



Simulating the impacts of roads on  
the foraging opportunities of the  
Indiana Bat (*Myotis sodalis*)

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# Roads as Barriers

- Estimated >1 million vertebrate animals die on road in United States per day (Lalo 1987)
- Many species of vertebrates avoid roads
  - Surfaces (temperature, substrate)
  - Open spaces (roads, roadsides)
  - Traffic (noise, lights, perceived danger)



# Roads as Barriers

- Many small mammal species will not attempt to cross roads
  - Yellow-Necked Mouse, Bank Vole, Rat spp.
- Often only a small proportion of a spp. will attempt road-crossing
  - 3-10% (Hispid cotton rats and prairie voles)
  - 7.7% (White-footed mice)

# Purpose

- Bats response to vehicles  
*Zurcher et al. 2010*



- Do roads barriers impact foraging?

- What circumstances exacerbate barrier effects of roads?



# Simulation of Disturbance Activities

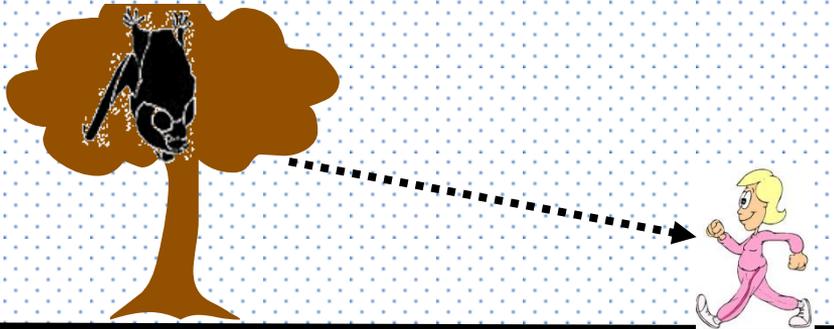
- Everything is a model
- Flexible (multi-species)
- Spatially explicit (realistic maps)
- Stochastic Individual-based model
- Behavioral not population model
- Designed specifically to investigate the effects of anthropogenic disturbance on wildlife.

*Bennett et al. 2009 & 2011*

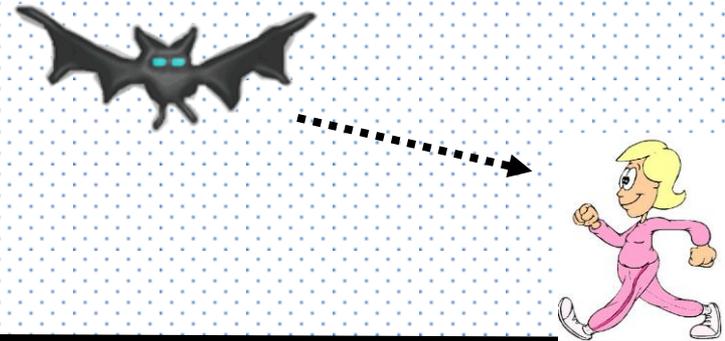


# Wildlife Response to Human Activity

## ❖ Detection Distance



## ❖ Flight Initiation Distance



## ❖ Time Spent Fleeing

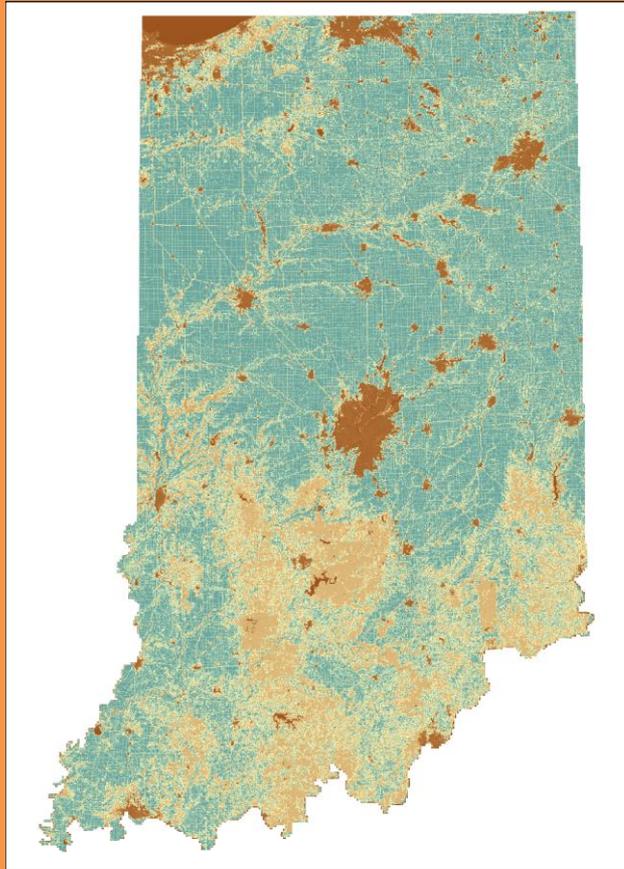
e.g. Approximately 40 minutes



## ❖ Time Spent Latent



# Two Questions



What characteristics make roads barriers to foraging?

How do real road network configurations impact access to foraging habitat by virtual bats?

# Parameters: Scenario

How big is an Indiana bat's foraging range around a summer maternity roost?



Max distance from primary roost site = 8 km

*From studies by Sparks et al.*

# Parameters: Wildlife

## Natural Behaviour Variables

From telemetry studies  
by Sparks et al.  
undertaken from 2003 to 2008.



### •Foraging range



•Minimum *0.8 km*

•Maximum *8 km*

•Primary foraging period *9 pm to 12 pm*

### •Speed



•Foraging *0.4 km/5 min*

•Commuting *1.3 km/5 min*

### •Movement tortuosity

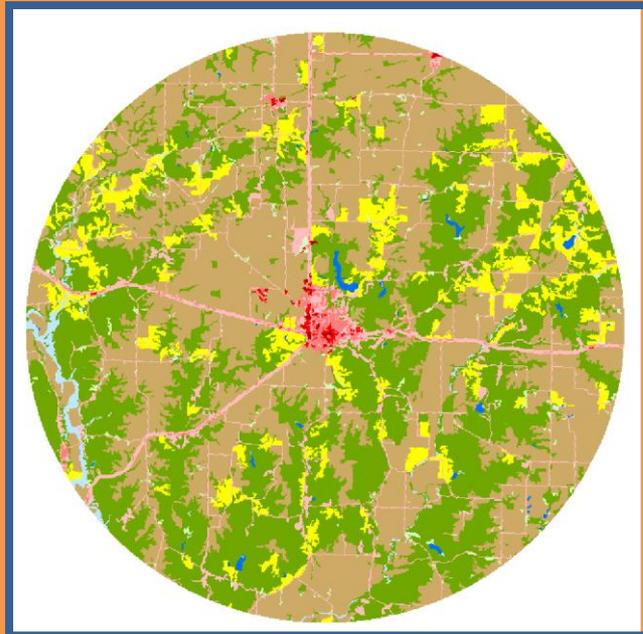


•Foraging *0.2355*

•Commuting *0.98*

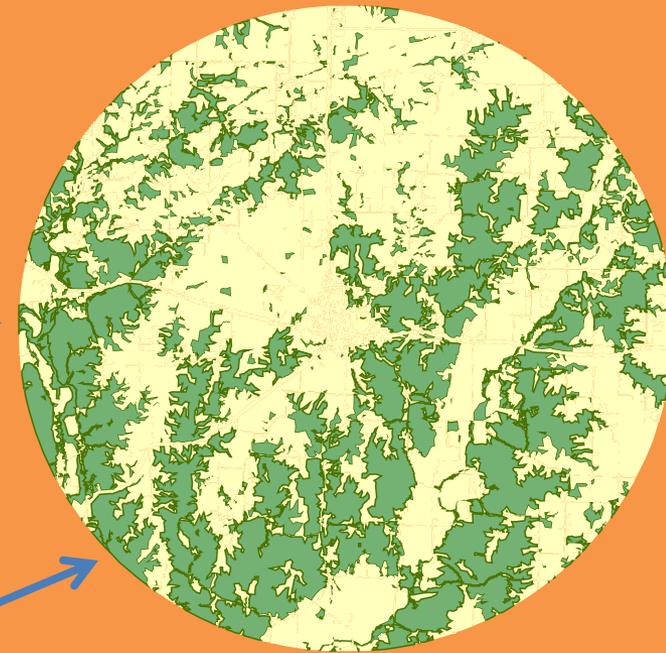
# Parameters: Scenario

Does the proportion of **foraging habitat** available influence the foraging success of bats when a road is present within their foraging range?



-  Open Water
-  Developed, Open Space
-  Developed, Low Intensity
-  Developed, Medium Intensity
-  Developed, High Intensity
-  Barren Land
-  Deciduous Forest
-  Evergreen Forest
-  Mixed Forest
-  Shrub/Scrub
-  Grasslands/Herbaceous
-  Pasture/Hay
-  Cultivated Crops
-  Woody Wetlands
-  Emergent Herbaceous Wetlands

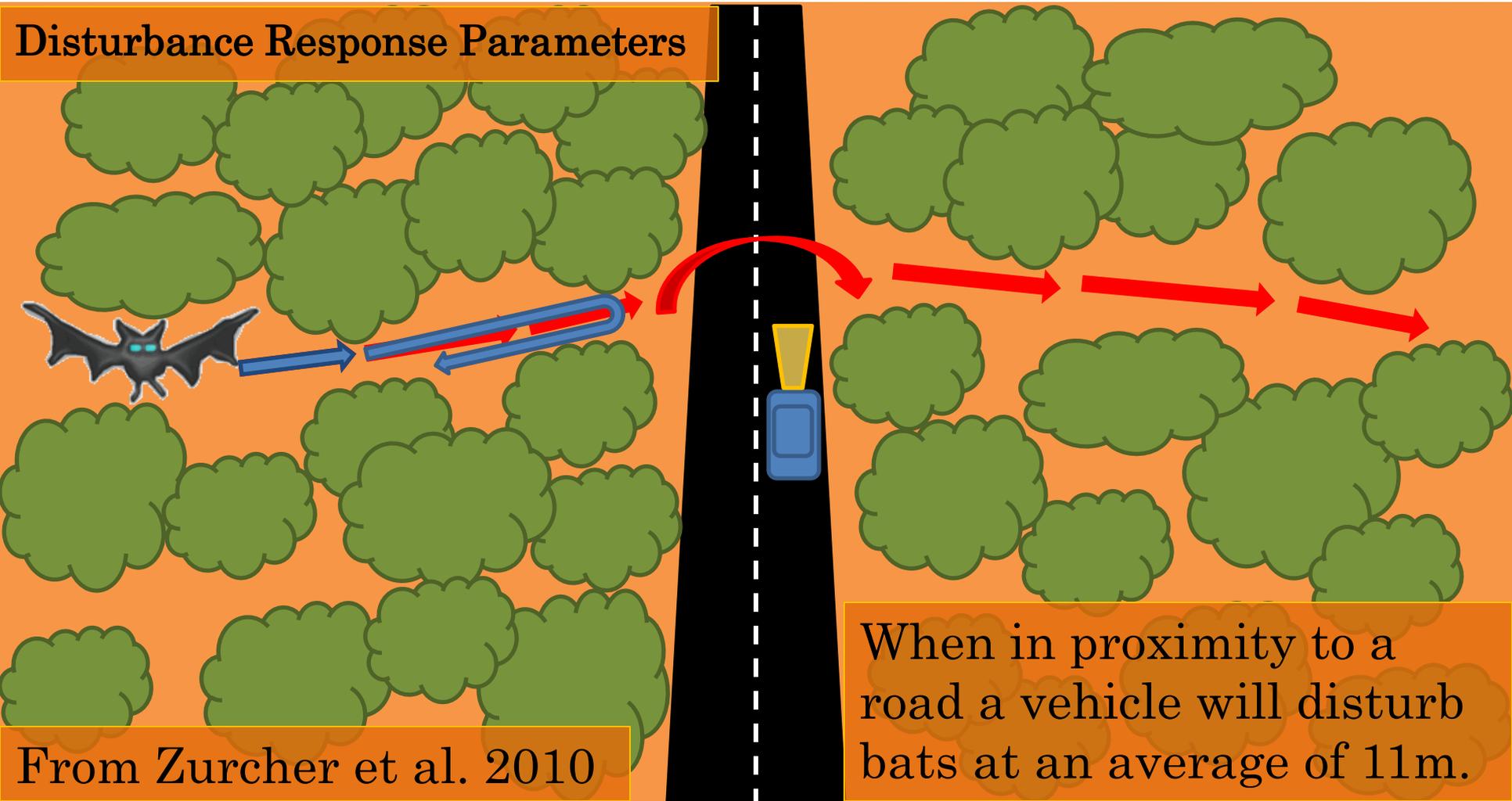
Suitable foraging habitat



GOOD = green  
BAD = yellow

# Parameters: Wildlife

## Disturbance Response Parameters

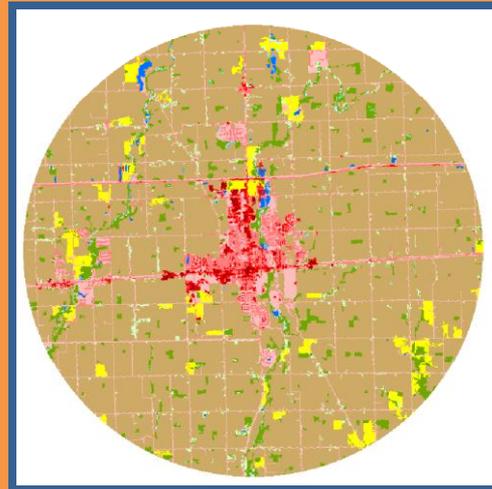
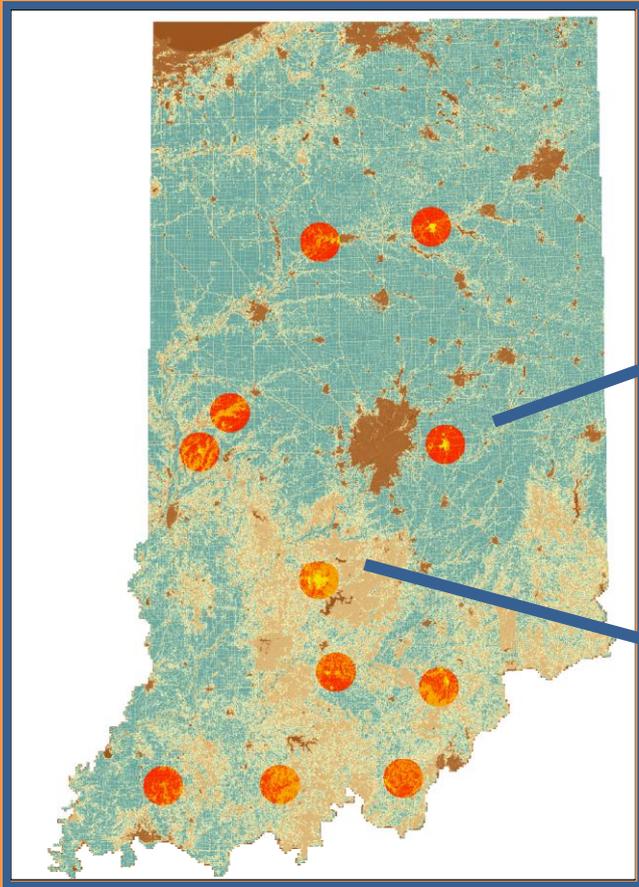


When in proximity to a road a vehicle will disturb bats at an average of 11m.

From Zurcher et al. 2010

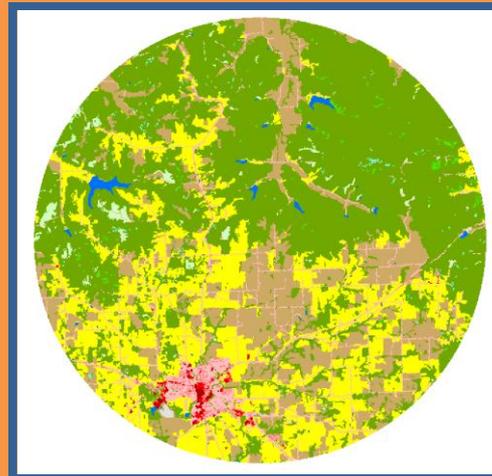
# When is a road a barrier?

Does the proportion of **foraging habitat** available influence the foraging success of bats when a road is present within their foraging range?



11 habitats  
selected  
ranging from

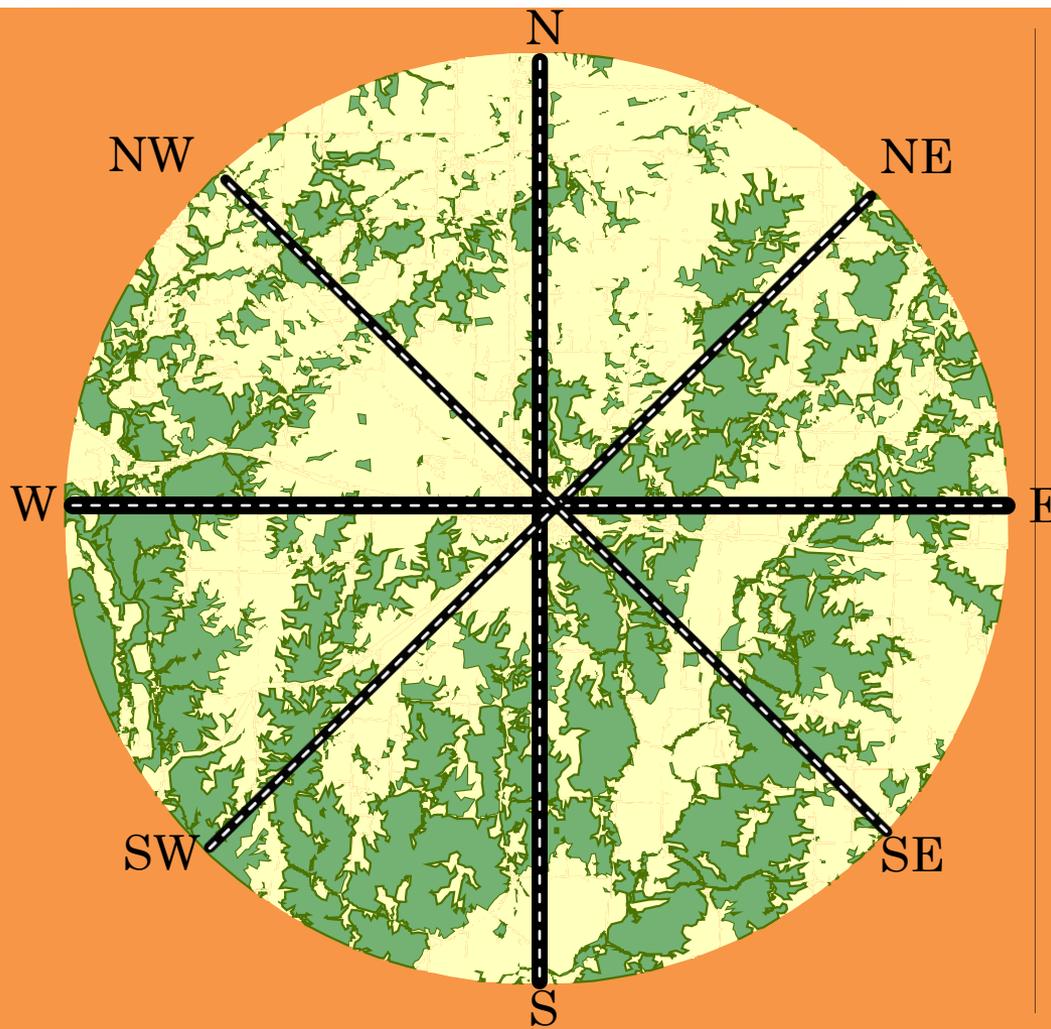
$5 \text{ km}^2$  to  $56 \text{ km}^2$



of suitable  
foraging habitat

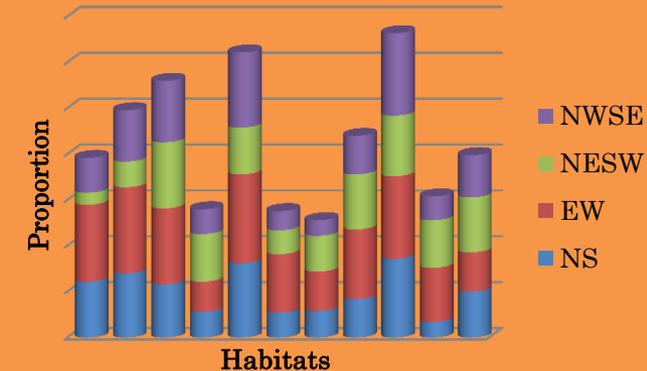
# Parameters: Anthropogenic

Does the orientation of a road in the landscape influence the foraging success of bats within their foraging range?

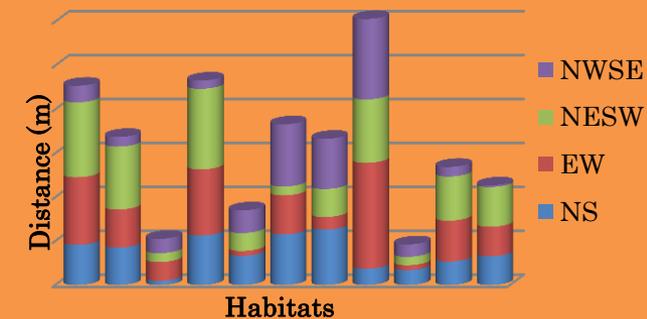


## Road Direction (RD)

Proportion of suitable habitat on roost-side of road

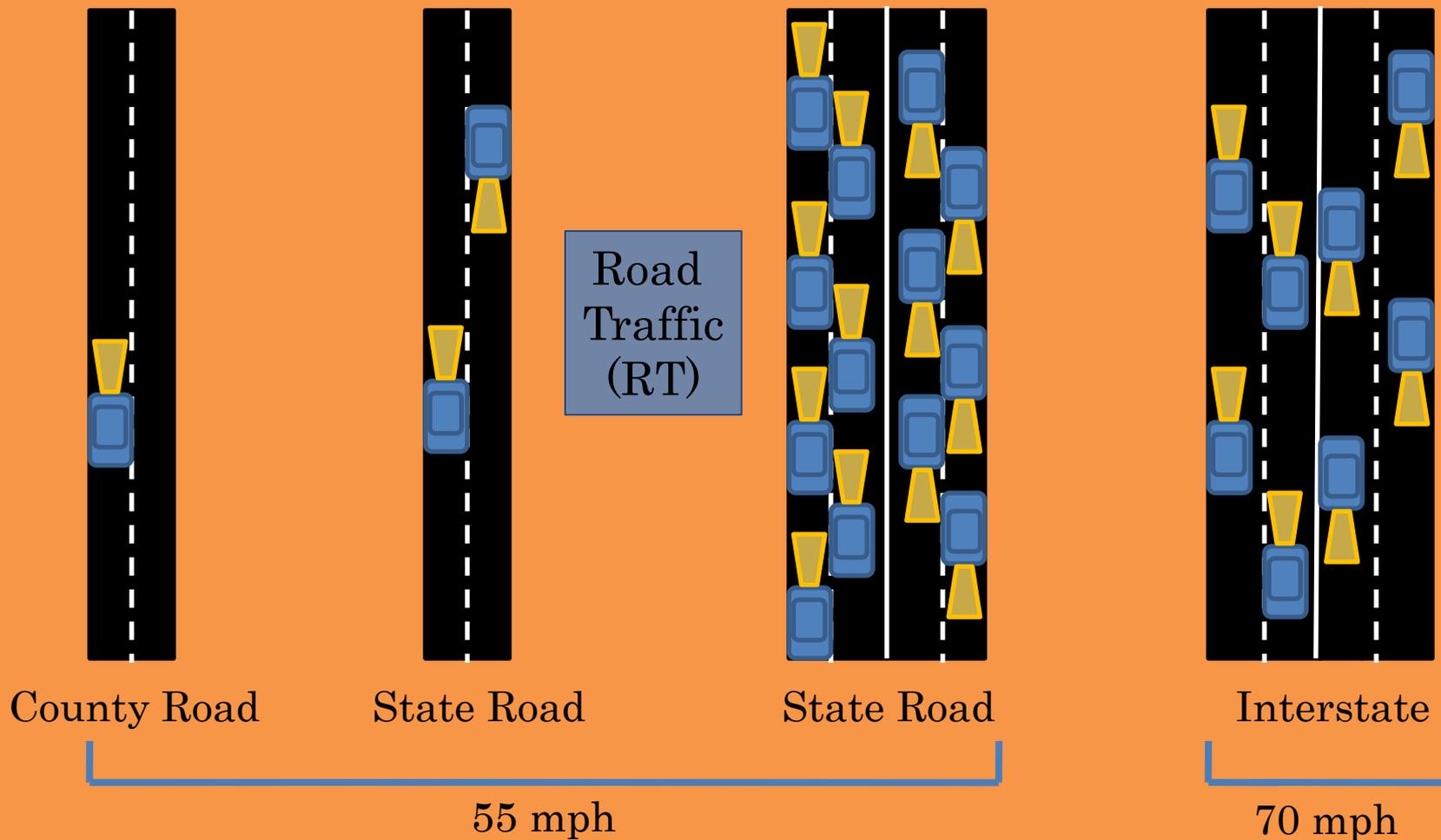


Distance of road from roost



# Parameters: Anthropogenic

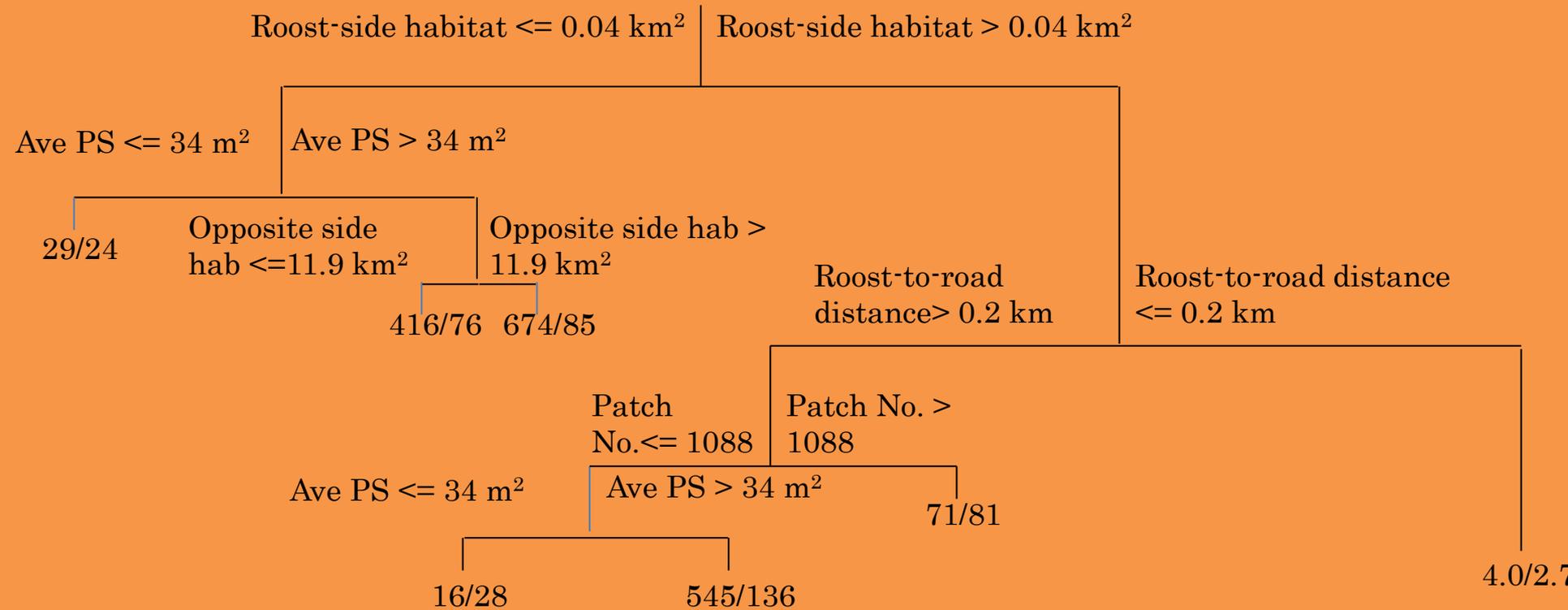
Comparing the influence of different classes of road.



# Results

When is a road a barrier?

**Foraging Success CART (area under ROC curve = 0.8 with a relative error of 0.4)**



A photograph of a forest with trees in autumn foliage, showing shades of yellow, orange, and red. The image is used as a background for the top section of the slide.

# Results

When is a road a barrier?

## Two Variables Stand Out

GOOD habitat patch size (Average patch size  $> 34 \text{ m}^2$ )

Amount of GOOD habitat on the roost-side of the road ( $> 0.4 \text{ km}^2$ )

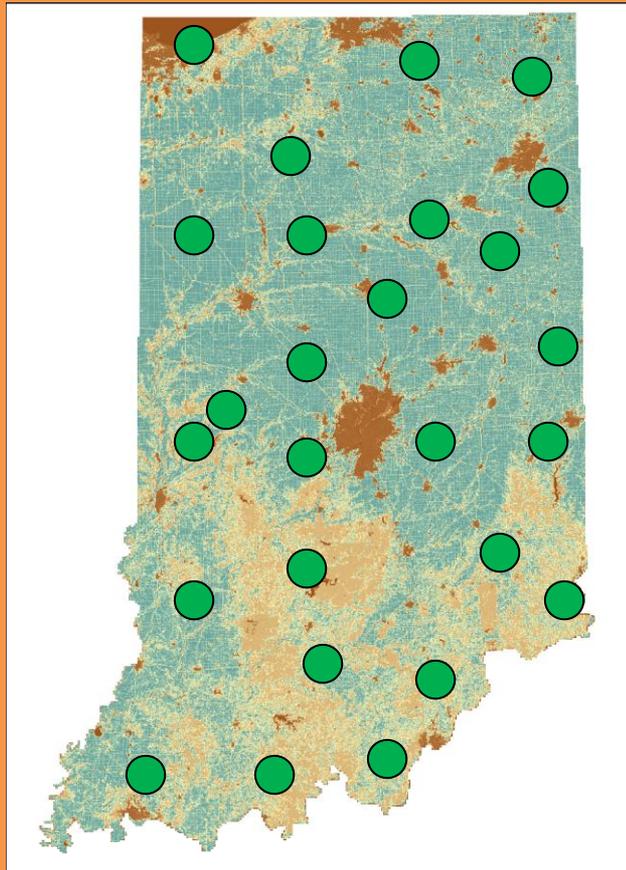
## Conclusions

4 lane highways impermeable

Country lanes indistinguishable roadless control scenarios

Impacts of road barrier effects on foraging determined by habitat  
quantity  
configuration  
traffic volume on road

# Real road network impacts?



32 Actual Roost Sites from ESI

10 km buffers in 1km annuli

Same rules

movement patterns

habitat quality

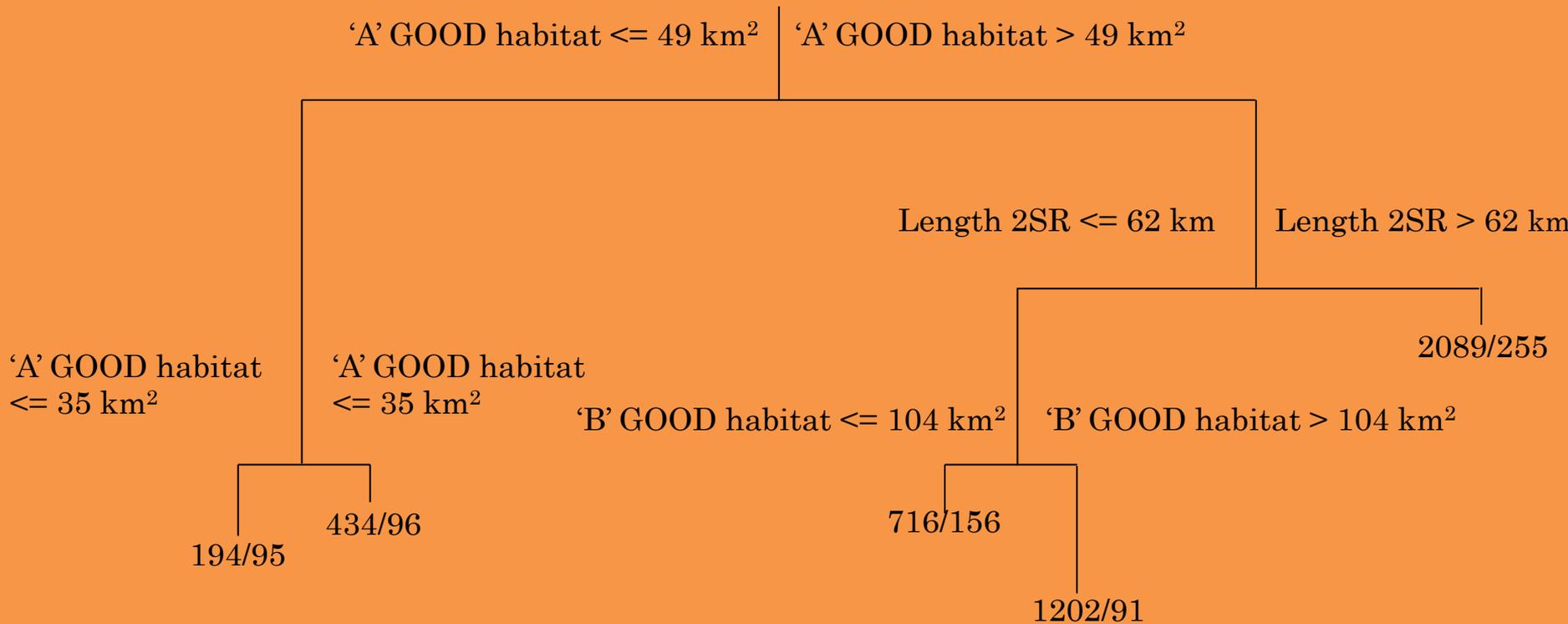
response to vehicle etc

Entire existing road networks

# Results

## Real Road Network Impacts?

**Foraging Success CART (area under ROC curve = 0.93 with a relative error of 0.1)**



A photograph of a forest with trees in autumn foliage, showing shades of yellow, orange, and red. The trees are dense and the lighting is soft, suggesting a misty or overcast day.

# Results

## Real road network impacts?

### Three Variables Stand Out

Amount of GOOD habitat in interior most annulus

Total length of two lane state roads in network

Amount of GOOD habitat in second annulus

### Conclusions

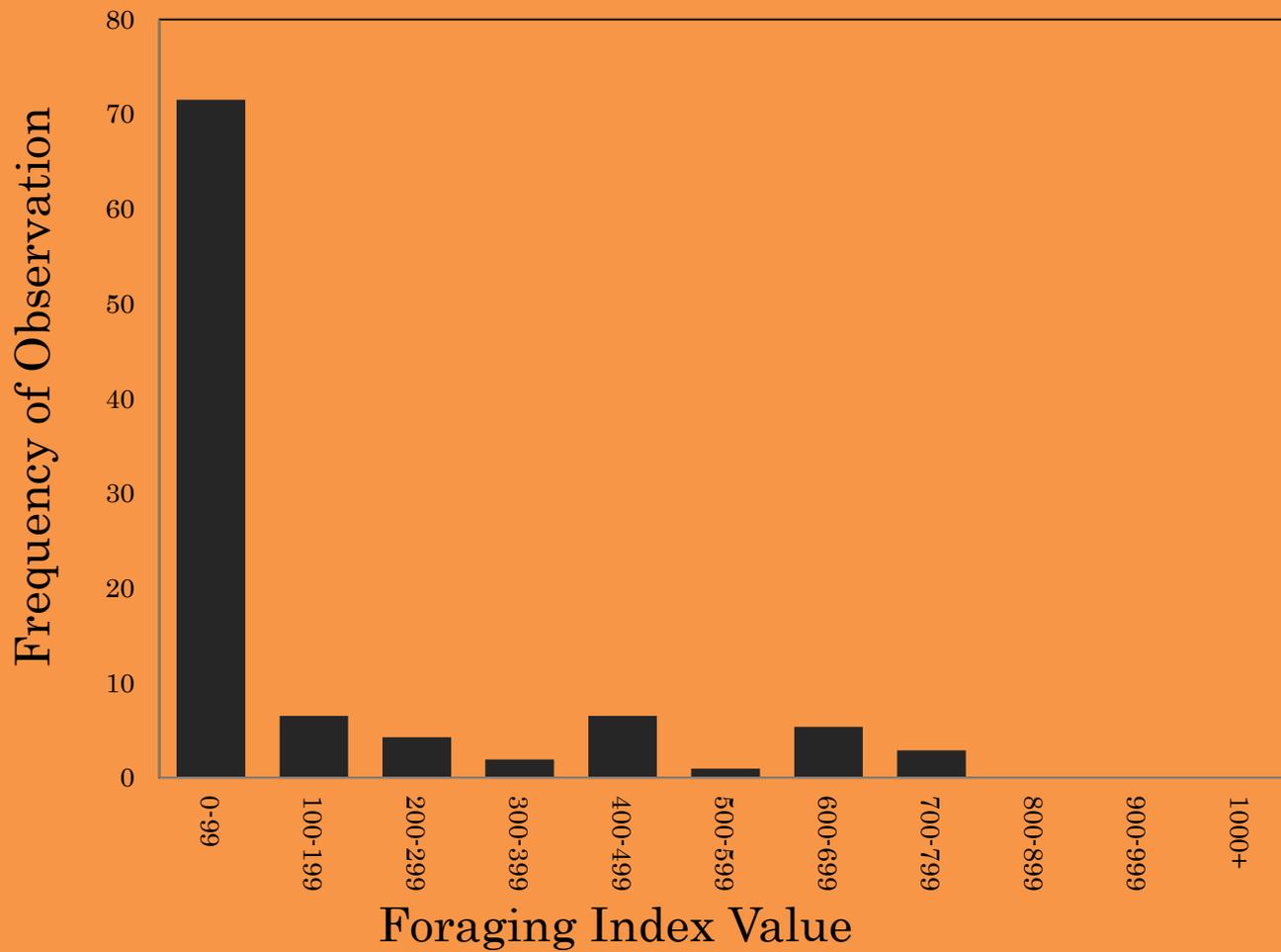
Consider entire road network within the foraging area

4 lane roads with high traffic volumes greatest implications

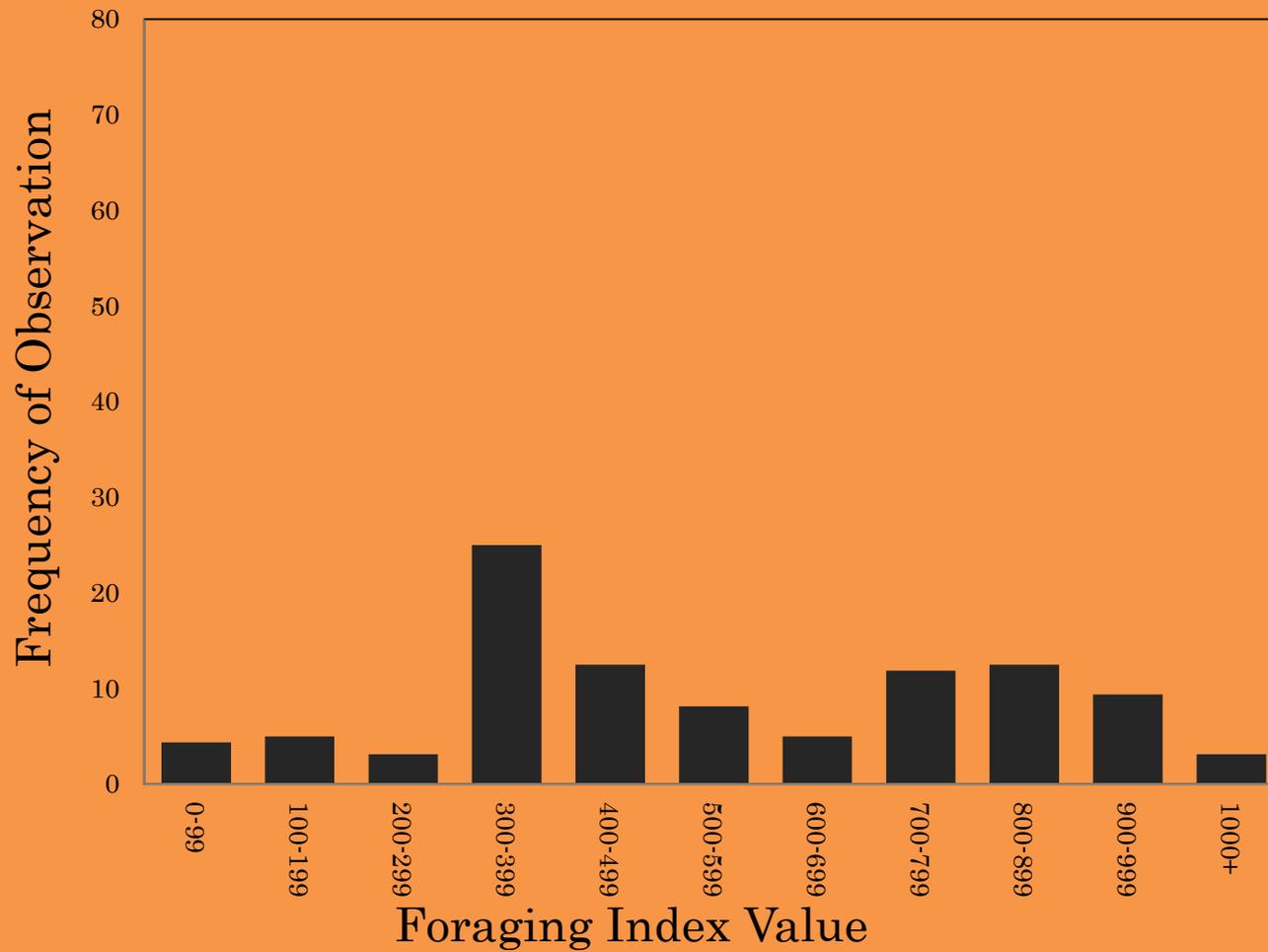
Networks mostly country lanes negligible impacts

Foraging index threshold simulating actual roosts

# When is a road a barrier?

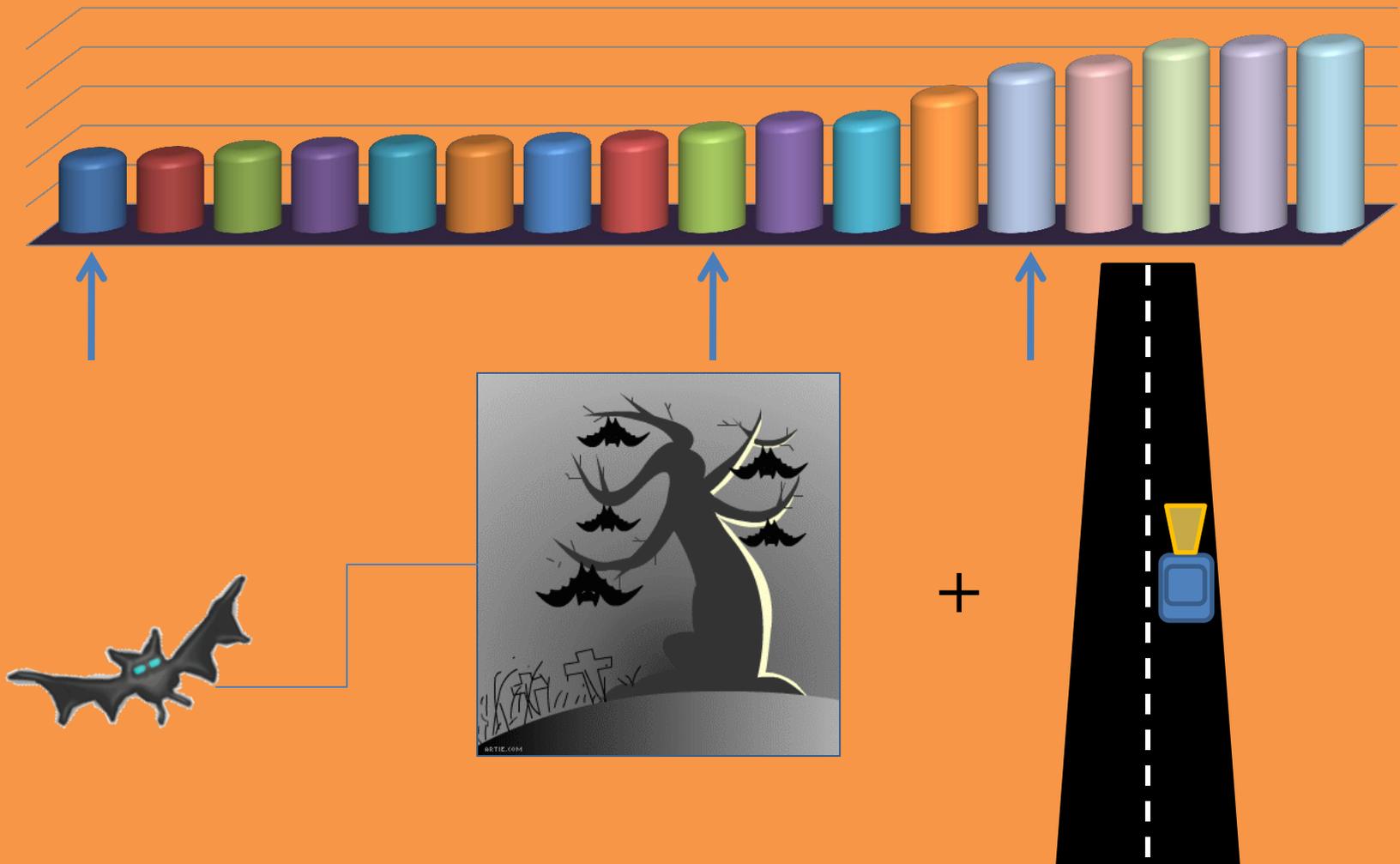


# Real road network impacts?





# Management and Road Development Implications





# Conclusion

- Roads act as barriers and filters to movements and may have important indirect effects (e.g. foraging success)
- Road networks reduce landscape permeability
- Parameterized model useful for scenario comparisons
- Caveats to modeling exercise
  - Variation in site suitability
  - Colony size
  - Alternate foraging preferences (streams & edges)
  - Ultimately modeling and field studies best as feedbacks

# Acknowledgements

- BP Leader Awards & USFS NRS
- David Glista: Indiana Department of Transportation
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