Why We Need to Incorporate Animal Behavior into Road Ecology:

A case history with aquatic turtles

Tom A. Langen
Dept. of Biology
Clarkson University
Impacts of Roads on Animals

Habitat Change

Barrier Effect

Road Mortality
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 do 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

Roads

Source: NYS Dept. of Transportation
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?

Nesting Season

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

<table>
<thead>
<tr>
<th>Ecological habit</th>
<th>Off-road</th>
<th>On-road</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aquatic</td>
<td>0.43 ± 0.02 (65)</td>
<td>0.66 ± 0.04 (30)</td>
</tr>
<tr>
<td>Semi-aquatic</td>
<td>0.52 ± 0.03 (29)</td>
<td>0.64 ± 0.06 (10)</td>
</tr>
<tr>
<td>Terrestrial</td>
<td>0.49 ± 0.04 (12)</td>
<td>0.47 ± 0.03 (11)</td>
</tr>
<tr>
<td>All</td>
<td>0.46 ± 0.01 (106)</td>
<td>0.61 ± 0.03 (51)</td>
</tr>
</tbody>
</table>

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.

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
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

Clustering at the Smallest Scale

Langen et al. 2012 Biodivers Conserv
Landscape Predictors of Road-kill Hotspots
# Predictors of Road-kill Locations vs Random Points

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

<sup>a</sup> back-transformed means and se  
<sup>b</sup> Akaike weights  
<sup>c</sup> 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.  
<sup>d</sup> Percentage of points within the causeway overlap zone.
Wetlands

High Traffic Volume Highway

Narrow verge

Attractive nesting habitat

Vehicles per hour

Time of Day

Sunrise

June

Sunset

June

Sunrise

October

Sunset

October
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.
Behavior When Encountering & Crossing Roads?

Behavior When Encountering & Crossing Roads?

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

**Incubation Temperature** affects

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

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

**Mean**

<table>
<thead>
<tr>
<th>Period</th>
<th>Mean East</th>
<th>Mean West</th>
</tr>
</thead>
<tbody>
<tr>
<td>June - July 2004</td>
<td>21.0 ± 0.36</td>
<td>24.0 ± 0.44</td>
</tr>
<tr>
<td>June - July 2005</td>
<td>24.5 ± 2.68</td>
<td>27.4 ± 3.26</td>
</tr>
<tr>
<td>July 2006</td>
<td>25.3 ± 0.33</td>
<td>28.0 ± 0.59</td>
</tr>
</tbody>
</table>

**Maximum**

<table>
<thead>
<tr>
<th>Period</th>
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<th>Maximum West</th>
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<tbody>
<tr>
<td>June - July 2004</td>
<td>24.0 ± 0.44</td>
<td>28.0 ± 3.17</td>
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<tr>
<td>June - July 2005</td>
<td>27.4 ± 3.26</td>
<td>33.0 ± 3.05</td>
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**Minimum**

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<th>Minimum West</th>
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</thead>
<tbody>
<tr>
<td>June - July 2004</td>
<td>18.4 ± 0.40</td>
<td>21.7 ± 2.54</td>
</tr>
<tr>
<td>June - July 2005</td>
<td>21.4 ± 2.54</td>
<td>22.4 ± 2.56</td>
</tr>
<tr>
<td>July 2006</td>
<td>22.3 ± 0.11</td>
<td>22.3 ± 0.11</td>
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**Mean Difference: Roadway - Control**

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<th>Mean West</th>
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<tbody>
<tr>
<td>June - July 2004</td>
<td>1.4 ± 0.10</td>
<td>2.4 ± 0.15</td>
</tr>
<tr>
<td>June - July 2005</td>
<td>1.8 ± 0.28</td>
<td>2.7 ± 0.35</td>
</tr>
</tbody>
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**Temperatures > 31 °C** may be lethal
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.
Summary Best Practices

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- 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.

- Evaluate options via behavioral observations and experiments.
Applied behavioral ecology can improve road design & management to benefit turtles & other small animals.