WILDLIFE MITIGATION PLAN STATE HWY 49, HORICON MARSH, WISCONSIN, USA

by

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The US Fish & Wildlife Service as well as other stakeholders (e.g. naturalists including bird watchers) have been concerned about the high number of animals being killed along the section of State Hwy 49 that bisects Horicon Marsh for well over a decade. In response, US Fish & Wildlife Service employees initiated a road-kill monitoring program. Several mitigation measures have been proposed in the past, but no mitigation has been implemented yet (situation 2014). This report contains an analysis of the existing wildlife road-kill data, especially for amphibians and reptiles, birds, and mammals. In addition it contains the results of interviews with different stakeholder groups; employees from natural resource management agencies, the Wisconsin Department of Transportation, and non-governmental organizations/university. The interviews focused on the problems related to State Highway 49 and wildlife as the individual stakeholders experienced it, their level of support for the implementation of various avoidance, mitigation and compensation strategies, how likely it is that the measures will be implemented in the future, and the problems that may be associated with the different measures. Based on the existing road-kill data and the interviews with stakeholders, the researchers formulated a series of objectives and suggested accompanying measures. The final recommendations were presented as different “packages” of measures, including how well they address the different potential objectives.</td></tr>
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1. INTRODUCTION

1.1. Background

Horicon Marsh is located about 50 miles north-east of Madison, Wisconsin (Figure 1). It is a national (Horicon National Wildlife Refuge) and state wildlife refuge (Horicon Marsh Wildlife Area), about 32,000 acres in size. It consists of a mixture of open water and marsh vegetation (mostly cattail (*Typha* spp.)) separated by embankments to control water levels. The northern section of Horicon marsh is bisected by State Highway 49 (about 2.3 miles (3.7 km) in road length) (Figure 1). This highway connects Waupun and US Hwy 151 (west side of the marsh) to Brownsville and US Hwy 41 (east side of the marsh) and has a daily traffic volume of about 4,100 vehicles (in 2008), has 2 lanes, and the posted speed limit is 55 mi/h (88 km/h) (Lee et al., 2013; Personal communication Brandon Jutz, Regional Transportation Coordinator, U.S. Fish & Wildlife Service - Region 3; Wisconsin Department of Transportation, 2008). Average vehicle speed is about 59 mi/h (95 km/h), and the 85th percentile is about 61 mi/h (98 km/h) (Kemnitz, 2007). Truck traffic is about 22-26% (Kemnitz, 2007). While there are other paved and unpaved roads in and around Horicon Marsh, the current project only relates to State Highway 49.

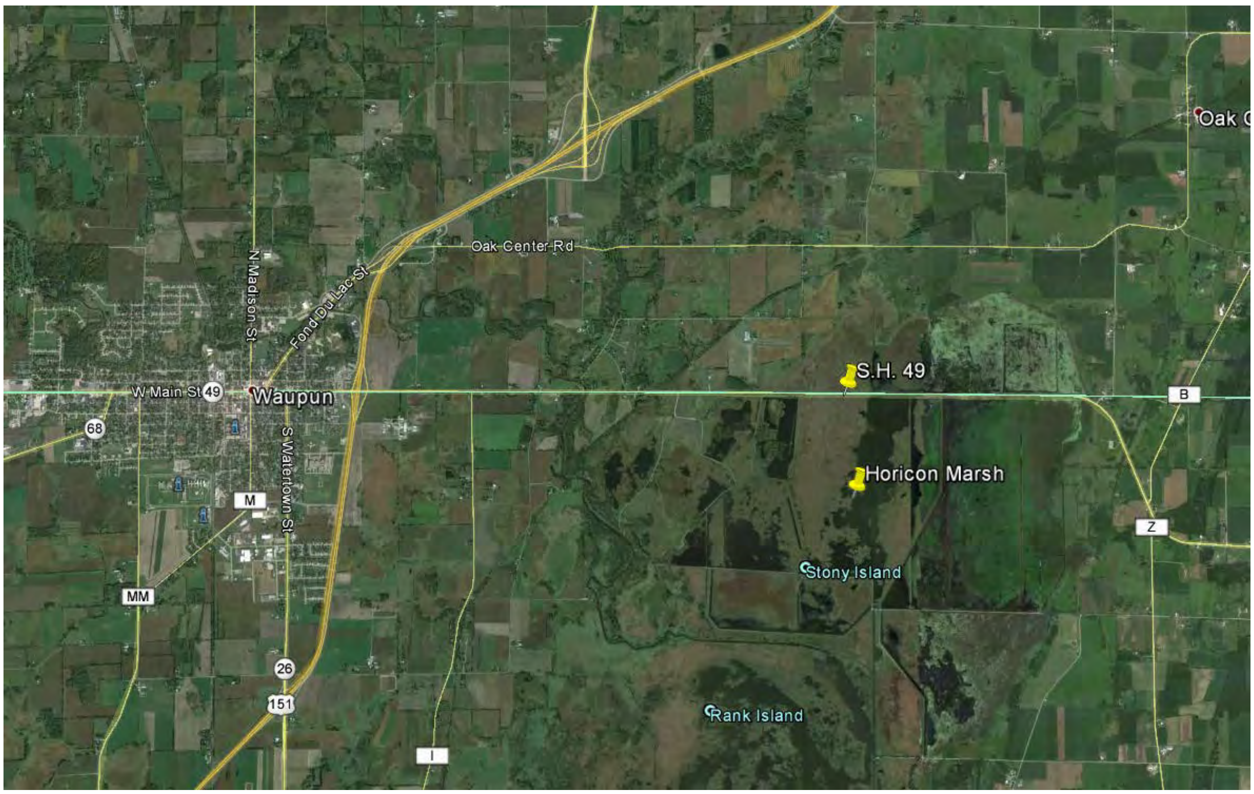

Figure 1: State Highway 49 and Horicon Marsh, just east of Waupun, Wisconsin, USA.

The US Fish & Wildlife Service as well as other stakeholders (e.g. naturalists including bird watchers) have been concerned about the high number of animals being killed along the section of State Hwy 49 that bisects Horicon Marsh for well over a decade. In response, US Fish & Wildlife Service employees initiated a road-kill monitoring program. The species groups that are hit include amphibians, reptiles, birds, and mammals; 7,480 road-killed animals have been recorded from 2001 through 2012 by Horicon National Wildlife Refuge staff (Lee et al., 2013; Pers. Comm. Sadie O'Dell). The most commonly recorded species found dead on or along State Highway 49 are muskrat (*Ondatra zibethicus*) (47.9%), painted turtle (*Chrysemys picta*) (6.9%), Canada goose (*Branta canadensis*) (6.8%) (Lee et al., 2013). Geese (6.8% of all reported road-killed animals) and ducks (mallard (*Anas platyrhynchos*) 2.2%; blue-winged teal (*Anas discors*) 0.5%; redhead (*Aythya americana*) 0.2%; ruddy duck (*Oxyura jamaicensis*) 0.1%; wood duck (*Aix sponsa*) <0.1%) may be a concern for traffic safety. The observed number of goose and duck carcasses totaled 730 between 2001 through 2012 (Lee et al., 2013).

While one can argue that any road-killed animal should be a concern, only one federally listed threatened or endangered species has been reported as road-kill between 2001-2012; Piping plover (*Charadrius melodus*). However, an experimental population of whooping cranes (*Grus americana*) is nearby (Personal communication Brandon Jutz, Regional Transportation Coordinator, U.S. Fish & Wildlife Service - Region 3), whooping cranes are now also residing at Horicon Marsh (Personal communication Steve Lenz, Horicon National Wildlife Refuge) and a low flying whooping crane has had several narrow escapes with vehicles along State Hwy 49 through Horicon Marsh in spring 2014 (Personal communication and images of the situation through Sadie O'Dell, Horicon National Wildlife Refuge).

1.2. Brief History of Horicon Marsh

In the Pleistocene, the area that is now known as Horicon Marsh was a glacier. After the glacier retreated, about 12,000 years ago, a lake (Glacial Lake Horicon) formed behind the moraine and the drumlins (small hills) left behind by the glacier became islands in the lake (Wikipedia, 2014). As the Rock River eroded the moraine the lake drained, but layers of silt, clay and peat meant that that the area remained a wetland. In 1846 a dam was built to power a sawmill and a grist mill, and also to transport logs and agricultural products (US Fish & Wildlife Service, 2014a). This caused the water level behind the dam to rise 2.7 m (9 ft) with "Lake Horicon" as a result (Wikipedia, 2014). However, farmlands and other property flooded and damage claims eventually caused the dam to be removed in 1869 transforming the lake into a marsh once again. The birds and other wildlife species were subjected to unregulated hunting which resulted in massive slaughter of the bird populations (US Fish & Wildlife Service, 2014). Between 1910 and 1914 there was an attempt to drain the marsh for agricultural purposes (Wikipedia, 2014). This attempt failed and the marsh was left to itself again, but the dry peat caused massive fires. In 1927 the Horicon Marsh Wildlife Refuge Bill was passed which allowed for the construction of a dam (completed in 1934) to bring the water levels up to what was considered "normal". The southern third of the marsh became the "Horicon Marsh State Wildlife Area", managed by the Wisconsin Department of Natural Resources (DNR) (Wisconsin Department of Natural Resources, 2014a). The US Fish & Wildlife Service purchased the northern two-thirds of the marsh (now "Horicon National Wildlife Refuge") in the 1940s (Wikipedia, 2014). The two refuges are now known as “Horicon Marsh” which is one of the largest freshwater marshes in the United States. The marsh provides important habitat for a range of bird species, especially for migrating ducks and Canada geese. In addition, the marsh is important for fish, frogs, snakes, turtles, mammals, insects and plants. In 1990 Horicon Marsh was designated as a Ramsar site; a wetland of international importance. The marsh, especially the area managed by the US Fish & Wildlife Service, is split into different water level management units separated by dikes, levees or embankments. This results in optimum habitat for ducks with a mixture of open water, and vegetated portions of the marsh. Depending on the phase in the water level management cycle, different sections of the reserve are more attractive to ducks than others.

The current State Highway 49 was built in the 1950s - 1960s (Personal Communication Jon Krapfl, US Fish & Wildlife Service). It replaced the old route (“old marsh road”) that is now used for management and non-motorized recreational purposes only. The current State Highway 49 has 13 culverts under the road. In 1999 “elbows” were installed on one side of the culverts (north of the highway), allowing for more effective water management, reduced culvert maintenance, and higher wetland quality (Personal Communication Jon Krapfl, US Fish & Wildlife Service). Note that the area on the north side of State Highway 49 has a different water level management than the area on the south side (Personal Communication Jon Krapfl, US Fish & Wildlife Service).

1.3. Goal and Objectives

US Fish & Wildlife Service approached the Western Transportation Institute at Montana State University (WTI-MSU) to explore the potential implementation of mitigation measures aimed at improving human safety and reducing the overall road-kill of wildlife along the section of State Highway 49 through Horicon Marsh, without increasing the existing barrier effect of the road and traffic on wildlife.

The goal is to eventually implement effective mitigation measures along the highway section described above. However, implementing effective mitigation measures is likely to come with some difficult choices or the measures may require creative solutions. One of the complications is that the water levels north and south of State Highway 49 are managed differently; the culverts under the highway are blocked at least part of the year to allow for different water levels on the north and south side of the highway. Therefore water may not be allowed to flow freely under an elevated highway should a long bridge be constructed. Landscape aesthetics of measures that encourage birds to fly high enough to avoid being struck by vehicles may also be an issue as this may involve tall poles at regular intervals (similar to Bard et al., 2002) that may be visible from a long distance. Note that such tall poles have been suggested in the past (Lee et al., 2013).

The objective of the project that this report reports on is to have a better understanding what the different stakeholders experience as a problem with regard to State Highway 49 and wildlife through Horicon Marsh.

1.4. Tasks

This report is structured around the following tasks:

Task 1. Establish contact with the local reserve managers (National Wildlife Refuge (NWR) and State), representatives of Friends of Horicon National Wildlife Refuge, and employees of the Wisconsin Department of Transportation for review of and comment on the goals and tasks of WTI-MSU’s technical support.

Task 2. Conduct a field visit and interview representatives or employees of reserve managers (NWR and State), Friends of Horicon NWR, and of the Wisconsin Department of Transportation with regard to the problems they would like to see solved (along State Highway 49 and other roads through and around Horicon Marsh) – species of concern and road segment locations - and their perspective on the various mitigation measures that have already been suggested for State Highway 49 in the past.

Task 3. Acquire and analyze existing road-kill data for State Highway 49 through Horicon Marsh.

Task 4: Compile potential mitigation measures for State Highway 49, and document the pros and cons of these mitigation measures, estimate relative costs of implementation, and highlight the measures that seem most appropriate.

Task 5: Provide a written report.

2. PROBLEM DEFINITION AND STRATEGIES TO ADDRESS THE PROBLEM

2.1. Collision Data Types and Problem Definition

For most federal and state roads in the U.S. there are two types of wildlife-vehicle collision data available: crash data collected by law enforcement agencies and carcass removal data collected by road maintenance crews. By definition, the crash data relate to the most serious collisions from the human perspective with substantial vehicle damage and/or human injuries and human fatalities. The reported crashes tend to be associated with large mammals because of their size and weight. Carcass removal data typically also relate to large mammals only as their size and weight can be a serious obstacle and safety risk and distraction to the traveling public. Small and medium sized animal species, including most amphibians, reptiles, and small and medium sized mammal species are typically not removed and thus not recorded in carcass removal databases maintained by transportation agencies. Thus, in most cases, crash data and carcass removal data can only be used to identify and prioritize locations along highways that that may require wildlife mitigation measures from the perspective of human safety or from the perspective of reducing collisions with large mammals. Furthermore the crash and carcass data are dominated by the most common ungulates in North America such as white-tailed deer (*Odocoileus virginianus*), mule deer (*Odocoileus hemionus*), elk (*Cervus canadensis*) and moose (*Alces alces*) rather than threatened or endangered large mammal species.

If the concern is with direct road mortality for species or species groups other than common large mammals, specifically large common ungulates, then data sources other than crash data and carcass removal data may be required. A specific road-kill monitoring program may have to be developed. Depending on the exact goals of the project and the associated requirements such data may be collected by personnel from natural resource management agencies, researchers or the public.

While there is much emphasis on mitigating for wildlife-vehicle collisions in North America, crashes, dead animals, and associated costs and risks to humans are not the only reason mitigation for wildlife along highways may be considered. The authors of this report distinguish five different categories of effects of roads and traffic on wildlife that may trigger action (Figure 2):

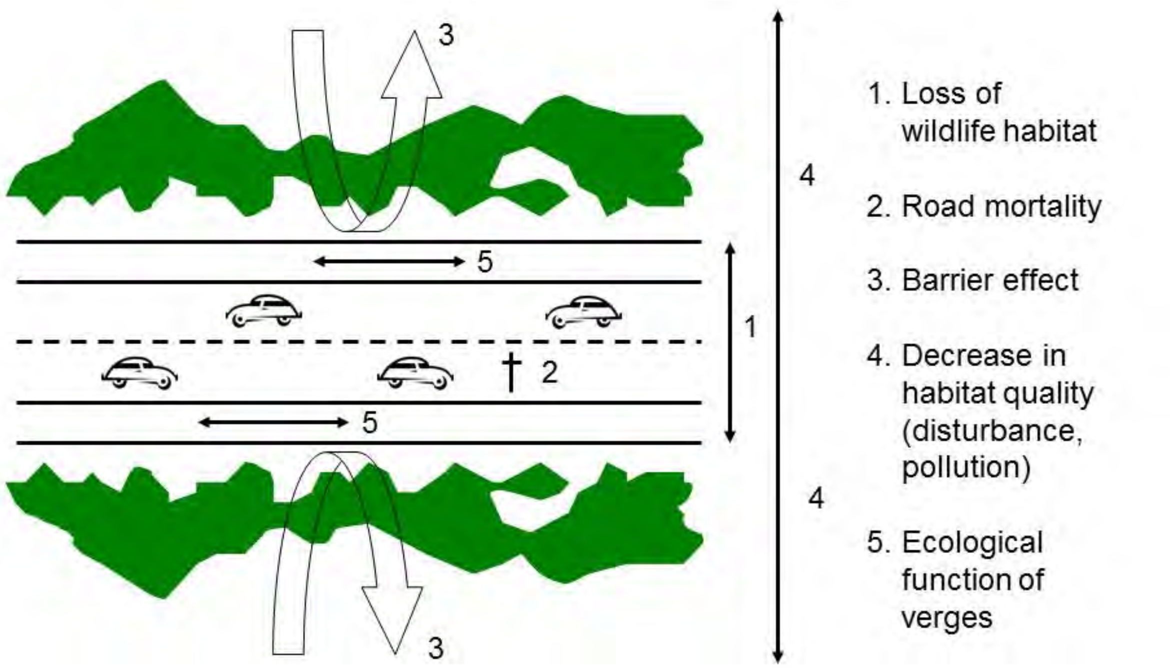

Figure 2: The effects of roads and traffic on wildlife.

- Habitat loss: e.g., the paved road surface, heavily altered environment through the road bed with non-native substrate, and seeded species and mowing in the clear zone.
- Direct wildlife road mortality as a result of collisions with vehicles.
- Barrier to wildlife movements: e.g., animals do not cross the road as often as they would have crossed natural terrain and only a portion of the crossing attempts is successful. This may disrupt daily, seasonal, and dispersal movements required for long term population persistence.
- Decrease in habitat quality in a zone adjacent to the road: e.g., noise and light disturbance, air and water pollution, increased access to the areas adjacent to the highways for humans.
- Right-of-way habitat and corridor: Depending on the surrounding landscape the right-of-way can promote the spread of non-native or invasive species (surrounding landscape largely natural or semi-natural) or it can be a refugium for native species (surrounding landscape heavily impacted by humans).

If mitigation is required for habitat loss, barrier effects, a decrease in habitat quality in a zone adjacent to the road, or the ecological functioning of right-of-ways, other types of data are needed than wildlife-vehicle collision data. Examples of such data are data on the quantity and quality of the habitat impacted, animal movement data, data on noise or chemical pollutants, and the presence and spread of non-native invasive species. Note that wildlife-vehicle collision hotspots are not necessarily the locations where animals cross the road most frequently or where safe crossing opportunities would have the greatest benefit to the long-term population viability for selected species.

For the current project the problem, as defined by the U.S. Fish and Wildlife Service (regional and local level), is the relatively high number of wildlife-vehicle collisions in general, specifically with birds, amphibians and reptiles, and the associated impacts on their populations.

2.2. Strategies to Address the Problem

While mitigation (reducing the severity of an impact) is common, avoidance is better and should generally be considered first (Cuperus et al., 1999). For example, deer-vehicle collisions, or the negative effects of roads and traffic on wildlife in general, may be avoided if a road is not constructed, or the most severe negative effects may be avoided by re-routing away from the most sensitive areas (Figure 2). If the effects cannot be avoided, mitigation is a logical second step. Mitigation is typically done in the road-effect zone (Figure 3) and may include measures aimed at reducing wildlife-vehicle collisions and reducing the barrier effect (e.g., through providing for safe wildlife crossing opportunities) (Huijser et al., 2008a; b; Clevenger & Huijser, 2011). However, mitigation may not always be possible or the mitigation may not be sufficient. Then a third approach may be considered: compensation or mitigation off-site. Compensation may include increasing the size existing habitat patches, creating new habitat patches or improving the connectivity between the habitat patches that would allow for larger, more connected, and more viable network populations. Finally, in some situations a combination of avoidance, mitigation, and compensation may be implemented.

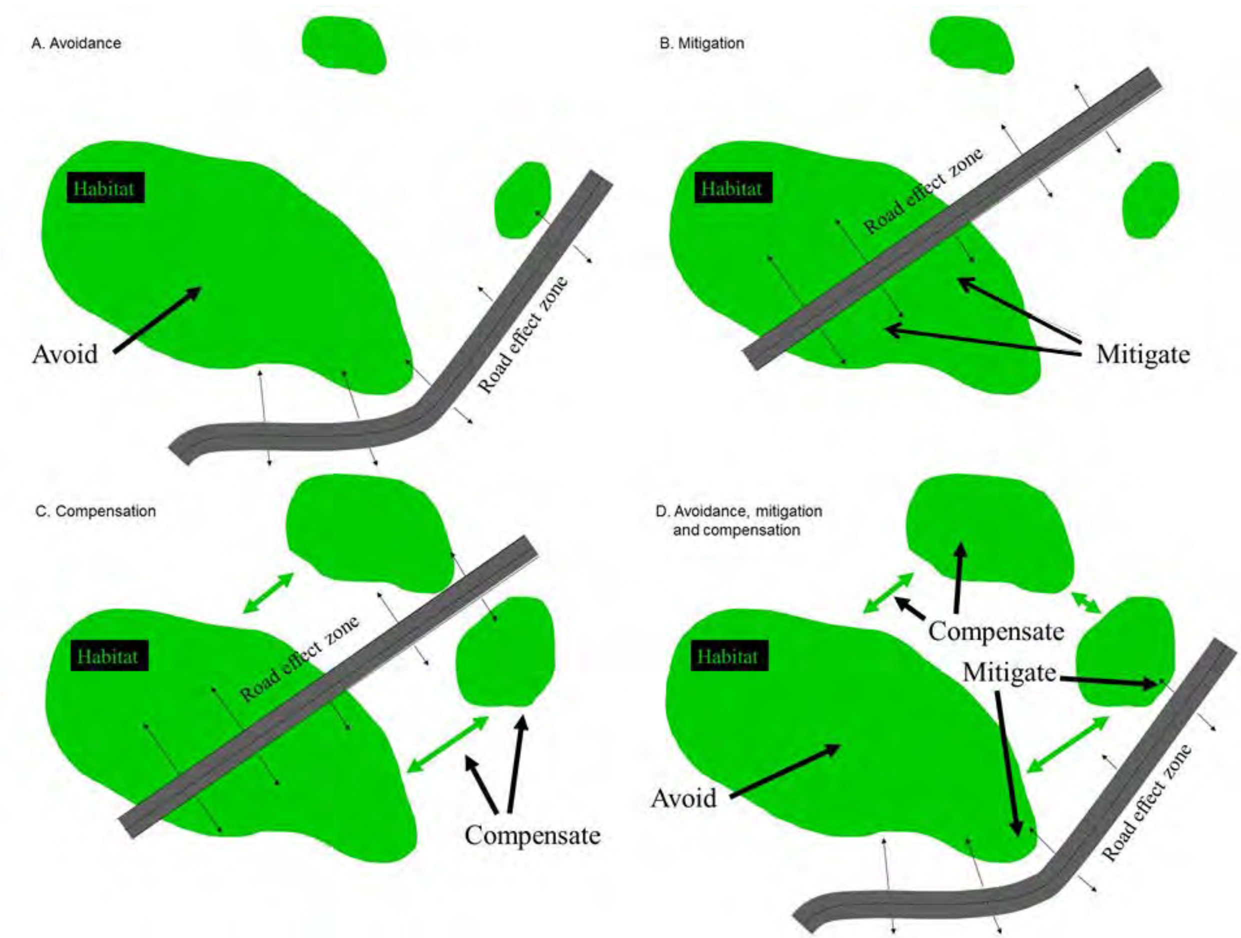

Figure 3: A three step approach: A. Avoidance, B. Mitigation, C. Compensation, D. Combination of avoidance, mitigation and compensation.

For the current project the approach is primarily to suggest measures aimed at mitigating (reducing) the relatively high number of collisions with wildlife in general and birds, amphibians and reptiles in specific. However, some of the suggestions in this report can be classified as avoidance or compensation rather than mitigation.

Note that the potential implementation of mitigation measures aimed at reducing wildlife-vehicle collisions should not increase the barrier effect of roads and traffic for wildlife, particularly not for species which may already be threatened or endangered. Therefore measures that keep (terrestrial) wildlife from entering the road (e.g. wildlife fencing) are typically implemented in combination with safe crossing opportunities for terrestrial wildlife (e.g. wildlife underpasses or overpasses).

3. ROAD-KILL COUNTS ALONG S.H. 49 THROUGH HORICON MARSH

3.1. Introduction

The US Fish & Wildlife Service as well as other stakeholders (e.g. naturalists including bird watchers) have been concerned about the high number of animals being killed along the section of State Hwy 49 that bisects Horicon Marsh for well over a decade. In response US Fish & Wildlife Service employees initiated a road-kill monitoring program, mostly as part of their commute to work.

3.2. Methods

Between March 2001 and 31 December 2013 a survey was conducted for road-killed animals along a 2.3 mi (3.7 km) long section of State Highway 49 through Horicon Marsh (Figure 4). The survey was conducted on every weekday (Monday through Friday), though during some periods (e.g. when snow accumulated) the frequency dropped to three times per week or no survey at all (Stoddard, 2014).

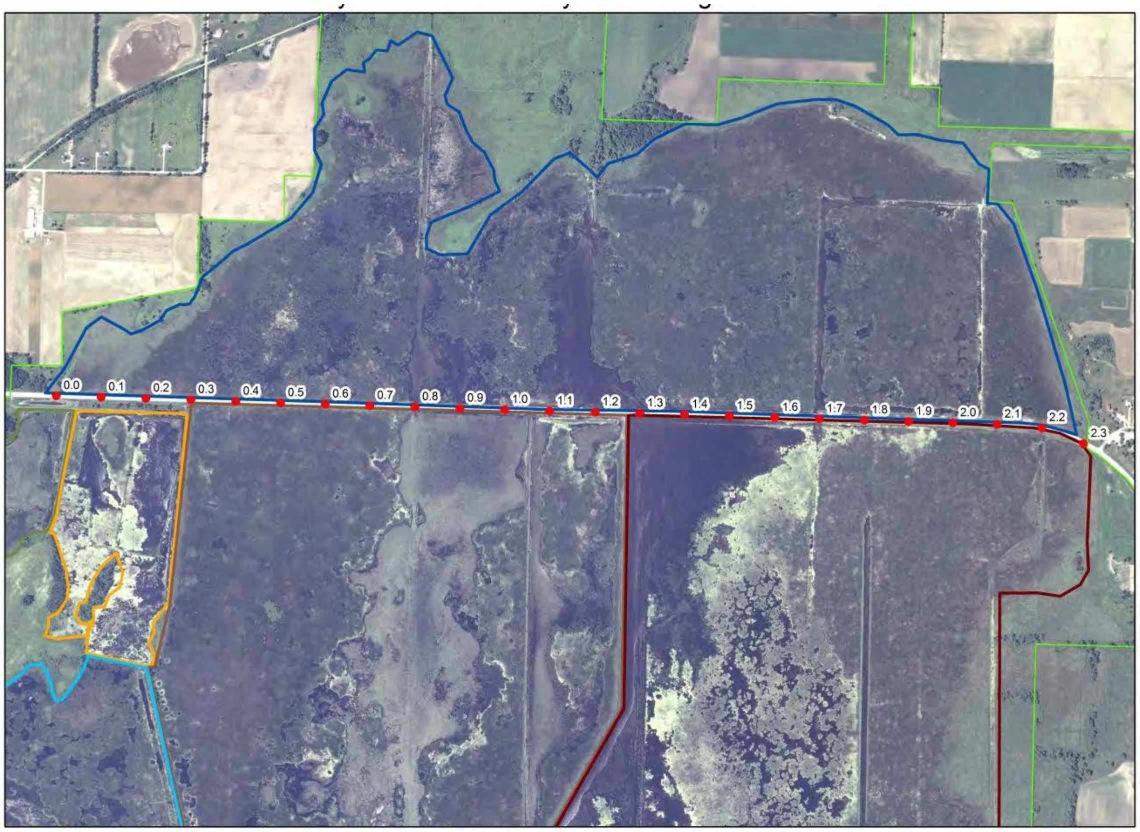

Figure 4: The 2.3 mi long (3.7 km) monitoring route along State Highway 49 through Horicon Marsh. While the highway does not have actual mile markers, the monitoring route started at mi 0.0 and ended at mi 2.3 based on the vehicle's odometer (Image courtesy of US Fish and Wildlife Service). The other colored lines indicate other (unpaved and paved) roads, embankments or dikes or levees, or impoundment boundaries.

The observers always started a survey at the I-4/I-5 dike gate (gravel road) just inside the west boundary of the refuge where it intersects Highway 49 (Stoddard, 2014). The observers set the vehicle's odometer to 0.0 and monitored State Highway 49 for road-killed animals while driving 10-20 mi/h (16-32 km/h) headed east on the south shoulder. When a road-killed animal was observed, the date and location (to the nearest tenth of a mile) were recorded. The specific location of a carcass (e.g. which lane or shoulder) was recorded to reduce the likelihood of counting the same carcass more than once on different days. When needed, the observers (wearing a safety vest) left the car and approached the carcasses for species identification. When leaving the vehicle was considered too dangerous, binoculars were used instead for species identification.

Note that the files made available to the researchers did not contain location information (to the nearest 0.1 mi) between March 2001 and December 2002. Therefore data from this period were excluded from certain analyses.

3.3. Results

3.3.1. Species Groups

Mammals, amphibians, birds and reptiles were most frequently recorded along the monitoring route (Figure 5). However, only a small portion of the small mammals (e.g. mice and shrews), and amphibians (e.g. frogs, toads and salamanders) that were hit were recorded. Their small size in combination with the traffic driving over the carcasses made it hard for the observers to even see the carcasses. In addition, at certain times of the year, e.g. warm moist nights in the spring, amphibian migration and mortality was so substantial that the observers gave up counting completely from 2009 onwards (Personal communication Jon Krapfl, U.S. Fish & Wildlife Service, also see Appendix A). While the number of invertebrates killed by vehicles is likely extremely high only a few were recorded (Figure 5). There were also a few fish recorded as road-kill. It may be that birds dropped the fish on the highway (Personal Communication Jon Krapfl, US Fish & Wildlife Service).

Mammal mortality seems to be relatively evenly distributed along the route (Figure 6). However, amphibian road-kill was most frequent between mile markers 1.2-2.0. This road section is largely characterized by open water on one or both sides of the highway (Figure 4). Bird road-kill was more spread-out but appears highest between mile markers 0.9-1.8. Reptile mortality seems to be relatively evenly distributed along the route, but appear less frequent between mile markers 1.7-2.3. Interestingly, there appears a peak in road mortality around mile marker 1.3 for mammals, amphibians and birds. This location coincides with the embankment perpendicular to State Highway 49 on the south side.

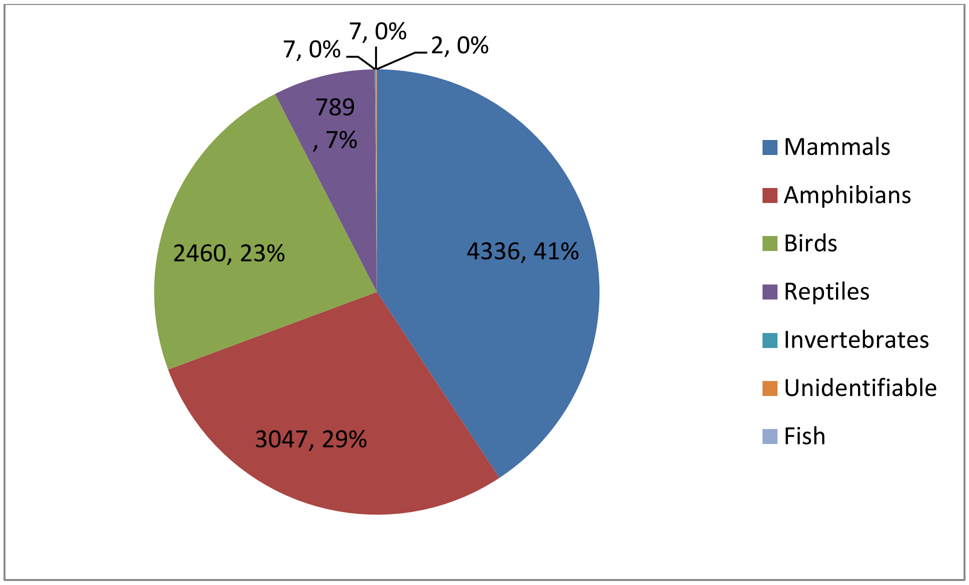

Figure 5: The number and percent of the different species groups recorded as road-kill along monitoring route along State Highway 49 through Horicon Marsh from 2001 through 2013 (n=10,648) (Based on data provided by the US Fish and Wildlife Service).

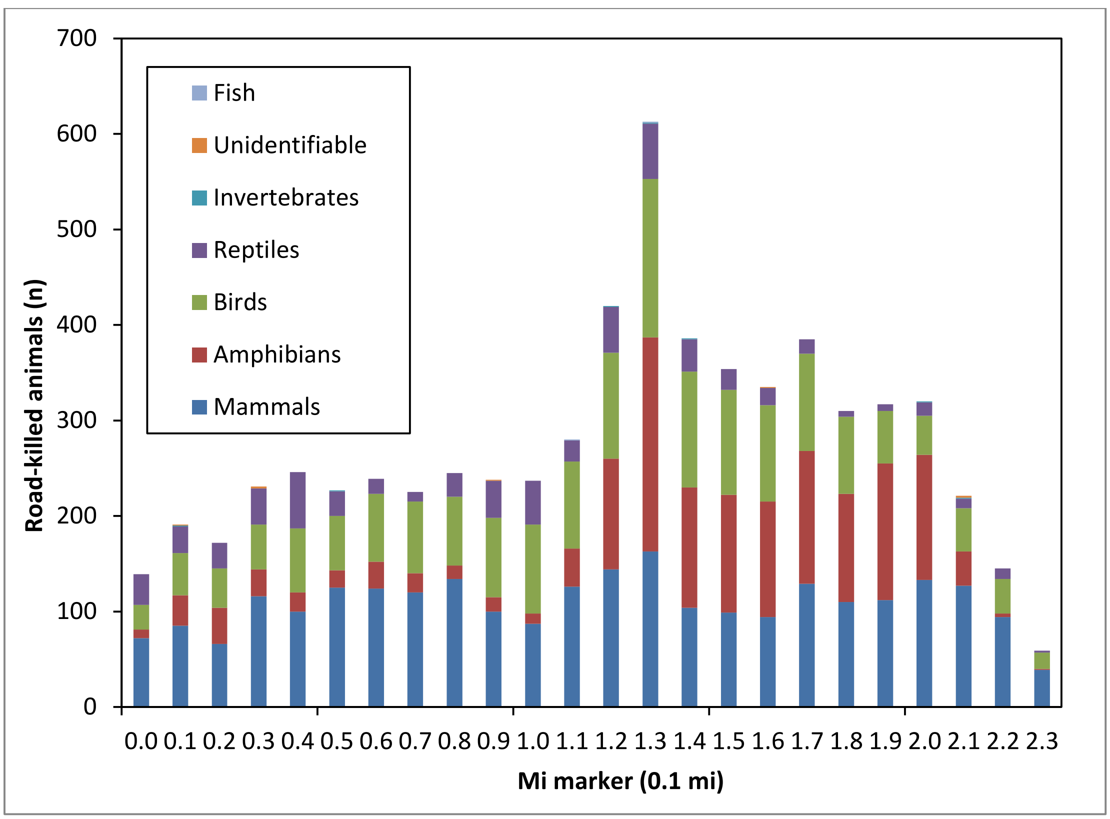

Figure 6: The number of the different species groups recorded as road-kill per 0.1 mile (160 m) along the monitoring route along State Highway 49 through Horicon Marsh from 2001 through 2013 (n=6,535) (Based on data provided by the US Fish and Wildlife Service).

3.3.2. Most Frequently Hit Species

The individual road-killed species within each species group are listed in Appendix A. Muskrat (*Ondatra zibethicus*) (82.8%) and raccoon (*Procyon lotor*) (5.81%) made up over 88% of all recorded road-killed mammals (Appendix A). Apart from the first and last few hundred meters (yards) muskrats are hit in relatively high numbers throughout the route (Figure 7). Raccoons appear to be hit in highest numbers around the start and end of the route where it is drier.

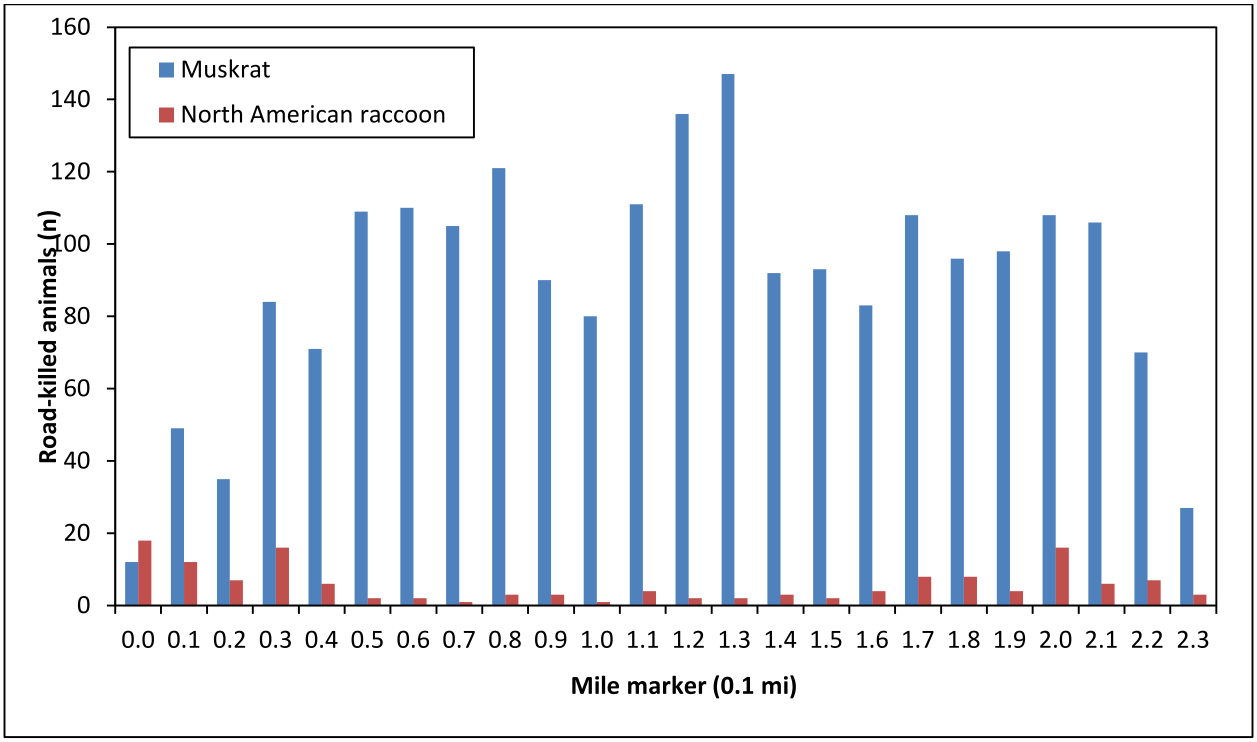

Figure 7: The number of the most frequently hit mammal species per 0.1 mile (160 m) along the monitoring route along State Highway 49 through Horicon Marsh from 2001 through 2013 (Based on data provided by the US Fish and Wildlife Service).

Amphibian road-kills were dominated by "frogs" (Anura) (96.95%) but some amphibian including the leopard frog (*Rana pipiens*) (2.95%) were identified to the species level (Appendix A). Frogs were seen most frequently between mile markers 1.2-2.0 (Figure 8), a road section that is mostly characterized by the proximity of open water (Figure 4).

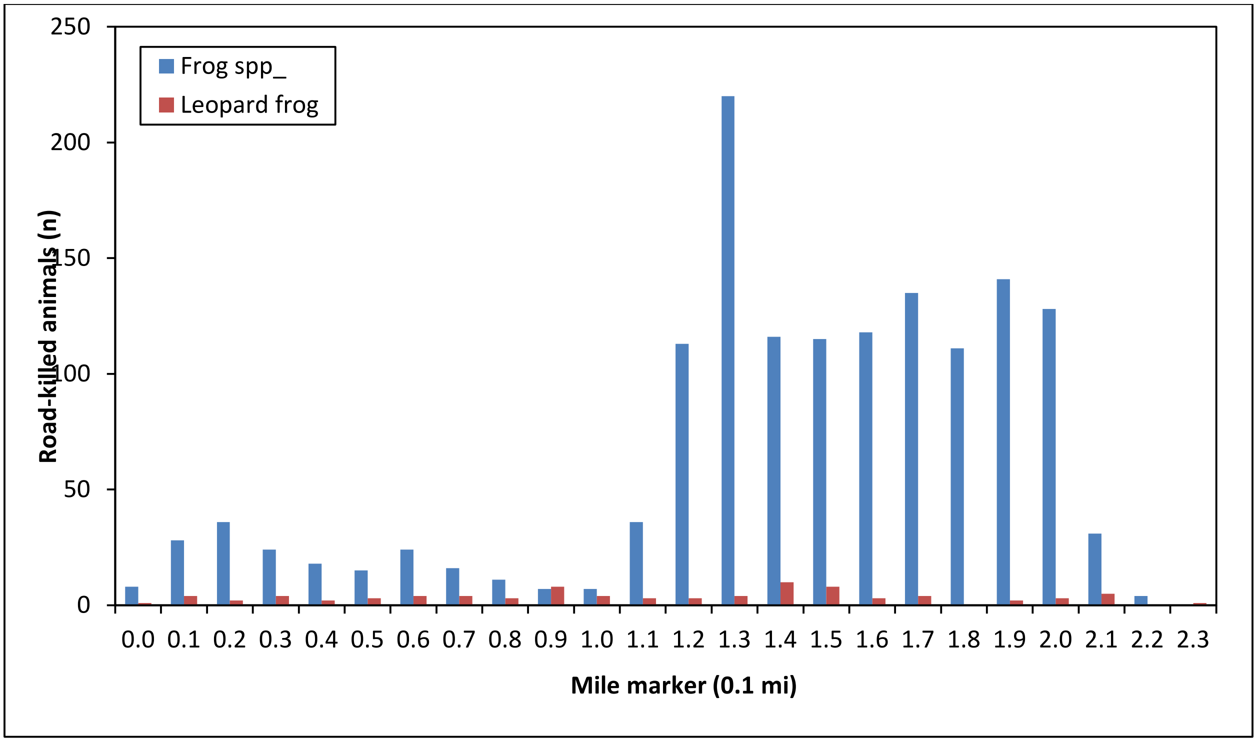

Figure 8: The number of the most frequently hit amphibian species per 0.1 mile (160 m) along the monitoring route along State Highway 49 through Horicon Marsh from 2001 through 2013 (Based on data provided by the US Fish and Wildlife Service).

Bird mortalities were mostly with Canada goose (*Branta canadensis*) (20.89%), American coot (*Fulica americana*) (14.63%), red-winged blackbird (*Agelaius phoeniceus*) (12.07%), "unidentifiable birds" (8.89%), Mallard (*Anas platyrhynchos*) (6.71%), and tree swallow (*Tachycineta bicolor*) (5.12%) (Appendix A). Canada goose, American coot and tree swallows were mostly hit between mile markers 0.7-1.9 (Figure 9) where open water is close to the highway (Figure 4). The same is true for mallards, especially between mile markers 1.0-1.4. Apart from the first and last few hundred meters (yards) red-winged blackbirds are hit in relatively high numbers throughout the route.

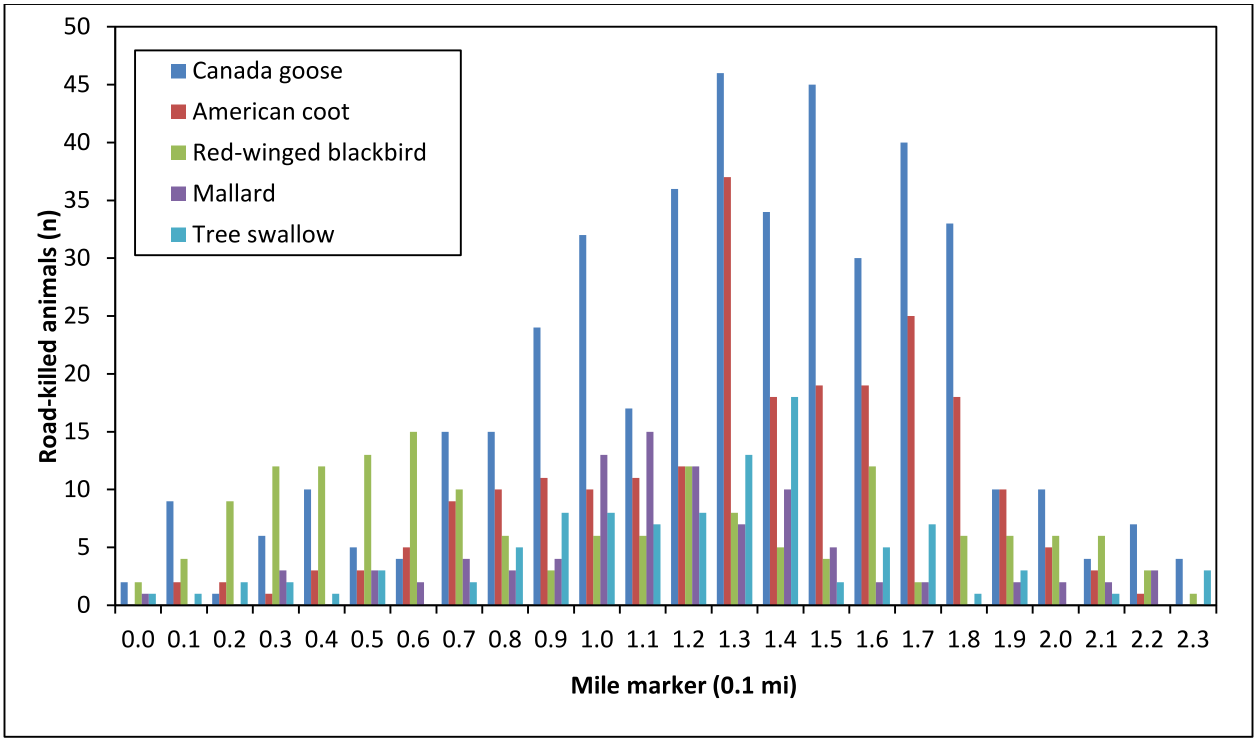

Figure 9: The number of the most frequently hit bird species per 0.1 mile (160 m) along the monitoring route along State Highway 49 through Horicon Marsh from 2001 through 2013 (Based on data provided by the US Fish and Wildlife Service).

Reptile mortalities were dominated by painted turtle (*Chrysemys picta*) (66.54%) and common snapping turtle (*Chelydra serpentine*) (29.28%) (Appendix A). There seem to be two road sections where turtle mortality is highest: mile markers 0.0-0.5 and 0.8-1.7 (Figure 10).

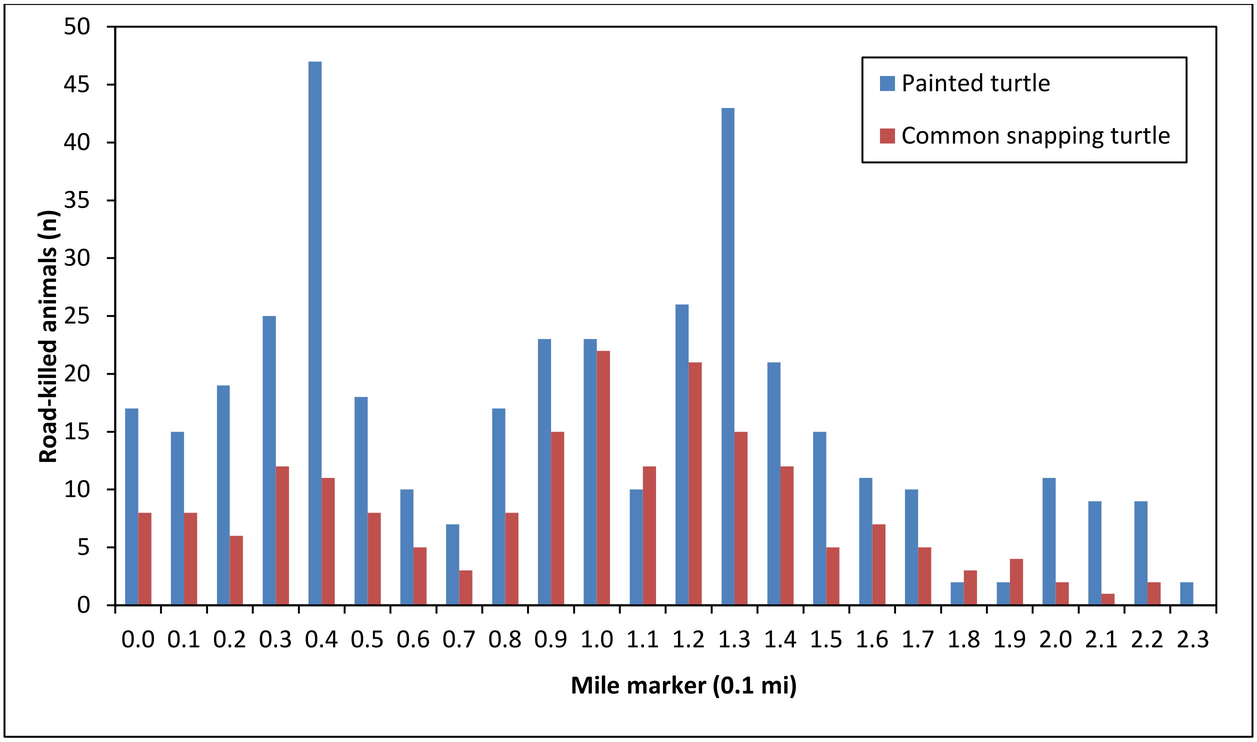

Figure 10: The number of the most frequently hit reptile species per 0.1 mile (160 m) along the monitoring route along State Highway 49 through Horicon Marsh from 2001 through 2013 (Based on data provided by the US Fish and Wildlife Service).

3.3.3. Large, Rare, Threatened, and Endangered Species

Species that may require specific attention include animals that are large enough to pose a serious threat to human safety, or those that are rare, or listed as threatened or endangered (Table 1). Note that the number of road-killed individuals for rare, threatened, or endangered species is almost always relatively low because of their scarcity.

Table 1: Species hit that are large enough to pose a serious threat to human or that are a substantial conservation concern according to federal, state or expert sources.

Species	Road-kill (n)	Threat to human safety	Federal[1]	Wisconsin[2]	Experts[3]
White-tailed deer (*Odocoileus virginianus*)	66	X			
Piping plover (*Charadrius melodus*)	1		Endangered	Endangered	X
Black tern (*Chlidonias niger*)	15			Endangered	X
Forster's tern (*Sterna forsteri*)	5			Endangered	X
Great egret (*Ardea alba*)	2			Threatened	
Least bittern *(Ixobrychus exilis)*	102				X
Yellow-headed blackbird (*Xanthocephalus xanthocephalus*)	45				X

[1] US Fish & Wildlife Service (2014b), [2] Wisconsin Department of Natural Resources (2014b), [3] Personal Communication William Mueller (Western Great Lakes Bird and Bat Observatory) and Karen Etter Hale (Wisconsin Bird Conservation Initiative, Madison Audubon Society)

White-tailed deer were predominantly hit between mile markers 0.0-0.5 where it is relatively dry and where there are some shrubs and trees (Figure 11). Black tern and Forster's tern were hit along open water (mile markers 1.0-1.6) and least bittern between mile markers 0.8-2.2 covering both open water and cattail stands. Yellow-headed black bird hits appear somewhat erratic in location. The number of hits for piping plover and great egret were so low that one cannot expect to detect a meaningful spatial pattern.

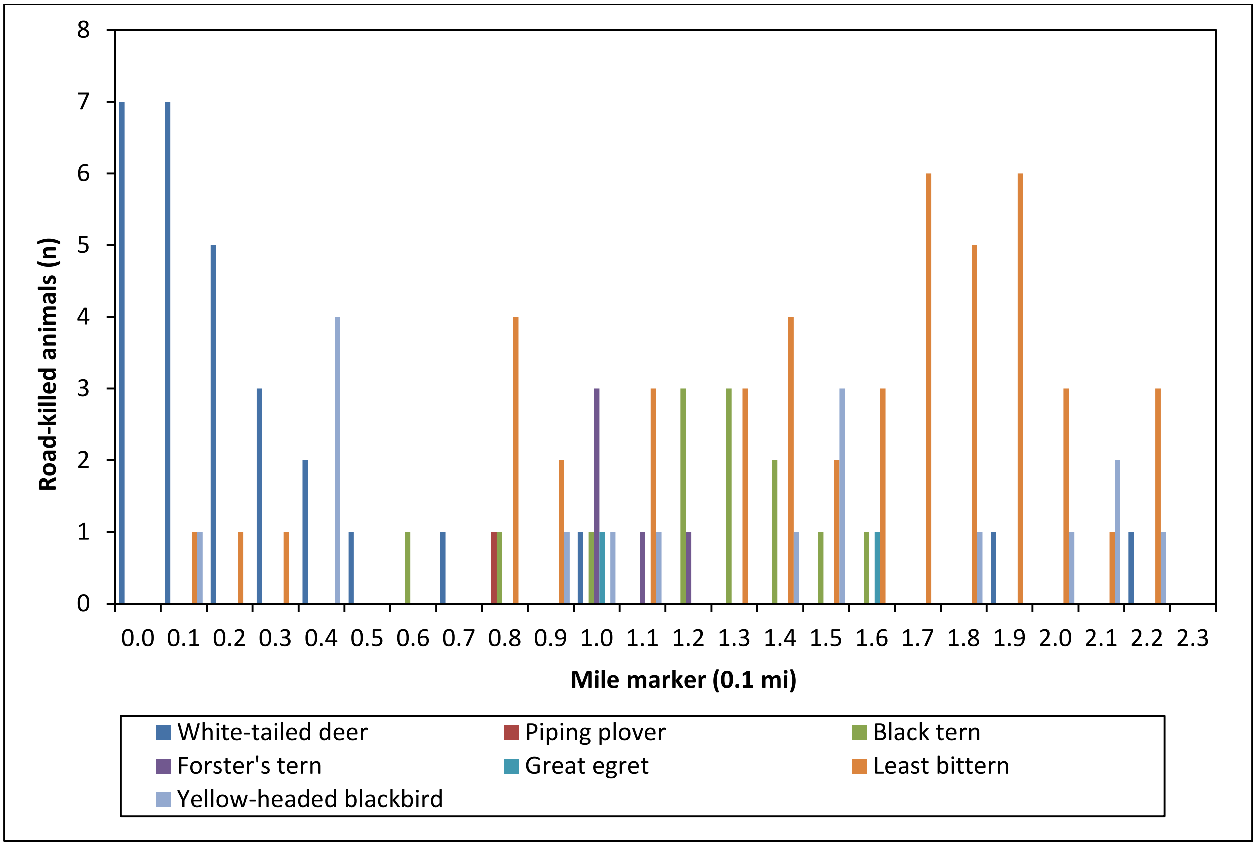

Figure 11: The number of individuals hit of species that are large enough to pose a serious threat to human safety or that are a substantial conservation concern according to federal, state or expert sources per 0.1 mile (160 m) along the monitoring route along State Highway 49 through Horicon Marsh from 2001 through 2013 (Based on data provided by the US Fish and Wildlife Service).

3.4. Discussion

The road-kill data show that while bird mortality was the primary concern (at least at the regional level of US Fish & Wildlife Service), the recorded mammal and amphibian mortality was higher than that for birds. This is despite the fact that amphibian mortality was severely underreported, especially from 2009 onwards. Amphibians and reptiles appear particularly vulnerable to direct road mortality and about half of all federally listed species for which direct road mortality is among the primary threats to the persistence of these species in the United States are amphibians or reptiles (Huijser et al., 2008a). In this context the high mortality of painted turtles and common snapping turtles may be of particular concern. Mature female turtles are typically attracted to roadsides to lay eggs; it is above the water level and the slope of the roadbed allows for higher temperatures (Aresco, 2005a; Steen et al., 2006). Natural mortality among adult turtles is very low, and the persistence of turtles in the landscape depends on that. This means that whenever large numbers of adult turtles, especially females, are dying of unnatural causes, there is a substantial conservation concern (Aresco, 2005a;b; Steen et al., 2006; Crawford et al., 2014). Direct road mortality of turtles has led to substantial mitigation projects elsewhere such as Jackson Lake and Paynes Prairie in Florida and the Mobile Causeway in Alabama (e.g. Aresco 2005b; Dodd et al., 2004; Alabama Department of Transportation. 2011; Ecopassage, 2014)

The most frequently hit bird species were Canada goose and American coot. Interestingly, the vast majority of these mortalities most likely occurred when the birds were walking on and alongside the highway rather than flying (Personal communication Jon Krapfl, U.S. Fish & Wildlife Service). The geese (including goslings) and coots were likely walking on and along the road where they can find food (vegetation along the edge of the pavement and water), water, and grit.

The number of road-killed individuals of rare, threatened or endangered species is low almost by definition. However, black terns (listed in Wisconsin) were recorded 15 times, and least bittern and yellow-headed blackbirds (expert judgment) were recorded 102 and 45 times respectively. Interestingly, least bittern were hit predominantly in only two of 13 years. The high mortality of least bitterns in 2001 and 2006 was likely related to a phase in the water level management which in turn may have influenced the location of the colony in relation to the highway.

4. INTERVIEWS WITH STAKEHOLDERS

4.1. Introduction

The US Fish & Wildlife Service as well as other stakeholders (e.g. naturalists including bird watchers) have been concerned about the high number of animals being killed along the section of State Hwy 49 that bisects Horicon Marsh for well over a decade. In response, US Fish & Wildlife Service employees initiated a road-kill monitoring program (see Chapter 3 for results). In addition various types of mitigation measures have been suggested at different times (e.g. US Fish & Wildlife Service. 2007; Lee et al., 2013). However, up until now (2014) no mitigation measures have been implemented. Therefore, the researchers conducted interviews with the stakeholders to document what they perceive as the problems and potential solutions with regard to State Highway 49 and wildlife through Horicon Marsh.

4.2. Methods

The researchers contacted 13 stakeholders associated with eight organizations for an interview (Table 2). The stakeholders were asked about what, if any, problems they perceived with regard to State Highway 49 through Horicon marsh in relation to wildlife, what measures they support implementing, how likely it is that these measures will be implemented, and what problems may be associated with the individual measures. Note that the responses are based on the personal experience, knowledge, and opinion of the respondents, and that their responses do not necessarily reflect the position of the organizations they are affiliated with.

While over 40 different mitigation measures aimed at reducing collisions with wildlife – particularly with large ungulates - have been described (e.g. Huijser et al. 2008a), the researchers selected the mitigation measures presented to the stakeholders based on reducing the number of road-killed birds, amphibians and reptiles.

Table 2: Stakeholder organizations and interviewees. Note: the views and opinions of the interviewees are not necessarily those of organizations they are affiliated with.

Stakeholder group	Stakeholder (organization)	Name interviewees
Natural resource management agency	US Fish & Wildlife Service, Horicon National Wildlife Refuge	Jon Krapfl Sadie O'Dell Steve Lenz
	Wisconsin Department of Natural Resources	Andrew Badje Eric Heggelund Lisie Kitchel Rori Paloski Jay Schiefelbein*[1]
Transportation agency	Wisconsin Department of Transportation, Maintenance	Pat Gavinski Ryan Murray
Nature oriented non-governmental organizations (NGO) and universities	Wisconsin Bird Conservation Initiative / Madison Audubon Society	Karen Etter Hale
	Friends of Horicon	Dave Edwards
	Western Great Lakes Bird and Bat Observatory	William Mueller
	Loras College, Dubuqueia, Iowa	David Shealer*[1]

*[1]Abbreviated interview through phone.

4.3. Results

Most stakeholders strongly agree that collisions with flying birds are primarily a conservation problem rather than a human safety issue (Table 3). Collisions with large mammals are mostly a problem for human safety, whereas collisions with small-medium sized mammals are both somewhat of a human safety and conservation concern. Collisions with reptiles and amphibians are generally considered a conservation problem.

State Highway 49 is considered a substantial barrier to reptiles and amphibians and (young) birds walking, and slightly less for small-medium and large mammals. Though mortality of birds flying across State Highway 49 is an issue, the highway is not considered a substantial barrier to flying birds.

The greatest perceived threat to human safety results from people pulling over on the side of the road to view wildlife, especially birds. The mixture of slower and faster vehicles on the highway, vehicles pulling off and on the highway, the opening of car doors of vehicles parked on the side of the road, and people walking alongside and on the highway often create dangerous situations.

Though the number of whooping cranes in Horicon Marsh is still relatively small, there is substantial concern about vehicles hitting whooping cranes. For example, a low flying whooping crane has had several narrow escapes with vehicles along State Hwy 49 through Horicon Marsh in spring 2014 (Personal communication and images of the situation through Sadie O’Dell, Horicon National Wildlife Refuge).

Table 3: State Highway 49 and wildlife problems as perceived by the different stakeholder groups. Light grey =range; Dark grey = ≥50% of responses.

	Nat. Res. mgmt agencies					Wisconsin DOT					NGO's and University				
	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
A. Collisions															
Human safety: Cars hitting flying birds	1	1	1	2	2				2					2	1
Conservation: Cars hitting flying birds	0	1	0	2	4			1	1						3
Human safety: Cars hitting large mammals	1	0	0	4	2				2						3
Conservation: Cars hitting large mammals	3	0	0	4	0				2			2	1		
Human safety: Cars hitting medium or small sized mammals	0	1	0	6	0				2				1	2	
Conservation: Cars hitting medium or small sized mammals	2	1	0	4	0				2						3
Human safety: Cars hitting reptiles (e.g. turtles) or amphibians	0	1	2	3	1				2		1		1	1	
Conservation: Cars hitting reptiles (e.g. turtles) or amphibians	0	1	0	1	5				2						3
B. Connectivity for wildlife															
Flying birds	1	1	0	2	3		2				2				1
Non-flying / young birds walking	0	0	0	4	3				2						3
Large mammals	2	1	0	4	0		1	1			2				1
Medium or small sized mammals	0	1	1	5	0				2					2	1
Reptiles or amphibians	0	0	0	1	6				2						3
Fish (limit spread carp, a non-native species)	0	0	3	1	3				2				1	2	
Other species groups?	0	0	0	1	0			1	1						
C. Other problems?															
Safety for people pulled off on shoulder to view birds	0	0	0	0	2					2					3
Potential whooping crane strikes by vehicles	0	0	0	0	1										1

Natural resource management agencies and NGO's/university are generally supportive of avoiding the most severe impacts of State Highway 49 to Horicon Marsh through rerouting the highway around the marsh (Table 4). Most of the stakeholder groups think re-routing is very unlikely to happen though (Table 5) because of opposition by the public (longer commuting route), lack of political support, the costs, the difficulty of acquiring land for a new route.

Measures that encourage birds to fly higher over State Highway 49 may include poles installed at regular intervals along the road (e.g. Bard et al., 2002), shrubs and trees planted adjacent to the road (Kruidering et al., 2005), and embankments alongside the road (Huijser et al., 2008b). Poles have reduced strikes with royal terns on a high bridge by 64% (Bard et al., 2002). However, there are no effectiveness data available for shrubs/trees or embankments alongside the road. Interestingly NGO's/University generally support the implementation of poles whereas the natural resource management agencies and Wisconsin Department of Transportation are not or less supportive (Table 4). All stakeholder groups, including NGO's/University are concerned about the effect that poles will have on landscape aesthetics and wildlife viewing opportunities. Poles also do not address the amphibian and reptile mortality along the highway, and there may be problems with installation (habitat loss, clear zone) and maintenance. The different stakeholder groups have widely varying opinions on the likelihood that poles will be installed (Table 5). There is no or weak support for shrubs and trees or embankments alongside the highway (Table 4) and these measures are generally considered unlikely to be implemented (Table 5), mostly because of their effects on landscape aesthetics and wildlife viewing opportunities, habitat loss, costs, maintenance, shifting mortality to (bird) species that live in the shrubs and trees, and potential difficulties for water level management.

There is strong support among all stakeholder groups for a stretch of elevated highway above the marsh (Table 4) for non-flying species, but this is generally considered unlikely to be implemented because of the associated costs and effect on landscape aesthetics. Should the highway be placed on pillars though, the stakeholders strongly suggest attaching poles to the bridge to encourage birds to fly higher. In addition, if the highway would be elevated, the stakeholders would still like to see the existing embankment on which the current highway is located stay in place for water level management (different water level management units north and south of the highway), and to provide wildlife viewing opportunities away from high speed traffic.

The stakeholder groups are somewhat supportive of wildlife fencing for terrestrial species, but do not think it is very likely that fences will be implemented. The stakeholder groups are mainly concerned about the effect of fences on landscape aesthetics including opportunities to view wildlife, and maintenance issues. Tall wildlife fences (2.4 m (8ft)) reduce collisions with large mammals 79-99% (review in Huijser et al., 2009).

Barrier walls can be integrated into the roadbed (i.e. they act as a retaining wall and they do not stick out above the landscape). Depending on the target species the barrier walls may be 0.30-1.20 m (1-4 ft) high. They are mostly intended for amphibians, and higher barrier walls also for amphibian and reptile species including frogs (but excluding tree frogs that can climb walls), alligators, lizards, turtles and snakes. Barrier walls can be very effective in reducing road mortality: about 94% for all vertebrate species combined, excluding tree frogs (Dodd et al., 2004).

Barrier walls appear to have stronger support from the stakeholders than wildlife fencing (Table 4), and barrier walls are slightly more likely to be implemented (Table 5). Costs, maintenance (i.e. access for mowing, possible amphibian/reptile mortality when mowing), and landscape aesthetics were named as potential problems.

Wildlife underpasses have strong support from natural resource management agencies and NGO's/university and less so from the Wisconsin Department of Transportation (Table 4). Underpasses might be implemented or are considered likely to be implemented (Table 5). Concerns regarding wildlife underpasses include the ability to control water levels on the two sides of the highway separately, and costs.

Compensation strategies have most support from the natural resource management agencies, and less so from Wisconsin Department of Transportation and NGOs/university. Some of these strategies are already being implemented, but not necessarily in the context of compensating for the impacts of State Highway 49. The fact that compensation strategies would not address the ongoing impacts of State Highway 49 was a concern to some of the stakeholders. Other problems identified include costs and resources available to manage the areas.

Table 4: Level of support for various measures by the stakeholder groups. Light grey =range; Dark grey = ≥50% of responses.

	Nat. Res. mgmt agencies					Wisconsin DOT					NGO's and University				
	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
MEASURES															
Avoidance: rerouting highway away from marsh	0	1	0	2	4		1		1						3
Measures that encourage birds to fly higher															
Poles	0	2	1	1	3		2					1			2
shrubs/trees	1	0	4	2	0	1	1				2	1			
Embankments	0	3	2	1	1		1	1			2		1		
Measures that keep terrestrial wildlife off road															
elevated roadway	0	0	0	0	7				2		1				2
Fences	1	0	1	2	3				2		1			2	
barrier walls	0	0	0	4	3				2					1	2
Measures that allow for safe crossing for terrestrial wildlife															
Underpasses	0	0	1	1	5		1		1				1		2
Compensate: increase size marsh	0	1	3	1	2				2					1	
Compensate: new marsh habitat further away	0	2	2	0	3							1			
Compensate: Increase connectivity between marsh patches	0	2	1	0	4									1	
Other															
Reduce posted speed limit															1

Table 5: Likelihood for implementation of various measures according to the different stakeholder groups. Light grey =range; Dark grey = ≥50% of responses.

	Nat. Res. mgmt agencies						Wisconsin DOT						NGO's and University				
	Won't happen	Might happen	Likely to happen	Very likely to happen	Sure to happen		Won't happen	Might happen	Likely to happen	Very likely to happen	Sure to happen		Won't happen	Might happen	Likely to happen	Very likely to happen	Sure to happen
	1	2	3	4	5		1	2	3	4	5		1	2	3	4	5
MEASURES																	
Avoidance: rerouting highway away from marsh	5	2	0	0	0		2						2		1		
Measures that encourage birds to fly higher																	
Poles	1	2	3	1	0			2					1				2
shrubs/trees	4	1	1	1	0		1	1					3				
Embankments	3	3	0	1	0		1	1					3				
Measures that keep terrestrial wildlife off road																	
elevated roadway	2	4	0	0	1		2						3				
Fences	1	2	3	1	0			1	1				2	1			
barrier walls	0	2	3	2	0			1	1				1	2			
Measures that allow for safe crossing for terrestrial wildlife																	
Underpasses	0	3	3	1	0			2					1	2			
Compensate: increase size marsh	1	4	2	0	0			2						1			
Compensate: new marsh habitat further away	1	3	2	0	1								1				
Compensate: Increase connectivity between marsh patches	1	2	4	0	0										1		
Other																	

4.4. Discussion

Based on the interviews it became clear what the different stakeholders perceive as the problem with State Highway 49 and wildlife through Horicon Marsh, which measures they would support, how likely they think it is they will be implemented, and what may be of a concern with regard to the individual mitigation measures. Note that the views and opinions of the interviewees are not necessarily those of the agencies they are affiliated with. The authors of this report use the names of the organizations only to better understand the statements made by the interviewees.

The key findings are:

1. Interviewees of the Wisconsin Department of Transportation, natural resource management agencies and NGOs/University have all identified cars pulling off and on State Highway 49 and people on and alongside the highway as a serious ongoing human safety concern.
2. Interviewees of the Wisconsin Department of Transportation see the wildlife-vehicle collisions and wildlife road-mortality as something that is the result of the water level management by US Fish & Wildlife Service.
3. The viewpoint of interviewees of natural resource management agencies is that over the last few hundred years many wetlands have disappeared due to agriculture and other human activities and that many wildlife species depending on wetlands are now a conservation concern. This is why we have so many laws and regulations with regard to wetlands now. The history of Horicon Marsh is “messy” in the sense that there have been many different types of substantial influences by humans over the last 150 years or so. The reality is that now Horicon Marsh is largely a human-managed wetland, but it is nevertheless considered a refuge that is critical to the survival of many wetland species. It is therefore essential that massive unnatural mortality, including that on State Highway 49, is addressed, regardless of what the habitat on the north side of the road may have looked like a few decades ago.
4. All stakeholders recognize that, depending on the species group, wildlife-vehicle collisions along State Highway 49 are both a human safety and a conservation concern. The conservation concern is especially with birds and reptiles and amphibians.
5. Connectivity for wildlife is especially a concern for walking (young) birds and reptiles and amphibians.
6. It seems only a matter of time before the first whooping crane is hit by traffic along State Highway 49 through Horicon Marsh. Note that a captive bred and released whooping crane (one single individual animal) is estimated to represent an investment of about $100,000 (Wikipedia, 2014b).
7. Avoiding the most severe impacts of State Highway 49 on Horicon Marsh through rerouting is supported by the stakeholders but is thought to meet stiff opposition from both the public and politicians.
8. Elevating the highway (i.e. putting the highway on pillars) is strongly supported by the stakeholders, but its implementation is thought less than likely.
9. Even if State Highway 49 is rerouted around Horicon Marsh rather than going through it, or even if the highway would be put on pillars on its current route, the embankment on which State Highway 49 is positioned will remain in place to allow for different water

level management units north and south of the embankment. In addition, there is a strong desire to keep access to this part of the marsh for birdwatchers. Therefore the embankment may have a low volume low speed road on top of it.

10. Measures that encourage the birds to fly higher may not address the most frequently hit bird species as Canada goose and American coot, which are mostly walking on and alongside the road rather than flying. These types of measures also do not address the massive amphibian and reptile mortality. Therefore, possible mitigation measures should not be restricted to measures that encourage birds to fly higher.
11. Measures that encourage birds to fly higher or tall fences along the current embankment for State Highway 49 are mostly regarded as unacceptable as they affect landscape aesthetics and opportunities for wildlife viewing.
12. Lower fences (e.g. 0.90-1.20 m (3-4 ft)) may be less unacceptable but barrier walls integrated into the road bed are preferred.
13. Compensation strategies seem unsatisfactory as they do nothing to stop or reduce the massive wildlife mortality along State Highway 49.

5. RECOMMENDATIONS

The following recommendations for State Highway 49 through Horicon Marsh are based on different potential objectives:

5.1. Objective 1: Avoid the Most Severe Impacts on Wildlife in Horicon Marsh

This may consist of **rerouting State Highway 49, potentially north of Horicon Marsh**. This is likely the most drastic measure, and also a relatively costly one, but it would avoid most of the impacts of the highway on the wildlife in Horicon Marsh. Naturally, the new route would have its own set of impacts to wildlife, but that should be put into perspective to what the current impacts on the wildlife in Horicon Marsh are.

Alternatively, **State Highway 49 may be tunneled under Horicon Marsh**. This is likely an even more costly option than rerouting, but there would not be other impacts elsewhere.

Note that both of the options described above would also improve human safety as the high speed through traffic would be spatially separated from where the wildlife viewers are (see next objective).

Note that both of the options would not eliminate the embankment on which State Highway 49 is currently located. The embankment is likely to remain in place for water level management purposes and to provide access to the marsh for bird watchers (see Chapter 4).

5.2. Objective 2: Improve Human Safety

The greatest threat to human safety is vehicles pulling off and on the highway and people on and along the highway looking for birds. There are two basic approaches to addressing this hazard:

a. No longer allow or no longer make it possible for drivers to park their vehicle on the shoulder and in the right-of-way along the highway section through the marsh. Note that this is likely to result in public opposition and it may lead to slow driving vehicles on State Highway 49, mixed in with commuting and through traffic. Speed dispersion and associated impacts on human safety could result.
b. Human safety is more likely to be improved **if the desire of people to watch wildlife is accepted** and if appropriate measures are taken to improve the safety for wildlife watchers as well as people driving through on State Highway 49. This may include **wider shoulders or wider right-of-ways, and/or designated pull-outs** in combination with measures that make it impossible to stop elsewhere (e.g. guard rails).

Human safety can be further improved by addressing collisions with white-tailed deer, particularly on the west side of the marsh (mile markers 0.0-0.5). Note that white-tailed deer collisions are very likely to continue further to the west (west of the 0.0 mile marker), and those measures should probably be further extended in the direction of Waupun. Typical measures for large ungulates include **2.4 m (8 ft) tall wildlife fencing in combination with safe crossing opportunities for wildlife** (Clevenger & Huijser, 2011). The terrain is generally flat and the water level is generally very close to the surface. This makes the construction of wildlife underpasses suitable for white-tailed deer a challenge (e.g. 7 m (23 ft) wide, 4 m (13 ft) high). The **bridge across the Rock River** could be expanded to include space for terrestrial and semi-aquatic species, but the height of the bridge may remain a challenge. In addition, **at grade crossing opportunities** may be provided through **gaps in the fence on either side of the road and electric mats embedded in the roadway** to discourage wildlife from wandering in the fenced road corridor. Note that the east side of the fence should also have a safe crossing opportunity around mile marker 0.5. Alternatively, the wildlife fence could extend through mile marker 1.0, to include a buffer zone to discourage white-tailed deer from simply crossing at the fence end. However, the latter would mean that fence extends well into the open area of the marsh. This would likely not be acceptable because the fence affects landscape aesthetics and wildlife viewing opportunities. Safe crossing opportunities for large mammals are typically about 2 km (1.2 mi) apart (Huijser et al., 2013).

Lower vehicle speed is sometimes suggested as a way to reduce wildlife-vehicle collisions. It may also reduce hazards associated with vehicles turning off and on a highway (e.g. similar to the situation for the highway through Horicon Marsh). However, lowering the posted speed limit substantially below the design speed of the highway is typically not recommended. Drivers tend to drive a speed that is consistent with the design speed of a highway rather than adhere to a posted speed limit that is substantially lower than the design speed. On the other hand, some drivers will obey the posted speed limit which results in having both slow and fast moving vehicles on the same highway. This is referred to as "speed dispersion". Speed dispersion is associated with an overall increase in crashes because it triggers dangerous and irresponsible maneuvers (e.g. drivers of fast moving vehicles get annoyed with the drivers of slow moving vehicles and overtake when it is not safe). A common response to drivers disobeying the posted is limit is to increase law enforcement effort. However, the law enforcement effort would have to continue in perpetuity, and ticketed drivers will likely experience the ticket as "unjust" as the design of the highway encourages drivers to drive a speed that is substantially higher than the posted speed limit. For these reasons it is almost never a good idea to have a posted speed limit that is substantially lower than the design speed of a highway. Thus, if a lower operating speed is desired (i.e. the actual speed of the vehicles), it typically requires a lower design speed of the highway. A lower design speed may include narrower lanes and shoulders, reduced sight distance, and traffic calming measures such as bulb-outs and speed bumps. These types of measures are typically not appropriate for highways that are to provide safe and efficient transportation over longer distances.

5.3. Objective 3: Reduce Mass Bird Mortality

The two most frequently hit bird species are Canada geese and American coot (35.61% of all recorded bird road-mortalities). These two species were likely walking on or adjacent to the road when they were hit by vehicles rather than flying across State Highway 49. This supports the **placement of barriers alongside the highway to discourage geese and coots from entering**

the actual lanes with traffic. **Fences** (e.g. 0.90-1.20 m (3-4 ft) tall) would likely keep these birds off the roadway, but will possibly affect landscape aesthetics and wildlife viewing opportunities, and may require substantial maintenance including repairs. **Barrier walls** integrated into the roadbed (i.e. like a retaining wall) would not affect landscape aesthetics and roadside wildlife viewing opportunities. Barrier walls are likely to be more robust than wildlife fences. On average there were 67.2 (SD 40.8) Canada geese and American coots recorded per year (Appendix A). Assuming that fencing or barrier walls reduce collisions with walking birds by 86% (Huijser et al., 2009), it would take 3 years to detect a reduction of 86% in Canada goose and American coot strikes (power analyses, 80% power, α=0.05), should the 86% reduction indeed exist.

Fences or barrier walls should generally be accompanied by **safe crossing opportunities**. There may only be (0.6-0.9 m (2-3 ft) of space between the top of the pavement and the water level above which the US Fish & Wildlife Service does not mind that the water level would be equal north and south of the road, but in general the US Fish & Wildlife Service wants to be able to control the water levels north and south of the highway independently. At this time it is unknown whether Canada geese, American coot, or other terrestrial species for which the fence or barrier wall is a barrier would use underpasses with limited (2-3 ft) height. One option is to install barriers and underpasses on a limited road section and evaluate their performance before implementing the measures on a larger scale. The underpasses should probably be relatively wide to compensate for their limited height (perhaps about 5 m (16 ft) wide). As a long term alternative, it is also possible to increase the height of the road bed to increase the potential height of underpasses. Of course there are substantial costs associated with such an effort and the road and traffic would stick up above the surrounding landscape more. Somewhat similar sized culverts for a wide variety of species, but specifically amphibians and reptiles, have been spaced about 350 m (1,150 ft) apart (Dodd et al., 2004).

Massive bird mortality may be further reduced by **mitigation measures that encourage birds to fly higher (e.g. poles, shrubs/trees or embankments)**. However, if such measures are implemented along the current embankment of State Highway 49, the negative effects to landscape aesthetics and wildlife viewing opportunities probably be at an unacceptable level for several of the stakeholders. Note that, given the objective, measures aimed at encouraging birds to fly higher are secondary to keeping birds from walking onto the road. On average there were 122 (SD 72.9) birds (excluding Canada geese and American coots) recorded per year (Appendix A). Assuming that poles reduce collisions with flying birds by 64% (Bard et al., 2002), it would take 3 years to detect a reduction of 64% in strikes with birds (excluding Canada goose and American coot) (power analyses, 80% power, α=0.05), should the 64% reduction indeed exist.

Another approach to reducing mortality of birds walking on and along State Highway 49 is to **elevate the road over the length of the marsh**. Any terrestrial species would be able to cross freely under the road which would be situated on pillars. Poles may need to be installed on the bridge to reduce strikes with flying birds (Bard et al., 2002). The embankment on which the current State Highway 49 is located would remain in place to allow for water levels in the areas north and south of the highway. In addition, the **embankment could house a low volume, low speed road, perhaps even a one-way road, with parking spaces** over (nearly) the entire length of the embankment through the marsh. Birdwatchers appear to prefer that the elevated road to be situated north of the current embankment to provide unhindered views of the marsh to the south. The view to the north would be hindered by the pillars and the elevated road itself. The poles on the bridge would likely not impact the view from the embankment. Naturally an elevated road and poles would be visible from a greater distance from areas away from the road. It is important though to clearly distinguish between landscape aesthetics from the highway/recreation corridor vs. landscape aesthetics from elsewhere in the area.

Note that elevated highways are typically installed over floodplains. They do not only allow individual species to cross safely under the road, but they also allow for ecosystem processes (e.g. water flow) to continue under the transportation corridor. In the case of Horicon Marsh, the "ecosystem process" argument does not apply as the water level management north and south of the current embankment requires the embankment to stay in place.

5.4. Objective 4: Reduce Mortality of Rare, Threatened or Endangered Bird Species

Mortality of rare, threatened or endangered bird species may be reduced by encouraging birds, especially piping plover, black tern, Forster's tern, great egret, least bittern, and yellow-headed blackbird, to fly higher when they cross State Highway 49. Note that, almost by definition, the number of road-killed rare, threatened or endangered bird species is relatively low: 13.1 recorded individuals per year on average (SD = 18.5). The relatively low numbers and high standard deviation makes that it is relatively difficult to demonstrate that the mitigation measures are addressing the objective. Assuming that poles reduce collisions with flying birds by 64% (Bard et al., 2002), it would take 14 years to detect a reduction of 64% in strikes with flying rare, threatened or endangered birds (power analyses, 80% power, α=0.05), should the 64% reduction indeed exist.

Note that poles, shrubs/trees or embankments along the current embankment of State Highway 49, will affect landscape aesthetics and wildlife viewing opportunities, perhaps at an unacceptable level for several of the stakeholders. However, if the highway would be elevated and poles would be attached to the elevated highway, the poles may not affect landscape aesthetics or wildlife viewing opportunities from the current embankment on which State Highway 49 is located.

5.5. Objective 5: Reduce Mass Amphibian and Reptile Mortality

On average, there were 60.7 (SD 27.6) reptiles and amphibians recorded per year (Appendix A). Assuming that fencing or barrier walls reduce collisions with reptiles and amphibians by 94% (Dodd et al., 2004), it would take 3 years to detect a reduction of 94% in amphibian and reptile mortality (power analyses, 80% power, α=0.05), should the 94% reduction indeed exist. Bear in mind that amphibian mortality was likely severely underreported and also inconsistently reported.

On average there were 58.4 (SD 57.2) turtles recorded per year (Appendix A). Assuming that fencing or barrier walls reduce collisions with turtles by 94% (Dodd et al., 2004), it would take 3 years to detect a reduction of 95% in turtle mortality (power analyses, 80% power, α=0.05), should the 94% reduction indeed exist.

Another measure that may reduce turtle mortality on State Highway 49 is to provide alternative nesting sites away from the roadbed (Paterson et al., 2013). This may reduce the number of adult female turtles on and alongside State Highway 49. It may also lead to higher reproduction, perhaps somewhat compensating the high mortality associated with State Highway 49.

5.6. Final Recommendations

5.6.1. Re-routing

Re-routing State Highway 49 north of the marsh is likely the best option to avoid the negative effects of the highway and traffic on the birds in Horicon Marsh. It also eliminates the human safety risk of having people on and alongside State Highway 49 who may be viewing wildlife and high speed and high volume traffic driving by. However, re-routing is also an option that comes with its own set of problems (see earlier).

5.6.2. Elevated Highway

The “next best” option would be to:

a. Elevate the highway for the road section that cuts through Horicon Marsh. It appears birdwatchers prefer the elevated highway to be on the north side of the current embankment.
b. Keep the embankment on which the current highway is situated to allow for different water level management regimes north and south of the highway, and turn the current highway on the embankment into a recreational, low volume, low speed route. Consider one-way traffic with ample parking space or large pull-outs. On certain road sections consider only one lane and no stopping opportunity to reduce the barrier effect of the low speed low volume road for wildlife (less unnatural substrate to cross). Also consider making it only accessible to non-motorized traffic (except for people who depend on motorized transport) or installing traffic calming measures (speed bumps, bulb-outs etc.).
c. Install poles (e.g. Bard et al., 2002) on the elevated roadway.

This option would address the following objectives:

a. Human safety concerns with vehicles pulling off and on State Highway 49 and people on and alongside the road.
b. Reduce mass bird mortality as the most frequently recorded road-killed species (Canada goose and American coot) can mostly walk safely across the low volume low speed road on the current embankment (likely a very substantial reduction, perhaps 80% or greater) and can cross safely under the new elevated highway (100% mortality reduction).

c. Reduce mass mortality further through the poles installed on the elevated roadway that encourage birds to fly higher (perhaps 64% mortality reduction).
d. Reduce mortality of rare, threatened or endangered species that fly across State Highway 49 (perhaps 64% mortality reduction).
e. Reduce mass amphibian and reptile mortality on the current embankment (likely a very substantial reduction, perhaps 80% or greater mortality reduction) and eliminate it for the elevated State Highway 49 altogether (100% mortality reduction).

Note that this option would not eliminate the embankment on which State Highway 49 is currently located. The embankment is likely to remain in place for water level management purposes and to provide access to the marsh for bird watchers.

5.6.3. Barrier Walls and Underpasses along the Current State Highway 49

A less preferred option would be to:

a. Keep State Highway 49 on its current embankment.
b. Create a limited number of pull-outs so that people who want to watch wildlife can safely pull off the road.
c. In the immediate future, install barrier walls (about 0.60—1.20 m high on both sides of the highway, integrated into the road bed (i.e. "retaining walls). Make the barrier walls out of concrete or other material that will stand the test of time, vegetation maintenance, and the weight of the roadbed pushing against it. Allow for "mowing space" at the bottom and top of the barrier walls. Mowing is essential as vegetation growing up against the barrier walls would allow certain species to climb over the barrier wall. In addition, have a certain minimum mowing height (e.g. about 15 cm (6 inches) above the ground level) to minimize injuring and killing animals, specifically reptiles and amphibians.
d. In the immediate future, install underpasses in the roadbed (open roof structure so that air and soil temperature and humidity are similar to the surroundings, top of overpass is at the pavement level). Make the underpasses as high as possible. Currently there is only perhaps 0.6-0.9 m (2-3 ft) between the top of the pavement and the water level above which US Fish & Wildlife Service does not mind equal water levels on the north and south side of the highway, but in general the US Fish & Wildlife Service wants to be able to control the water levels north and south of the highway independently. Consider making the underpasses at least 5-7 m (16-23 ft) wide. Somewhat similar sized culverts for a wide variety of species, but specifically amphibians and reptiles, have been spaced about 350 m (1,150 ft) apart (Dodd et al., 2004).
e. On the long term, consider raising the height of the embankment so that taller barrier walls (e.g. 1.5 m (5 ft) high) and taller underpasses can be constructed (e.g. 1.2-4.0 m (4-13 ft) high). Consider making the underpasses at least 5-7 m (16-23 ft) wide.
f. Do not install poles along the current embankment because of the effects on landscape aesthetics and hindering the view for wildlife watchers. If poles are installed along the current embankment they would likely not have the support of natural resource management agencies and birdwatchers, and therefore the project would risk losing their support altogether.

This option would address the following objectives:

a. Human safety concerns with vehicles pulling off and on State Highway 49 and people on and alongside the road. However, people may still stop in dangerous road sections where there is no pull-out.
b. Reduce mass bird mortality as the most frequently recorded road-killed species (Canada goose and American coot) – at least the young individuals - can no longer access the actual travel lanes and they may or may not be willing to use the underpasses (likely a very substantial reduction, perhaps 80% or greater).
c. Reduce mass amphibian and reptile mortality on the current embankment (likely a very substantial reduction, perhaps 95% mortality reduction).

This option would not or only partially address the following objectives:

a. Human safety concerns with vehicles pulling off and on State Highway 49 and people on and alongside the road. Despite designated pull-outs people may still stop in dangerous road sections for birds where there is no pull-out.
b. Reduce mass mortality further for flying birds as there are no measures that encourage birds to fly higher over State Highway 49.
c. Reduce mortality of rare, threatened or endangered species that fly across State Highway 49 as there are no measures that encourage birds to fly higher.

5.6.4. No Changes to State Highway 49

The least preferred alternative is to not implement any measures that would address the problems with regard to State Highway 49 and wildlife through Horicon Marsh.

5.7. Cost Considerations

Avoidance, mitigation and compensation strategies are deployed regularly to address the negative effects of highways and traffic on human safety and wildlife. However, the costs associated with the avoidance, mitigation or compensation strategies are almost always regarded a substantial problem though they may only represent a fraction of the total project costs of highway (re)construction. This is partly because the strategies are often regarded as stand-alone projects after a road has been built, or after plans for new roads are all but complete. It is essential to incorporate these human safety and wildlife considerations in plans from the earliest phase onwards, and to not treat the efforts as an add-on. That is how avoidance, mitigation, and compensation strategies can be most effective, both with regard to human safety and wildlife as well as the costs.

While the model is heavily based on parameters associated with human safety, Huijser et al. (2009) illustrated that mitigation measures aimed at reducing collisions with large ungulates and at providing safe crossing opportunities are not necessarily a cost to society. In fact, there are many road sections in North America where it is more expensive to not implement wildlife mitigation than it is to invest in effective mitigation measures. There is no reason why this model cannot be expanded to include a wider range of parameters. These parameters may include those that relate to the values and costs associated with threatened and endangered species (e.g. a captive bred and released whooping crane represents an investment of about $100,000 (Wikipedia, 2014b)), and the economic importance of wildlife and nature based recreation (Carver & Caudill, 2013).

Indicative costs for the measures recommended are summarized in Table 6.

Table 6: Indicative costs measures.

Measure	Cost indication	Source
2.4 m high mesh wire fencing for large ungulates	$96,000 / km road length with fencing on both sides	Huijser et al. (2009)
Large mammal underpass (7 m wide, 4-5 m high)	$500,000	Huijser et al. (2009)
Turtle Fencing(excluding underpasses)	$31,000 / km road length ($50,000 /mi)	LA Times (2012)
Barrier wall (1.1 m (3.6 ft) high with 15 cm (6 inches) overhang) in combination with 8 culverts (varying sizes 0.9 m (3 ft) diameter,1.8x1.8 m (6x6 ft) 2.4x2.4 m (8x8 ft), all structures spanned 44 m (144 ft) of road width)	$3,6 million for 2.8 km (1.7 mile) of road length	Ocala Star Banner (2000)
Elevated roadway and bridges	$285,000,000 for 5.5 mi of elevated highway and bridges	National Park Service (2012)
Poles on bridge (3 m (10 ft) long metal poles, 5.1 cm (2 inches) diameter, 3.7 m (12 ft) spacing)	$5,900 for 122 poles	Bard et al. (2002)

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7. APPENDIX A

Species group	Common name	Scientific name	Total (n)	%	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Amphibians	Frog spp.	Anura	2954	96.95		1370			119	1218	245	2					
Amphibians	Leopard frog	*Rana pipiens*	90	2.95			81	7	2								
Amphibians	American toad	*Anaxyrus americanus*	2	0.07			1			1							
Amphibians	Spotted salamander	*Ambystoma maculatum*	1	0.03						1							
Total			3047	100.00	0	1370	82	7	121	1220	245	2	0	0	0	0	0
Birds	Canada goose	*Branta canadensis*	514	20.89	28	41	18	13	7	20	80	113	81	35	29	41	8
Birds	American coot	*Fulica americana*	360	14.63	51	64	26	97	2	16	9	27	27	21	8	5	7
Birds	Red-winged blackbird	*Agelaius phoeniceus*	297	12.07	40	87	9	17	13	21	31	19	28	11	4	13	4
Birds	Unidentifiable	Unidentifiable	221	8.98					19	55	46	38	21	13	7	9	13
Birds	Mallard	*Anas platyrhynchos*	165	6.71	34	26	12	20	32	8	9	6	5	7	1	3	2
Birds	Tree swallow	*Tachycineta bicolor*	126	5.12	7	15	21	6	3	13	30	4	3	14	8	2	
Birds	Least bittern	*Ixobrychus exilis*	102	4.15	41	12	1	2		31	6	4	5				
Birds	Sparrow spp.	Passeridae spp.	50	2.03	4	9	9	15	9		2	1	1				
Birds	Yellow-headed blackbird	*Xanthocephalus xanthocephalus*	45	1.83	18	9		1	2	5	3	2	5				
Birds	Marsh wren	*Cistothorus palustris*	36	1.46	6	1		1	2	4	13	3	6				
Birds	Blue-winged teal	*Anas discors*	35	1.42	7	6	4	1	5	4	2	2	2			2	
Birds	Swamp sparrow	*Melospiza georgiana*	32	1.30		2	3	4	2	10	5	6					
Birds	Virginia rail	*Rallus limicola*	29	1.18	3	6	3	2	4		2	5	1	1		1	1
Birds	Bird spp.	Aves	28	1.14	0	1	26	1									
Birds	Common gallinule	*Gallinula galeata*	28	1.14	9	12	2	2			1	2					
Birds	European starling	*Sturnus vulgaris*	28	1.14	3	3	1	5		2	10	2		1		1	
Birds	Sora	*Porzana carolina*	26	1.06	5	5	6	3	1	2	1	1		2			
Birds	Common pheasant	*Phasianus colchicus*	25	1.02	1	1	2	7	5	4	3	1			1		
Birds	Barn swallow	*Hirundo rustica*	20	0.81	0	5	9		1	1	4						

Birds	American yellow warbler	*Setophaga petechia*	19	0.77	2	8	2		2	4							1
Birds	Common yellowthroat	*Geothlypis trichas*	19	0.77	2	3	3	4	1		1	4				1	
Birds	Gull spp.	*Larus* spp.	18	0.73			1	2		2	2	5	2	1	3		
Birds	Black tern	*Chlidonias niger*	15	0.61	2	0	2			6	1	1	1	1			1
Birds	Cedar waxwing	*Bombycilla cedrorum*	14	0.57		1			1		8		4				
Birds	Swallow spp.	*Hirundinidae* spp.	14	0.57	0	0	5	3	5	1							
Birds	Common grackle	*Quiscalus quiscula*	13	0.53	3	1	1		2	1	1	3	1				
Birds	Pied-billed grebe	*Podilymbus podiceps*	13	0.53		4	2			2		1	1	1			2
Birds	Redhead	*Aythya americana*	12	0.49	6	3	1	1		1							
Birds	Great horned owl	*Bubo virginianus*	11	0.45		3		3	2	1	1	1					
Birds	Ring-billed gull	*Larus delawarensis*	11	0.45	1	5							1		1	3	
Birds	Ruddy duck	*Oxyura jamaicensis*	10	0.41		3				2		2	3				
Birds	Blackbird spp.	Unknown	8	0.33			2	3		2		1					
Birds	Black-crowned night heron	*Nycticorax nycticorax*	8	0.33	4	2	1	1									
Birds	Gray catbird	*Dumetella carolinensis*	7	0.28		1					4			1	1		
Birds	Killdeer	*Charadrius vociferus*	7	0.28	0	2	2		1								2
Birds	Chipping sparrow	*Spizella passerina*	6	0.24							2		1	3			
Birds	American bittern	*Botaurus lentiginosus*	5	0.20	2			1		1		1					
Birds	Forster's tern	*Sterna forsteri*	5	0.20							1	3	1				
Birds	Wild turkey	*Meleagris gallopavo*	5	0.20		1	1					2				1	
Birds	American goldfinch	*Carduelis tristis*	4	0.16	1	1			1			1					
Birds	American herring gull	*Larus argentatus*	4	0.16	3							1					
Birds	Warbler spp.	Passeriformes spp.	4	0.16		1	1				1					1	
Birds	Wilson's snipe	*Gallinago delicata*	4	0.16	1	1	1					1					
Birds	Yellow-rumped warbler	*Setophaga coronata*	4	0.16	1	3											
Birds	American robin	*Turdus migratorius*	3	0.12		1			1	1							
Birds	Red-tailed hawk	*Buteo jamaicensis*	3	0.12		2								1			
Birds	Semipalmated sandpiper	*Calidris pusilla*	3	0.12		1			1							1	

Birds	Songbird	Passeriformes spp.	3	0.12	0	0	3										
Birds	Wren spp.	*Troglodytes* spp.	3	0.12			2		1								
Birds	Brown-headed cowbird	*Molothrus ater*	2	0.08		1						1					
Birds	Great egret	*Ardea alba*	2	0.08								1			1		
Birds	Least sandpiper	*Calidris minutilla*	2	0.08													2
Birds	Mourning dove	*Zenaida macroura*	2	0.08							2						
Birds	Wood duck	*Aix sponsa*	2	0.08								1			1		
Birds	American black duck	*Anas rubripes*	1	0.04				1									
Birds	American crow	*Corvus brachyrhynchos*	1	0.04									1				
Birds	American golden plover	*Pluvialis dominica*	1	0.04									1				
Birds	American white pelican	*Pelecanus erythrorhynchos*	1	0.04								1					
Birds	Bank swallow	*Riparia riparia*	1	0.04		1											
Birds	Black-bellied plover	*Pluvialis squatarola*	1	0.04									1				
Birds	Chickadee	*Parus* spp.	1	0.04				1									
Birds	Chimney swift	*Chaetura pelagica*	1	0.04			1										
Birds	Cliff swallow	*Petrochelidon pyrrhonota*	1	0.04			1										
Birds	Duck spp.	Unknown	1	0.04		1											
Birds	Eastern screech owl	*Megascops asio*	1	0.04							1						
Birds	Flycatcher spp.	*Empidonax* spp.	1	0.04					1								
Birds	Great blue heron	*Ardea herodias*	1	0.04		1											
Birds	Great Crested Flycatcher	*Myiarchus crinitus*	1	0.04		1											
Birds	Greater yellowlegs	*Tringa melanoleuca*	1	0.04													1
Birds	Green heron	*Butorides virescens*	1	0.04	1												
Birds	Hawk sp.	*Buteo* spp.	1	0.04						1							
Birds	House sparrow	*Passer domesticus*	1	0.04			1										
Birds	House wren	*Troglodytes aedon*	1	0.04			1										
Birds	Litlle gull	*Larus minutus*	1	0.04											1		
Birds	Oriole spp.	*Icterus* spp.	1	0.04		1											

Birds	Piping plover	*Charadrius melodus*	1	0.04												1	
Birds	Shorebird spp.	*Charadriiformes spp.*	1	0.04		1											
Birds	Snow bunting	*Plectrophenax nivalis*	1	0.04								1					
Birds	Snowy owl	*Bubo scandiacus*	1	0.04	1												
Birds	Song sparrow	*Melospiza melodia*	1	0.04			1										
Birds	Western sandpiper	*Calidris mauri*	1	0.04			1										
Birds	Willow flycatcher	*Empidonax traillii*	1	0.04									1				
Total			2460	100.00	287	359	188	217	126	221	282	268	204	113	66	85	44
Fish	Bullhead spp.	*Ictalurus* spp.	2	100.00			1					1					
Invertebrates	Monarch butterfly	*Danaus plexippus*	7	100.00			1					4	1				1
Mammals	Muskrat	*Ondatra zibethicus*	3591	82.82	597	842	71	13	80	22	97	180	378	1089	169	44	9
Mammals	North American raccoon	*Procyon lotor*	252	5.81	36	40	14	17	9	10	29	31	14	15	16	8	13
Mammals	Virginia opossum	*Didelphis virginiana*	150	3.46	4	31	16	14	12	32	15	3		4	6	10	3
Mammals	White-tailed deer	*Odocoileus virginianus*	66	1.52	4	4	6	6	8	5	8	5	5	7	2	3	3
Mammals	Eastern cottontail	*Sylvilagus floridanus*	64	1.48			7	9	1	22	14		3	2		1	5
Mammals	Skunk spp.	*Mephitidae* spp.	47	1.08	8	0	5	4	5	3	4	5	2	1	4	3	3
Mammals	North American river otter	*Lontra canadensis*	33	0.76	2	2	2	8	2	1	1	7	1	2	1	2	2
Mammals	American mink	*Neovison vison*	22	0.51	2			1		2	6	5	2	1			3
Mammals	Vole spp.	Arvicolinae spp.	21	0.48			1	1	1	16				1	1		
Mammals	Rodent spp.	Rodentia spp.	11	0.25	0	6	5										
Mammals	Woodchuck	*Marmota monax*	11	0.25	1	2	1	2		1	1	1		2			
Mammals	North American beaver	*Castor canadensis*	9	0.21			2	2	1			1	2		1		
Mammals	Weasel spp.	*Mustela* spp.	8	0.18	0	0	4				3			1			
Mammals	Squirrel spp.	Sciuridae spp.	7	0.16	4	1				2							
Mammals	Coyote	*Canis latrans*	5	0.12		1					1		1		2		
Mammals	Eastern gray squirrel	*Sciurus carolinensis*	5	0.12			3							1		1	

Mammals	Mole spp.	Talpidae spp.	5	0.12						3			1	1			
Mammals	Bat spp.	Chiroptera spp.	4	0.09	0	0	2		2								
Mammals	Domestic cat	*Felis catus*	4	0.09		2				2							
Mammals	Eastern fox squirrel	*Sciurus niger*	4	0.09				1				1			1	1	
Mammals	Mouse spp.	Muridae spp.	3	0.07						3							
Mammals	Shrew	Soricidae spp.	3	0.07		2	1										
Mammals	Short-tailed weasel	*Mustela erminea*	2	0.05					1								1
Mammals	Unidentifiable	Unidentifiable	2	0.05						1				1			
Mammals	American short-tailed shrew	*Blarina brevicauda*	1	0.02		1											
Mammals	Chipmunk spp.	Sciuridae spp.	1	0.02				1									
Mammals	Ground squirrel spp.	Sciuridae spp.	1	0.02						1							
Mammals	Norway rat	*Rattus norvegicus*	1	0.02						1							
Mammals	Red fox	*Vulpes vulpes*	1	0.02		1											
Mammals	Star-nosed mole	*Condylura cristata*	1	0.02			1										
Mammals	Thirteen-lined ground squirrel	*Ictidomys tridecemlineatus*	1	0.02		1											
Total			4336	100.00	658	936	141	79	122	127	179	239	409	1128	203	73	42
Reptiles	Painted turtle	*Chrysemys picta*	525	66.54	54	69	40	66	34	47	63	43	33	25	27	10	14
Reptiles	Common snapping turtle	*Chelydra serpentina*	231	29.28	6	25	6	17	22	41	40	25	6	6	7	9	21
Reptiles	Garter snake	*Thamnophis* spp.	28	3.55	2	5	12		2		2	1	3		1		
Reptiles	Turtle spp.	Testudinata spp.	3	0.38								3					
Reptiles	Northern redbelly snake	*Storeria occipitomaculata*	1	0.13			1										
Reptiles	Unidentifiable	Unidentifiable	1	0.13						1							
Total			789	100.00	62	99	59	83	58	89	105	72	42	31	35	19	35
Unidentifiable	Unidentifiable	Unidentifiable	7	100.00	0	0	6					1					