinois in 2009 (ILL. ADM. CODE, CH. I, SEC. 1010). A growing body of literature strongly suggests that predation rates on turtle eggs and hatchlings is increasing, resulting in decreased recruitment and diminished population growth, which has led to population declines in many turtle species (Christiansen and Gallaway 1984, Boarman 2003, Engeman et al. 2005, Engeman et al. 2006, Browne and Hecnar 2007, Munscher et al. 2012), including Blanding's Turtles (Congdon et al. 1993, Congdon et al. 2000, COSEWIC 2005). Numerous studies have attributed increased predation rates of turtle eggs and hatchlings to Raccoons (*Procyon lotor*) (Butler et al. 2004, COSEWIC 2005, Engeman et al. 2005, Engeman et al. 2006, Munscher et al. 2012). In urbanized areas, predators such as Raccoons have been reported to have higher densities, increased survival, and higher annual recruitment compared to rural areas; these de-

mographics are mainly attributed to the abundance of artificial food resources available (Prange et al. 2004). Further, high densities of subsidized predators can result in "spillover predation" (Schneider 2001, Kristan and Boarman 2003) where subsidized predators utilize native prey in the natural habitats, such as preserves, that are associated with urban areas.

Many conservation efforts have included head-starting programs as a technique to improve Blanding's Turtle recruitment and thus increase population viability (Arsenault and Mockford n.d., Magnum 1999, USFWS 2011). However, head-starting programs are time consuming, expensive, and their efficacy long-term is largely unknown (Arsenault and Mockford n.d.; Heppel et al. 1996, Burke 2015). Subsidized predator management has been investigated for other turtle species (Engeman et al. 2005, Engeman et al. 2006, Munscher et al. 2012) and may be a more efficient and less-intrusive alternative to headstarting. For example, predation rates on sea turtle nests (*Caretta caretta*, *Dermochelys coriacea*, and *Chelonia mydas*) dropped from a high of 95% prior to removal to 9.4% following removal of Nine-banded

Armadillos (*Dasypus novemcinctus*) and Raccoons (Engeman et al. 2005). Although results such as these are promising, only one published study has specifically documented the results of predator control on Blanding's Turtle nest success. Standing et al. (1999) excluded predators from Blanding's Turtles' nests in Nova Scotia by constructing a screened wood-framed box around each nest. Success of these protected nests (defined as at least one hatchling emerged) ranged from 18.2–93.3% in the three years of their study and nest failure was attributed to flooding and low incubation temperatures. Standing et al. (1999) also reported that less than 15 unprotected Blanding's Turtle nests were depredated during their study. Although the Raccoon was designated as the predator of the nests in their study, nest failure of Blanding's Turtles in Nova Scotia is clearly driven by factors other than predation.

Our goal was to determine the efficacy of Raccoon removal efforts to increase nest success of Blanding's Turtles in one of the largest remaining populations in Illinois. Our specific objectives were to: (1) capture and remove Raccoons; (2) estimate pre-removal abundance and density of Raccoons; and (3) quantify Blanding's Turtle nest success. The results of the study were evaluated to determine the long-term feasibility of conducting subsidized Raccoon control activities and aid in the conservation of the Blanding's Turtle.

## METHODS

**Study Site** — The Lake County Forest Preserve District (hereafter, District) has been monitoring the Blanding's Turtle population at a designated state nature preserve and adjacent natural areas within the Lake Michigan Lake Plain since 2004. The Lake Plain macrosite is approximately 198 ha and represents one of the larger ( $N = 165$  turtles) and better-studied populations in the state. However, modeling has indicated that the population is in decline due to low juvenile recruitment combined with unsustainable levels of adult mortality (Kuhns 2010). Recruitment is suppressed by high levels of predation of both nests and hatchlings. Since we began monitoring nests and prior to predator management, 92.3% of documented and unprotected natural Blanding's Turtle nests (12 of 13) and 88% of artificial nests (Kuhns 2010) have been at least partially depredated.

The Lake Plain macrosite is located on the Wisconsin-Illinois border directly adjacent to Lake Michigan. Located in the northeast corner of Illinois, 93 ha is owned and managed by the District and consists largely of dune and swale topography that includes sand prairie, sand savanna, marsh, and a graminoid fen. The western third of the preserve contains a mesic sand prairie and a Black Oak (*Quercus velutina*) sand savanna covers a small northern portion that extends through the center of the preserve. The other 105 ha is located in the southeast corner of Wisconsin and is owned and managed by The Nature Conservancy and the Wisconsin Department of Natural Resources. This portion of the site also consists of dune and swale topography that includes sedge meadow and sand prairie. In addition to wet, mesic, and dry sand prairies, Bur Oaks (*Quercus macrocarpa*) and Black Oaks are located in the southern and western areas of this portion of the macrosite. The Lake Plain macrosite is bordered predominantly by a mix of residential, commercial, and agricultural lands in addition to an adjacent state park where camping, picnicking and recreation occur. Raccoons are not harvested or otherwise managed on either portion of the site.

**Raccoon Capture and Removal** — During April–May 2013 and 2014, we captured Raccoons using Sterling Grizz Dog Proof Raccoon traps (Minnesota Trapline Products, Inc., Pennock, MN). The traps we used are specifically designed for raccoons; we did not capture any other species. Traps were set opportunistically in the vicinity of water and where previous Blanding's Turtle nests were located; coordinates were recorded using a Garmin GPS (Garmin Co., Olathe, KS) (Figure 1). We checked

traps between 0600–1000hr once every 24hrs. We anesthetized captured Raccoons using an intramuscular injection of either ketamine hydrochloride (8–10 mg/kg) or Telazol (2–4 mg/kg). Following immobilization, we immediately euthanized the captured Raccoons via an intracardial injection of Euthasol (90–100 mg/kg) and aged (juvenile vs adult) and sexed individuals.

**Raccoon Pre-removal Estimates** — The Leslie depletion model is a catch per unit effort (CPUE) technique that estimates population size based on the cumulative catch of individuals over several sampling periods and requires that samples (captured individuals) are removed from the population and not returned. We calculated the parameters of this model using Microsoft Excel (Microsoft Co., Redmond, WA) to estimate pre-removal abundance and density of Raccoons on the Lake Plain macrosite each year (Ricker 1978, Rosatte et al. 2006). We calculated total effective trap nights by summing the number of traps set each night and subtracting the product of 0.5 by the number of tripped traps. We also calculated the effective trapping area for each year to determine if the majority of the study site was being affected by the Raccoon removals. Prange et al. (2004) estimated mean home range sizes of Raccoons residing in a similar suburban nature preserve in the Chicago Metropolitan Area as 21.9 ha during March–May. Additionally, Chamberlain et al. (2002) reported that Raccoons in their study readily traversed their seasonal home ranges in a single day. Hence, we determined our effective trapping area to include a buffer around all of our traps equivalent to the average distance across Prange et al.'s (2004) home range estimates (i.e., the square root of 0.219 km<sup>2</sup>, or 468 m). We used ArcGIS (Environmental Systems Research Institute, Redlands, California) to create a 468 m radius around our trapping locations and to calculate an effective trapping area each year. We examined trends in CPUE over the

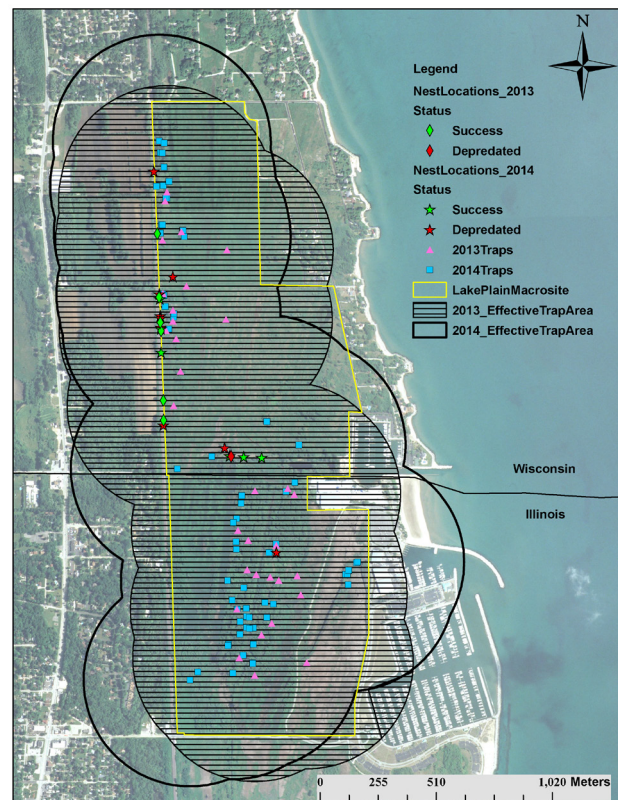


Figure 1. Raccoon (*Procyon lotor*) trapping locations and effective trap area with nesting locations of Blanding's Turtles (*Emydoidea blandingii*) at a Lake Plain macrosite near Lake Michigan, 2013–2014.

Table 1. Demographic summary of Raccoons (*Procyon lotor*) trapped and removed from a Lake Plain macrosite near Lake Michigan, 2013–2014.

Year	Total #	# Male	# Female	# Adult	# Juvenile	Pre-removal N (95% CI)	Pre-removal Density (Raccoons/km <sup>2</sup> ) (95% CI)
2013	45	34	11	41	4	54 (27–59)	16 (8–18)
2014	33	28	5	23	10	37 (17–41)	10 (2–10)

sampling periods using Wilcoxon two-sample tests and used Pearson chi-square tests with Fisher's exact P values to determine if differences in CPUE existed ( $\alpha = 0.05$ ) between sexes, years, and ages of the study.

**Blanding's Turtle Nest Monitoring** — Twenty-five female Blanding's Turtles were captured via hoop nets or opportunistically by hand and affixed with radio-transmitters (30g, model AI-2F; Hohloh Systems, Ltd., Carp, Ontario, Canada). In May–June of both study years we used a R-1000 telemetry receiver and hand-held 3-element Yagi antenna (Communication Specialists, INC., Orange, California), and ground-based radiotelemetry techniques (Millsbaugh et al. 2012) to monitor movements of radio-tagged Blanding's Turtles. We hand-caught radio-tracked female Blanding's Turtles 2–3 times a week to determine if they were gravid by palpating the inguinal pockets. Once eggs felt hard and the turtles began migrating to nesting grounds, the turtles were monitored 1–2 times a day until egg deposition.

The first 10 Blanding's Turtles that were found with sufficiently hardened eggs were temporarily removed from the site to collect eggs as a part of the District's headstarting program. The remaining turtle nests were confirmed by directly observing the full nesting process and palpating the inguinal pockets of the turtles to confirm that eggs were no longer present. During nesting, we attempted to distance ourselves from the nesting turtles to reduce disturbance. Nests were marked with a Garmin GPS and descriptive location notes were recorded (e.g., 15 paces from oak tree, directly east of trail). When no unique physical objects were available, flagging tape was tied to a stick to note the general vicinity (e.g., 5 m east of flagged stick). Burke et al. (2005) reported that flagging as close as 25 cm around a turtle nest does not increase the likelihood of depredation.

We monitored nests for signs of cavity excavation by a predator or hatching. Nests were checked daily for the first two weeks after nesting or until a depredation event occurred. After the first two weeks, nests were checked 2–3 times a week until evidence of hatching or depredation was recorded. We considered nests that were clearly excavated with only shell fragments remaining (usually outside of the nest chamber) prior to typical nest emergence in late August or September as fully depredated. A nest was considered partially depredated if the nest was clearly excavated but some seemingly viable eggs remained intact within the nest chamber. Success was indicated by the presence of an emergence hole with no sign of excavation and shell fragments inside the nest chamber during late August and September. Live hatchlings within the chamber or near the entrance additionally confirmed successful emergence with some of the nests. We summarized the total number of Blanding's Turtle nests monitored and the number of nests depredated in 2013 and 2014.

### RESULTS

We removed 78 Raccoons from the Lake Plain macrosite and monitored 22 Blanding's Turtle *in situ* unprotected nests during 2013 and 2014 (Table 1; Figure 1). From 12 April–25 May 2013 and 8 April–23 May 2014, we expended 466.5 and 439.5 effective trap nights for Raccoons, respectively. Our effective trapping area was 338 ha and 389 ha in 2013 and 2014, respectively, which covered the majority of the Lake Plain macrosite and surrounding area each year (Figure 1). We removed more

Raccoons in 2013 than 2014 (Table 1). There was no clear pattern to CPUE over the sampling dates for either year (Figure 2) and CPUE did not differ between April and May in 2013 (Wilcoxon 2-sample test = 184.5 Exact P = 0.2464) or 2014 (Wilcoxon two-sample test = 187.5 Exact P = 0.1876). In both years, most (76–85%) of the removed Raccoons were males. Adults predominated our raccoon captures in both years but we captured a larger proportion (Pearson chi-square = 5.93; df = 1; Fisher's Exact P = 0.015) of adults in 2013 (91%) compared to 2014 (70%). There was no difference in the proportion among sex (Pearson chi-square = 0.24; df = 1; Fisher's Exact P = 0.6237) and age (Pearson chi-square = 0.731; df = 1; Fisher's Exact P = 0.3926) caught between April and May in 2013. We only caught 5 females in 2014 and all captures occurred in the month of May. There was no difference in the proportion among age (Pearson chi-square = 0.12; df = 1; Fisher's Exact P = 0.7295) captured between April and May in 2014.

Based on our pre-removal abundance estimates, it appeared that we removed 83–89% of the Raccoons from the study site in both years (Table 1). We also estimated that pre-removal density of Raccoons was 37.5% lower in 2014 than 2013. In 2013, only one of seven (14%) Blanding's Turtle nests was partially depredated; no nests were completely depredated (Table 2; Figure 1). One hatchling was found alive in the vicinity of a depredated nest, thus we labeled the nest as partially depredated. However in 2014, nine of 15 (60%) Blanding's Turtle nests were depredated (Table 2; Figure 1).

### DISCUSSION

Previous reports investigating other turtle species have

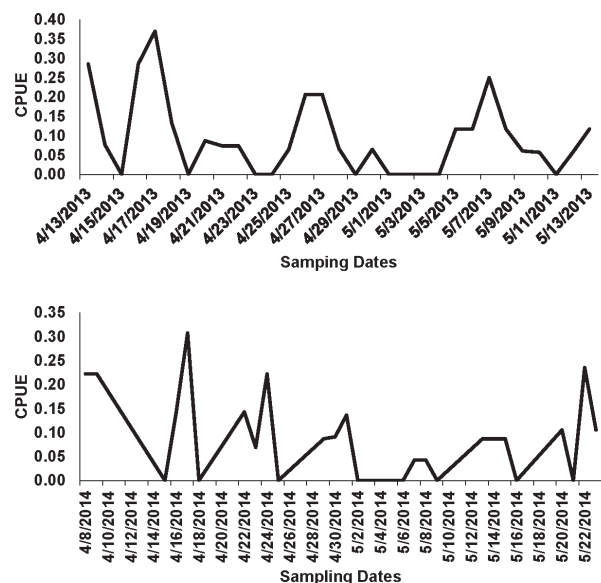


Figure 2. Daily catch per unit effort of Raccoons (*Procyon lotor*) at a Lake Plain macrosite near Lake Michigan, 2013–2014.

Table 2. Date of oviposition and nest fate of Blanding's Turtles (*Emydoidea blandingii*) at a Lake Plain macrosite near Lake Michigan, 2013–2014.

Turtle	Oviposition Date	Nest Fate	Comments
Lucinda	19-Jun-13	Successful Emergence	>14 Shell Fragments in Chamber
Gillian	20-Jun-13	Successful Emergence	>18 Shell Fragments in Chamber
Davey	24-Jun-13	Successful Emergence	>9 Shell Fragments in Chamber
Nancy	24-Jun-13	Successful Emergence	5 Undeveloped Non-viable Eggs and 7 Shell Fragments in Chamber
Betsy	25-Jun-13	Successful Emergence	>14 Shell Fragments in Chamber
Myrna	25-Jun-13	Successful Emergence	16 Live Hatchlings Observed In/Near Nest on 10-Sept-13
Sara	26-Jun-13	Partial Depredation	1 Live Hatchling Observed In/Near Nest on 5-Sept-13; >9 Shell Fragments Found in Nest Cavity
Betsy	17-Jun-14	Partial Depredation	4 Eggs Remained in the Nest on 19-Jun-14
Gene	17-Jun-14	Depredated	Evidence Found on 18-Jun-2014
Lyda Jane	17-Jun-14	Successful Emergence	>18 Shell Fragments and 1 Hatchling In Chamber on 29-Sept-14
Geri	20-Jun-14	Depredated	Evidence Found on 21- Jun-14
Zelda	20-Jun-14	Successful Emergence	>18 Shell Fragments in Chamber on 9-Sept-14
Quin	22-Jun-14	Depredated	Evidence Found on 24-Jun-14
Elle Mae	23-Jun-14	Depredated	Evidence Found on 24-Jun-14
Gillian	23-Jun-14	Depredated	Evidence Found on 24-Jun-14
SNTU	23-Jun-14	Successful Emergence	31 Shell Fragments in Chamber
Betty Ann	24-Jun-14	Depredated	Evidence Found on 25-Jun-14
Davey	27-Jun-14	Successful Emergence	10 Shell Fragments in Chamber on 23-Sept-14
Nico	27-Jun-14	Depredated	Evidence Found on 28-June-14
Mary	29-Jun-14	Successful Emergence	>11 Shell Fragments in Chamber on 26-Sept-14
Nancy	29-Jun-14	Successful Emergence	>13 Shell Fragments in Chamber on 23-Sept-14
Josephine	30-Jun-14	Depredated	Evidence Found on 14-Jul-14

indicated that removal of subsidized predators during nesting season has had a positive influence on nest success (Engeman et al. 2005, Engeman et al. 2006). In the contrary, Standing et al. (1999) investigated this possible influence on a Blanding's Turtle population in Nova Scotia but found that contributing factors other than predation may affect Blanding's Turtle nest success. Our goal was to determine if the removal of subsidized Raccoons prior to the nesting season from an area with a known breeding population of Blanding's Turtles would increase nest success.

In 2013, we appeared to effectively reduce the Raccoon population by 83% based on our pre-removal abundance estimate. Similar to the decrease in depredation observed by Engeman et al. (2005) and Engeman et al. (2006), the depredation rate on Blanding's Turtle nests also decreased to 14% in the first year of our study. Although these results appear successful, depredation rates of turtle nests often vary annually (Congdon et al. 2000). In contrast to 2013, 60% of the 2014 nests in this study were depredated even though it appeared we removed 89% of the Raccoons prior to the nesting season. Engeman et al. (2006) also observed an increase in predation rates in their second year of predator removal, however depredation only increased from 6.9% to 13.5% in their study. At first, we suspected that the increase in depredation we observed may be reflective of a density-dependent recruitment response of Raccoons to removal given that we captured a higher proportion of juvenile Raccoons in 2014. However, considering we captured and removed the Raccoons immediately prior to the nesting season, this increased recruitment of Raccoons was likely not the main cause of the higher depredation rate we observed. Another hypothesis in the observed higher depredation rates during the second year

is because the surviving Raccoons may have increased their predation rates on the Blanding's Turtle nests as a result of less intraspecific competition. More research is warranted to understand the functional responses of Raccoons when their abundance is decreased.

We observed a 37.5% decrease in our pre-removal density estimate of Raccoons in 2014 compared to 2013. Our trapping area effectively covered most of our study area and bordering lands (Figure 1). Considering we trapped Raccoons through the pregnancy and parturition stage that usually lasts through 30 May and juveniles do not begin dispersing until September in this region (Prange et al. 2003), the likelihood of a large amount of Raccoons outside of our effective trapping area recolonizing the macrosite during the nesting season was improbable. Raccoons in urbanized areas are generally sedentary (Rosatte 2000) and Prange et al. (2004) found that seasonal activity centers of adult raccoons in suburban areas of northeastern Illinois only changed by 101-105 m which is still largely outside of our effective trapping area. Additionally, Rosatte et al. (2006) showed that Raccoon dispersal is not density-dependent, especially when Raccoons in areas outside of removal areas are not limited by food resources such as in suburban and urban areas. Further, although Rosatte et al. (2006) explained that recolonization into areas where Raccoons have been removed eventually occurs, "population reduction of Raccoons does not immediately evoke a mass immigration from the surrounding vicinity (5-10 km)." Hence, we have strong evidence that we were successful in reducing depredation caused specifically by Raccoons due to the removal program.

The increase in depredation rate observed in 2014 was likely due to other subsidized predators (Temple 1987, Ross and Anderson 1990, Congdon et al. 1993, Kuhns

2010). In 2007, Kuhns (2010) monitored mesopredator presence at the Lake Plain macrosite using scent stations and recorded evidence of Raccoons, Opossums (*Didelphis virginianus*), Coyotes (*Canis latrans*), Domestic Dogs (*Canis lupus familiaris*), and two other canid species. He also identified other potential egg predators including squirrels (*Sciurus* spp. and *Spermophilus* spp.), mice (*Peromyscus* spp.), and Eastern Chipmunks (*Tamias striatus*). Mink (*Neovison vison*), Muskrat (*Ondatra zibethicus*), Striped Skunks (*Mephitis mephitis*), and Red Foxes (*Vulpes vulpes*) are also present on the site (pers. obs.). Kuhns (2010) used motion-triggered cameras to capture evidence of both a Coyote and a Domestic Dog digging up an artificial Blanding's Turtle nest of Bobwhite Quail (*Colinus virginianus*) eggs and we recorded opportunistically on a motion-triggered camera a Striped Skunk unearthing one of our Blanding's Turtle study nests in 2013.

Hence, although increasing densities of Raccoons due to human subsidies in suburban areas (Prange et al. 2003) have been associated with increasing rates of turtle depredation, several other subsidized predators may be culpable. For example, Meckstroth and Miles (2005) documented more waterfowl nests depredated by Striped Skunks and Red Foxes than Raccoons in their study. However, their study sites had higher abundances of these species compared to Raccoons. Red fox in conjunction with Raccoons, are main predators of loggerhead turtles in North and South Carolina (Kurz et al. 2011, SCDNR 2011). Common ravens (*Corvus corax*) are also known to be a main predator of juvenile desert tortoises (*Gopherus agassizii*) (Boarman 2003). Given the multitude of subsidized predators inhabiting the macrosite, there is ample evidence that other species are contributing to the depredation of Blanding's turtles at our study site other than Raccoons.

In summary, Raccoon removal appears to help reduce depredation rates on Blanding's Turtle nests but it is not the entire solution to reducing nest depredation. Further research is necessary to determine if surviving Raccoons exhibit a functional response to a reduction in the Raccoon population and subsequent increase in viable Blanding's turtle nest availability. To retain the success we observed during this study, intensive Raccoon removal will need to persist prior to each nesting season. After predation control ceased in the Engeman et al. (2006) study, they observed an increase in Raccoon predation 1.5–3 times the rates during predator control within the egg incubation period. Rosatte et al. (2006) also found that Raccoons recolonized removal areas to densities at or above pre-removal densities within one year, however as aforementioned, recolonization was not immediate (i.e., it likely would not take place during the nesting season). Munscher et al. (2012) also reported an immigration of Raccoons and subsequent depredation on Carolina Diamondback Terrapin nests (*Malaclemys terrapin centrata*) following the end of their removal program. Lastly, because predators other than Raccoons are certainly contributing to the depredation of Blanding's Turtle nests (Temple 1987, Ross and Anderson 1990, Congdon et al. 1993, Boarman 2003, Kuhns 2010, Kurz et al. 2011), future research should examine the pressure of other subsidized predators on Blanding's turtle nest survival in the absence of Raccoons. Additionally, Boarman (2003) suggested that reducing anthropogenic food sources that support higher densities of subsidized predators in the surrounding landscape may also aid in the reduction of nest depredation.

#### ACKNOWLEDGMENTS

Andrew Kuhns and Kevin Cassel played an instrumental role in collecting baseline data, establishing monitoring efforts, and providing guidance for the District's Blanding's Turtle Recovery Program. We thank Kevin Cassel, Andrew Rutter, Jon Sammons, Michelle Minton, and Meghan Jedloe for assistance in the field. We thank the property owners including the Lake County Forest Preserve District and The Nature Conservancy (Wisconsin) who gave us permission to conduct research on their land and the Illinois Department of Natural Resources, Illinois Nature Preserve Commission, and Wisconsin Department of Natural Resources for providing the necessary permits. All capture euthanization operations were carried out using methods approved by the Institutional Animal Care and Use Committee at Southern Illinois University (Animal Assurance Number A-3708-01, protocol 13-011). This research was funded by the National Fish and Wildlife Foundation and US Fish and Wildlife Service through the Sustain Our Great Lakes Great Lakes Stewardship Program. Lastly, we thank the reviewers and D. Fogell for providing feedback to improve this paper.

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