Why We Need to Incorporate Animal Behavior into Road Ecology:

A case history with aquatic turtles

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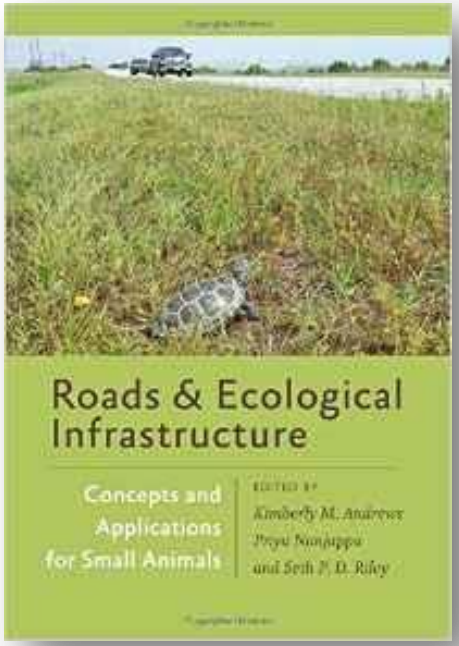
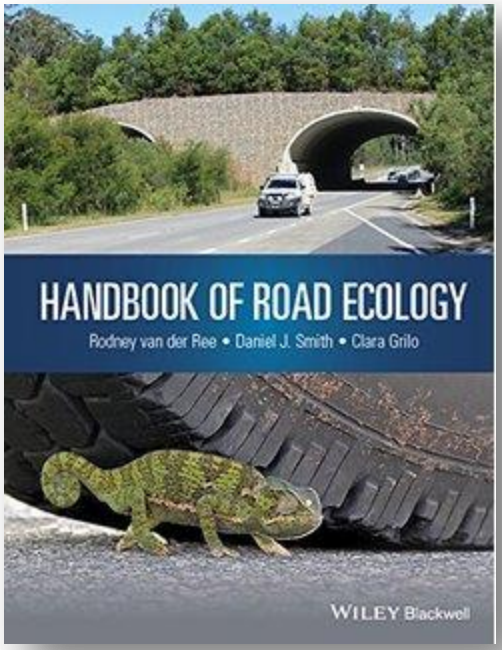

Roads & Ecological Infrastructure
Concepts and Applications for Small Animals
EDITED BY
Kimberly M. Andrews
Priya Nanjappa
and Seth P. D. Riley


HANDBOOK OF ROAD ECOLOGY
Rodney van der Ree • Daniel J. Smith • Clara Grilo
WILEY Blackwell

Impacts of Roads on Animals

Habitat Change

Road Mortality

Barrier Effect

Small Animals & Roads

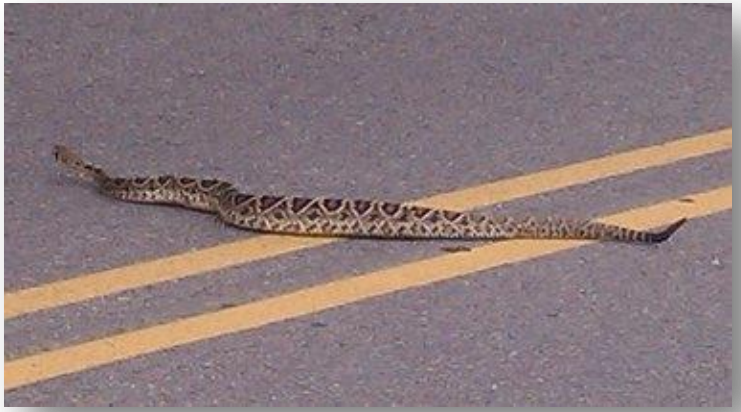
- **Slower & less perceptible.**
- **Roadside habitat a greater barrier.**
- **Less data available on road encounters.**
- **Less data available on habitat at appropriate scales.**
- **Lower public concern.**

Roadside Verge Habitat

- **Dry, windy, more variable & extreme temperature.**
- **Soil/fill compacted, dust.**
- **Little cover.**
- **Toxic exposures.**
- **Sensory overload: Noisy, bright lights, vibrations.**

Most Vulnerable Small Animals

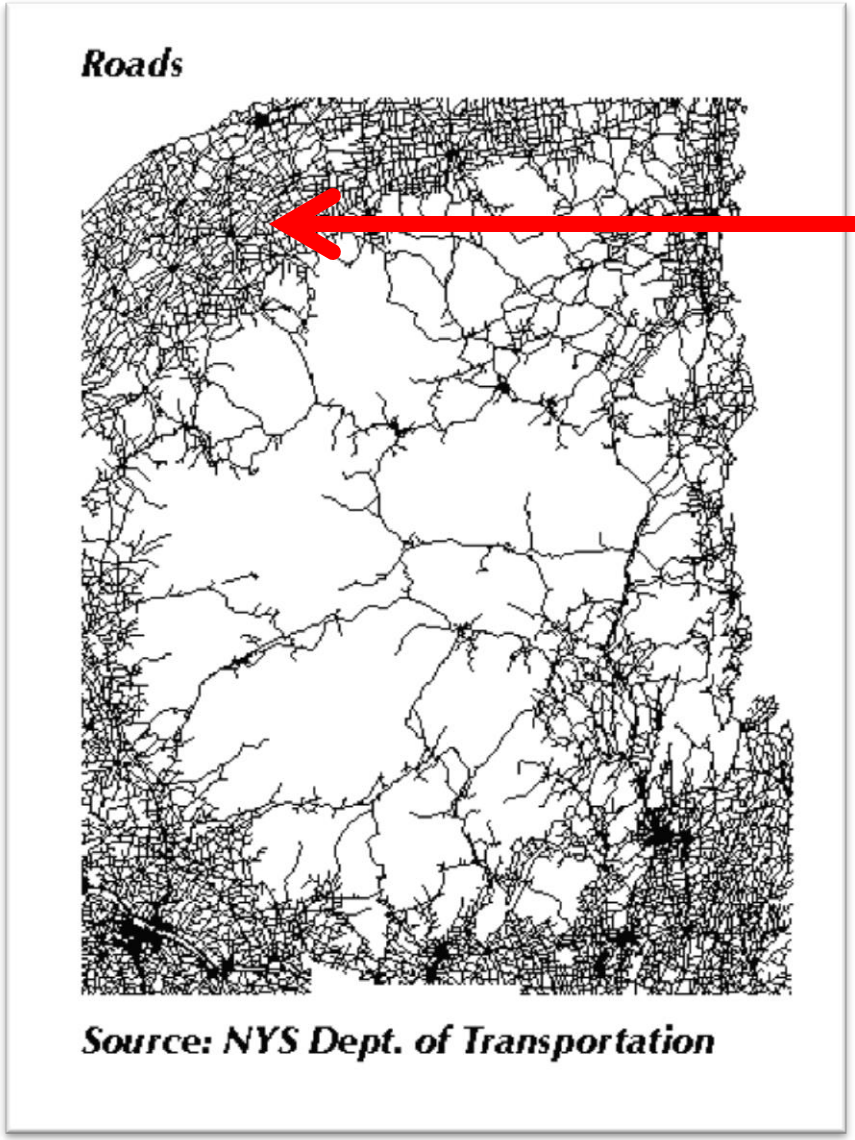
- **Those attracted to the verge or roadway.**
  - ***Butterflies, bees***
  - ***Nesting turtles***
- **Those for which migratory movements require crossing roads.**
  - ***Breeding amphibians***
- **Highly arboreal species.**
  - ***Marten, flying squirrels***
- **Demographically sensitive species.**
  - ***Rattlesnakes, turtles***

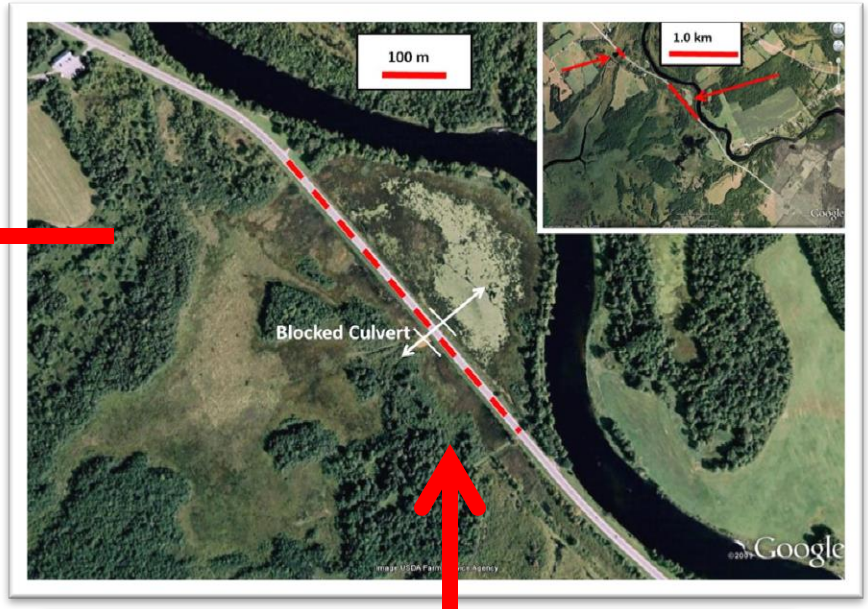


Big Questions in Behavioral Road Ecology

1. Where and when to animals encounter roads?
2. How do animals behave when encountering a road and road traffic?
3. Can we use animal behavior to design more effective road mitigation measures?

Scaling-Up Matters Behavioral Road Ecology





Why Focus on Turtles?

Turtle Populations are Inherently Vulnerable to Road Mortality

- **Slow recruitment** (late age of maturity, low annual fecundity).
- **High adult survivorship.**
- **Lack of density-dependent compensation**.
- **Wide ranging** or **migratory movements** that bring animals in contact with roads.
- **Attraction to the road corridor** (nesting females).

Recent research indicates that for wetland-associated species, road mortality may result in population declines.

Critical Sites for Monitoring & Mitigation

Where….

- ✓ **Animals are most likely to encounter roads.**
- ✓ **Road mortality is (or was) highest.**
- ✓ **Structural barriers or behavioral avoidance prevents animals from crossing .**
- ✓ **Where populations are otherwise likely to be viable.**

Locating Sites for Mitigation

Know the natural history of the critter, then use ….

- ✓ **Habitat-based predictors.**
- ✓ **Expert informants.**
- ✓ **Behavioral data on animal movements.**
- ✓ **Road-kill data.**

When Do Turtles Interact With Roads?

Langen et al. 2007 J Wildl Manage

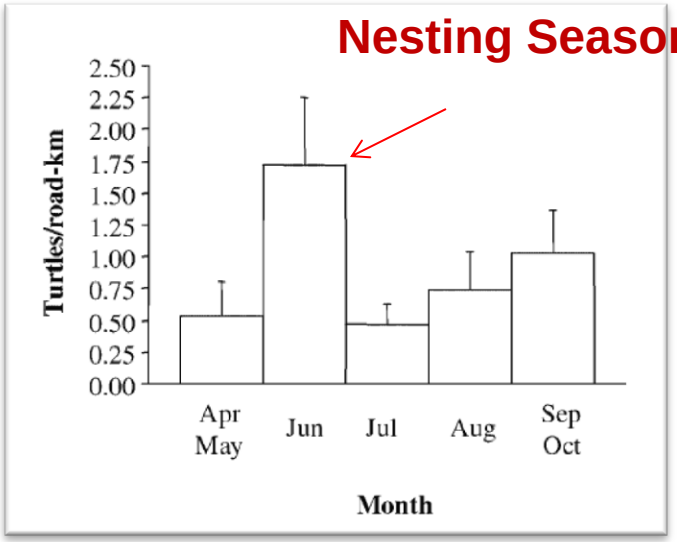


Table 2 Mean female fraction in turtle populations [±1SE (*n*) where *n* is the number of population samples] in relation to road association and ecological habit

Ecological habit	Off-road	On-road
Aquatic	0.43+0.02 (65)	0.66+0.04 (30)
Semi-aquatic	0.52+0.03 (29)	0.64+0.06 (10)
Terrestrial	0.49+0.04 (12)	0.47+0.03 (11)
All	0.46+0.01 (106)	0.61+0.03 (51)

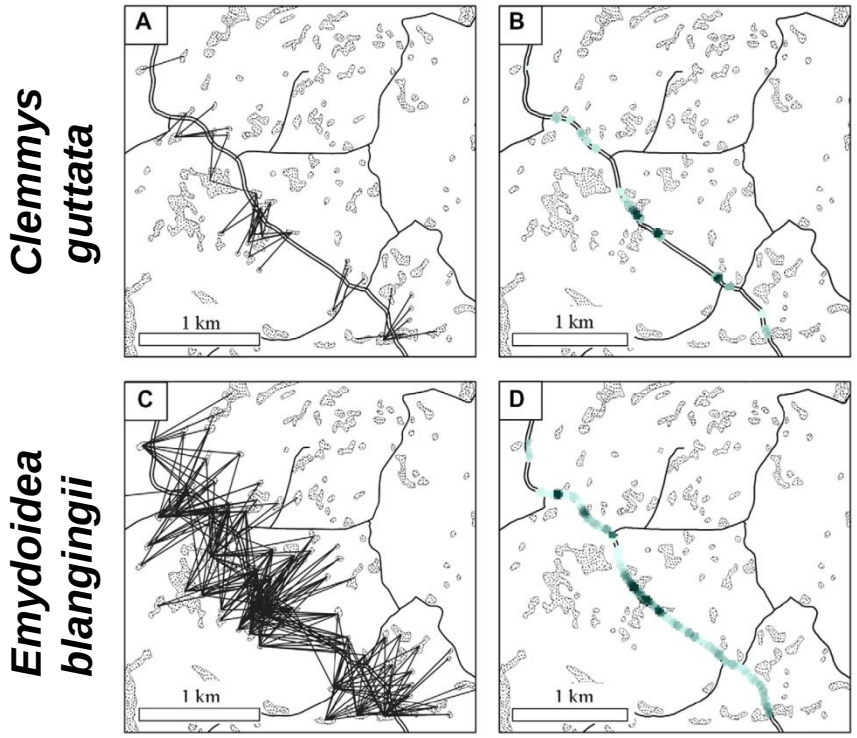
Steen et al. 2006 Biol Conserv

Hot Moments

caused by nesting.

Where Do Turtles Interact With Roads?

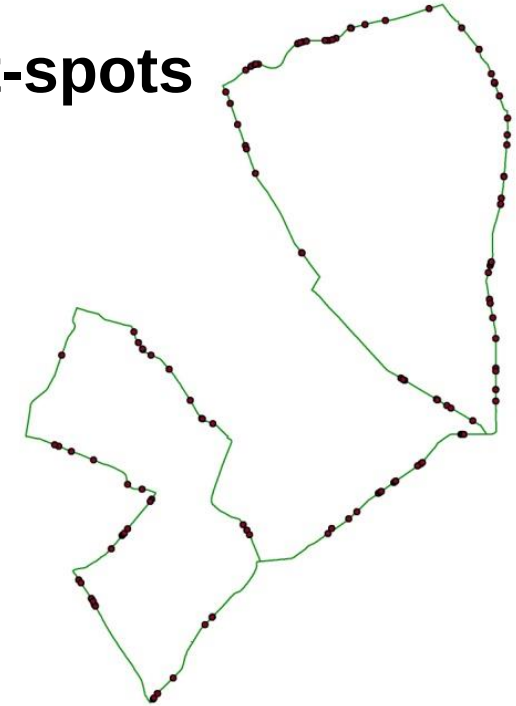
1. **Behavior-based Models**: Empirically characterize and then model movement patterns in relation to habitat patches and roads.
2. **Crossing-pattern Based Models**: Empirically characterize and then model ecological correlates of road-kill or road-crossing hotspots



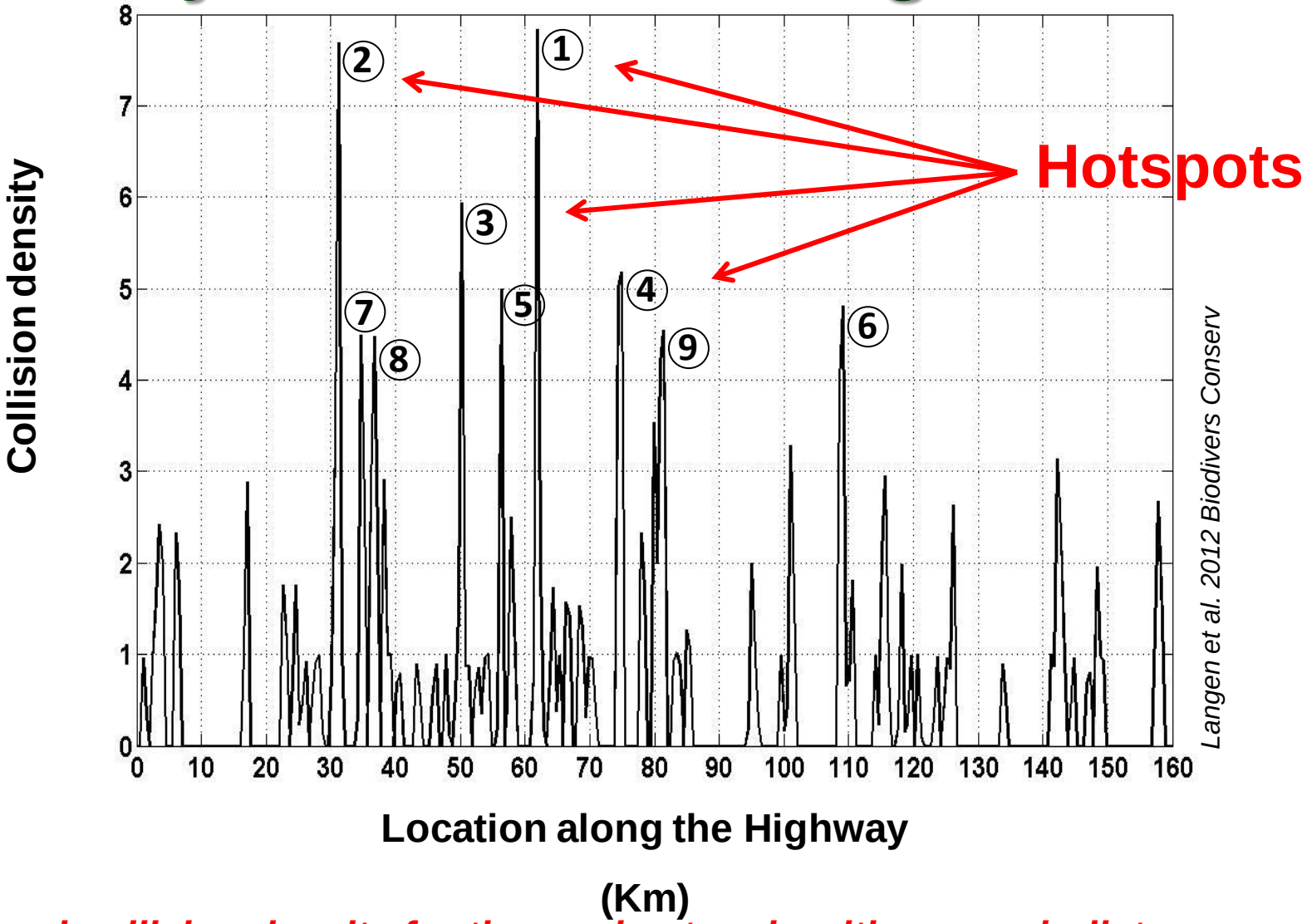
Beaudry F., P. G. deMaynadier, M. L. Hunter Jr. 2008. Identifying road mortality threat at multiple spatial scales for semi-aquatic turtles. Biological Conservation 141: 2550-2563.

Crossing-pattern Based Models

1. **Driving survey of a 160 km highway circuit.**
   a. Weekly over a two year period.
   b. Record location of each detected turtle DOR.
   c. N = 162 DOR turtles of 3 species.
2. **Locate hotspots.**
3. **Identify predictors of hotspot locations.**
4. **Evaluate causeways as predictors of hot-spots**

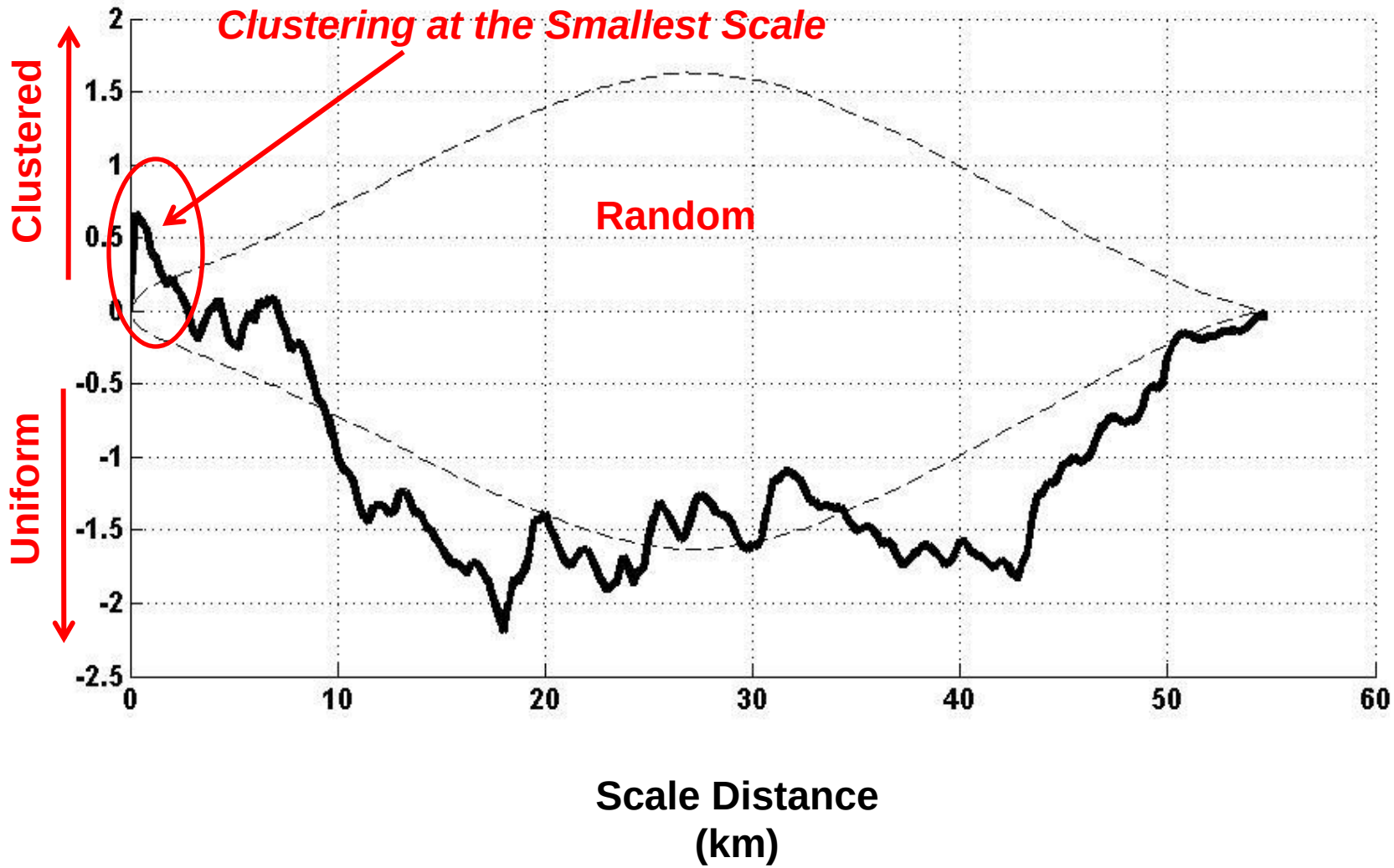


Density of Road-kill Along the Route



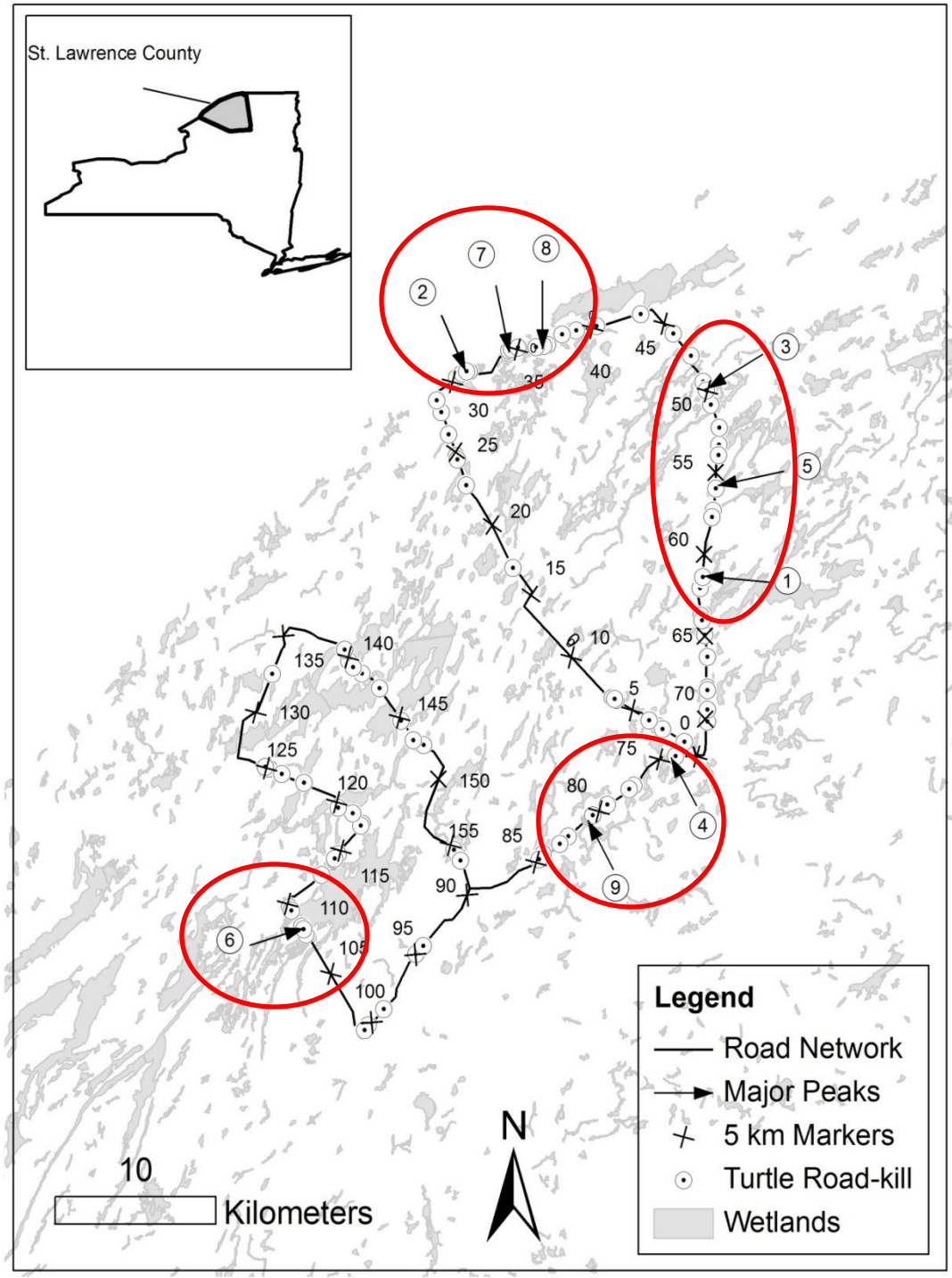
Kernel collision density for the road network, with a search distance (bandwidth) of 500 m at each kernel center. The crests represent relatively high densities of turtle mortalities ± the search distance (km).

Spatial Dispersion via Ripley's K-function



Langen et al. 2012 Biodivers Conserv

Landscape Predictors of Road-kill Hotspots



Predictors of Road-kill Locations vs Random Points

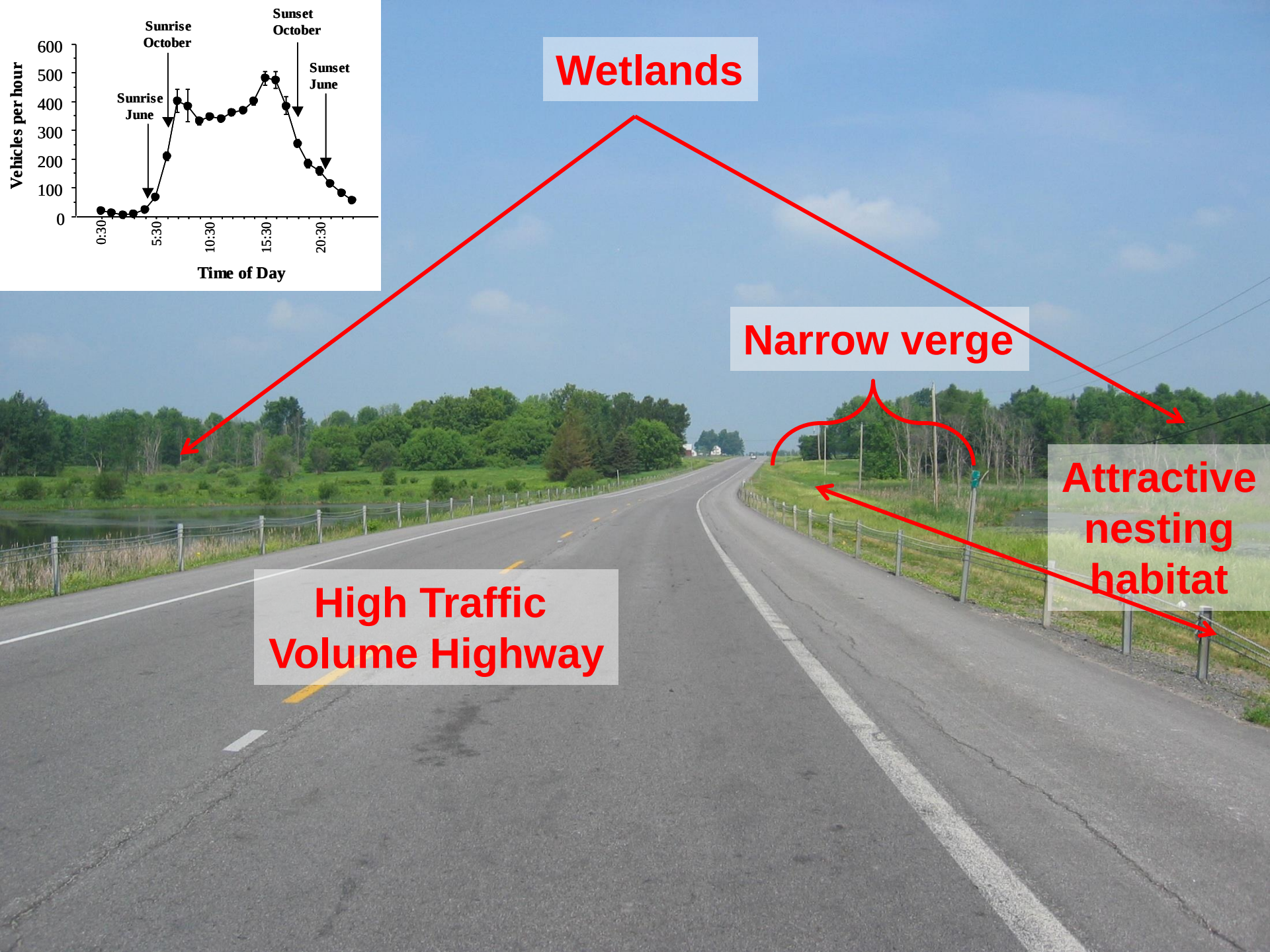
	No Mortality		Road-kill		Akaike
	Mean[a]	SE (+,-)	Mean	SE (+,-)	weight[b]
Distance to Water (m)	257	31.4, 27.9	46	6.6, 5.8	1.00
AADT	2463	253.6, 229.9	3320	255.1, 236.9	0.99
Forest[c]	7	1.5, 1.4	16	2.4, 2.2	0.83
Causeway[d]	4	0.4, 0.4	39	1.9, 1.9	0.74
Developed[c]	8	2.1, 1.9	6	1.5, 1.3	0.36
Wetland[c]	4	1.3, 1.1	20	2.3, 2.2	0.18
Developed Open Space[c]	35	2.6, 2.5	43	2.9, 2.9	0.13
Cultivated Cropland[c]	5	1.6, 1.4	1	0.3, 0.3	0.13
Grassland[c]	21	2.5, 2.4	10	1.4, 1.3	0.13

[a] back-transformed means and se

[b] Akaike weights

[c] Wetlands = proportion of land use within 100 m of a point is classified as wetland, whereas the other land use categories = the proportion of terrestrial (non Wetlands) area within the 100m buffer in that land use category.

[d] Percentage of points within the causeway overlap zone


Sunrise October
Sunset October
Sunrise June
Sunset June
Vehicles per hour
600
500
400
300
200
100
0
0:30
5:30
10:30
15:30
20:30
Time of Day
Wetlands
Narrow verge
Attractive nesting habitat
High Traffic Volume Highway

Management Implications

1. Road-kill is **highly aggregated** at **short & severe** hotspots
2. Hotspots can be **detected by driving surveys** or **targeted point-transect walking surveys**
3. Data collected from known hotspots can be used to create **predictive hotspot models**
4. Such models make it feasible to do **road network-wide monitoring and mitigation**
5. The best predictors are **local-scale wetland size**, **shape**, and **configuration**, and **traffic volume**

Behavior When Encountering & Crossing Roads?

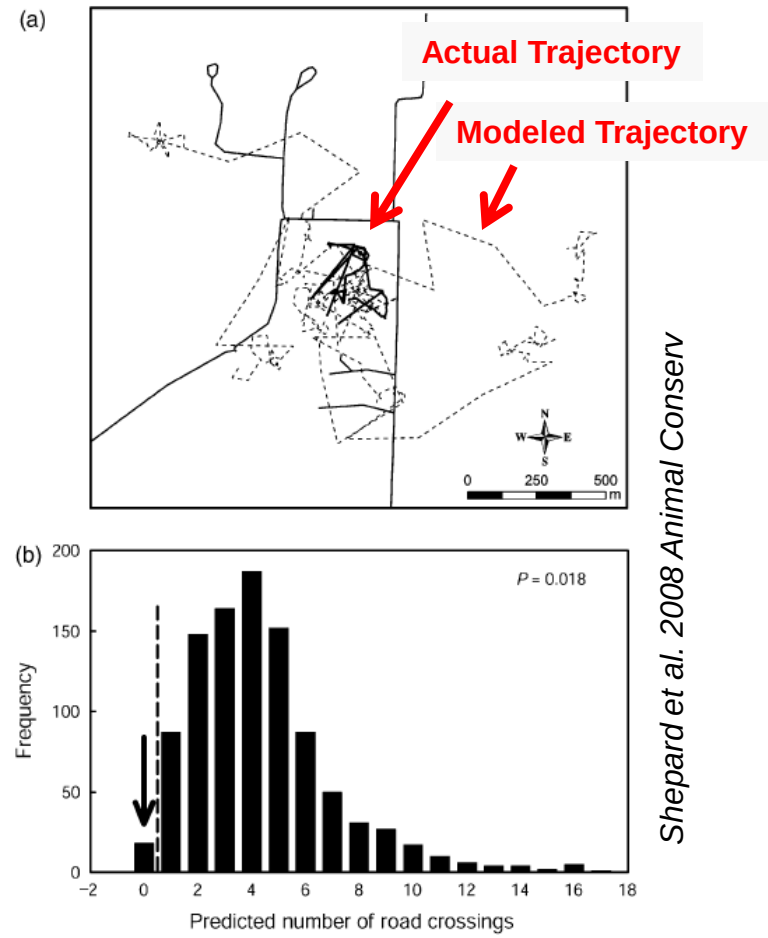
- **Reaction to road verge, roadway**: avoidance, neutral, attraction?
- **Approaching road:** Direct, random, parallel; use of cover?
- **When crossing**: Shortest distance, random walk; fast, normal gate, slow & cautious?
- **Reaction to traffic**: flee, ignore, freeze?

Behavior When Encountering & Crossing Roads?

Some species avoid roads (*Terrapene* box turtles), **some may be neutral** (Blanding's Turtle, Spotted Turtle), **some attracted** (nesting females of many species).

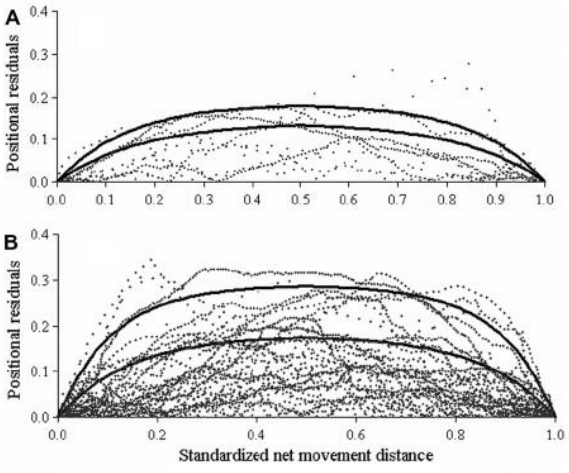
Few studies actually look at movements (trajectories, rates) **in relation to roads & traffic.**

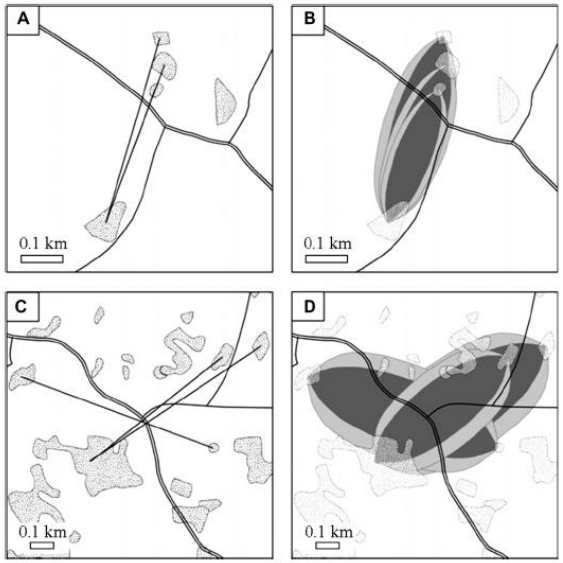
Terrapene carolina

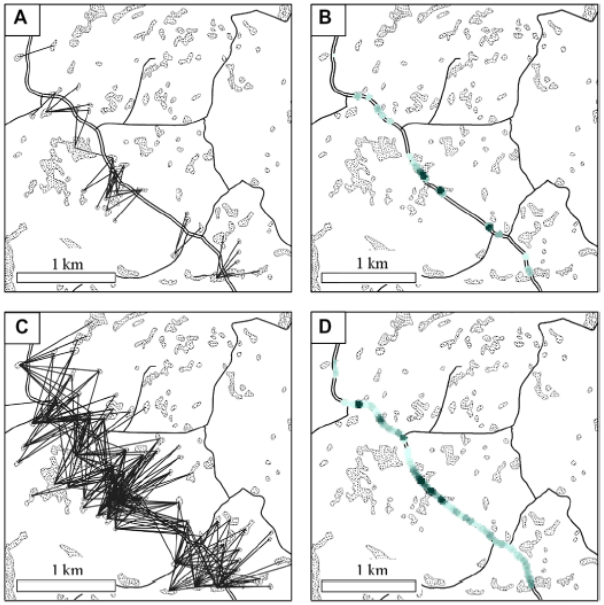


Shepard et al. 2008 Animal Conserv

Behavior When Encountering & Crossing Roads?



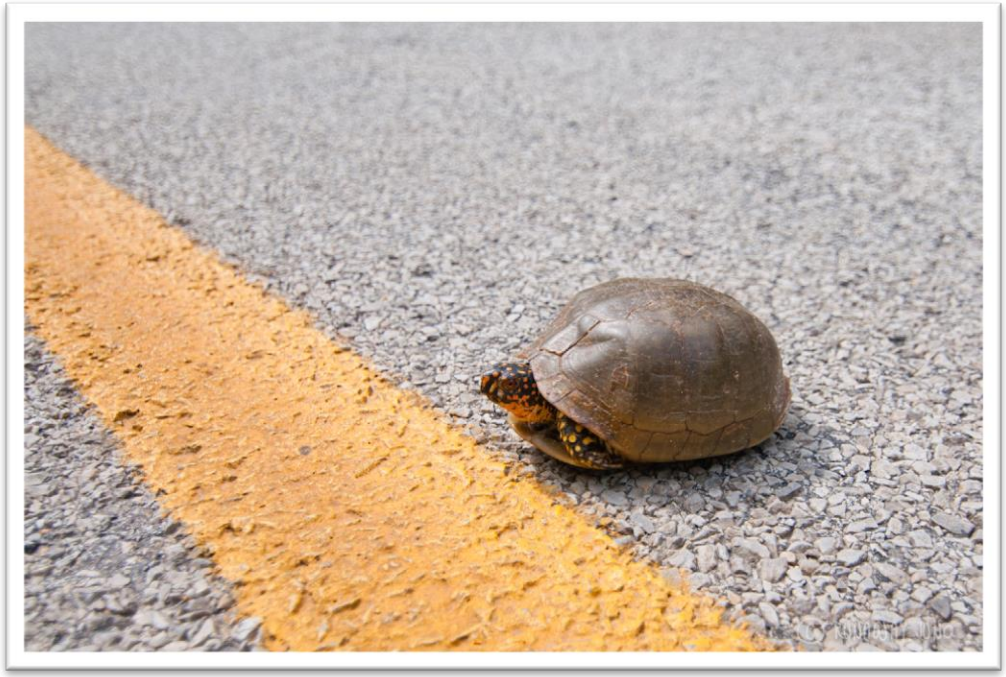




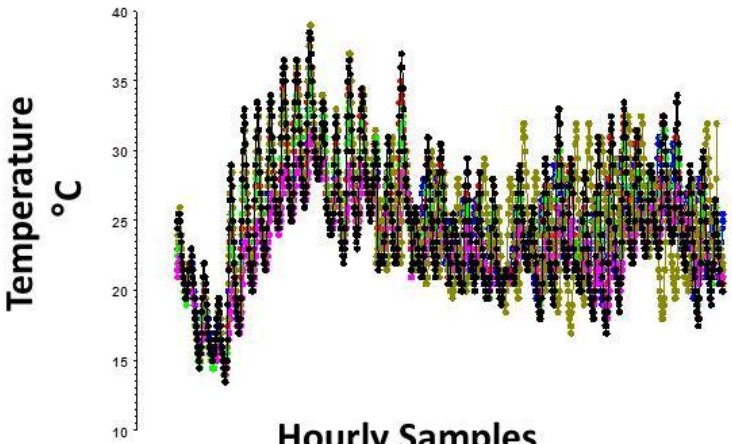
Beaudry F., P. G. deMaynadier, M. L. Hunter Jr. 2008. Identifying road mortality threat at multiple spatial scales for semi-aquatic turtles. Biological Conservation 141: 2550-2563.

Behavior When Encountering & Crossing Roads?

- Many turtles slowly cross roads.
- Turtles freeze when vehicles approach.
- Drivers avoid or aim for turtles.



Nest Temperature



Hourly Samples
28 June – 9 August 2010
N = 6 sensors

Incubation Temperature affects

- Development rate
- Developmental stability
- Primary sex ratio
- Hatchling size
- Hatchling behavior
- Overwinter survival

Temperatures > 31 ° C may be lethal

	Mean		Maximum		Minimum	
Period	**East**	**West**	**East**	**West**	**East**	**West**
June - July 2004	21.0 ± 0.36		24.0 ± 0.44		18.4 ± 0.40	
June - July 2005	24.5 ± 2.68	25.1 ± 2.73	27.4 ± 3.26	28.0 ± 3.17	21.7 ± 2.54	22.4 ± 2.56
July 2006	25.3 ± 0.33		28.0 ± 0.59		22.3 ± 0.11	

	Mean Difference: Roadway - Control					
	Mean		Maximum		Minimum	
Period	**East**	**West**	**East**	**West**	**East**	**West**
June - July 2004	1.4 ± 0.10		2.4 ± 0.15		0.5 ± 0.09	
June - July 2005	1.8 ± 0.28	2.3 ± 0.27	2.7 ± 0.35	3.3 ± 0.33	0.9 ± 0.23	1.6 ± 0.25

Objectives of Mitigation

- **Prevent Roadkill.**
  - **Wildlife barriers**
  - **Verge habitat management**
  - **Signage**
  - **Seasonal road closures or rerouting**

- **Increase Habitat Connectivity.**
  - **Wildlife crossing structures**
  - **Verge habitat management**

- **Discourage use of the verge.**
  - **Verge habitat management**

Design Considerations

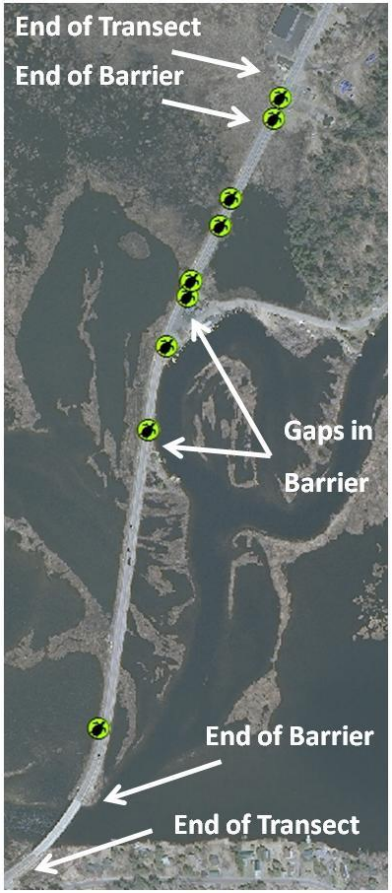
- **Location**
- **Cost** (materials, labor)
- **Safety**
- **Impacts on ROW management**
- **Durability & Maintenance Needs**
  - Including ‘ownership’
- **Public Buy-in**
  - Including aesthetics
- **Effectiveness at preventing road-kill**
- **Impacts on other species**
- **Impacts on predation risk** (including harvest)
- **Impacts on population connectivity**
- **Ends, gaps, and animals trapped on the wrong side of the barrier**

Turtle Barriers and Passages

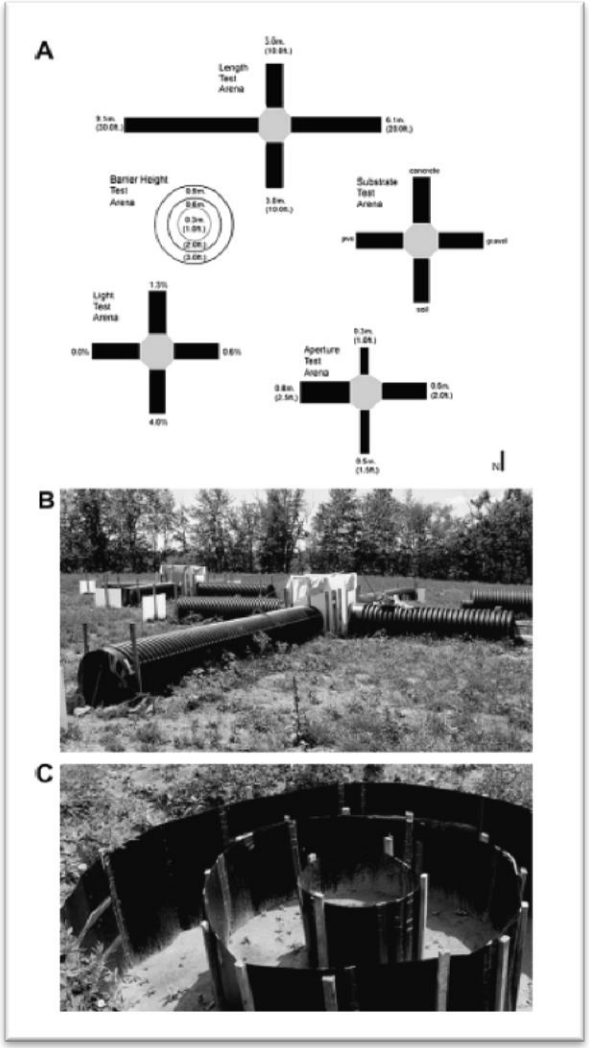
Turtle Barriers and Passages

Images from Lisa Masi

Barrier & Passage Effectiveness



Behaviorally-informed Road Mitigation?



Woltz et al. 2008 Biol Conserv

Langen et al. 2009 SWG Report

Other Potential Mitigation Options

Constructed Nest Sites

Signage

Summary Best Practices

- **Know your objectives before you plan your mitigation.**
- **Chose mitigation that fits the natural history of the species of concern.**
- **Local wildlife experts often know where mitigation would be effective.**
- **Habitat management should be a component of any mitigation.**
- **Incorporate wildlife mitigation into necessary infrastructure repair and upgrades.**

Wildlife biologist Whisper Camel-Means and her colleagues needed to know precisely where to build crossing structures, so they talked to locals, set up video cameras, mapped roadkill, counted deer scat, and tracked animals using GPS collars.
© Steven Gnam

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© Steven Gnam

- **Evaluate options via behavioral observations and experiments.**

Applied behavioral ecology can improve road design & management to benefit turtles & other small animals.