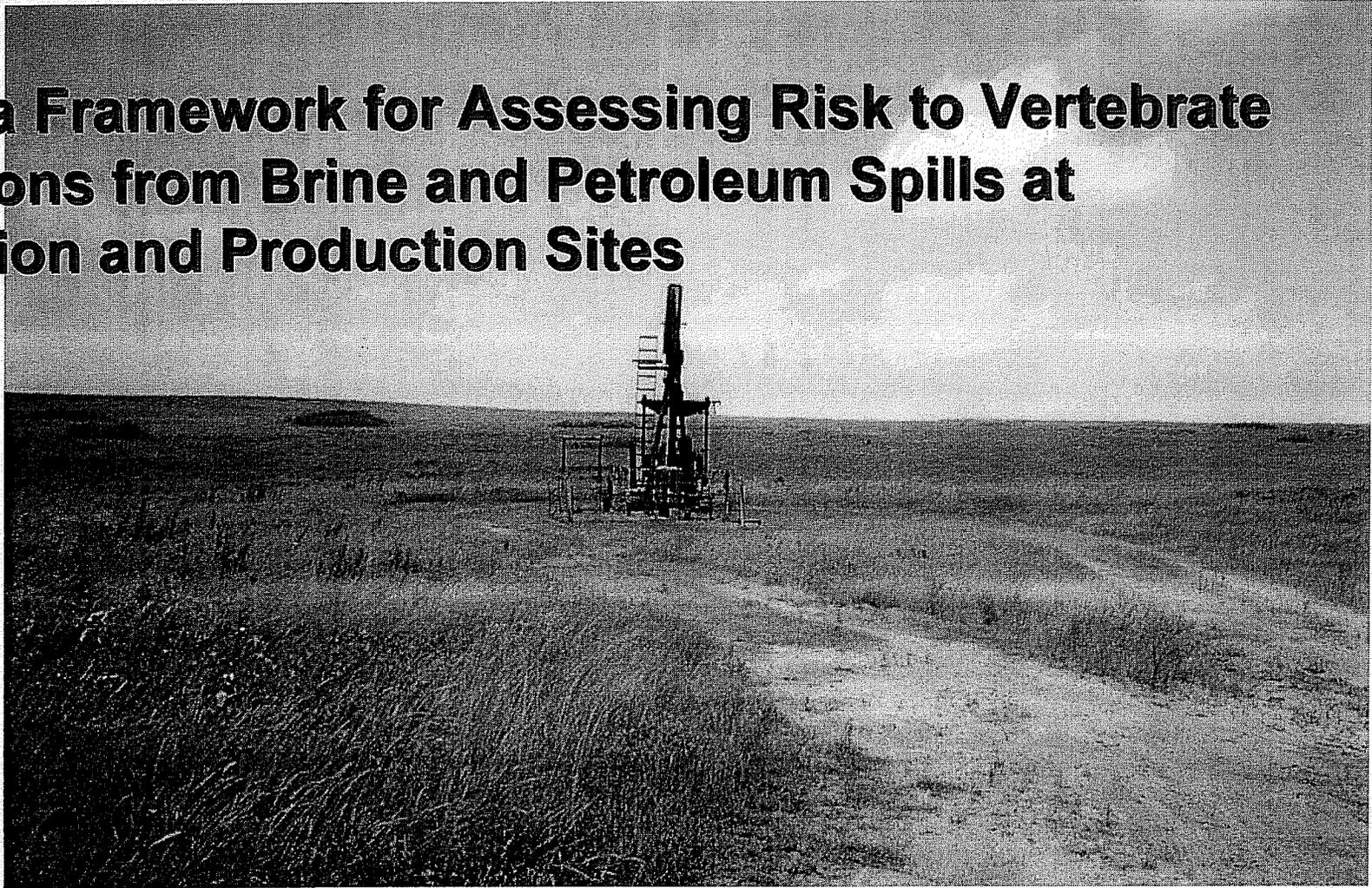


# **Toward a Framework for Assessing Risk to Vertebrate Populations from Brine and Petroleum Spills at Exploration and Production Sites**



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- **The Nature Conservancy**
- **University of Tulsa**
- **Oklahoma State University**

# **General Research goals**

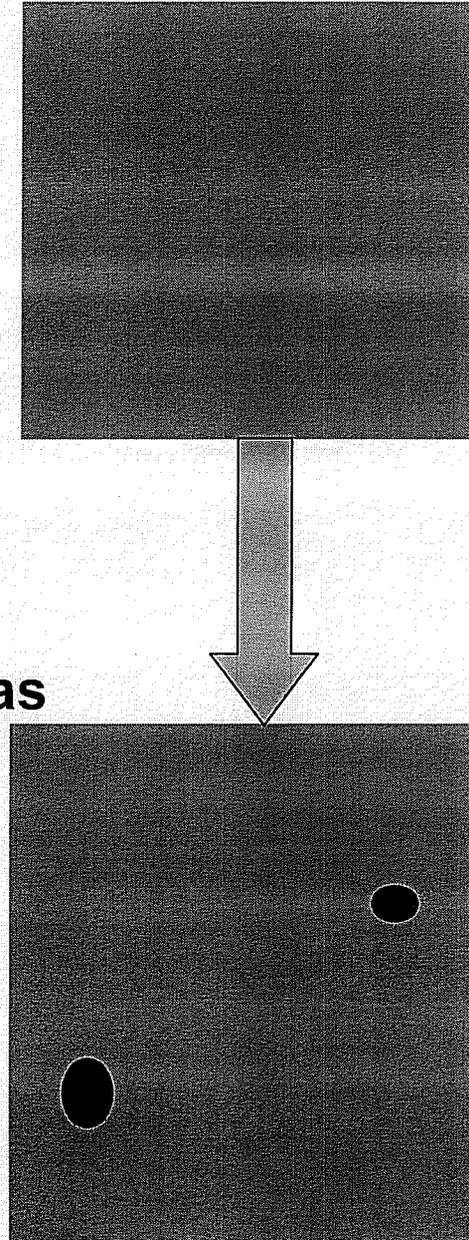
- **Quantify the effects of habitat removal and fragmentation on population densities of vertebrates, especially Allee (density-dependent extinction) effects**
- **Develop an ecological framework for evaluating impacts of brine or oil spills at exploration & production (E&P) sites**
- **Develop exclusion criteria from the ecological risk assessment process based on *de minimus* size and spatial configuration of spills**

# **Justification for habitat-based approach**

- **Large literature on impacts of habitat disturbance and fragmentation on vertebrate populations**
- **Little evidence of terrestrial wildlife exposure to hydrocarbons at E&P sites**
  - **Little uptake of hydrocarbons by wildlife foods**
    - **Little accumulation in plants**
    - **Avoidance by earthworms**
  - **Avoidance of contaminated areas (esp. those with visible well pads) by many vertebrates (exceptions: house mouse, Lochmiller et al. 2000; caribou, Cronin et al. 1998; and lesser prairie chickens, Haukos and Smith 1999)**
  - **Exception: San Joaquin kit fox (>circulating immature red blood cells), deer mice (extramedullary hematopoiesis and adenocortical vacuolation), Charlton et al. 2001.**

# Disturbances at E&P sites

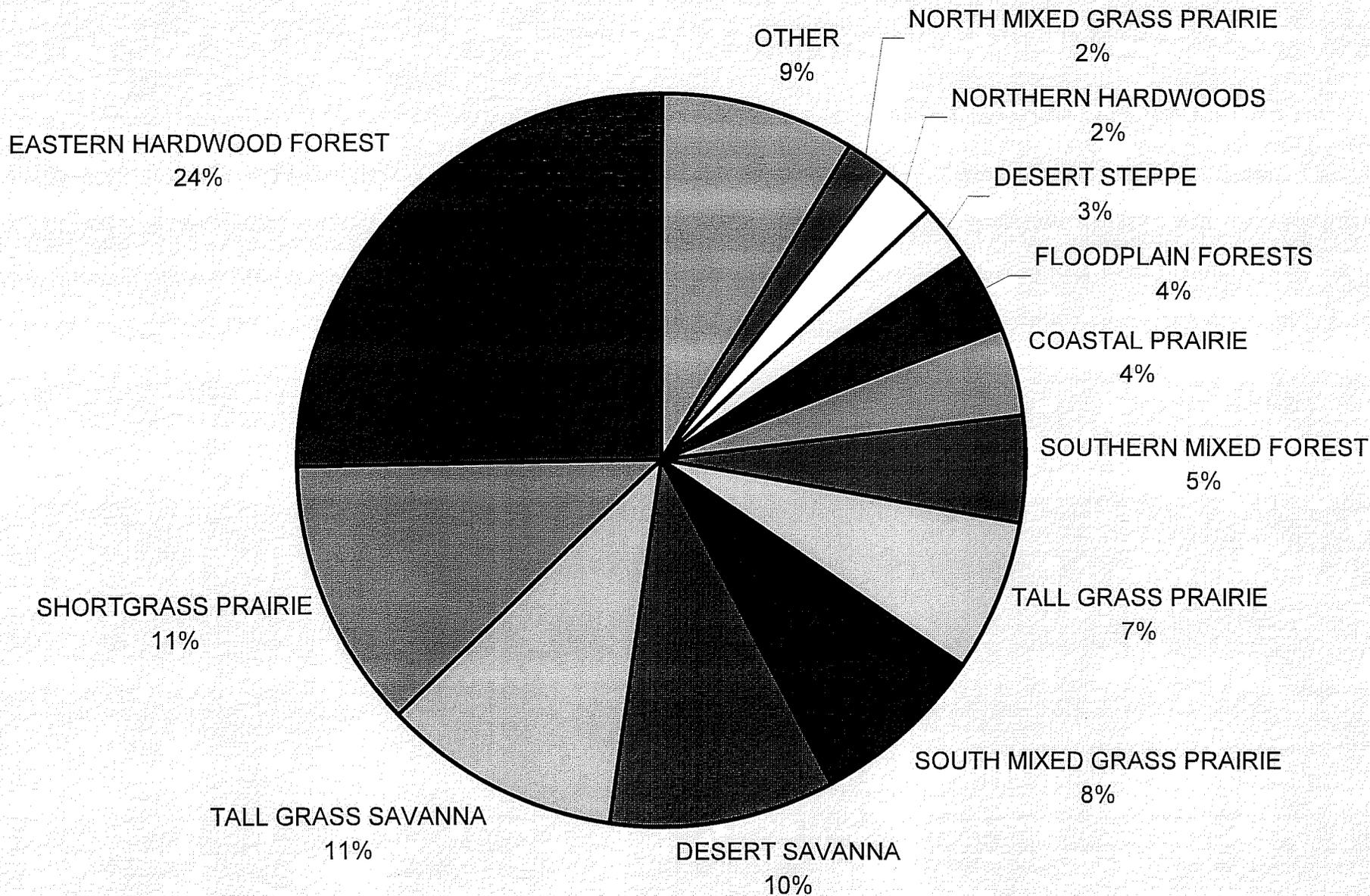
- **Brine spills**
  - Bare ground, denuded of vegetation
  - Erosion
  - Slow recovery, difficult restoration
- **Hydrocarbon spills**
  - Biodegradation, enhanced remediation
  - Rapid recovery, given enough nutrients
  - Slower recovery if plants are sprayed
- **Wellheads, well pads**
  - Large number of small, isolated disturbed areas
- **Pipelines**
- **Roads**
- **Other management disturbances**
  - Grazing
  - Prescribed burns
  - Mowing



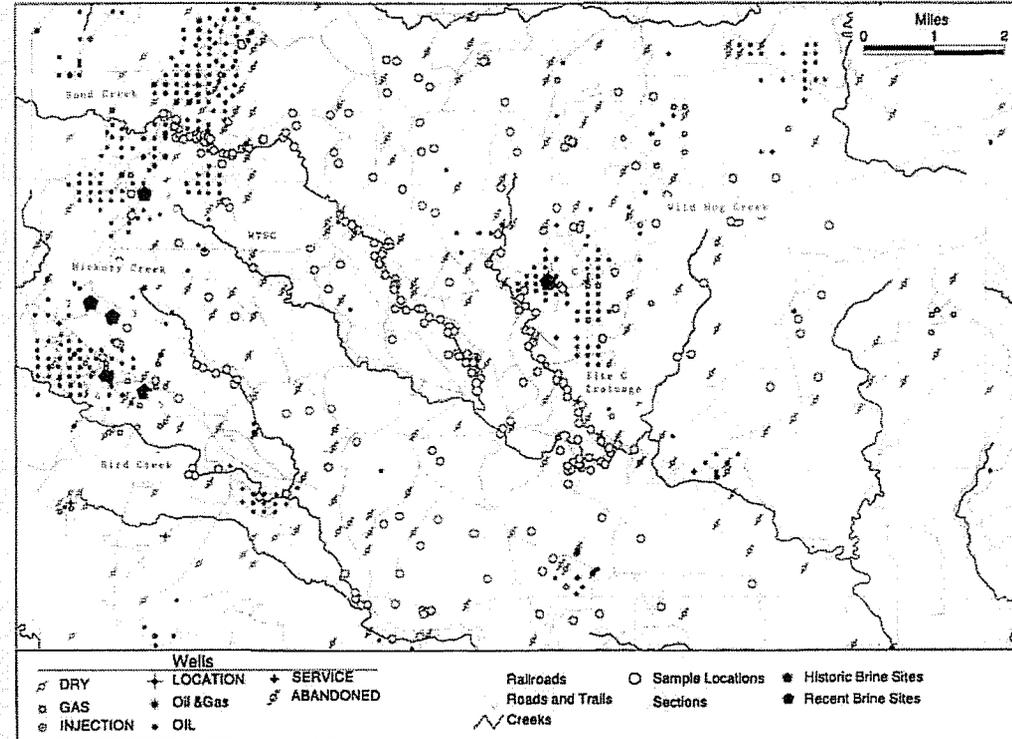
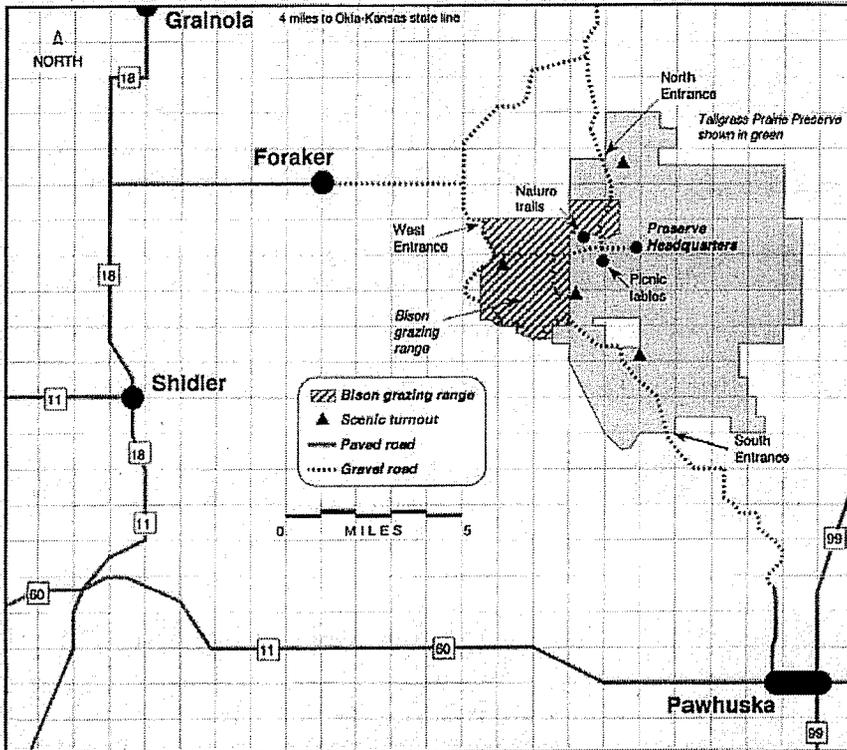
# **Link from habitat disturbance to population-level effect**

- **Individuals unable to find territories may emigrate**
- **Movement costs may increase for animals that avoid or do not settle in disturbed areas**
- **Forage vegetation or prey may be less available**
- **Animals may be unable to find mates or breeding territories**
- **Remaining habitat may provide fewer refuges from predators**

# Ecosystems where wells are located in the US (Kuchler vegetation form)

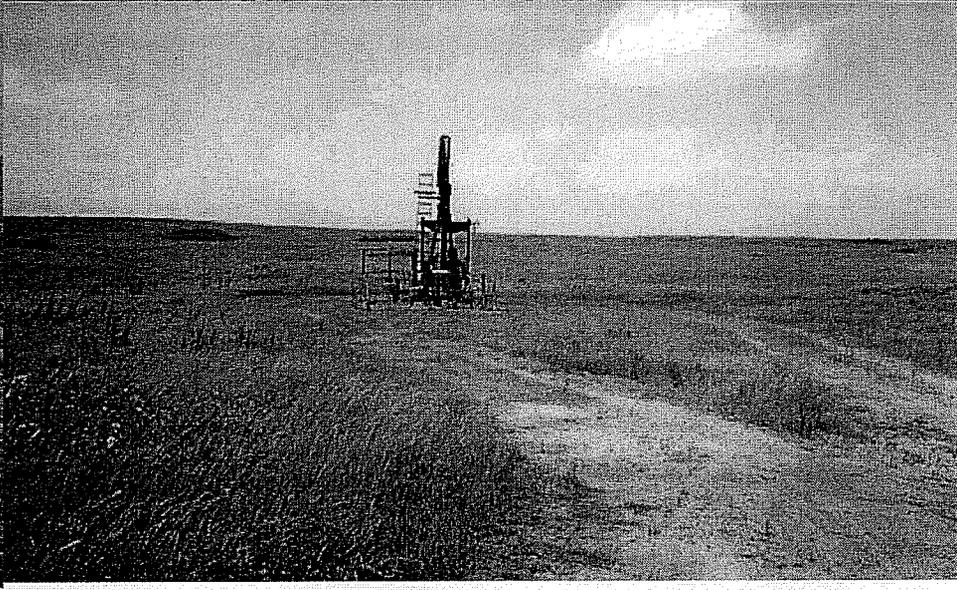
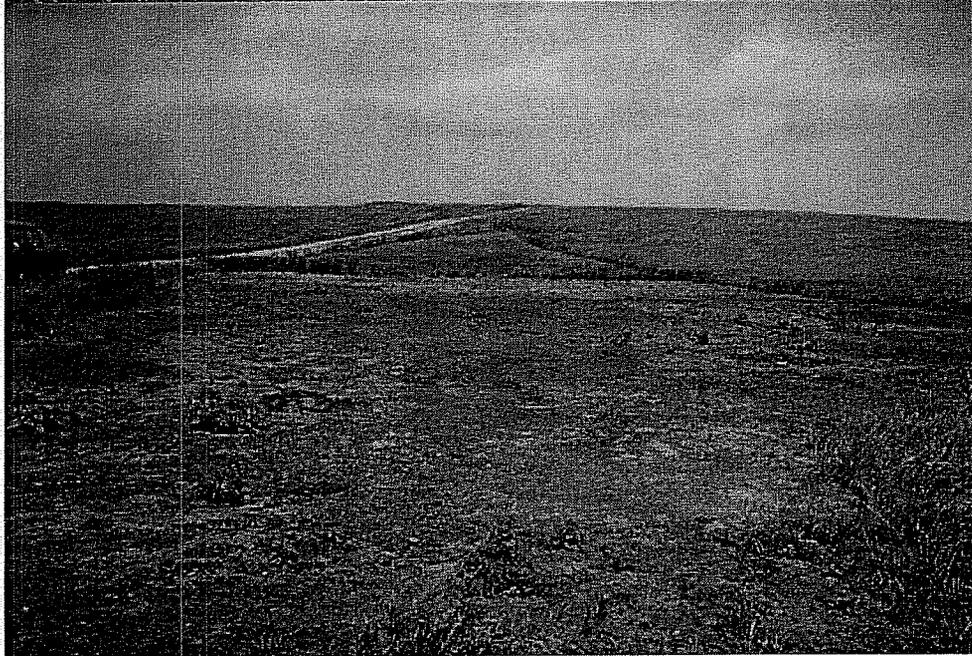
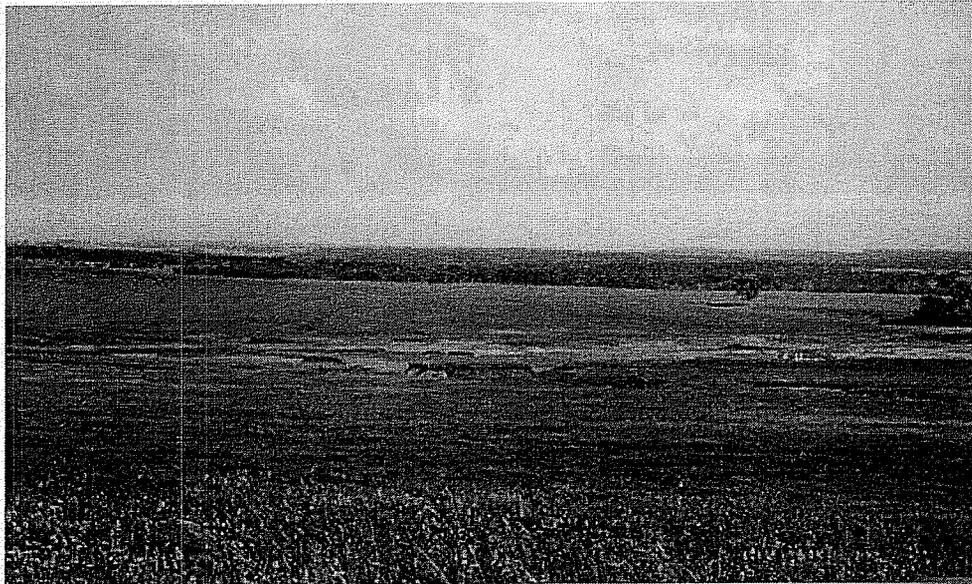


# Tallgrass Prairie Preserve, Osage County, OK



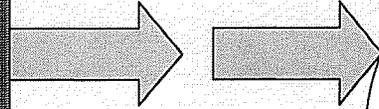
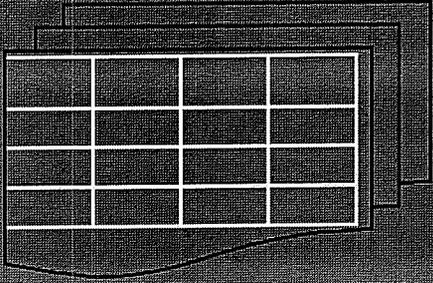
- 15200 ha, owned by Nature Conservancy
- 0.1% disturbed by brine scars, maximum spill area--4.9 ha
- 1% directly disturbed by spills, well pads, structures, roads
- 600 historic, 120 active oil and gas wells
- Additional wells outside preserve
- Bison grazing, prescribed burns

# Example areas of impact



# HABITAT

Maps of  
(1) disturbed area/spills,  
(2) foraging habitat,  
(3) predator habitat

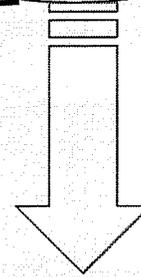


Juveniles

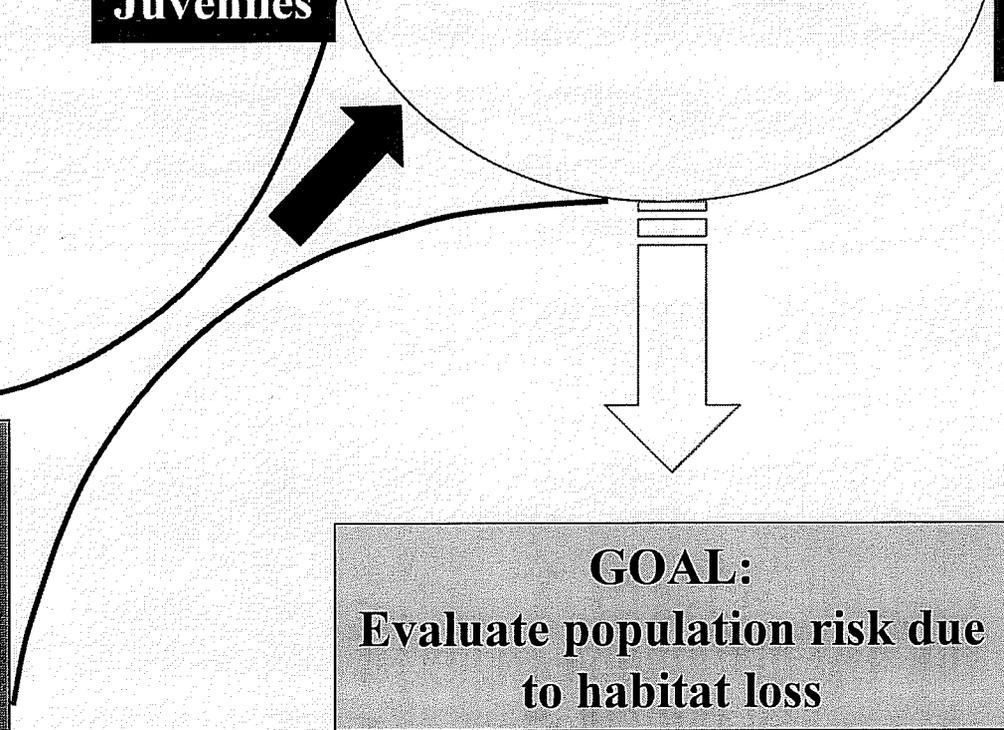
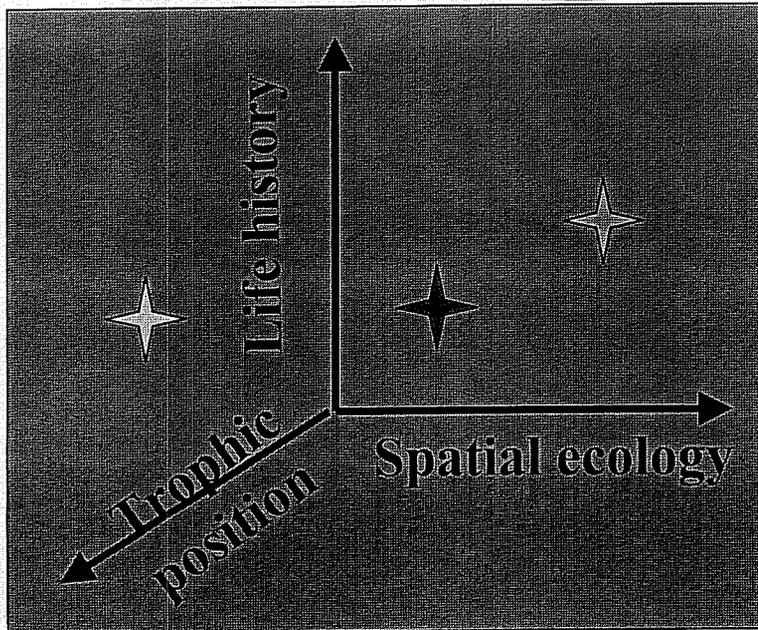
Offspring

POPULATION  
MODEL

Adults



# SPECIES

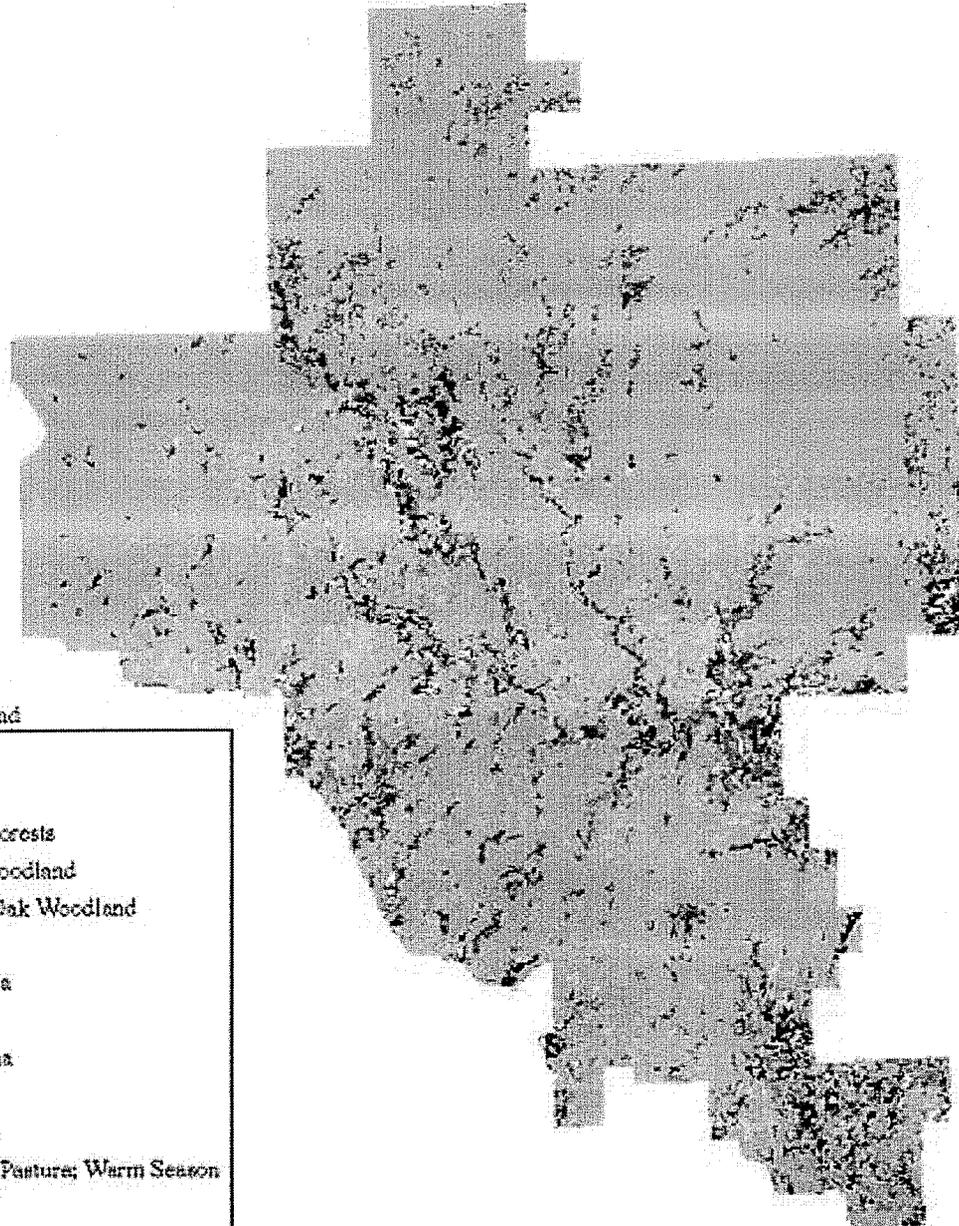


**GOAL:**  
Evaluate population risk due  
to habitat loss

# **GIS layers for use in modeling vertebrate populations at E&P sites**

<b>Data layer</b>	<b>Use</b>
<b>Digital elevation model</b>	<b>Predict pipeline rupture, fluid flow, erosion, slopes unsuitable for animal movement</b>
<b>Raster coverage of vegetation categories</b>	<b>Depict forage, predator refuges; habitat suitability</b>
<b>DOQQ, Landsat, AVIRIS</b>	<b>Depict changes in spill boundaries, habitat suitability over time</b>
<b>Vector coverages of roads, fence-lines</b>	<b>Depict potential barriers to movement or habitat suitability</b>
<b>Vector coverage of site boundary</b>	<b>Depict boundary of local population of concern</b>
<b>Raster coverages of wells, tank farms, other structures</b>	<b>Depict potential barriers to movement or low habitat suitability</b>
<b>Raster coverages of veg. disturbances (e.g, grazing)</b>	<b>Contribute to habitat suitability</b>
<b>Raster coverage of soil taxonomy</b>	<b>Provide soil texture information relevant to burrowing mammals</b>

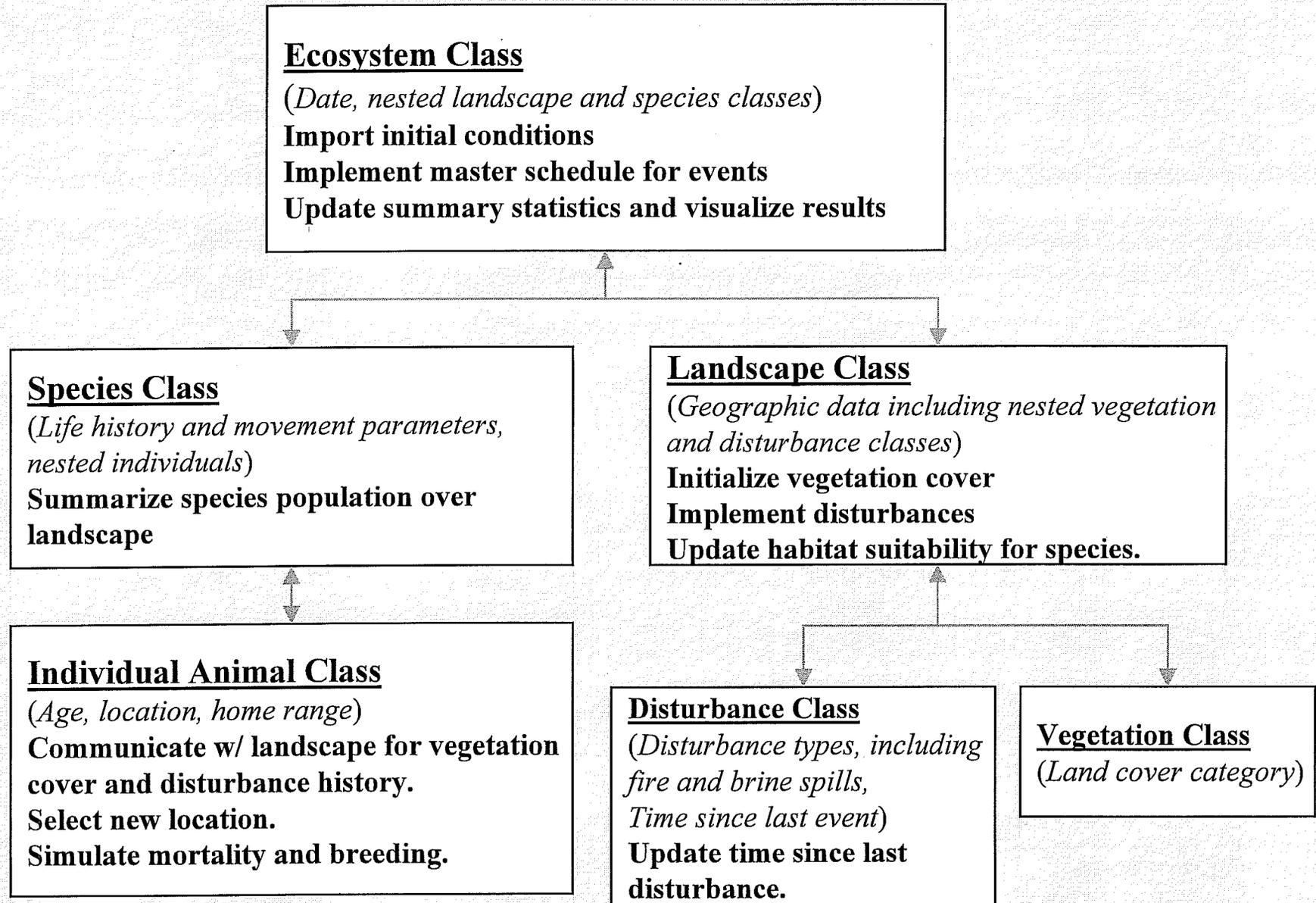
# Vegetation map from Oklahoma GAP program



Legend

- Oak - Cedar Forests
- Central Crosstimbres
- Central Bottomland Forests
- Eastern Red Cedar Woodland
- Eastern Red Cedar - Oak Woodland
- Oak Woodland
- Tallgrass Oak Savanna
- Tall Grass Prairie
- Midgrass Oak Savanna
- Midgrass Prairie
- Crop - Warm Season
- Improved/Introduced Pasture; Warm Season
- Residential/Industrial
- Lake/Reservoir
- Tallgrass Cedar Savanna

# Diagram of General Model Template



# Habitat-based model (ORNL)

- **Individual-based model**
  - Includes breeding, mating, post-mating, birthing, rearing offspring, and dispersal
- **Daily time-steps**
- **30-meter resolution**
- **Flexible approach to variation in life history**
- **American badger--test species**
- **Territory acquisition and movement, major components**
- **Habitat suitability based on vegetation cover (presence of small, fossorial mammals, of burrowing requirements), disturbance history**
- **Brine scar disturbances**
  - assumed to be complete with no benefit to badgers
  - result in high movement survival costs
- **Daily chance of survival influenced by age, habitat quality, and movement**

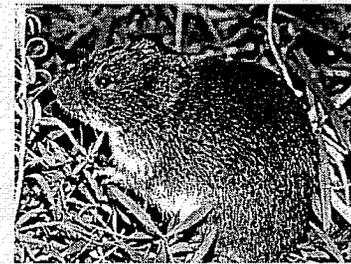


# Trophic model (LLNL)

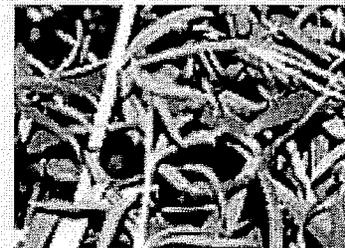
- Individual-based model
- 30-meter resolution
- Prairie vole--test species
- Resource (green vegetation) growth and grazing
- Climatic dependence of breeding and vegetation growth
- Territorial behavior (residents and wanderers, home range)
- Survival based on sufficient food and age constraints
- Reproduction based on mating, nesting, maturity, generation time
- Spatial dispersal due to search for empty nesting locations with sufficient vegetation
- Predation



predator



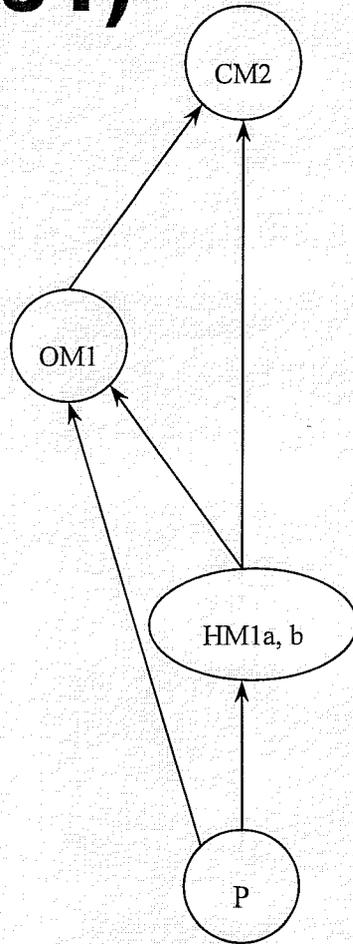
herbivore



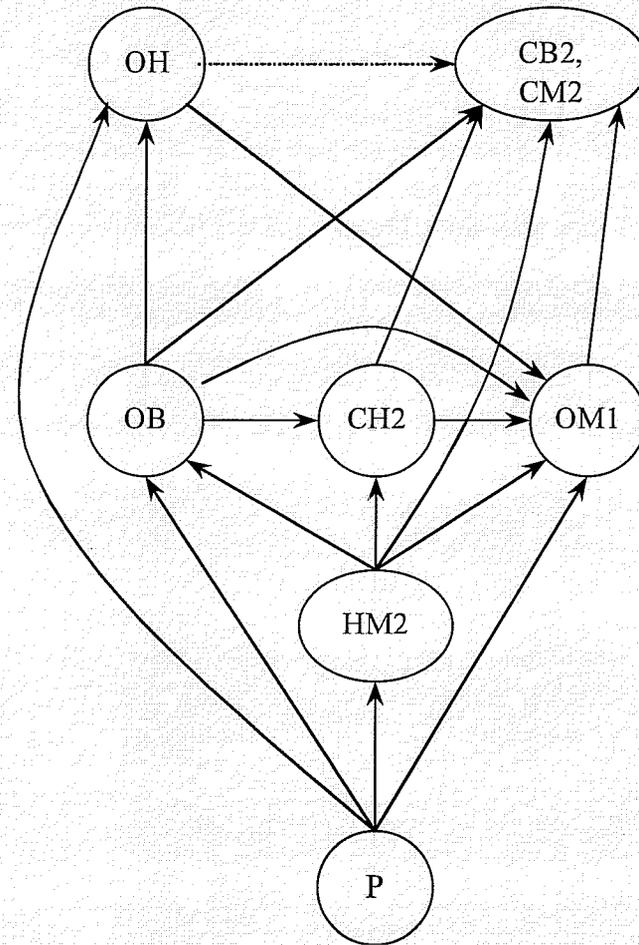
resource



# Protocol for developing site-specific conceptual trophic models (Stevenson et al. 2001)



(a) Large Herbivorous Mammals



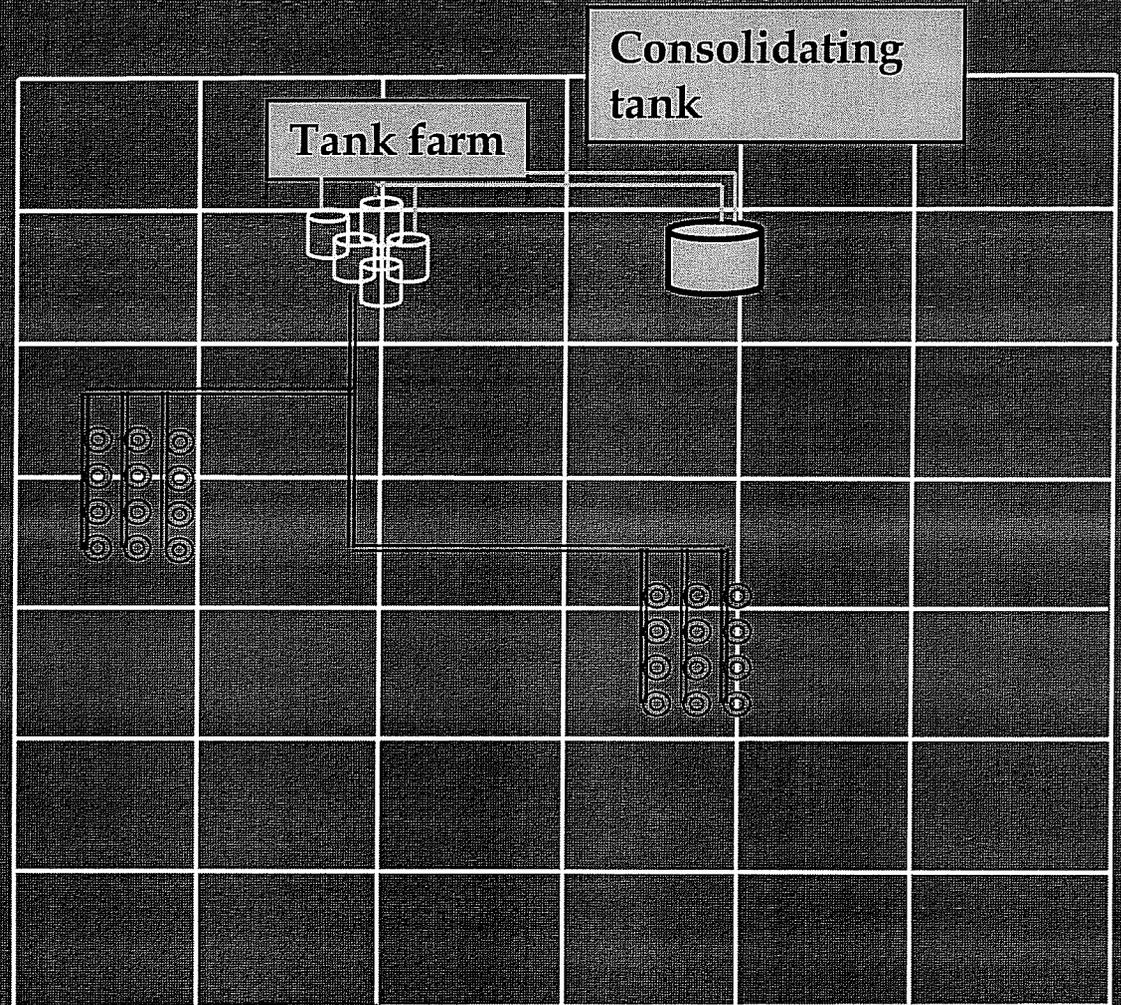
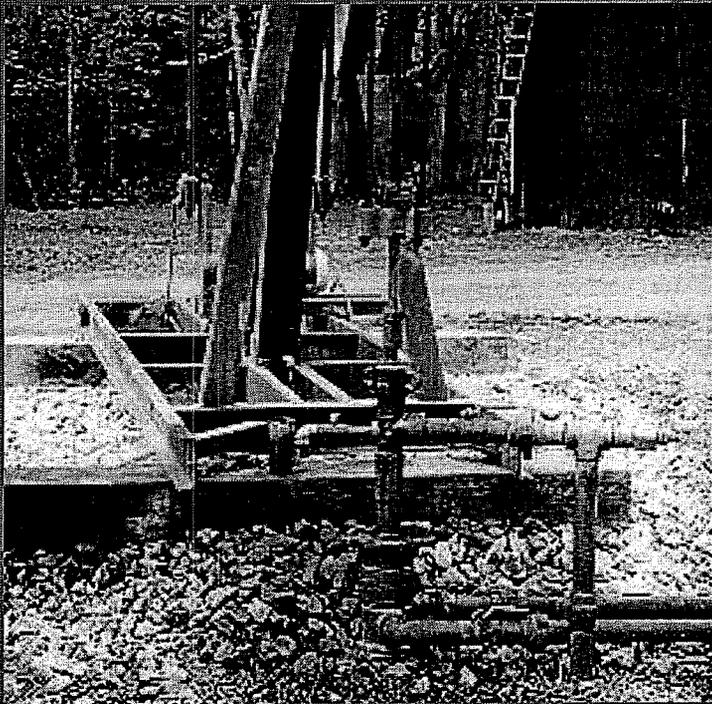
(b) Small Herbivorous Mammals

Example source food webs for the Tallgrass Prairie Preserve

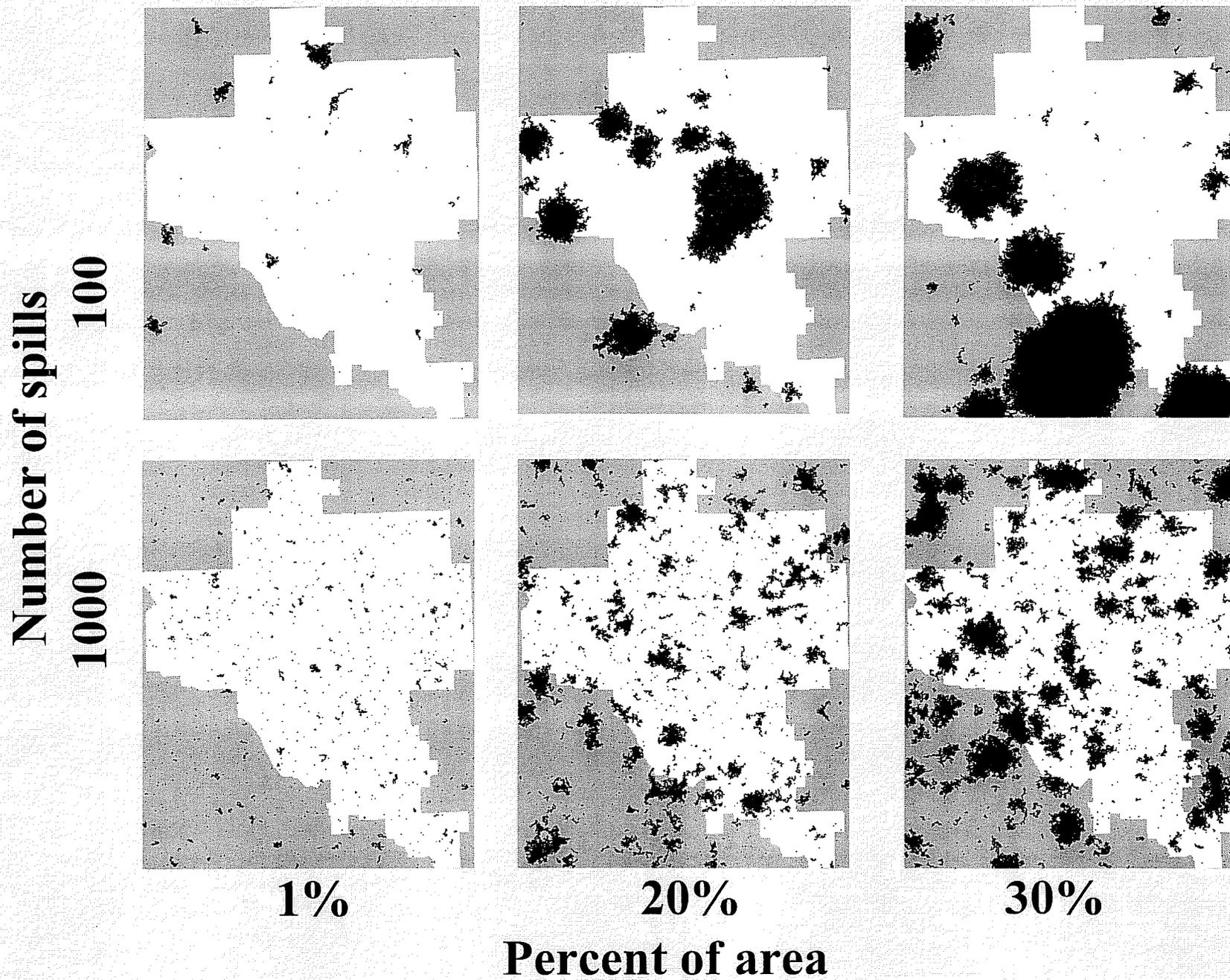
# **Artificial landscapes**

- 1. Impenetrable structures distributed randomly across landscape (trophic model)**
- 2. 0.09-ha spills distributed randomly across landscape (trophic model)**
- 3. Two alternative stochastic models for generating brine spills :**
  - a. Poisson-gamma model (less realistic) selects the center gridcell for each spill at uniform random and draws the area of spill from a gamma distribution. The spread of the spill from the center is determined by this spill area.**
  - b. Well-complex model places wells on a grid with a typical network of pipes. The length of pipe in each cell determines its likelihood of experiencing a spill, whereas the upstream flow contribution of pipes carrying brine through the cell determines the area of spill, if one occurs.**

# Well-complex arrangement

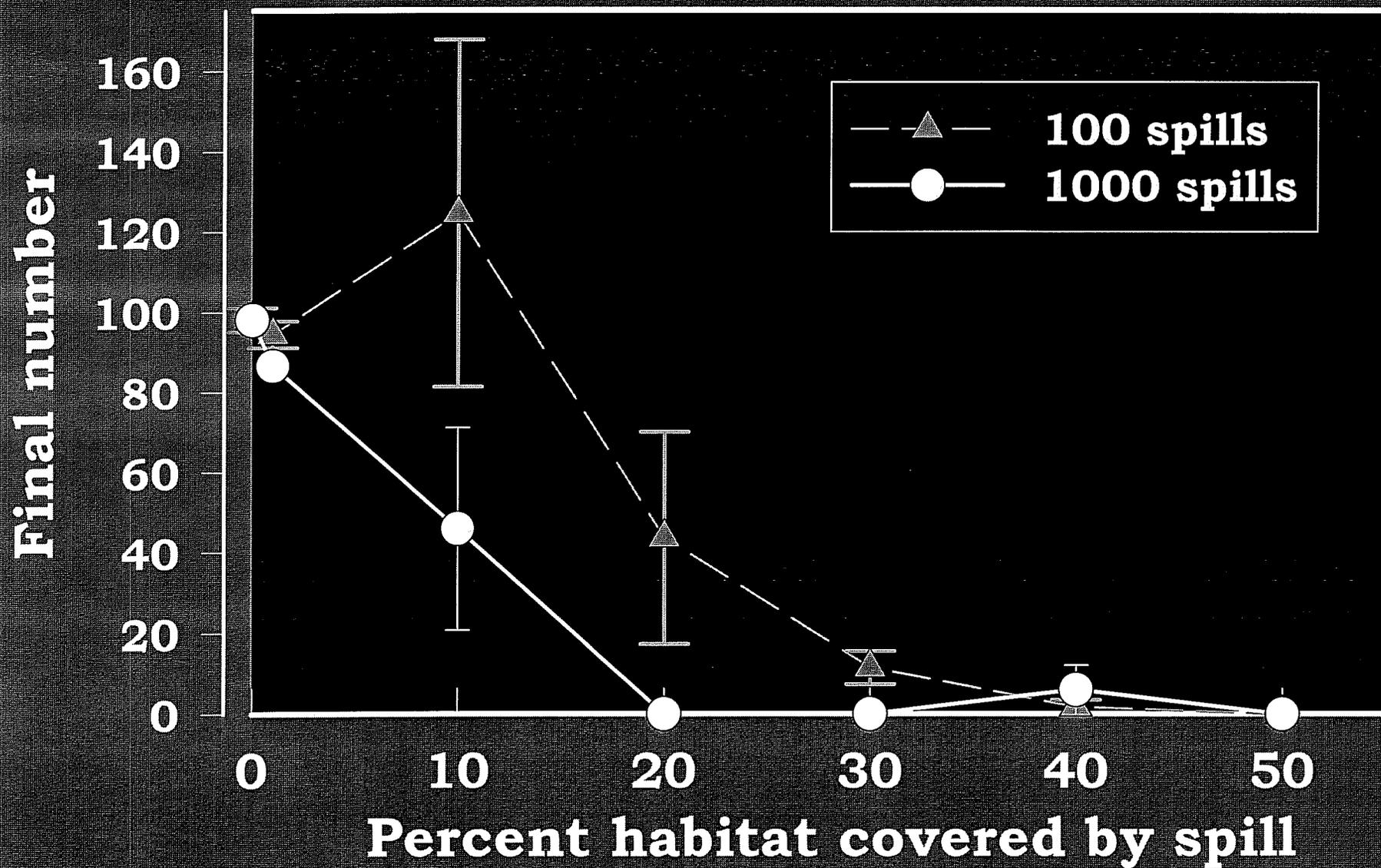


# Example spills

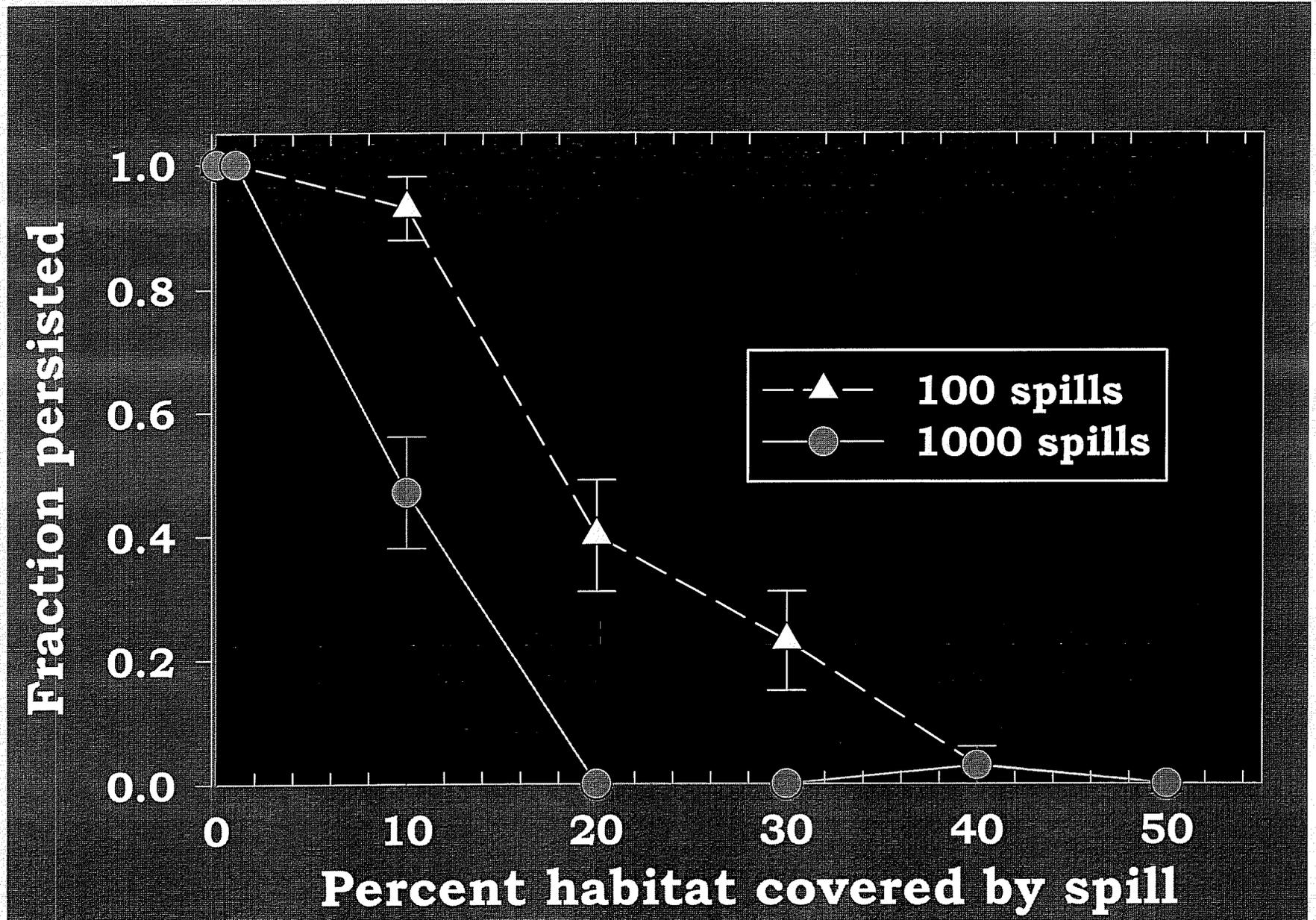


# Results

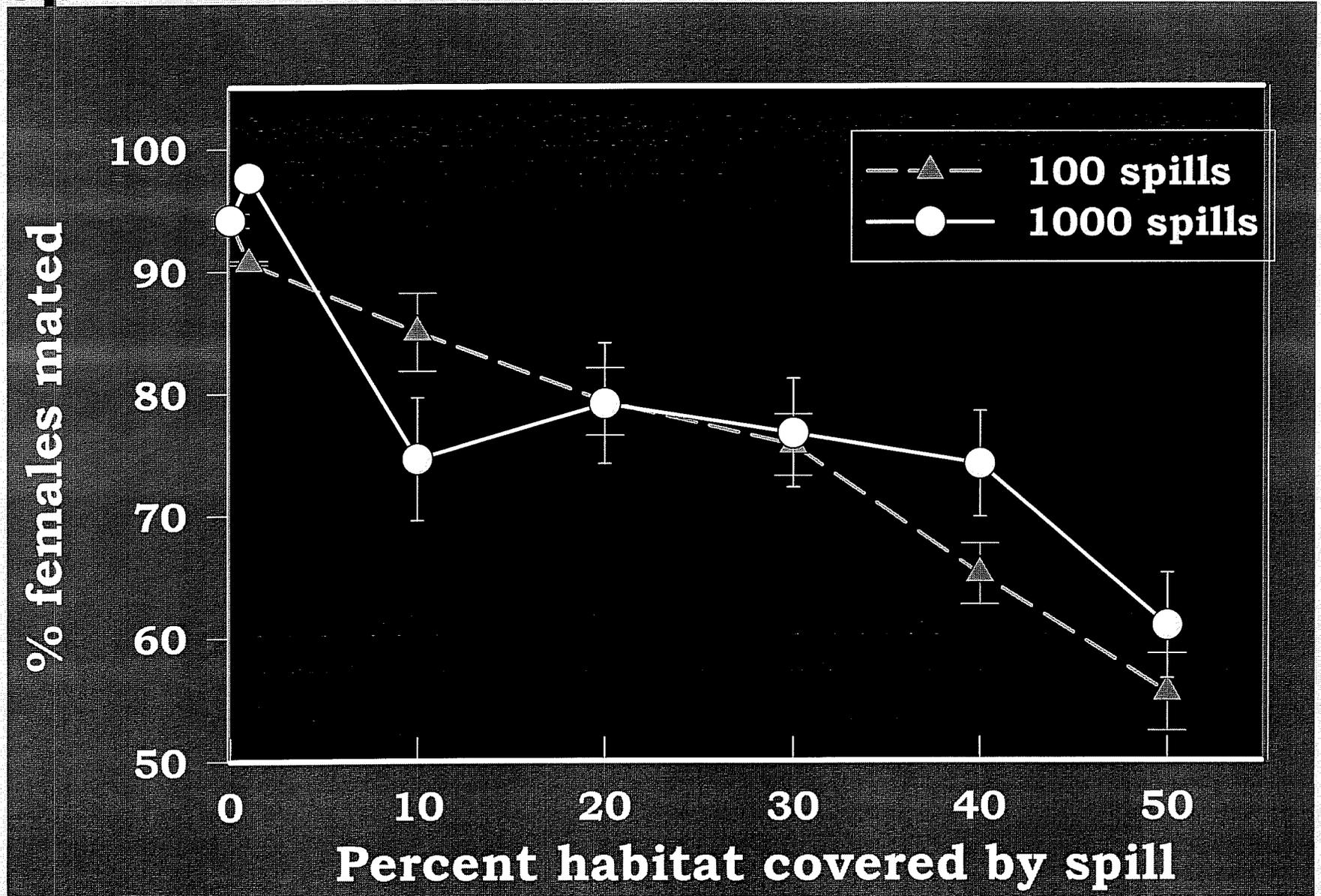
# Simulated habitat loss caused decrease in final badger population size



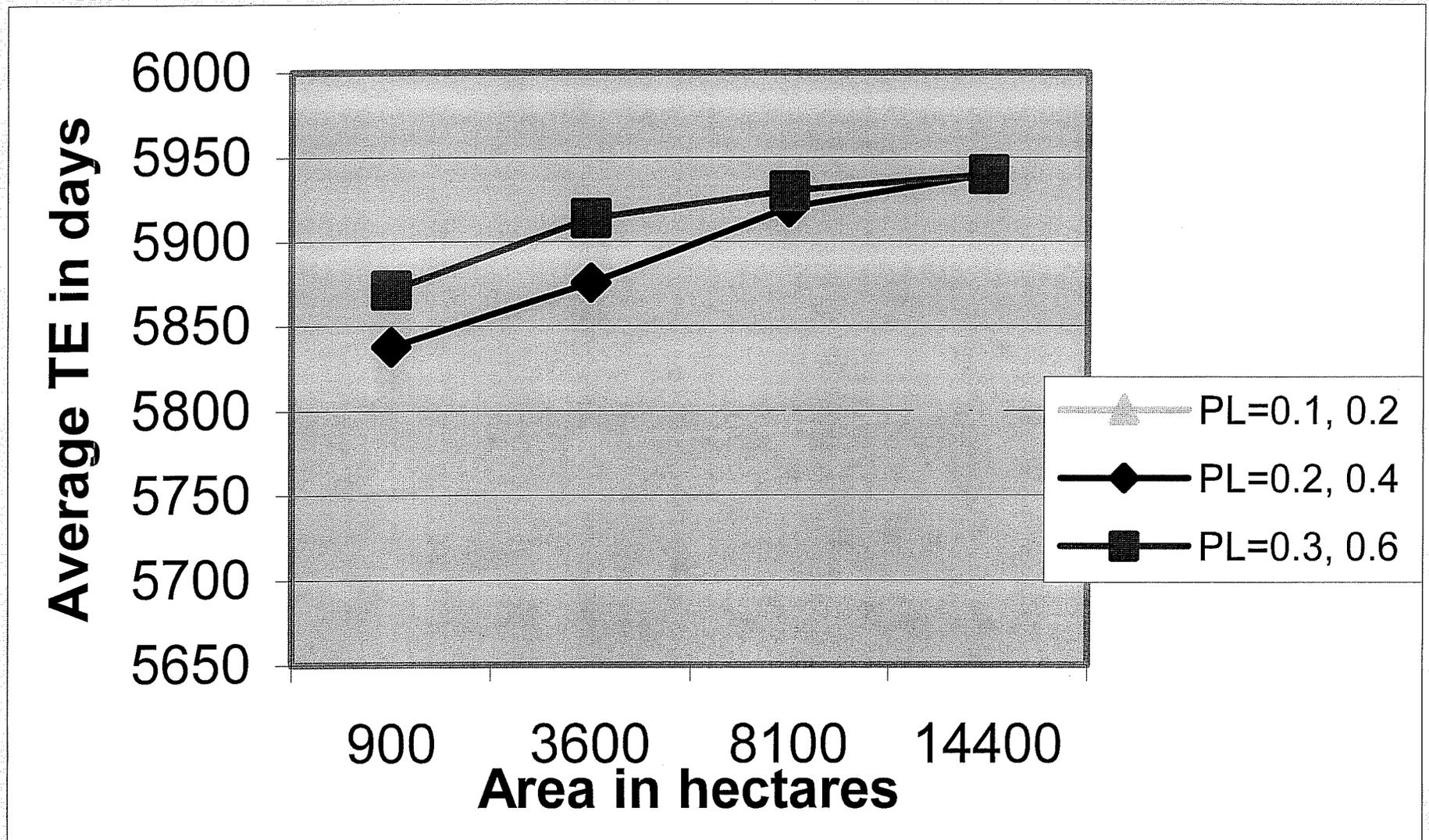
# Simulated habitat loss caused decrease in persistence to 100 y



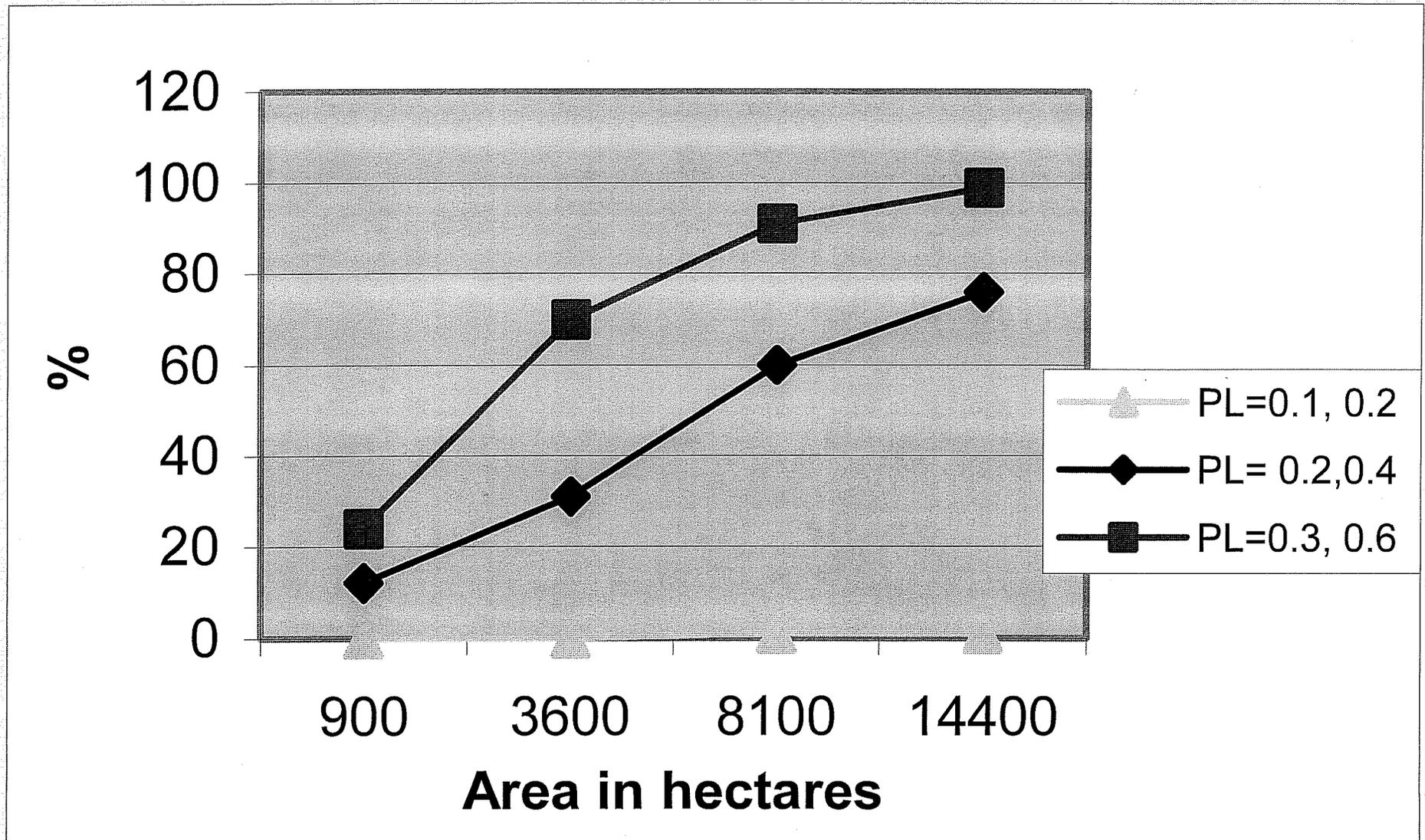
# Allee effects (failure to find mates at low densities) contributed to simulated population declines



# Time-to-extinction for vole populations persisting less than 30 years, as a function of habitat area and predation



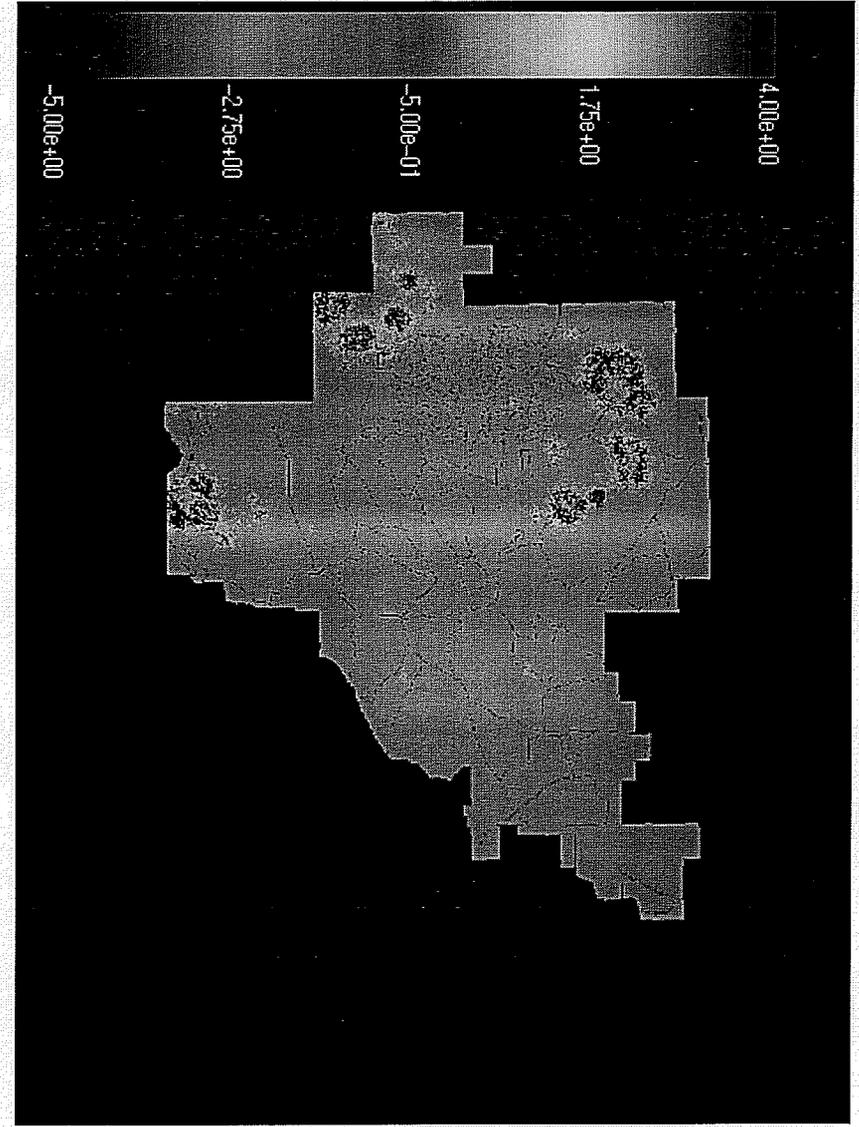
# Percentage of simulations in which vole populations persisted more than 30 years, as a function of habitat area



# Simulated vole density dynamics in TPP



A) Realistic representation of roads, non-grass vegetation patches

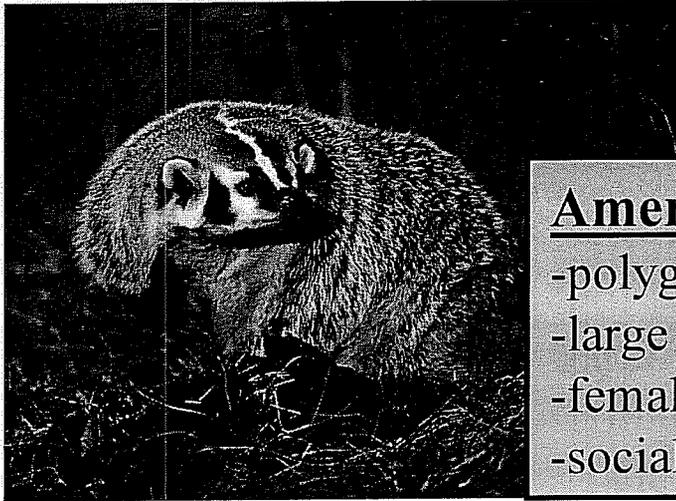


B) Fragmentation from A + 1000 artificial 0.09-ha spills in the north

# **Summary of simulation results**

- **American badger populations decrease with increasing spill area, and the probability of a population crash increases with disturbance area.**
- **Fragmentation, as measured by number of spills, increases effects on badger populations.**
- **The time to extinction for prairie vole populations decreases with increasing spill area, if the ratio of spill area to total area is large enough.**
- **Vole density is sensitive to the interaction of predation and fragmentation, with fragmentation causing population extinction in the presence of predation and stabilizing the population in the absence of predation.**

# Potential species differences in response



## American badger

- polygynous
- large territory
- female parental care
- socially intolerant

## Higher sensitivity?

- species with high site fidelity
- edge-sensitive species
- habitat specialists
- less-mobile species

## Prairie chicken

- polygynous
- form leks to breed
- avoid high vegetation



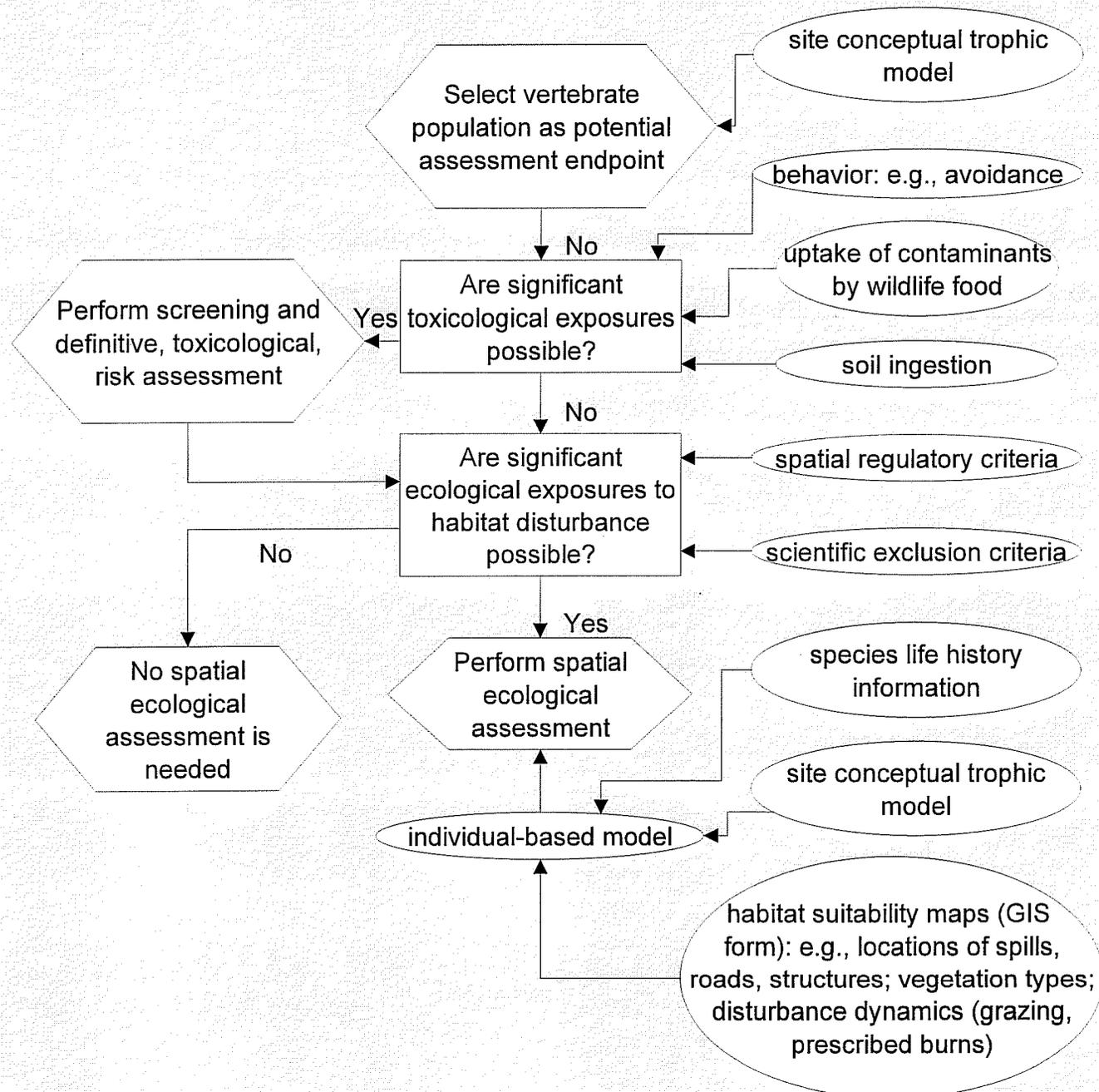
## Grasshopper sparrow

- monogamous, territorial
- male parental care
- avoids high vegetation



Photo by J.A. Spendlow

# Preliminary ecological framework for evaluating vertebrate populations at E&P sites



# **Exclusion criteria**

- **Precedent**
  - **Pennsylvania Department of Environmental Protection assumes that 2 acres of surface soil contamination does not pose risk to vertebrate populations**
- **Thresholds in ecological literature**
  - **Coty et al. (2003) review minimum patch size requirements (e.g., areas below which species are never found or which are associated with unsustainable populations) of several species and taxonomic groups**
- **This study**
  - **Insufficient species, ecosystems, and model structures have been tested to recommend general criteria for excluding E&P sites from formal ecological assessment.**
  - **Declines of population density and time to extinction are observed, related to area of disturbance (arguably not precipitous enough to be called thresholds).**
  - **The disturbed area of concern may depend on the number of spills.**
  - **Predation can alter the result of fragmentation on a prey species.**

# **Future Plans**

- **Conduct sensitivity analyses.**
- **Modify habitat model for animals of different life histories.**
- **Simulate impacts of fragmentation caused by different patterns of new roads and wells on vertebrate populations.**
- **Provide results that are useful for developing good management practices for new road and well development during petroleum exploration.**
- **Develop spatial decision framework for locating new wells or restoring spills or old well pads.**
- **Verify results with field investigations.**