Report No. C-10-06: Monitoring Functionality and Durability of the New York State Highway 30 Turtle Barrier and Adjacent Nesting Substrate

Final Report

Prepared by ***Tom A. Langen, Dept. of Biology, Clarkson University***

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Contributors

Principal Investigator

Tom A. Langen, Clarkson University

Address: **Box 5805 Clarkson University, Potsdam NY 13699**

Phone: **315 268 7933** Email: **tlangen@clarkson.edu**

Field Technicians

Matthew Whalen, College of Hobart and William Smith

Jeremy Ozolins, Clarkson University

Andrew McCulley, Clarkson University

Cody Merrill, Clarkson University

Cory Symonds, Clarkson University

DISCLAIMER

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16. Abstract. **In 2008, the NYS Department of Transportation installed a wildlife barrier along NYS Route 30 in Tupper Lake, Franklin County, NY. The major objectives of the study that is the subject of this report were to: evaluate the effectiveness of the Route 30 wildlife barrier for preventing turtle mortality and turtle trespass onto the roadway, assess the impacts of the barrier on turtle nesting, evaluate the wildlife barrier design, and provide general design recommendations for future turtle barriers along roadways. The study area was monitored from May to October in 2010 and 2011, and the barriers were judged to be partially effective. Adjacent roadside nesting was also monitored and did not appear to suffer elevated failure due to predation. The report concludes that the wildlife barrier was generally effective but could be enhanced with modifications at the ends of barriers, and recommends regular monitoring and annual maintenance.**			
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1. Shapefile (prepared in ArcGIS 9.2) of road mortality by turtles at the Tupper Lake Highway 30 turtle barrier.

2. Shapefile (prepared in ArcGIS 9.2) of nesting by turtles at all surveyed locations at the Tupper Lake Highway 30 turtle barrier.

3. Excel file containing survey data at all sites.

4. Langen, T.A. 2011. Design considerations and effectiveness of fencing for turtles: three case studies along northeastern New York state highways. Proceedings of the 2011 International Conference on Ecology and Transportation. *In press*.

5. Langen, T.A. 2009. Design and Testing of Prototype Barriers & Tunnels to Reduce the Impact of Roads on Turtle Survival & Reproductive Success. Final Report for the State Wildlife Grant Program, NYSDEC.

6. Powerpoint slide file. Dissemination talks given at (1) 2011 International Conference on Ecology and Transportation (ICOET), (2) 2011 New York State Wetlands Forum, and (3) 2010 Northeast Transportation and Wildlife Conference.

1. EXECUTIVE SUMMARY

A wildlife barrier intended to prevent turtle trespass was designed and installed by the New York State Dept. of Transportation (NYSDOT) in 2008 along New York State (NYS) Highway 30 in Tupper Lake, Franklin County, New York State**.** The major objectives of the study that is the subject of this report were to (1) evaluate the effectiveness of the Highway 30 wildlife barrier for preventing turtle road mortality and turtle trespass onto the roadway, (2) assess the impacts of the barrier on turtle nesting, and (3) evaluate the wildlife barrier design and provide general design recommendations for future turtle barriers along roadways. The Highway 30 causeway and two similar road segments that lacked wildlife barriers were monitored throughout the active season of turtles (May to October) in 2010 and 2011. Two other wildlife barriers intended for turtles and a control segment lacking a barrier were monitored along NYS Highway 68 at Upper & Lower Lakes Wildlife Management Area, St. Lawrence County, New York State. At all sites, georeferenced data were collected on road mortality, nest presence and fate, and fence damage.

The barriers were judged to be partially effective, but there remain problems with road kill along the ends and discontinuities in fencing. On the NYS Highway 30 barrier, the most serious discontinuities were the driveways into three private inholdings along the NYS Highway 30 causeway. Using a before-after, control-intervention (BACI) analysis of road mortality at the NYS Highway 68 wildlife barriers and their controls, there was some evidence that the barriers reduced road-kill of turtles, but also evidence that further modifications and monitoring were needed.

Roadside nesting was common along the NYS Highway 30 barrier, and did not appear to suffer elevated failure due to predation. Soil temperatures near roadside nests spiked in late afternoon; on some days the soil temperatures exceeded those that would cause impaired embryo development or death if prolonged. However, it is not known whether such transient high temperature do affect egg viability.

In general, the designs of the wildlife barriers at NYS Highway 30 and the two along NYS 68 are adequate for reducing road mortality. However, annual maintenance before late May is required to repair damages and therefore make the fence fully functioning. Most damage detected during the study was due to broken twist ties or else intentional cutting of the fence to make it easier to cross. Vegetation management is also needed each year, especially on the barrier sides closest to water; turtles prefer to nest in bare soil or where vegetation is cropped short.

A design solution is needed for reducing the numbers of turtles that go around the ends of fences or at fence discontinuities; solutions may involve some kind of long ‘wing’ that redirects turtles toward the wetland, and gratings that deter turtles at the access driveway discontinuities in the fencing.

2. DESCRIPTION OF THE STUDY SITES

2.1 NYS State Highway 30 Tupper Lake Causeway Wildlife Barrier

Fencing intended to prevent turtle trespass onto a roadway was installed by contractors using NYSDOT design specifications along a long causeway on NYS Highway 30 (AADT = 2300 vehicles/d) at Tupper Lake in Franklin County, New York State in 2008 (Fig. 2.1 a). The causeway spans a major wetland complex that has large populations of two turtle species (Common Snapping Turtle *Chelydra serpentina*, Painted Turtle *Chrysemys picta*). The objective of the wildlife barrier project was to reduce turtle road mortality at this previously-localized major road-kill hotspot. NYSDOT installed the wildlife barrier to meet regulatory conditions that were part of the permitting process for a major road reconstruction project along the road segment. To inform the public about the function of the wildlife barrier, a parking pull-off with an informational kiosk was installed near one end of the barrier.

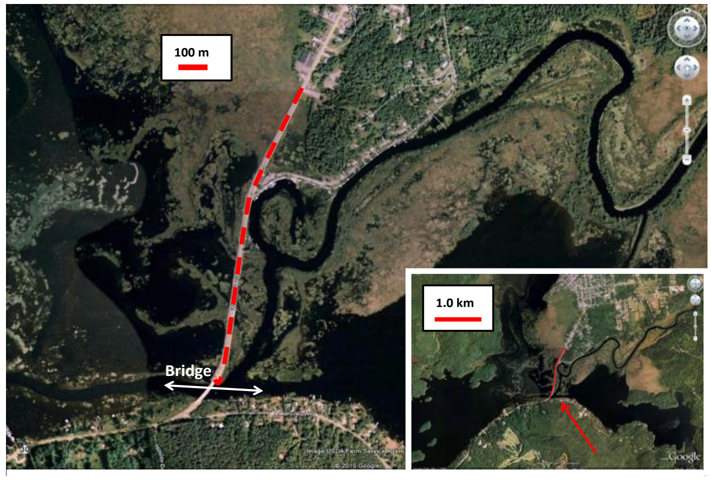


Fig. 2.1 a: ***Location of the NYS Highway 30 wildlife barrier (highlighted in red) at Tupper Lake, New York.***

Fencing was installed on both sides of the road, for a road centerline length of 1330 m; 20 m ‘wings’ were included at one end to reduce the risk of animals going around the end of the fence. Connectivity between the two roadsides was provided by a wide-span bridge and a culvert. There were three gaps in the fence (100 m, 20 m, 14 m) associated with property inholdings (a residence and a tavern) along the causeway.

Fig. 2.1 b: ***NYS Highway 30 wildlife barrier, constructed of vinyl-coated steel mesh affixed to the road guard rail.***

The design of the barrier is 0.6 m high, 5 x 10 cm mesh 12 gauge vinyl-covered wire fencing affixed to an existing steel guide rail post (Fig. 2.1 b). The fencing is affixed using heavy-duty, ultraviolet light-resistant cable ties (three per post). The base of the fence i flush with the road decking, and the top of the fence is flush with the guardrail (box beam).

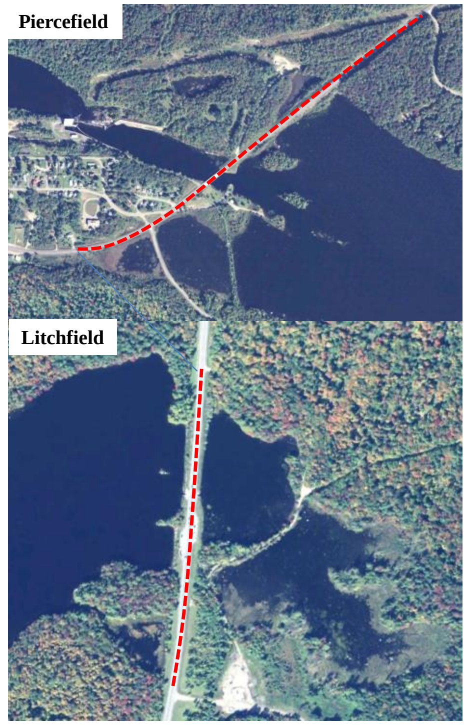


Fig. 2.1 c: ***Aerial images of the two reference road segments. The monitored segments are indicated in red.***

Two unfenced reference sites were selected for monitoring on road sections that were the most comparable in terms of traffic volume, proximity to wetlands on both sides of the road, and geographic proximity to the Highway 30 wildlife barrier. Reference Site 1 (Piercefield, 75.560344 W, 44.231868 N), located along NYS Highway 3, had a centerline distance of 1000 m, and traffic volume (AADT) of 2400 vehicles/day. Reference Site 2 (Litchfield Park, 75.523952 W, 44.143953 N), located along NYS Highway 30, had a centerline distance of 650 m, and traffic volume (AADT) of 2000 vehicles/day. Neither reference site appeared to support a turtle population size and level of turtle activity equal to the Highway 30 wildlife barrier, but these were the best matches that could be found in the region of the barrier. Aerial views of the two sites are shown in Fig. 2.1 c

2.2 State Highway 68 at Upper & Lower Lakes State Wildlife Management Area

Two wildlife barriers for turtles were built along causeways on NYS Highway 68 (AADT = 5200 vehicles/d) at Upper and Lower Lakes State Wildlife Management Area (ULL SWMA) in St. Lawrence County, New York State. ULL SWMA protects a major wetland complex that has large populations of three turtle species (Common Snapping Turtle *Chelydra serpentina,* Painted Turtle *Chrysemys picta,* Blanding's Turtle *Emydoidea blandingii*), one of which is of which is a very high conservation priority (Blanding's Turtle). The objectives of the two wildlife barrier projects were to experimentally test the effectiveness of some low-cost designs for turtle barriers, and to reduce turtle road mortality at two major road-kill hotspots. To inform the public about the function of the two wildlife barriers, a parking pull-off with an informational kiosk was installed at a public access area located along NYS 68.

2.2.1 *ULL SWMA Causeway Wildlife Barrier 1*

This wildlife barrier spans a short causeway that had been a previously localized turtle road-kill hotspot (Fig. 2.2.1 a). Barriers were placed on both sides of the road, for a road centerline length of 225 m; 20 m 'wings' were included at the end to reduce the risk of animals going around the end of the fence. Connectivity between the two roadsides was maintained by a partially submerged 1.3 m diameter water-equalization culvert. Several different designs and materials were used along the length of the barrier, which was installed by a NYSDOT work crew in 2006.

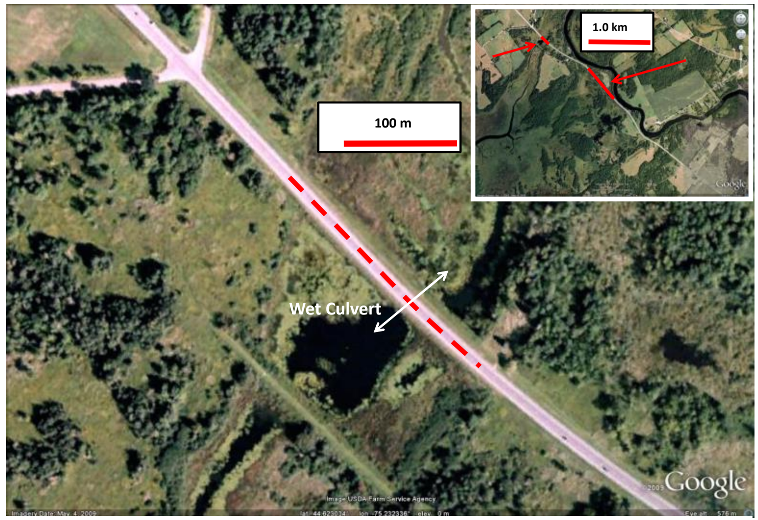


Fig. 2.2.1 a: ***Causeway Barrier 1 located at Upper & Lower Lakes SWMA. The red dashed line indicates the length of the barrier. The inset shows the location relative to Causeway Barrier 2.***

Design of Barrier: The site of the barrier was an elevated section of road with a steep verge. The east side, which included wire and wooden fence designs, was offset 6.5 m from the road. The length was 212 m, plus additional 7 m and 12 m wings on the ends of the barrier, oriented 45 degrees away from the road. The west side barrier, which was exclusively wire fencing, was 3 m from the road. The length was 213 m, plus additional 9 m and 12 m wings on the ends of the barrier, oriented 45 degrees away from the road. Wire fencing was used on each side to connect the fence to the water-equalization tube culvert (Fig. 2.2.1 b)

Fig. 2.2.1 b: ***Culvert connected to barrier fencing to serve as a passage.***

Wooden Barrier: The wooden barrier design was a fence consisting of three boards (each 1 inch x 10 inches x 10 feet or 2.5 cm x 25 cm x 3 m) set on each other with 1 inch (2.5 cm) gap between them (Figure 2.2.1 c). The gaps were intended to allow water flow. The boards were affixed using decking screws to 4 x 4 inch (10 x 10 cm) treated wooden posts that were set 4 feet (1.3 m) into the ground. A reflector was placed on every fifth post. About 5 inches (13 cm) of the lowest board was buried into the ground. Fine mesh (0.6 x 0.6 cm) metal fencing pieces were affixed (using a staple gun) to the gaps in the boards, after it became evident that frogs and snakes were crossing through the fence via the gaps. The total intended height of the barrier above the soil was 2 feet (0.6 m), but at installation it was actually 20 inches (60 cm).

Site preparation required use of a backhoe and trencher (Fig. 2.2.1 d). It proved to be extremely difficult to dig the trench and post-holes, because the fill of the causeway, below a superficial layer of soil, was rock, including large boulders. These site conditions may be typical of causeways.

Fig. 2.2.1 c: ***Causeway Barrier 1 just after installation. (a) Wooden barrier. (b) Vinyl-coated metal barrier. Both barriers are 2 feet (54 cm) high.***

Because of concerns by the NYSDOT engineer that the wooden barrier was a potentially-dangerous ‘fixed object’, this design was only used where a guardrail was present at the roadside. The wooden barrier design was not used on the west side, because the verge was too steep and narrow to use a back-hoe, and manual digging was impossible. Two sections of wooden fence were installed: a 29 m and a 79 m section.

During the first year, there were problems with water undercutting sections of fence after rainstorms. I had to regularly patrol and fill these holes. One year later, there were occasional problems with undercutting, but the soil had mostly stabilized. Now in the fifth year, plant roots and natural compaction have stabilized the soil, and undercutting is not a problem.

After the first year, a few boards warped and became un-nailed. Some could be repaired, and some replaced. In the second year, a couple more boards warped and needed repair or replacement.

Fig. 2.2.1 d: ***Construction of Causeway Barrier 1. The left panel shows installation of the wooden barrier, and the right panel shows installation of the vinyl-coated metal fence.***

Metal Fencing Barrier: The metal fencing barrier consisted of a base of 2 foot high (0.6 m) vinyl-coated over galvanized steel welded-wire metal fencing (Fig. 2.2.1 c). The fencing was affixed to metal posts (salvaged steel sign posts) using heavy-duty, ultraviolet light-resistant cable ties (three per post). The posts were spaced 6 feet (2 m) apart, and driven into the ground using a post-hole driver. A reflector was placed on every tenth post. When installing the fence, a trench a few inches was dug, and the bottom of the fence buried. Installation was fast (around 20 m / hr for a team of 5 men) and not difficult.

During the first year, a 1 foot (30 cm) high section of fine mesh (0.6 cm x 0.6 cm) coated wire fencing was placed at the bottom and secured using u.v.l. (ultraviolet light) resistant cable ties, to prevent hatchling turtles or frogs from passing through the fence. This was determined to be inadequate, and in the second year, the fine mesh coated wire fencing was used to the full 2 foot (60 cm) height on the barrier along the east side of the road. On the west side, uncoated galvanized fencing of the same mesh site was used, and the fence was raised to a height of 3 feet (1 m), including a small overhang that was fabricated by bending the wire (Fig. 2.2.1 e).

During the first year, there were problems with water undercutting sections of fence after rainstorms. We had to regularly patrol and fill these holes. One year later, there were occasional problems with undercutting, but the soil and mostly stabilized. By the fifth year, plant roots and natural compaction have stabilized the soil, and undercutting is not a problem.

There was little other maintenance: the first five years the cable-ties held up, and the fence on the east side of the road remained mostly undamaged except for minor repairs. In 2009, we trimmed the uncoated fence back to 2 foot (60 cm) height (the height of the vinyl-coated metal fence), while leaving a sort inward-facing lip at the top to prevent overtopping by turtles.

Fig. 2.2.1 e: ***Installation of additional fine mesh wire fencing. Above is uncoated metal mesh wire to 1 m height. Later, this was trimmed and bent as a lip. Below is vinyl-coated metal to 60 cm height.***

2.2.2 *ULL SWMA Causeway Barrier 2*

This wildlife barrier also spans a causeway that is a previously localized road-kill hotspot (Fig. 2.2.2 a). Barriers were placed on both sides of the road, for a road centerline length of 550 m; 20 m ‘wings’ were included at the end to reduce the risk of animals going around the end of the fence (Fig. 2.2.2 b). The distance of the barrier from the pavement was 4 m. Connectivity between the two roadsides was intended to be provided by a culvert, but during barrier construction it was discovered that the culvert had collapsed; presently there is no functioning passageway along the barrier. The design of the barrier was 60 cm high, 2.5 x 2.5 cm mesh vinyl-covered wire fencing affixed to standard light fence posts. The fencing was affixed to posts using heavy-duty, ultraviolet light-resistant cable ties (three per post). The base of the fence was buried 5 cm into the ground. The barrier was completed in 2010, and was installed by high-school student work crews under the supervision of NYSDOT employees and Clarkson University students.

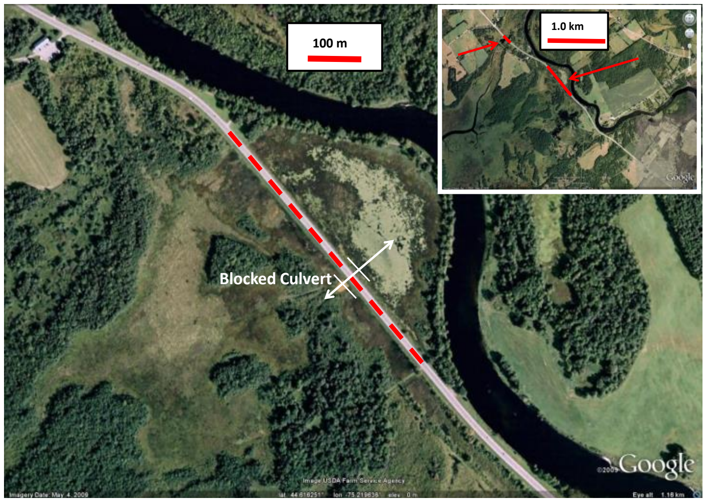


Fig. 2.2.2 a: ***Causeway Barrier 2 located at Upper & Lower Lakes SWMA. The red dashed line indicates the length of the barrier. The inset shows the location relative to Causeway Barrier 1.***

Fig. 2.2.2 b: ***Causeway Barrier 2 constructed of vinyl-coated wire fence.***

2.2.3 *ULL SWMA Reference Transect*

Immediately adjacent to the location of Causeway Wildlife Barrier 2, I delineated a reference or ‘control’ highway segment that lacked a wildlife barrier. This 1300 m segment of NYS Highway 68 included two causeways, but had fewer road-kill turtles and less dense nesting than the two segments that were eventually selected for sites of the wildlife barriers. Other descriptive information about this road segment and the locations of the two wildlife barriers is found in Langen et al. 2007.

3. SURVEY METHODS

3.1 NYS State Highway 30 Tupper Lake Causeway Wildlife Barrier

Two years of post-construction monitoring were done at the Tupper Lake Causeway Wildlife Barrier and the two reference sites. Surveys were done in 2010 and 2011, by repeatedly walking the road segment weekly throughout the active period of turtles (May to October) and every 2 to 3 days during the period of peak movements on land around the nesting season (late May to mid July). The methodology followed the validated walking transect methodology reported in Langen et al. 2007. During each monitoring visit, the location of any road-kill or living turtle on or near the roadway was georeferenced using a Garmin GPS with WAAS correction, as was any nest constructed alongside the road or fence.

At the NYS Highway 30 Causeway Wildlife Barrier, I placed six temperature sensors (Dallas Electronics ibutton thermochrons) into the soil at the depth of turtle eggs (about 6 cm) at three sites on each side of the road that had turtle nests present, to measure this critical microclimatic attribute. The thermocrons were deployed in late May (before the initiation of nesting), and retrieved in August (after the critical periods of embryonic development) in both 2010 and 2011.

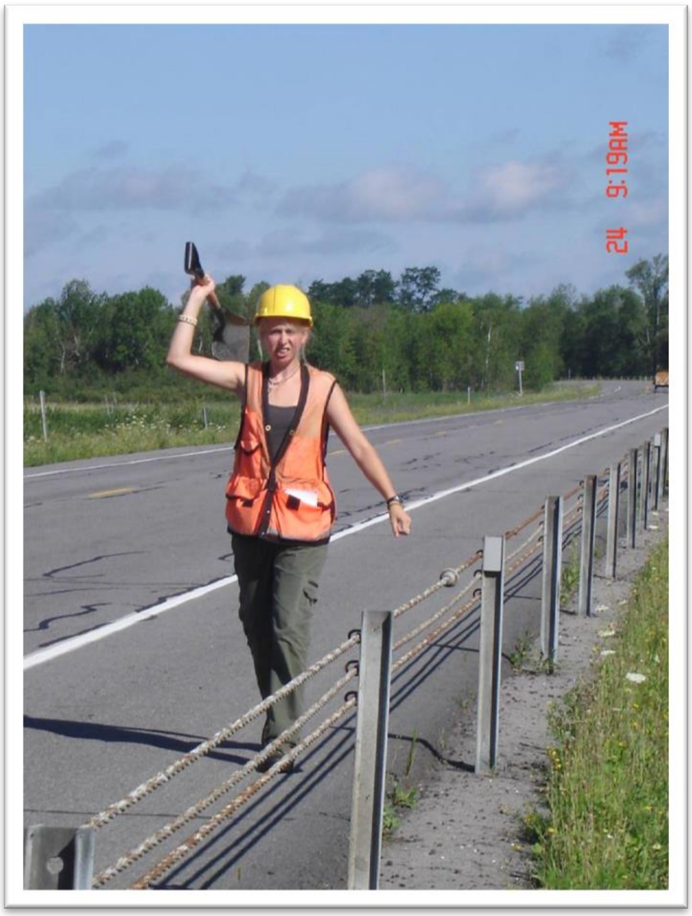
3.2 State Highway 68 at Upper & Lower Lakes State Wildlife Management Area Causeway Wildlife Barriers

Causeway Barrier 1. Evaluation of the effectiveness at reducing road-kill was done by comparing four years of pre-construction monitoring and six years post-construction monitoring. Monitoring was done by repeatedly walking the road segment during four years previous to construction (weekly, and more frequently during the nesting period) and six years post-construction. Two comparable 'control' segments along NYS Highway 68 were also monitored, thus the monitoring design used a BACI design (before-after, control-intervention). The methodology followed the validated walking transect methodology reported in Langen et al. 2007. During 2010 and 2011, the location of any road-kill or living turtle on or near the roadway was georeferenced using a Garmin GPS with WAAS correction.

Causeway Barrier 2. Evaluation of the effectiveness at reducing road-kill was done by comparing six years of pre-construction monitoring and one year post-construction monitoring. Monitoring was done by repeatedly walking the road segment during six years prior to construction (weekly, and more frequently during the nesting period) and six years post-construction. One comparable 'control' segment along NYS Highway 68 were also monitored, thus the monitoring design used a BACI design (before-after, control-intervention). The methodology followed the validated walking transect methodology reported in Langen et al.

2007. During 2010 and 2011, the location of any road-kill or living turtle on or near the roadway was georeferenced using a Garmin GPS with WAAS correction.

More details on pre-post wildlife barrier construction road-monitoring, nest monitoring, and related studies are in Appendices 3 and 4 (Langen 2009, Langen 2011).



4. FREQUENCY AND SPATIAL PATTERNS OF TURTLE ROAD-KILL ALONG THE TUPPER LAKE HIGHWAY 30 AND UPPER & LOWER LAKES WMA HIGHWAY 68 TURTLE BARRIERS.

4.1 Frequency and seasonality of road kill

Tupper Lake Highway 30 Wildlife Barrier: Along the Highway 30 wildlife barrier, a total of 12 painted turtles (*Chrysemys picta*) and 2 common snapping turtles (*Chelydra serpentina*) were detected as road-kill over the two years of monitoring (Table 4.1 a). Ten of the painted turtles (83%) were located during the months of May and June, when nesting migrations occur. Both snapping turtles were killed during fall (September and October), a time when turtles migrate to overwintering sites. Interestingly, eight of nine live snapping turtles were located along the Highway 30 fence during the nesting period (May and June), when no road-kill was detected.

Upper & Lower Lakes SWMA Highway 68 Wildlife Barriers: Seasonality of road-kill at all three monitored road segments was similar to that reported in Langen et al. 2007 and Langen 2009; most road-kill occurred in late May – early July, coinciding with nesting, with a second smaller peak in September and October coinciding with migration to overwintering sites. Along the older Highway 68 turtle barrier, a total of 12 painted turtles and 7 common snapping turtles were detected as road-kill over the two years of monitoring (Table 4.1 a). Along the newer Highway 68 turtle barrier, a disturbing total of 17 painted turtles and 13 common snapping turtles were detected as road-kill over the one year of monitoring (Table 4.1 a).

Table 4.1 a: ***Summary of road-kill and nests detected in 2011 and 2012 at all sites surveyed. Samples = number of dates surveyed, DOR = dead on the road (= road-kill), AADT = mean daily traffic volume. Barriers are highlighted in yellow, reference control sites in green.***

Year	Treatment	Highway	Distance (m)	AADT	Samples	DOR		Nests	DOR/Nest
						Painted	Snapping		
2010	Control	68	1010	5200	31	23	5	106	0.26
2010	Control	68	720	5200	31	16	1	31	0.55
2010	Fence	68	400	5200	31	3	4	36	0.19
2010	Control	3	1000	2400	33	2	1	56	0.05
2010	Control	30	650	2000	34	2	1	2	1.50
2010	Fence	30	1300	2300	41	7	1	133	0.06
2011	Control	68	1010	5200	26	8	8	32	0.50
2011	Fence	68	720	5200	26	17	13	22	1.36
2011	Fence	68	400	5200	26	5	3	24	0.33
2011	Control	3	1000	2400	30	5	1	13	0.46
2011	Control	30	650	2000	29	1	1	12	0.17
2011	Fence	30	1300	2300	30	5	1	53	0.11

4.2 Effectiveness of fencing at reducing turtle road mortality

Tupper Lake Highway 30 Wildlife Barrier: It is difficult to conclude anything from a comparison of the Highway 30 wildlife barrier to the two reference sites. Road-kill numbers were comparable among the three sites (Table 4.1 a). However, it is likely that there were much higher numbers of turtles at the Tupper Lake Highway 30 road segment than the two reference sites, and thus if a fence was not present the road-kill would be much higher. Informants familiar with the road segment report that road-kill historically was noticeably high along the road segment pre barrier construction. Without preconstruction baseline data, however, the effectiveness of the wildlife barrier is difficult to quantify.

I used the number of turtle nests along the road sides as an index of turtle population size along each monitored road segment. I calculated the ratio of road-kill numbers to number of nests (Table 4.1 a); the lower the ratio's value, the lower the road-kill frequency relative to population size. As expected if the wildlife barrier is functional, the Highway 30 wildlife barrier had a lower road-kill to nests ratio (0.08) over the two years combined than the two reference segments (0.13 and 0.36).

Another indicator of the relative effectiveness of the Tupper Lake Highway 30 Wildlife Barrier was the number of road-kill compared to the two State Highway 68 turtle barriers (Table 4.1 a). The road-kill tallies were lower on the Highway 30 barrier, even though it was longer and had more turtles nesting along it during the survey period (an indicator of population size and activity on roads). However, Highway 30 also had a lower traffic volume than State Highway 68, and that may have somewhat reduced the risk of road-kill to turtles entering the roadway.

Upper & Lower Lakes SWMA Highway 68 Wildlife Barriers: Causeway Barrier 1, the older barrier (constructed in 2006), had the lowest absolute numbers of road-kill among the three monitored road segments along Highway 68, and the lowest road-kill to nests ratio (Table 4.1 a). However, in a two-factor ANOVA comparing pre-construction and post-construction of Causeway Barrier 1 and the control reference transect, using data collected in June (when most road-kill occurs) of all years that the road was monitored, there has been no significant reduction in turtle road-kill associated with construction of the fence (Fig. 4.2 a; Interaction Treatment (Fence vs. Control) X Period (Pre vs Post Construction) $F_{1,243} = 0.6$, $P = 0.4$). Results were no different if just the two years prior to construction (2004, 2005) were compared to the two years post construction (2006, 2007) (Interaction Treatment X Period $F_{1,150} = 2.2$, $P = 0.14$). There are no obvious temporal trends associated with construction of the barrier (Fig. 4.2 b).

Causeway Barrier 2, the barrier constructed during the course of this study (installed in July, 2010), did not appear to be effective; the absolute number of road-kill was higher for both painted and snapping turtles, and this increase was high relative to changes between years at the other two segments (Table 4.1 a). In a two-factor ANOVA comparing pre-construction and post-construction of Causeway Barrier 1 and the control reference transect, using data collected in June (when most road-kill occurs) of all years that the road was monitored, there has been no significant reduction in turtle road-kill associated with construction of the fence (Fig. 4.2 c; Interaction Treatment (Fence vs. Control) X Period (Pre vs Post Construction) $F_{1,245} = 0.3$, $P = 0.6$). Results were no different if just the one year prior to construction (2010) was compared to the one year post construction (2011) (Interaction Treatment X Period $F_{1,33} = 0.002$, $P = 0.96$). Nevertheless, there did appear to be a drop in road mortality on the road segment along the barrier (as compared to the control segment; Fig. 4.2 d).

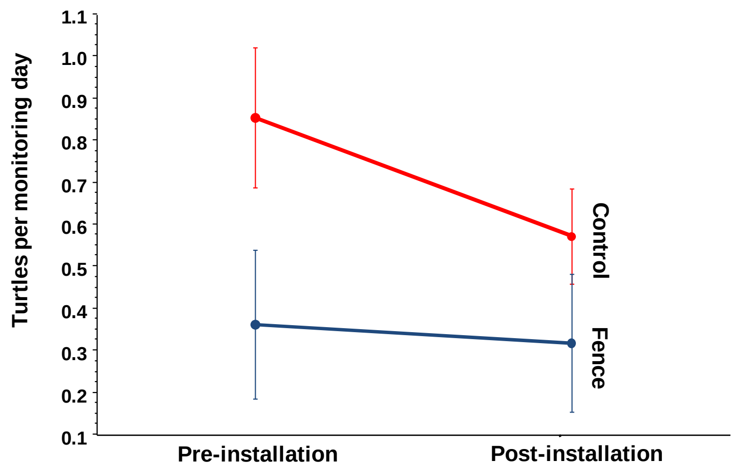


Fig. 4.2 a: ***Comparison of turtle road-kill detected in the month of June for Causeway Barrier 1 and the reference control site before and after construction of the barrier.***

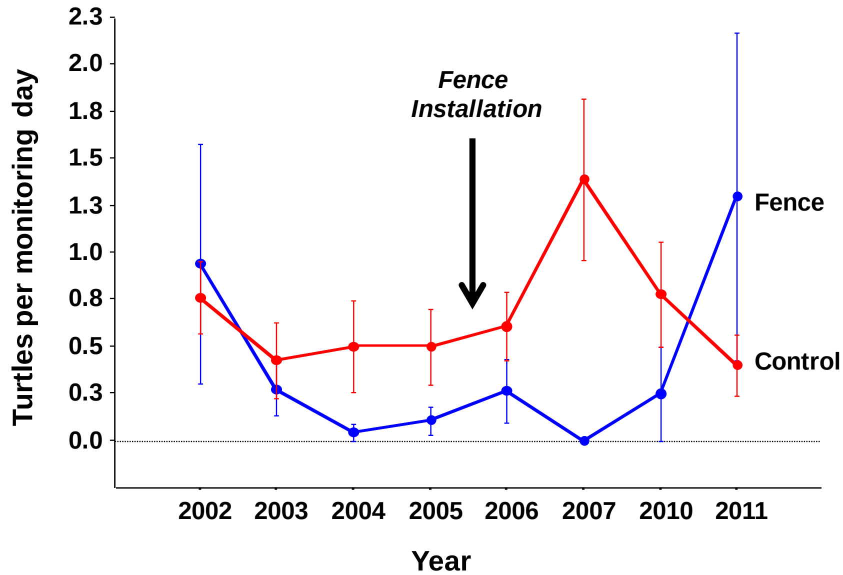


Fig. 4.2 b: ***Comparison of turtle road-kill detected in the month of June for Causeway Barrier 1 and the reference control site by year.***

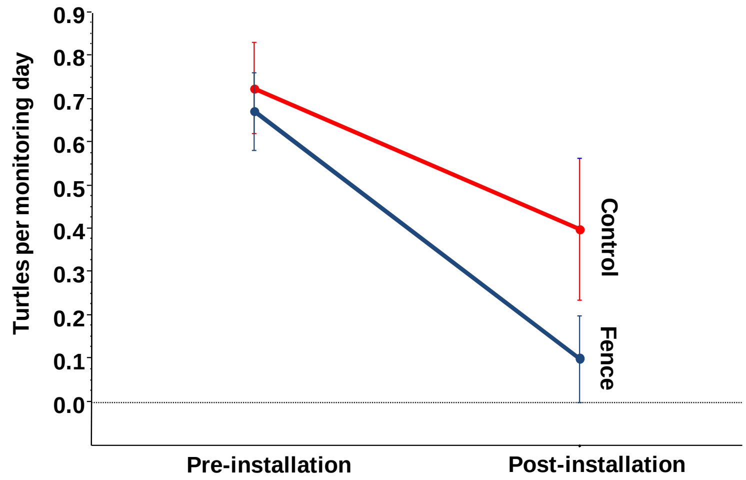


Fig. 4.2 c: ***Comparison of turtle road-kill detected in the month of June for Causeway Barrier 2 and the reference control site before and after construction of the barrier.***

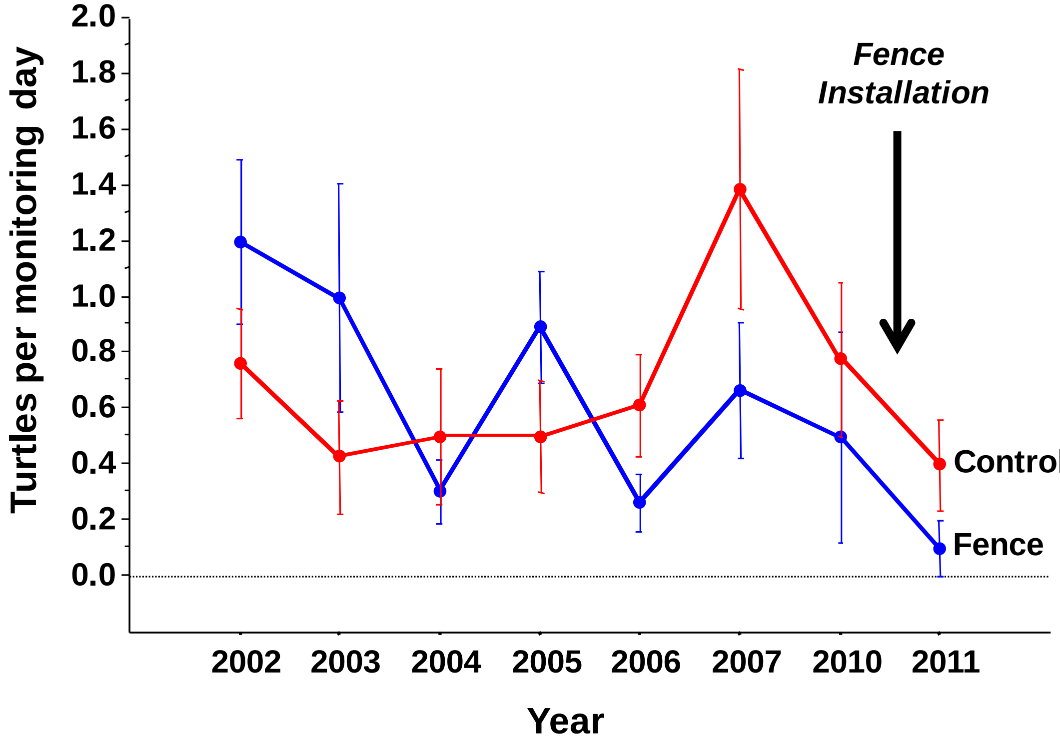


Fig. 4.2 d: ***Comparison of turtle road-kill detected in the month of June for Causeway Barrier 2 and the reference control site by year.***

4.3 Spatial patterns of road-kill along the turtle barriers

GPS location records for the common snapping turtle and painted turtle road-kill were superimposed over digital orthoimagery and a map of the barriers (using ArcGIS 9.2) .

Tupper Lake Highway 30 Wildlife Barrier: Most road-kill occurred at or very close to the three discontinuities along the barrier where driveways or access roads intersect with the highway. A lesser number of road-kill occurred at the two ends of the barrier, where turtles evidently walked around the wings of the barrier and accessed the road (Fig. 4.3 a). A small number of turtles were killed well-within the zone that was fenced. Fence trespass may have occurred by turtles moving through a break in the fence or else entering from the end or discontinuity in the fence and walking parallel to the road a distance before attempting to cross. Probably both occur on occasion. Recently, Angela Ross (NYSDEC Region 6) reported observing one painted turtle enter the roadway by passing through a fence gap caused by a broken fastener to the road surface (similar to shown in Fig. 6 a).

Upper & Lower Lakes SWMA Highway 68 Wildlife Barriers: For both barriers, most road-kill occurred at or beyond the two ends of the barrier, where turtles evidently walked around the wings of the barrier and accessed the road. At the older barrier (Highway 68 Barrier 1), a small number of painted turtles were killed well-within the zone that was fenced (Fig. 4.3 b). Whether this was from moving through a break in the fence or (more likely) entering from the end and walking parallel to the road a distance before attempting to cross is unknown.

At the newer barrier (Highway 68 Barrier 2), a significant number of painted turtles were killed well-within the zone that was fenced (Fig. 4.3 c). In this case, it appears that turtles were finding gaps in the fence or (less likely) scaling it. Subsequent evaluation (after the monitoring season) indicated that a number of repairs were needed, caused by problems originating from the initial installation (which was done by BOCES Environmental Tech Students and St. Lawrence County Youth Bureau).

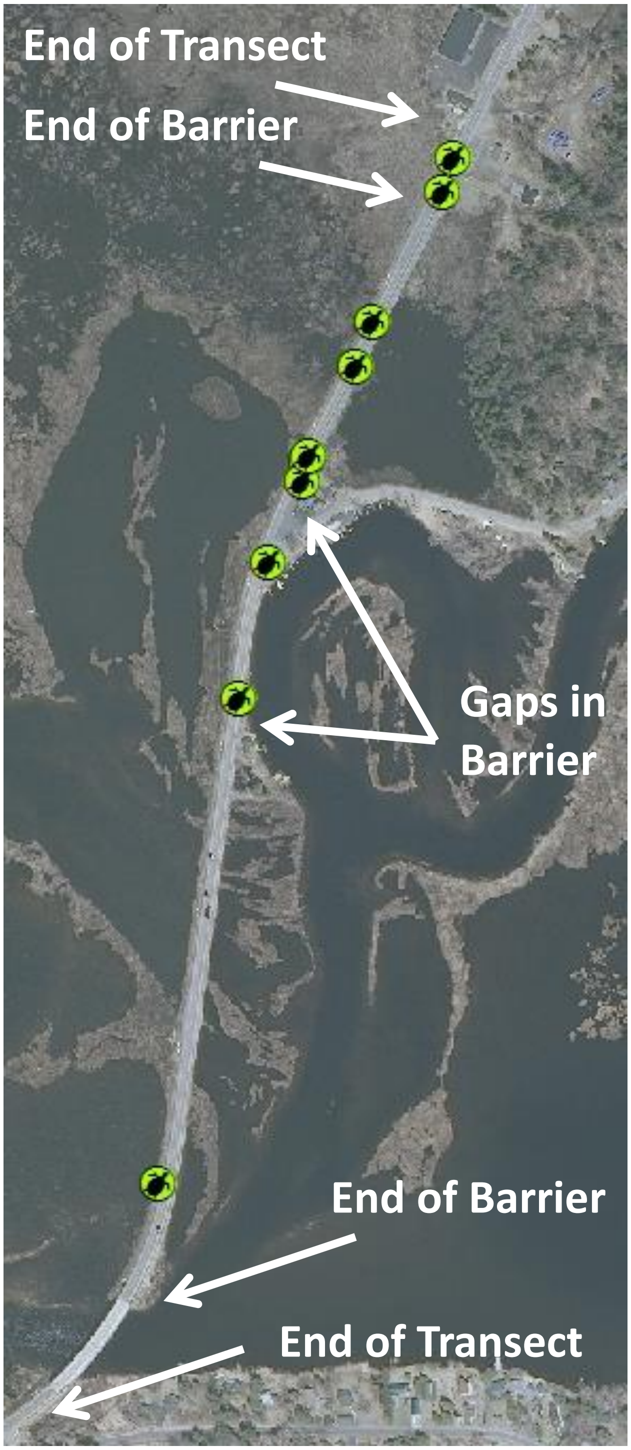


Fig. 4.3 a: ***Locations of turtle road-kill in 2010 and 2011 along the monitored transect of the Tupper Lake Highway 30 Turtle Barrier. Discontinuities in the barrier are indicated by arrows.***

Fig. 4.3 b: ***Locations of painted turtle (green) and snapping turtle (red) road-kill in 2010 and 2011 along the monitored transect of the ULL SWMA Highway 68 Turtle Barrier 1.***

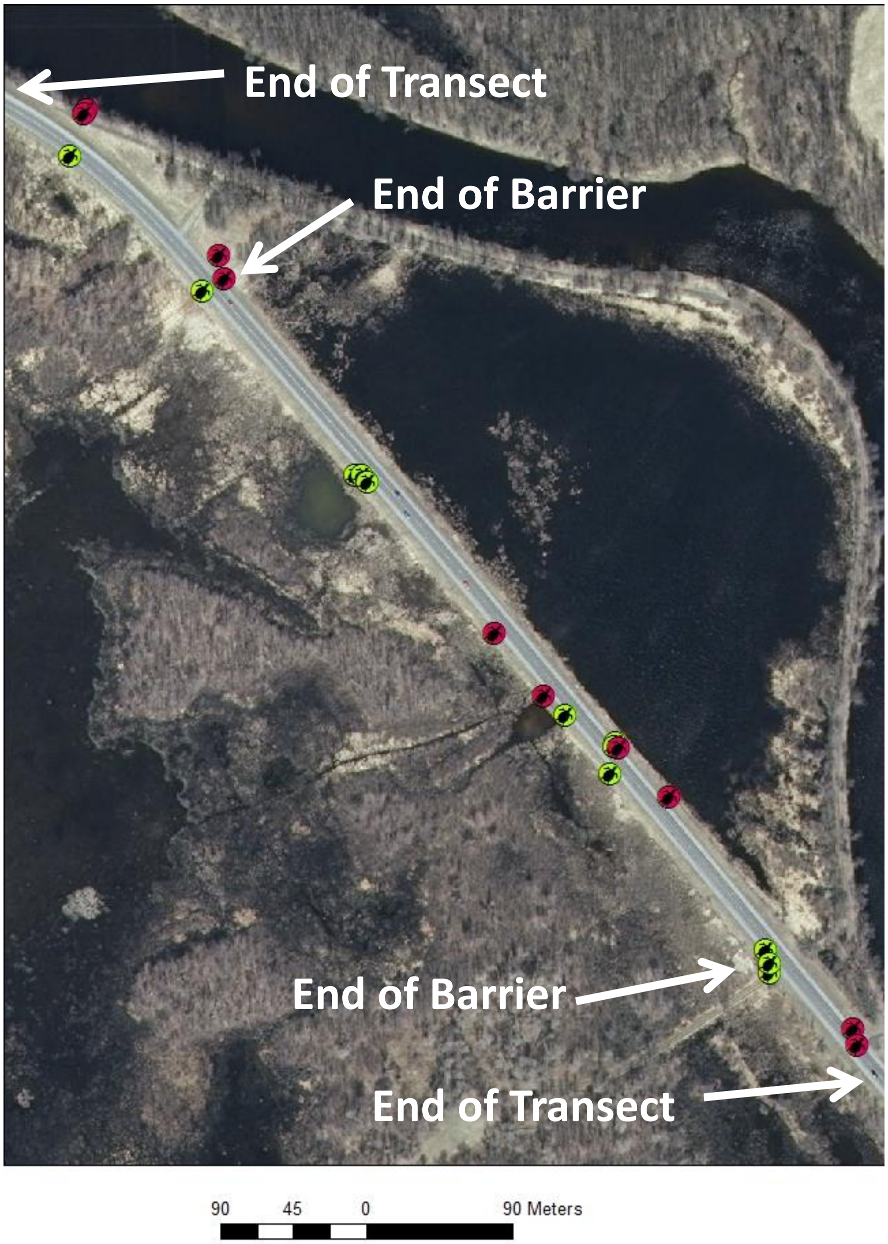


Fig. 4.3 c: ***Locations of painted turtle (green) and snapping turtle (red) road-kill in 2011 along the monitored transect of the ULL SWMA Highway 68 Turtle Barrier 2.***

5. PATTERNS AND SUITABILITY OF NESTING ALONG THE TUPPER LAKE HIGHWAY 30 TURTLE BARRIER

5.1 Nesting patterns along the Tupper Lake Highway 30 Turtle Barrier

Nesting was dense along the Tupper Lake Highway 30 Wildlife Barrier, and indeed had the most nests of any of the six sites I surveyed (Table 4.1 a). Most nests were made by common snapping turtles (based on the extent and form of the excavation, and in some cases by observing nesting turtles), but some were by painted turtles; painted turtles leave less obvious evidence of nesting, and doubtless some nests were missed. In 2010, 133 nests were detected along the turtle barrier between 2 June and 25 June. In 2011, 53 nests were detected along the turtle barrier between 9 June and 17 June. I am certain that some fraction of nests were missed, because of vegetation or rain obscuring the signs of nesting in the intervals between surveys. The difference in nesting between 2010 and 2011 did not indicate a population decline. It may be due to differences in detectability, or differences in the number of turtles breeding that year; snapping turtles may skip a year between breeding attempts.

Fig. 5.1 a: ***Common snapping turtle nests along the Tupper Lake Highway 30 Turtle Barrier.***

Nests were built immediately adjacent to the road pavement, and therefore adjacent to the turtle barrier. Nest placement was similar to that at the ULL WMA road segments (see Appendix 3: Langen 2009), and the two surveyed Adirondack ‘control’ road segments on Highway 30 and Highway 3. Nest predation rates were not measured for this study, but appeared to be low relative to other sites I monitored; relatively few nests were depredated (depredation is evident by excavation of the nest and discarded egg shells around the excavation site). My research at

ULL WMA indicated that nest predation rates at roadside nests are lower than other sites used by turtles (Langen 2009). More generally, roadside nesting at short distances from adjacent water is common in freshwater turtles, and may result in population reductions of breeding-age females (Appendix 4: Langen 2009, Steen et al. 2006, Steen et al. 2012, Langen et al. *in press*).

GPS location records for the detected turtle nests were superimposed over digital orthoimagery and a map of the barriers (using ArcGIS 9.2) . Along the Tupper Lake Highway 30 Wildlife Barrier, nests were located all along the barrier. Many were located very close to the three discontinuities along the barrier where driveways or access roads intersect with the highway (Fig. 5.1 b). As one might surmise, these locations were also hotspots of road-kill for turtles during this study (Fig. 4.3 a).

At both Upper & Lower Lakes SWMA Highway 68 Wildlife Barriers, nests were constructed all along the barriers, but many were clustered along the road outside of the fenced zone (Fig. 5.1 c, Fig. 5.1 d). This indicates that turtles were likely going around the wings of the fences, to gain access to the road edge for nesting (both fences are set back from the road, see sections 2.2.1 and 2.2.2). As one might predict, the ends of the fences were also hotspots of road-kill for turtles during this study (Fig. 4.3 b, 4.3 c).

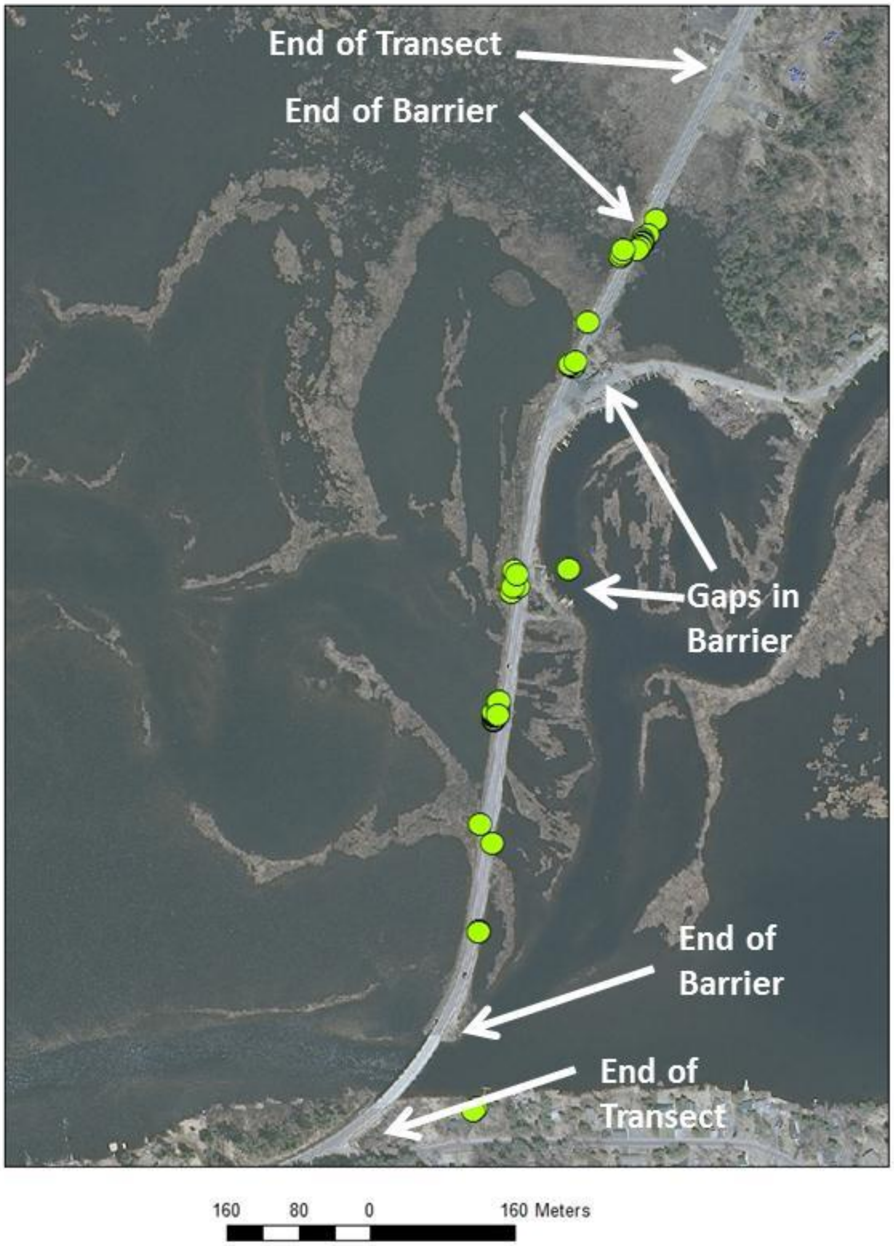


Fig. 5.1 b: ***Locations of detected turtle nests in 2010 and 2011 along the monitored transect of the Tupper Lake Highway 30 Turtle Barrier. Discontinuities in the barrier are indicated by arrows.***

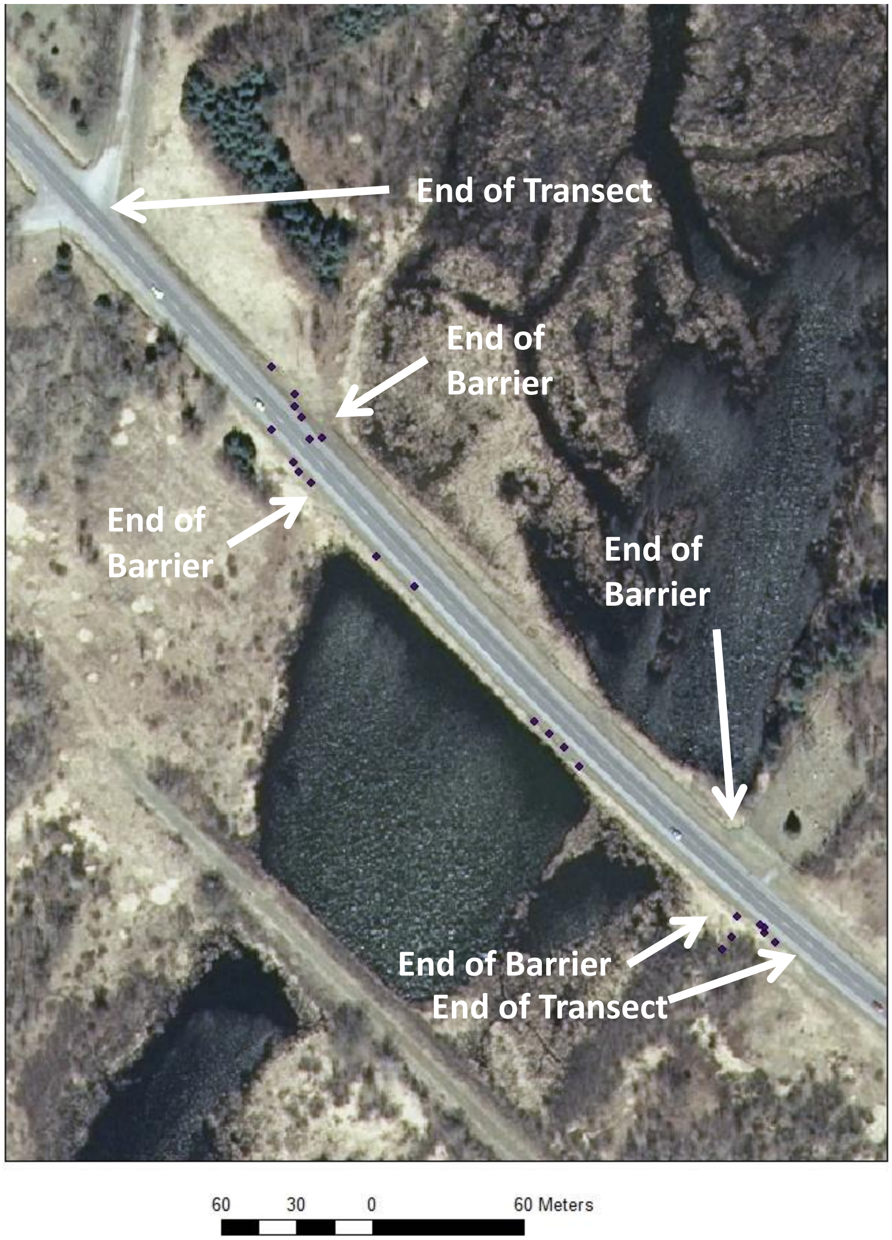


Fig. 5.1 c: ***Locations of detected turtle nests in 2010 and 2011 along the monitored transect of the ULL SWMA Highway 68 Turtle Barrier 1.***

Fig. 5.1 d: ***Locations of detected turtle nests in 2011 along the monitored transect of the ULL SWMA Highway 68 Turtle Barrier 2.***

5.2 Soil temperature around nests along the Tupper Lake Highway 30 Turtle Barrier

To record the temperature of the soil at depths relevant to egg and hatchling development in the nest, I planted iButton Thermocrons (Dallas Electronics) at a depth of approximately 20 cm (typical depth of incubating eggs). The sensors were placed in a plastic bag (to protect them from moisture), and a string was laced from the sensor to the surface to aid at relocating it (Fig. 5.2 a). The temperature sensors were programmed to record the temperature hourly. Locations included three evenly distributed sites adjacent to common snapping turtle nests along the Tupper Lake Highway 30 Turtle Barrier, on each side of the road (east and west facing) for a total of six sensors. Sensors were deployed in 2010 and 2011, and recorded data from early June to the beginning of August, spanning the critical period of development for turtle embryos (including sex determination).

Fig. 5.2 a: ***Placement of thermocron sensors near road. The lower panel shows placement, but when deployed the sensor was buried.***

Unfortunately, several thermocrons failed or disappeared during deployment in 2011. Subsequent correspondence with other researchers that use thermocons revealed that there was widespread failure of thermocrons, and allegations that Dallas Electronics has recently reduced quality control of the sensors. Fortunately, enough sensors were deployed and enough were recovered with complete data records (I intentionally incorporated redundancy the study design in case of sensor failure), so that I can make some firm conclusions about soil temperature around nests.

The Tupper Lake Causeway soil temperatures were quite variable within a day and across a season (Table 5.2 a, Figs. 5.2 b, 5.2 c). These data are similar to other roadside nest sites measured along State Highway 68 at ULL WMA Appendix 4: (Langen 2009).

			Mean Daily			Across Sampling Period			
		Orient	**Mean**	**Minimum**	**Maximum**	**Mean**	**SD**	**Minimum**	**Maximum**
2010	**Ibutton 1**	East	24.8	21.6	27.9	24.8	3.77	14.5	35.5
	Ibutton 2	East	25.0	21.4	28.9	25.0	4.36	13.5	38.0
	Ibutton 3	East	24.5	21.0	28.3	24.5	4.16	13.5	36.0
	Ibutton 4	West	23.1	21.2	25.2	23.1	3.15	14.0	31.5
	Ibutton 5	West	24.8	21.0	30.3	24.8	4.63	13.5	39.0
	Ibutton 6	West	24.8	20.5	30.4	24.8	4.71	13.5	38.5
2011	**Ibutton 1**	West	23.8	20	28.5	23.8	4	35	16
	Ibutton 2	West	25.6	18.6	38.1	25.6	7.79	49	14.5

Table 5.2 a: ***Daily and across sample period descriptive statistics for deployed temperature sensors. All temperatures are degrees celcius. The sensor highlighted in red had suspiciously high peak readings, which may indicate that it was displaced to near the soil surface by animal disturbance.***

One thing that is evident is that roadside nests, including the nests along the Tupper Lake Highway 30 Turtle Barrier and along State Highway 68 at ULL SWMA have peak daily temperatures that are much higher than other sites selected by turtles for nesting within the region (see Appendix 4: Langen 2009). In laboratory incubation studies, sustained temperatures greater than 31 C are fatal to embryos. However there are no published laboratory studies of egg viability or embryo development with temperatures as variable with in a day or across a season as I routinely record at roadside nests. Therefore, I do not know the effect on egg viability of the very high temperatures recorded in soils around roadside turtle nests.

The temperature differences are great enough in terms of average temperature and daily temperature variation that egg development, including sex determination, duration of incubation, and possibly egg viability (Ewert 2008, Janzen 2008), are likely to differ between roadside nests and nests made at other locations used by turtles. Higher temperatures at roadside nests will increase development rates (Ewert 2008), and potentially make it more probable that hatchlings will leave the nest in the fall (i.e. not overwinter in the nest). Differences in sex-ratios between nests along roadsides and other sites appears quite probable given the magnitude of the difference in average daily mean temperature among sites (Janzen 2008). However, the high temperature spikes at roadside nests could potentially cause developmental pathologies or even death (Ewert 2008). Unfortunately, it is not possible to directly compare my data to the vast number of studies on temperature effects on turtle embryo development, since all studies are done either at constant temperatures or by varying temperature to a much smaller degree than occur at the roadside nests sites. There is a critical need to evaluate in the field and laboratory the consequences of varying temperature on a daily basis to the degree experienced by embryos in roadside nests.

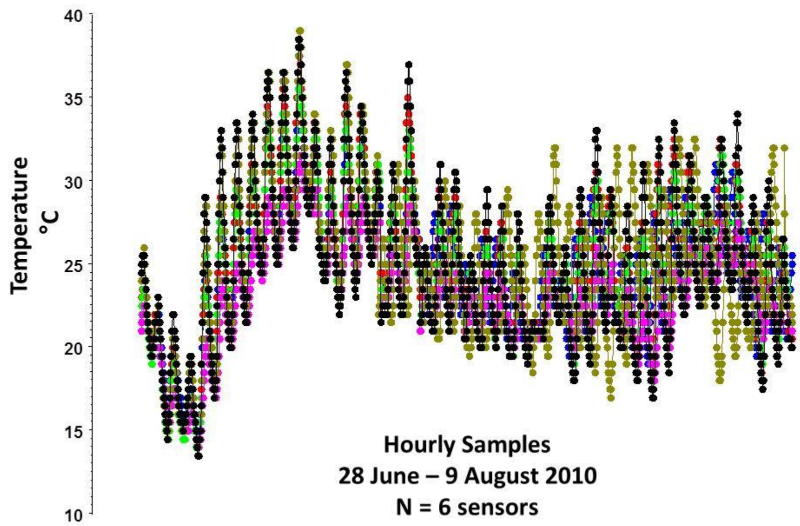


Fig. 5.2 b: ***Hourly temperature readings for six sensors in 2010.***

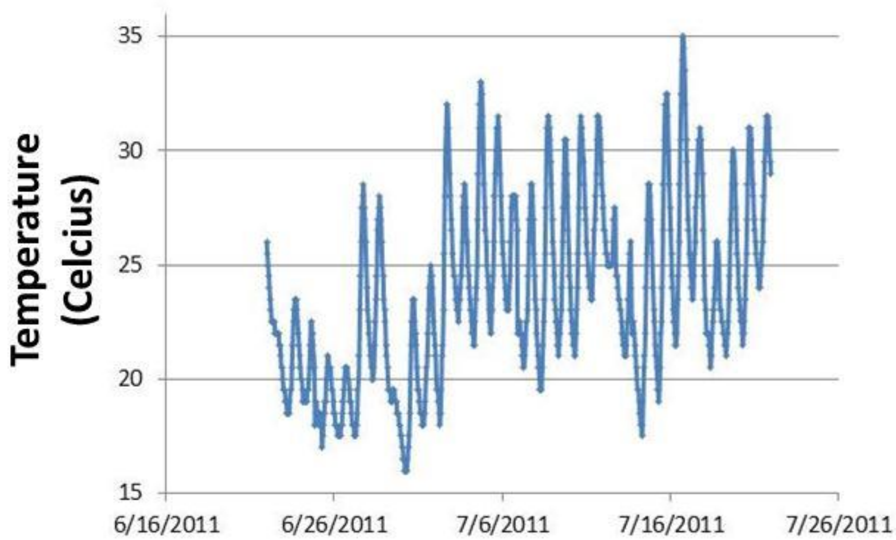


Fig. 5.2 c: ***Hourly temperature readings for a sensor in 2011.***

6. DURABILITY AND FUNCTIONALITY OF THE TUPPER LAKE HIGHWAY 30 TURTLE BARRIER

On each survey, any damage to the Tupper Lake Highway 30 Turtle Barrier was noted and promptly repaired. Overall, damage to the integrity of the barrier was minor, infrequent, and did not greatly reduce the effectiveness of it. This is despite severe seasonality, including heavy snowfall in winter. Most problems were detected the first survey after the winter, and included damage that had occurred during the previous winter and early spring.

Fig. 6 a: ***Fence break, likely caused by cutting.***

The most severe damage to the fences was caused by people intentionally cutting a section of fence to (presumably) make is easier to cross it (Fig. 6a). Less severe damage included two minor problems. First, some cable ties had to be replaced, having been broken or come undone. Second, the small fasteners that affixed the bottom of the fence, midpoint between support posts, to the asphalt broke in some places (Fig. 6b). In some cases, the gaps may have been large enough for smaller turtles (e.g. painted turtles, immature snapping turtles) to enter the roadway. In one instance, fill around a post shifted during the winter caused a post to lean.

Fig. 6 b: ***Break of fence at a bottom fastener.***

Problems with damage were similar at the two ULL SWMA Highway 68 fences, with additional problems caused by shifting posts, and erosional undercutting of the fences. More details on durability and functionality of these fences is found on Appendix 3.

At the two ULL SWMA Highway 68 turtle barriers, vegetation management was a challenge behind the barriers. Vegetation management at these sites required (minimally) mowing minimally a 0.5 m strip along the fence on the wetland (opposite of the road) side of the barrier. As turtles prefer to nest where vegetation is low, this is needed to provide nesting habitat. At the Tupper Lake Highway 30 Turtle Barrier, road salt and presumably other factors kept vegetation low near the edge of the road, and thus matching the nesting preferences of turtles. Nevertheless, vegetation did get high at spots adjacent to the road and certainly within a meter of the road surface (see Figs. 5.1 a, 5.2 a, 6 a). To provide conditions sought by turtles for nesting, vegetation should be periodically mowed or cut with a weed-wacker / brush-cutter tool.

To remain functional, the Tupper Lake Highway 30 Turtle Barrier will need annual inspection and maintenance. This should be done, minimally, each year in early May, before turtles become active on land. A repair kit should include packets of 10 inch UV-light resistant cable ties, some 1 m lengths of vinyl-coated fencing for patching major fence breaks (the same type as used in the installed barrier), wire cutters, pruning shears, pliers, and a post driver. Based on my experience, repairs can be completed within two worker-hours.

Further discussion on maintenance issues associated with turtle fencing and other barriers is in Appendix 3: Langen 2011. Appendices 3 and 4 also provide information on maintenance issues related to the ULL SWMA State Highway 68 Turtle barriers.

7. SUMMARY CONCLUSIONS AND RECOMMENDATIONS

There has been little research focused on developing and testing barriers for turtles (see review in Appendix 3). Such research is essential for improving the design, installation, and maintenance of economical wildlife barriers that successfully function to reduce mortality while maintaining connectivity and avoiding reductions in nesting success (Beckmann et al. 2010, Lesbarreres and Fahrig 2012). There is a need for critical evaluation of the various barrier designs that are currently in use, including their effectiveness at preventing turtle trespass onto roads, secondary impacts on nesting and habitat connectivity, cost, durability, and ease of installation and maintenance.

Specifically, the design considerations of wildlife barriers for turtles must include:

- ***Location***
- ***Cost (materials, labor)***
- ***Motorist Safety***
- ***Impacts on Right-of-Way Management***
- ***Durability & Maintenance Needs***
    - ✓ ***Including 'ownership' of maintenance duties***
- ***Public Buy-in***
    - ✓ ***Perceived value of reducing road-kill***
    - ✓ ***Aesthetics***
- ***Effectiveness at Preventing Road-kill***
- ***Impacts on Nesting Success***
- ***Impacts on Predation Risk (including harvest by humans)***
- ***Impacts on Population Connectivity***

For the Tupper Lake Highway 30 Turtle Barrier, I conclude the following:

Location: The location is highly appropriate. Long causeways are the most severe hotspots of turtle road mortality (Langen et al. in press), and Highway 30 causeway has all of the attributes of a likely road mortality hotspot, and indeed was anecdotally reported to be so before installation of the barrier.

Cost: The materials for construction of the barrier (vinyl-coated steel mesh fencing, cable ties) are very inexpensive, and labor requirements for installation are low, since the fence support structure is guard-rail posts that have already been installed. Installation is somewhat more expensive and labor intensive when fence posts must be installed, as at Upper and Lower Lake SWMA (see Appendix 3).

Motorist Safety: There is minimal negative impact on motorist safety, since the fencing is unobtrusive and affixed to existing guard-rails. Indeed, it is likely that motorist safety is improved, since turtle trespass on the roadway has likely been reduced, and thus lowering the risk of motorists swerving to miss or hit an animal, or else stopping in the roadway to examine or attempt to move the turtle.

Impacts on Right-of-Way Management: There is minimal impact on right-of-way management, since the fencing is affixed to a preexisting guard-rail. Barriers that are self-standing structures, such as at Highway 68 Upper and Lower Lakes SWMA, can provide a challenge to mowing. Mowing crews do not mow behind the barriers, resulting in heavy vegetation growth.

Durability & Maintenance Need: Over the first two years post installation, the Highway 30 Tupper Lake Causeway Turtle Barrier only required minor repairs and maintenance. The construction materials appear to be adequately durable. As discussed in Section 6, there is a need for annual inspection and repair.

It is not clear whether maintenance and repair of the barrier has been incorporated into the annual work plan of the local NYSDOT residency. Either it should be, or there should be a solicitation for some conservation or civic organization to 'adopt' the barrier. Such arrangements have been done at other wildlife barriers in the US and Canada.

Public Buy-in: NYSDOT has designed and installed an attractive and informative information kiosk at a safe parking spot overlooking the Tupper Lake Highway 30 Turtle Barrier that explain the purpose of the wildlife barrier. It is unknown how effective this is for informing the public, and whether there is general awareness in the region of the function of the wildlife barrier.

The barrier itself in unobtrusive (the black vinyl covering and black cable ties are only apparent if one looks for the barrier), and blends in well with the existing brown oxidized metal 'Adirondack style' guard-rail.

Effectiveness at Preventing Road-kill: As discussed in Section 4, it seems likely that the Highway 30 Tupper Lake Causeway Turtle Barrier has reduced turtle mortality, but quantitative evidence of the magnitude of reduction remains lacking because there was no pre-construction monitoring done at this site (essential for evaluating effectiveness of road mitigation, see Lesbarres and Fahrig 2012). Turtle road-kill continues to occur along the barrier, especially at the north end of the barrier (turtles moving around the barrier ends to access the roadway, probably to nest), and at gaps in the barrier at access roads to properties along the causeway. Some road-kill may be the result of smaller turtles going under the barrier at places where the bottom fasteners have broken.

Impacts on Nesting Success: The temperature of roadside nests are more variable, and peak at higher temperatures, than other sites that turtles chose to nest at. It is unknown whether the altered nest microclimate at nests adjacent to roads affects nest viability or nestling health but there are good reasons to suspect that it might (see Section 5.2, Appendix 3).The Tupper Lake Highway 30 Turtle Barrier does not prevent turtles from nesting alongside road, but roadside nesting occurred before the barrier's installation. Thus the barrier does not change nesting conditions from those prior to installation. The Upper and Lower Lakes SWMA Highway 68 turtle barriers to force turtles to nest away from the road where conditions are more similar to other places that turtles nest (Appendix 3).

I detected no evidence that turtle nests were more vulnerable to nest predators with a barrier present than would have been the case had it not been installed. Nests constructed near roads seem to suffer lower predation rates than other sites that turtles nest at (Appendix 3), either because predators avoid roads and road traffic or else because predator populations have been reduced due to road mortality.

Impacts on Predation Risk (including harvest by humans): I detected no evidence that predators (including free-running domestic dogs) depredated turtles along the barrier, nor that people harvested turtles for food or pets along it. At the Tupper Lake Causeway this seems inherently unlikely to occur, given the heavy traffic, lack of cover for predators, and lack of safe places to park along the roadway.

Impacts on Population Connectivity: A large perennial waterway connection under a long bridge on the south end of Highway 30 causeway (see Fig. 2.1 a) is ample to provide connectivity. Many radiotracking studies of painted and snapping turtles indicate that these animals will move much larger distances through water than the length of the causeway. In other words, it is unlikely that any turtles are completely prevented by the turtle barrier from accessing habitat or mates on the other side of the road.

Overall, in summary, the Highway 30 Tupper Lake Causeway Turtle Barrier appears to be a worthwhile mitigation measure for reducing turtle road mortality. The design could be used at other causeways where guardrails exist, and wildlife barriers based on this design should be considered for other sites that have been identified as turtle road-kill hotspots.

However there do remain some immediate and long-term management and research needs.

Recommendations for Immediate Action

1. Designate someone the responsibility of implementing a schedule of periodic inspection and maintenance of the Highway 30 Tupper Lake Causeway Turtle Barrier. The barrier will only remain functional if it is kept structurally intact. See Section 6 for further discussion.

2. Design, install, and test some retrofits to reduce the number of turtles accessing the roadway at the north end of the causeway and at the three gaps along the causeway. At the north end, this would likely be lengthened ‘wings’ at the end of the barrier that guide turtles away from the roadway. At the gaps within the causeway at access roads, either wings or a ‘cattle guard’ type barrier could be tested. Similar problems have been identified and solutions used at other wildlife barriers for herpetofauna (e.g. Dodd et al. 2004).

3. Create some nesting habitat along the causeway. There are many sites along the roadway that could be suitable for created nest habitat. Patches of tilled soil or sand mounds are likely to attract nesting turtles; turtles readily nest in plowed fields, gardens, mowed lawns and other human-managed environments that are located near water (Kolbe and Janzen 2002a, 2002b; Steen et al. 2012). If constructed a few meters from the roadway, fewer turtles may move adjacent to the fence and potentially discover and exploit breaks or gaps in it to enter the roadway. Nesting microclimate and soil conditions potentially may be better at such created nesting habitat than nests constructed immediately adjacent to roads.

4. Consider collaborating with the WILD Center (Natural History Museum of the Adirondacks) in Tupper Lake to create a display or exhibit on the Highway 30 Turtle Barrier.

Long-term Research Needs

1. To adequately test the effectiveness of wildlife barriers for turtles that use the Highway 30 Tupper Lake Causeway design, the same design of barrier should be installed and monitored at some other causeways that are known or suspected to be turtle road mortality hotspots. Pre-installation monitoring (ideally two years) should be done, followed by two years of post-installation. Monitoring could be done by ‘citizen-scientists’ (concerned community members) or local universities if the NYSDOT (or NYSDEC) lack funds or personnel. Indeed, the cost of materials and labor could be provided by other agencies or citizens groups who are concerned about turtles,, as was done at State Highway 68. Installing and maintaining a turtle barrier using

a simple and inexpensive design like that of the Highway 30 Tupper Lake Causeway is an ideal community conservation project that can be done as partnerships with NYSDOT.

2. The impact of roadside nesting on nest viability needs to be carefully researched. In particular, the effects of the altered soil microclimate along roads on embryo development and survivorship should be studied, as should the effects of the altered chemical and physical structure of soils adjacent to roads (reviewed in Langen et al. 2006). If roadside nests are as viable or are more viable than other sites at which turtles nest, then barriers placed at the immediate roadside such as at Highway 30 will be suitable. However, if nests are less viable, then barriers that are offset from the pavement by a few meters may be more effective at reducing the impacts of roads on turtle populations (see Appendix 3).

3. Projects to create and monitor suitable alternative nesting sites for turtles away from roadsides should be done, with the goal of determining whether (and how) turtles can be encouraged to select sites away from roads to nest. Given that turtles readily locate and chose to nest in soil disturbed by human activities such as gardening so long as a site is not far from water, and given that turtles avoid nesting in locations with tall, shady vegetation (Kolbe and Janzen 2002a, 2002b; Steen et al. 2012), it should be possible to create nesting sites that attract turtles away from roads. Since most road mortality is from nesting female turtles (e.g. Steen et al 2006), created nesting sites that are accessible and more attractive than roadsides could have a significant positive impact on adult survival. If nest and embryo viability is higher at the created nest habitat than roadsides, then this will provide a double advantage in terms of population conservation.

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