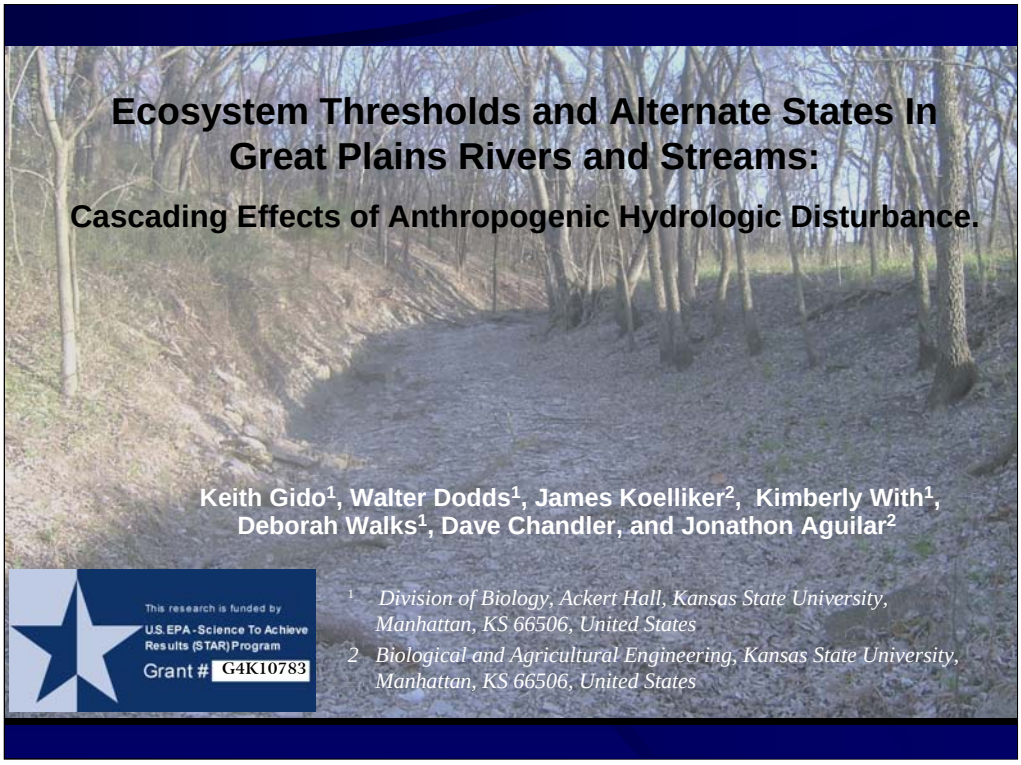


Ecosystem Thresholds and Alternate States In Great Plains Rivers and Streams:

Cascading Effects of Anthropogenic Hydrologic Disturbance.

Keith Gido[1], Walter Dodds[1], James Koelliker[2], Kimberly With[1], Deborah Walks[1], Dave Chandler, and Jonathon Aguilar[2]

This research is funded by U.S. EPA - Science To Achieve Results (STAR) Program
Grant # G4K10783

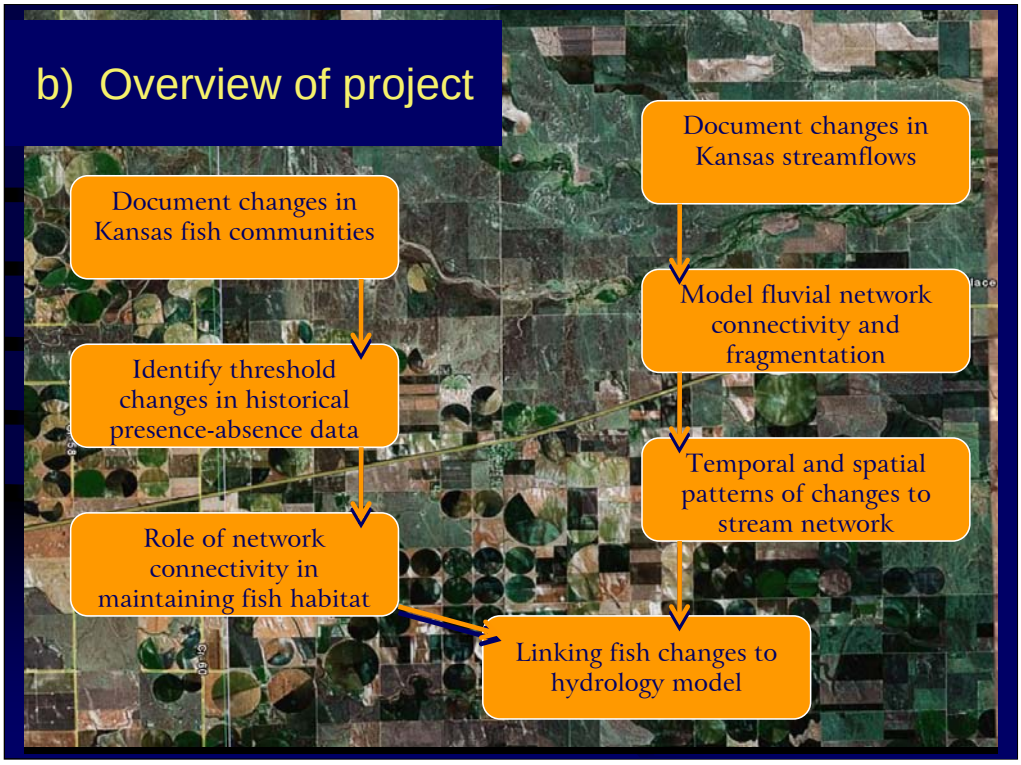
1 *Division of Biology, Ackert Hall, Kansas State University, Manhattan, KS 66506, United States*

2 *Biological and Agricultural Engineering, Kansas State University, Manhattan, KS 66506, United States*

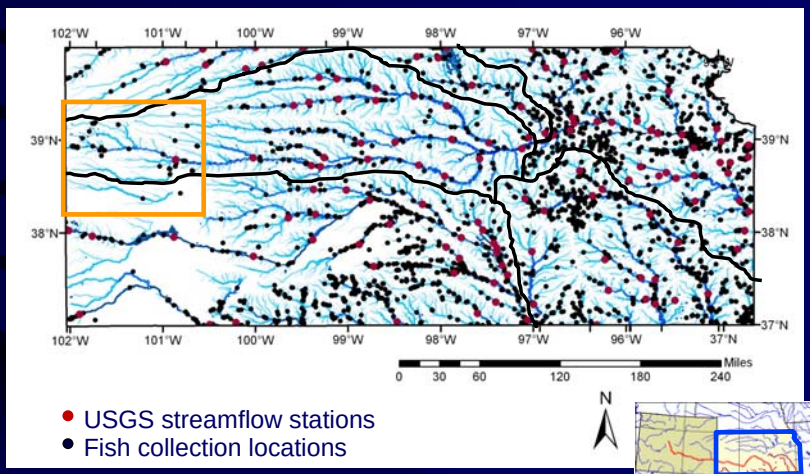
a) Streamflow and connectivity threshold

Streamflow controls the quality, quantity and connectivity of biotic habitat in rivers

- Ecological significance:
  - Fish species losses, introductions and redistribution
- Ecosystem services affected by threshold change in streamflow:
  - Water quantity and quality
  - Increased flood protection
  - Localized increased and decreased fishing opportunities
  - Loss of biodiversity, genetic resources
  - Reduced aesthetic value
  - Reduction in recreation and ecotourism


b) Overview of project
Document changes in Kansas fish communities
Identify threshold changes in historical presence-absence data
Role of network connectivity in maintaining fish habitat
Document changes in Kansas streamflows
Model fluvial network connectivity and fragmentation
Temporal and spatial patterns of changes to stream network
Linking fish changes to hydrology model

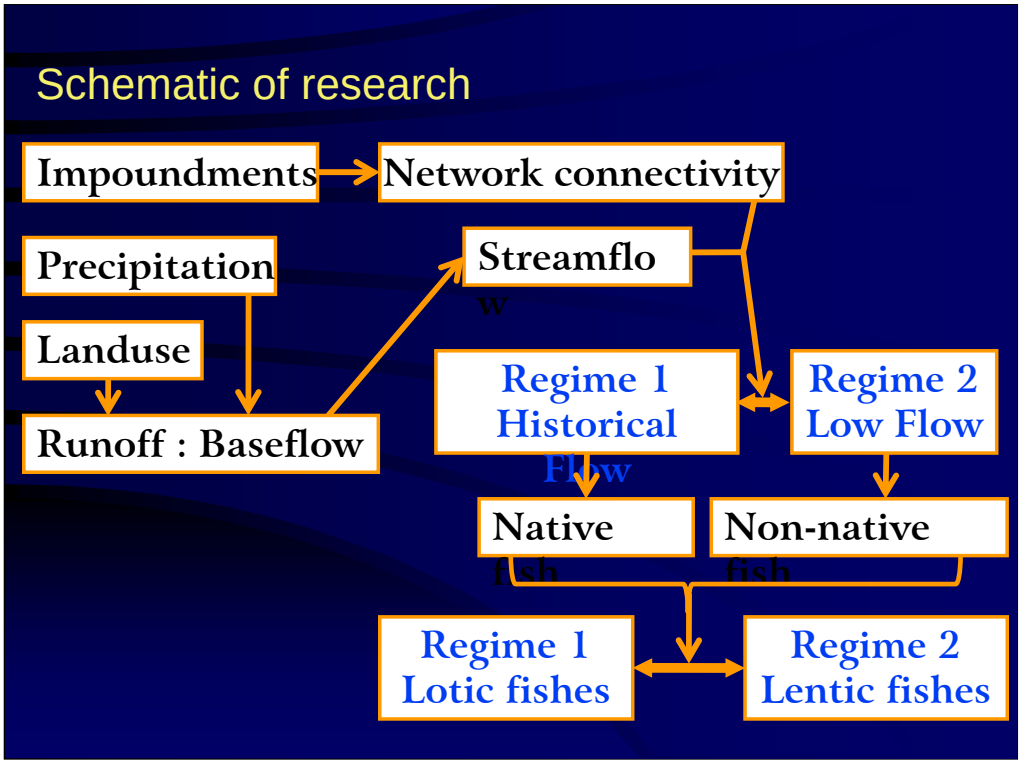
c) Study site



- USGS streamflow stations
- Fish collection locations

Division into major basins

Precipitation and land use records

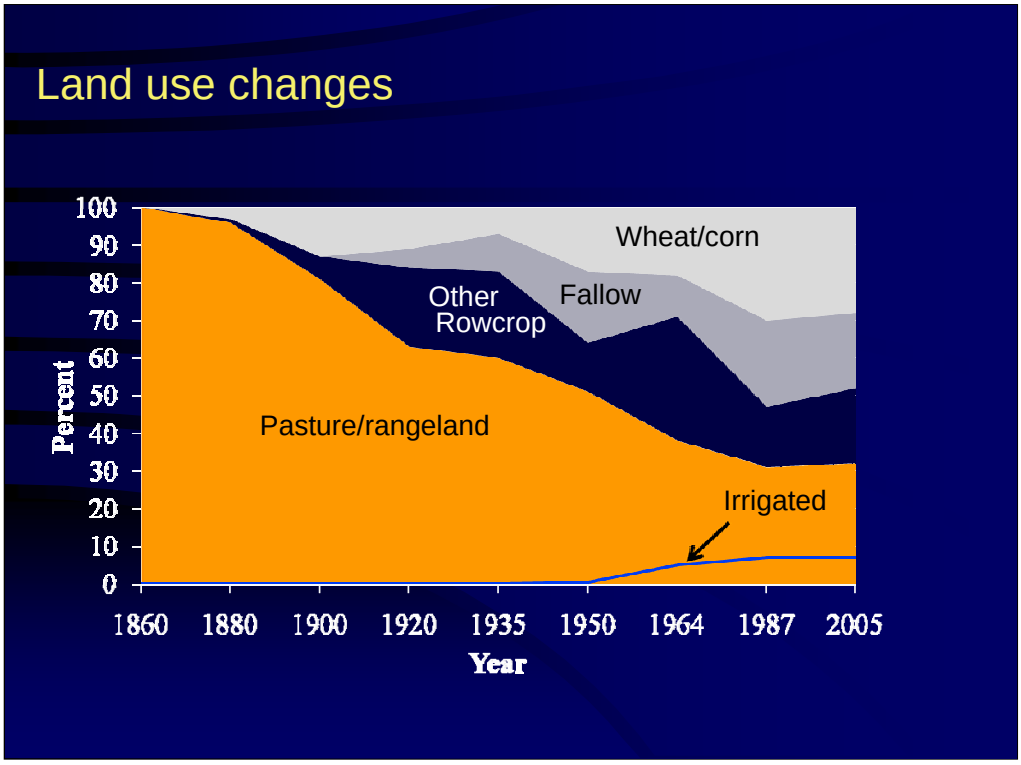


There are two study sites: the Smoky Hill River basin (the upper headwaters of the Kansas River basin) and the Arkansas River basin. Contrasting the changes in the two basins has been informative in evaluating the importance of the thresholds. In addition, much information on stream flow changes has come from eastern Kansas. Water quantity has not changed significantly, but fragmentation has occurred and new species have been introduced.

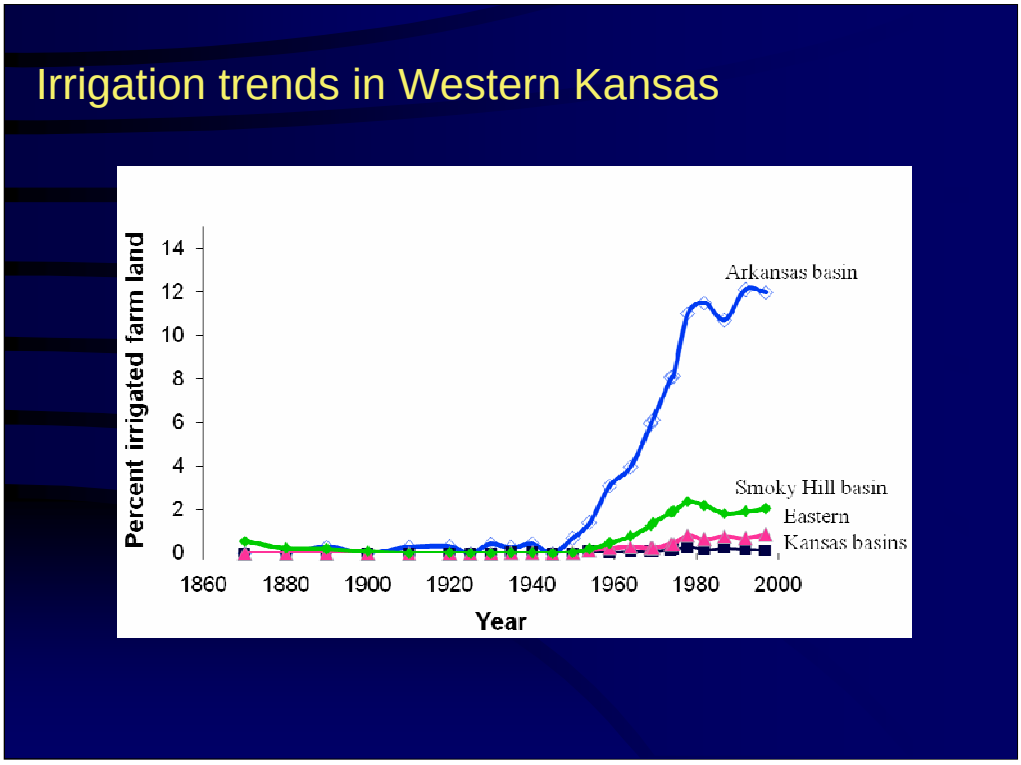
Outline

- **Land use and precipitation**
- Thresholds in streamflow
- Fish habitat changes
- Detecting changes in historical data
- Thresholds of fish community structure

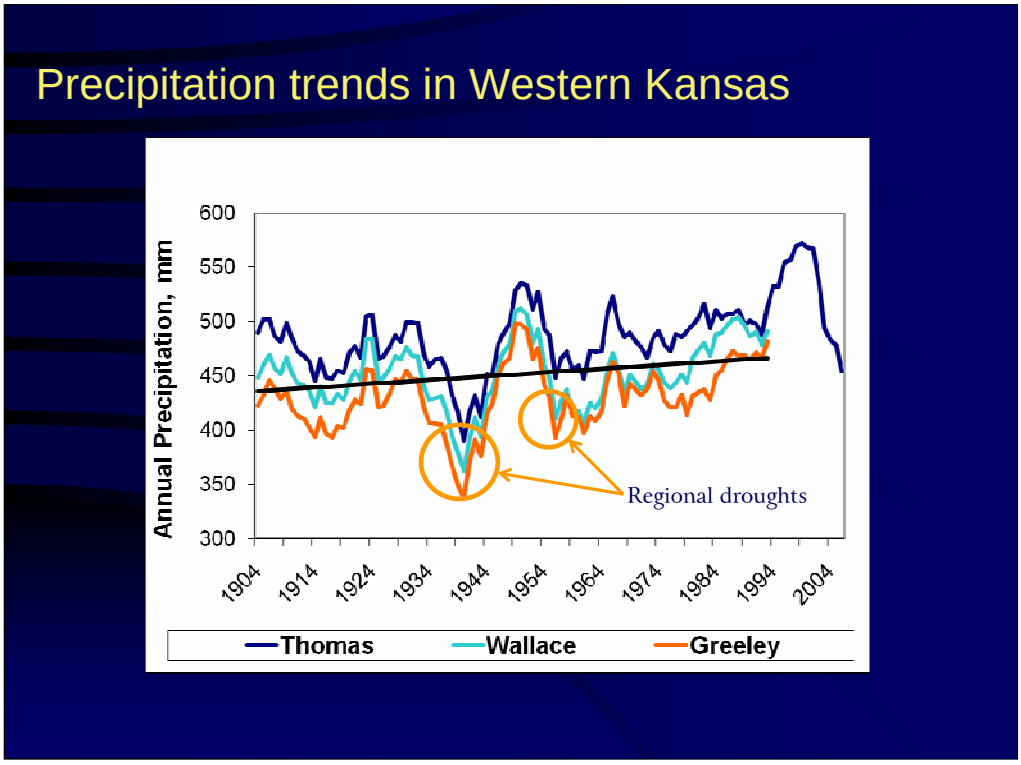
The researchers studied an abiotic template of the system to identify potential thresholds and the time periods in which those thresholds may have been crossed. To test the threshold hypothesis, biotic data are examined to identify if changes have occurred over the specified time period.



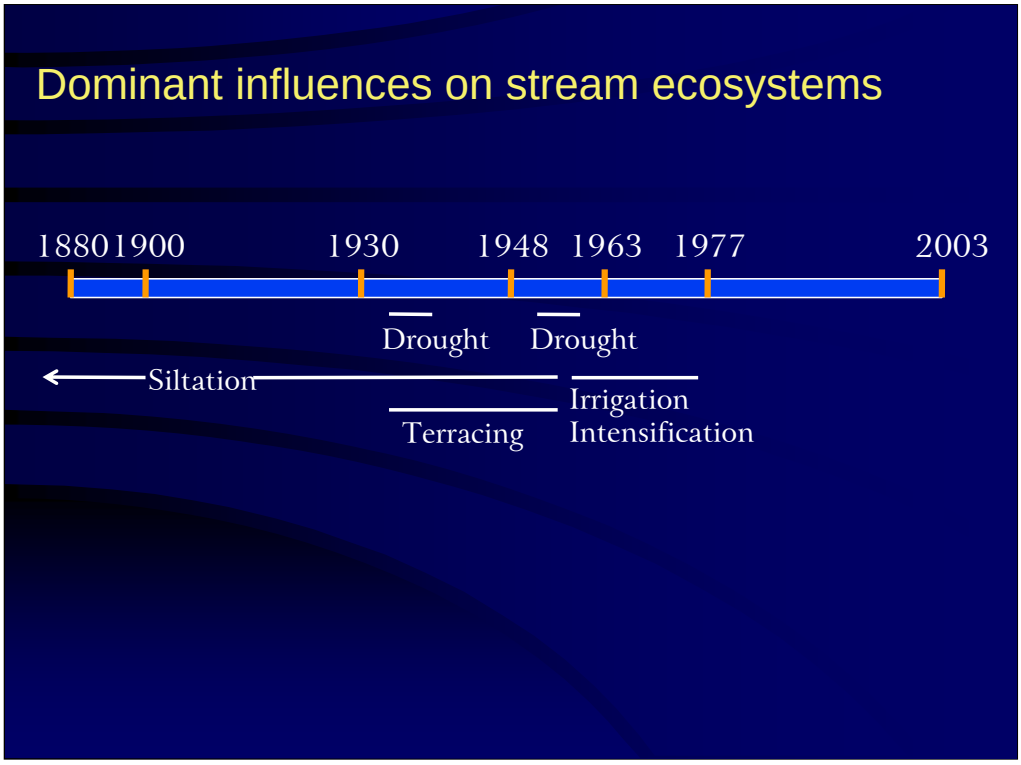
Agriculture has resulted in increased sedimentation in streams.



Irrigated farming really took off in the late 1950s and early 1960s. This graph shows that there is more intense mining of the Arkansas River basin groundwater.



Overall precipitation is increasing, but it is extremely variable.

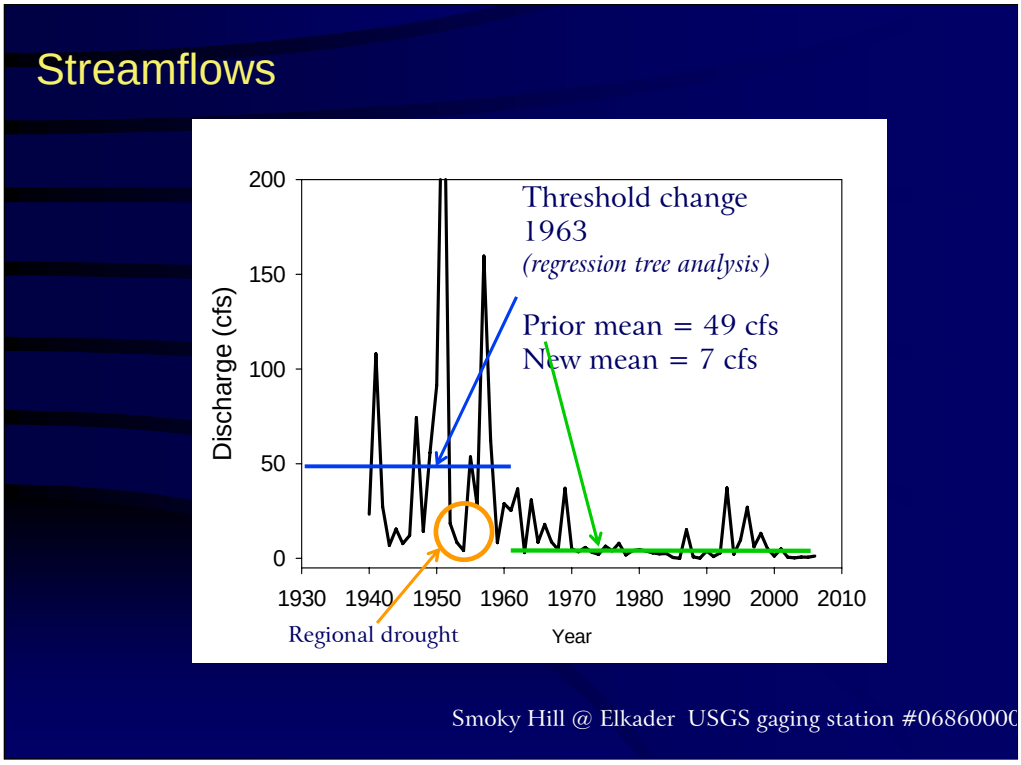


Siltation has been a problem since agriculture began in the area. There may have been some species that were silt-intolerant and died off at this point (late 1800s, early 1900s), making this a threshold.

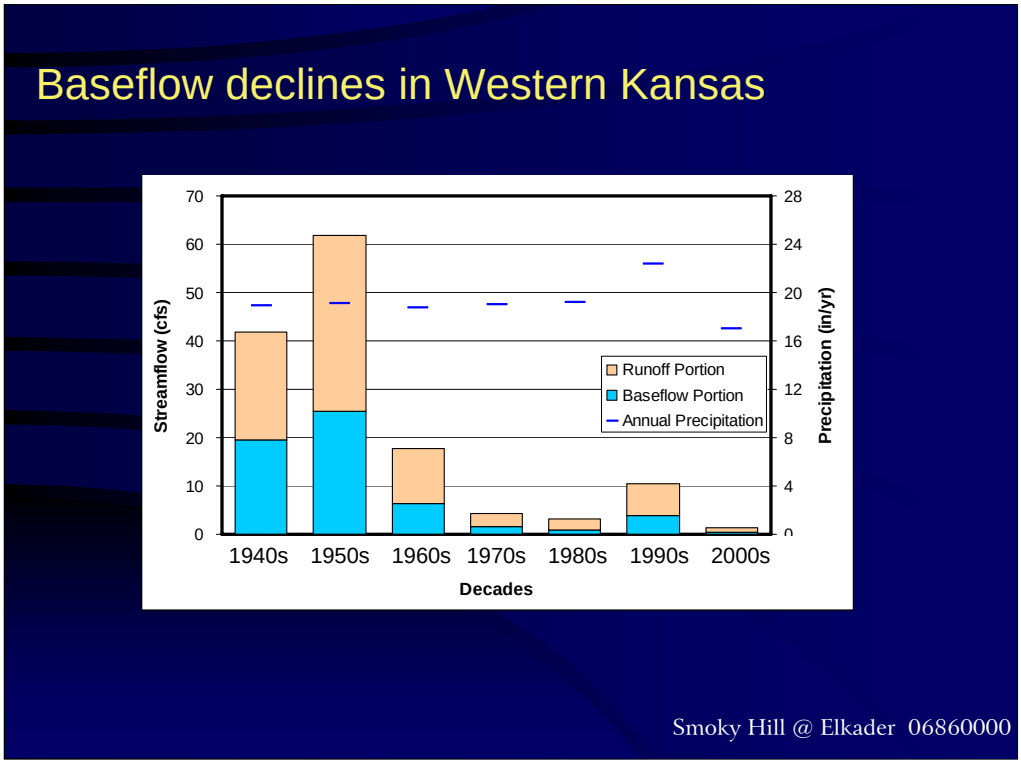
A threshold was crossed in 1963 due to increased mining of groundwater for irrigation.

Outline

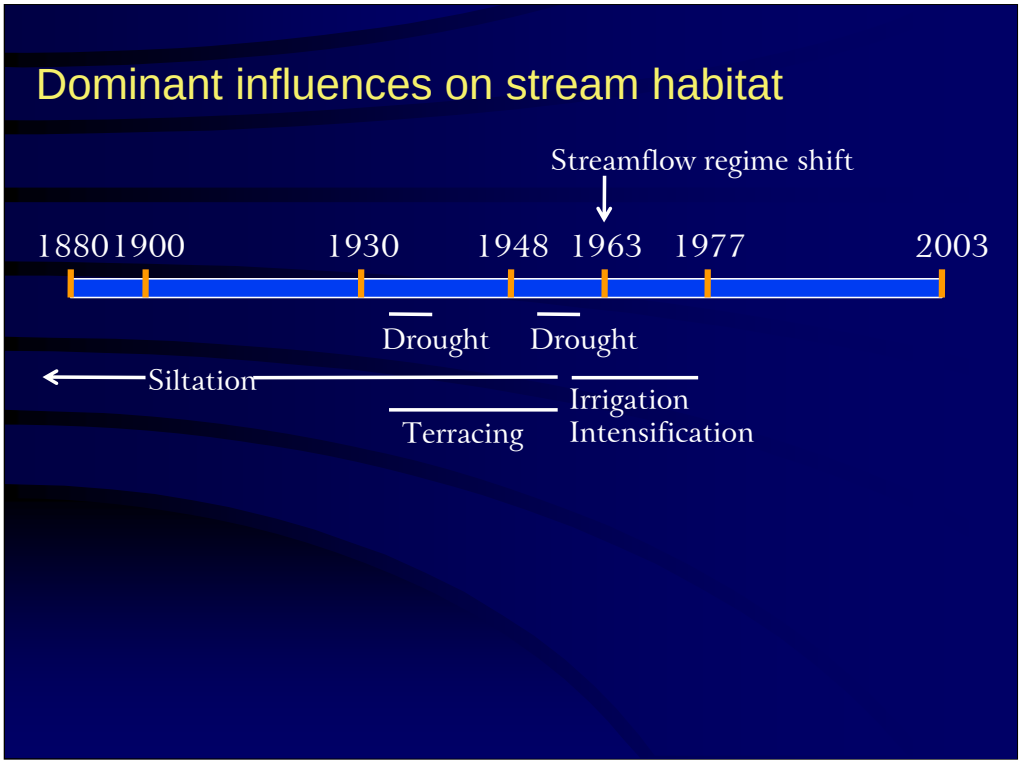
- Land use and precipitation
- **Thresholds in streamflow**
- Fish habitat changes
- Detecting changes in historical data
- Thresholds of fish community structure



Low flow during the 1950s drought was higher than current low flows.



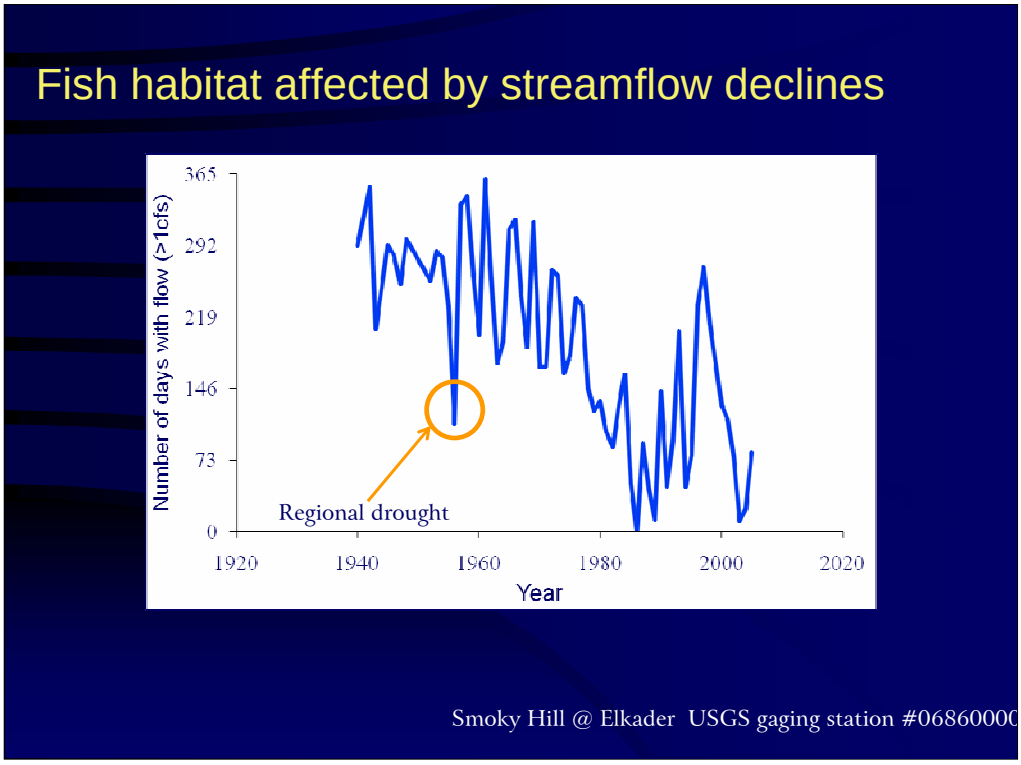
The dashes represent precipitation. Both the surface and base flow are decreasing over time.



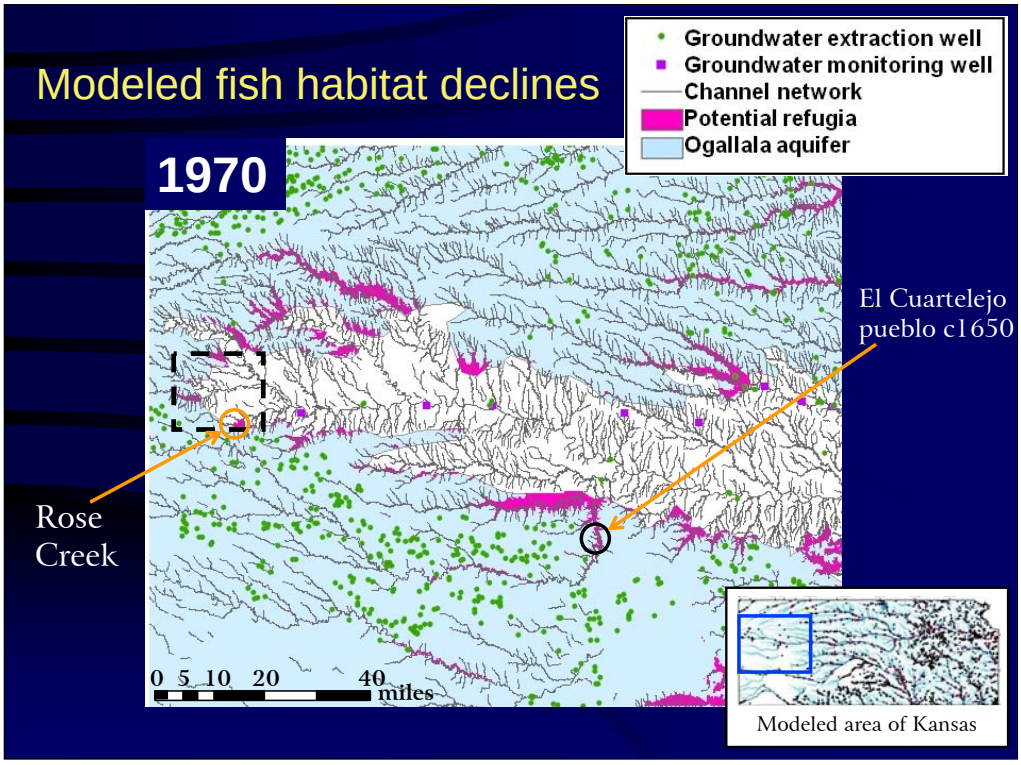
A streamflow regime shift occurred in 1963.

Outline

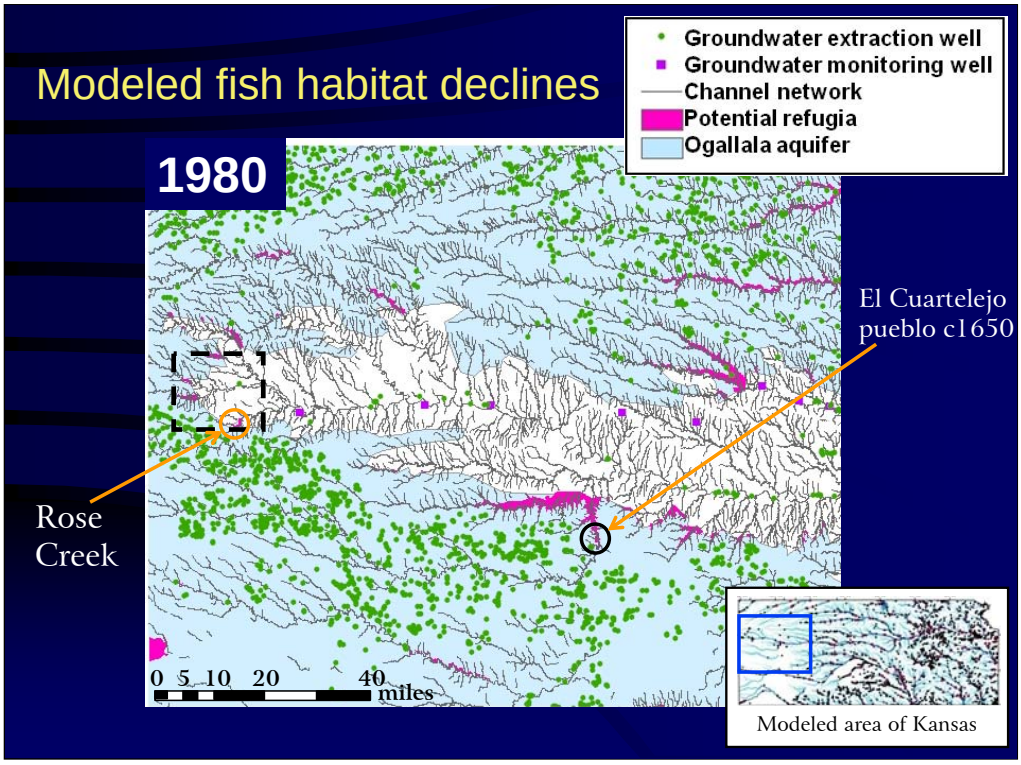
- Land use and precipitation
- Thresholds in streamflow
- **Fish habitat changes**
- Detecting changes in historical data
- Thresholds of fish community structure



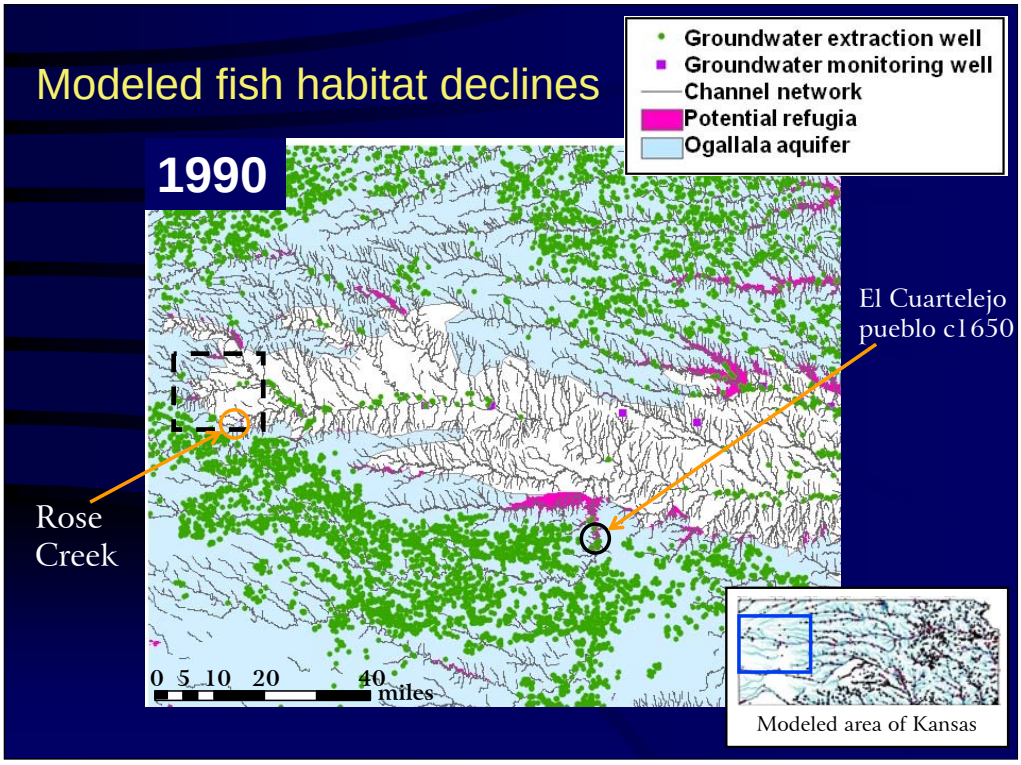
The number of days below a certain critical flow level is important.

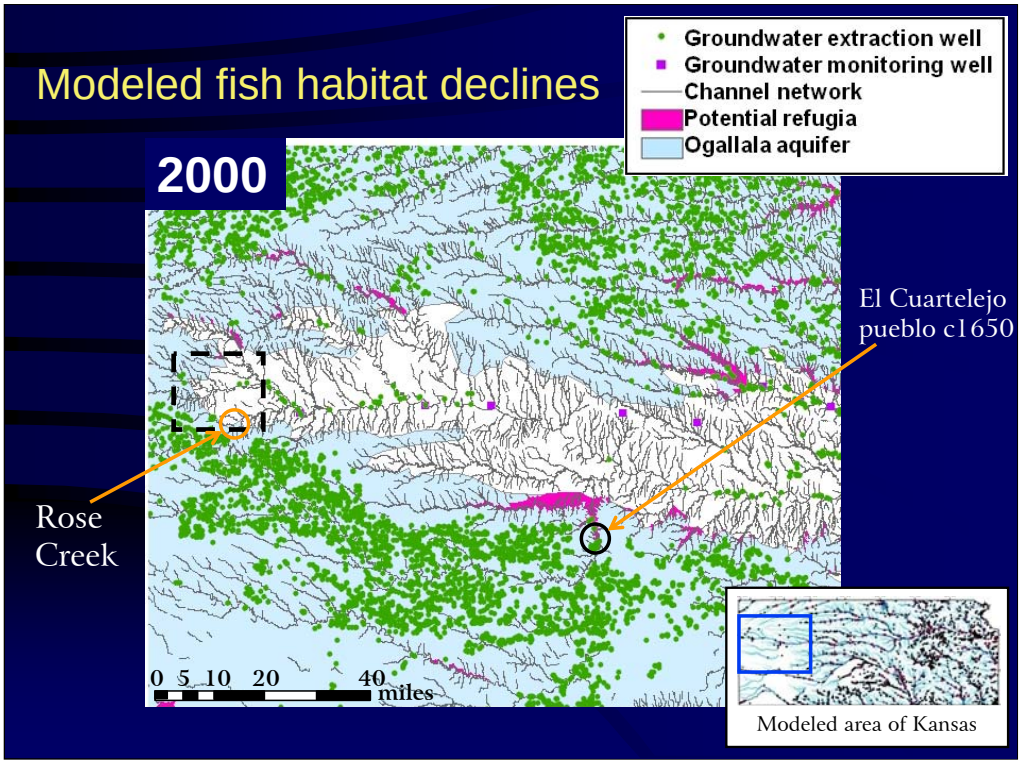


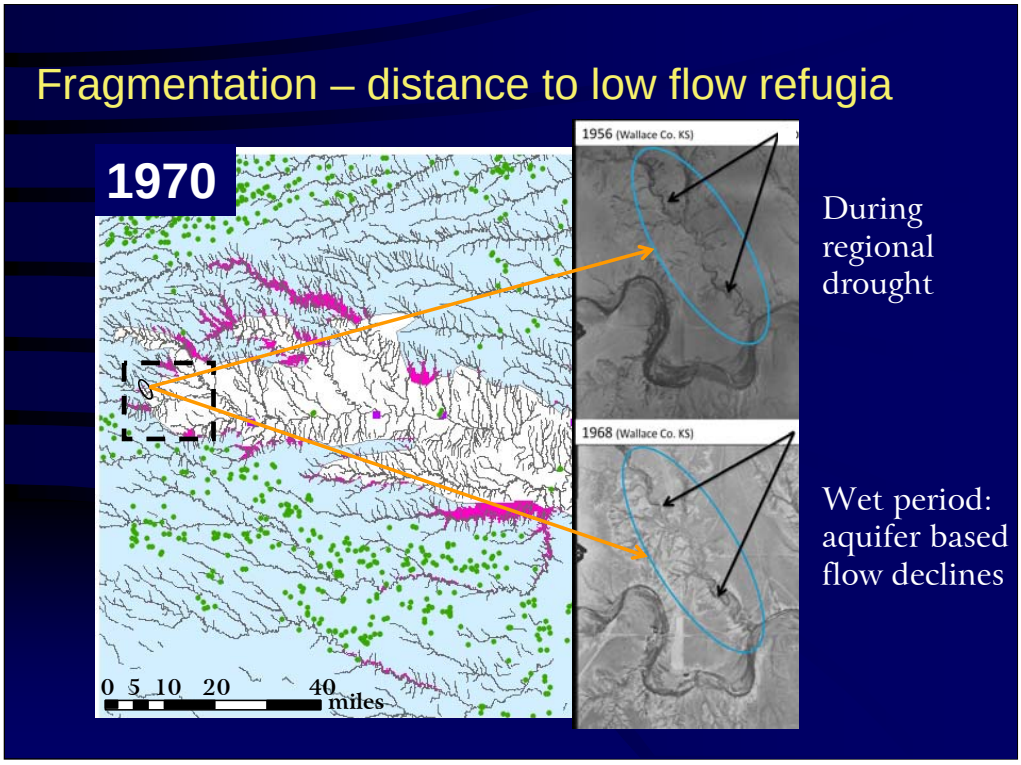
This is a retrospective look at potential refugia in a small area of western Kansas.



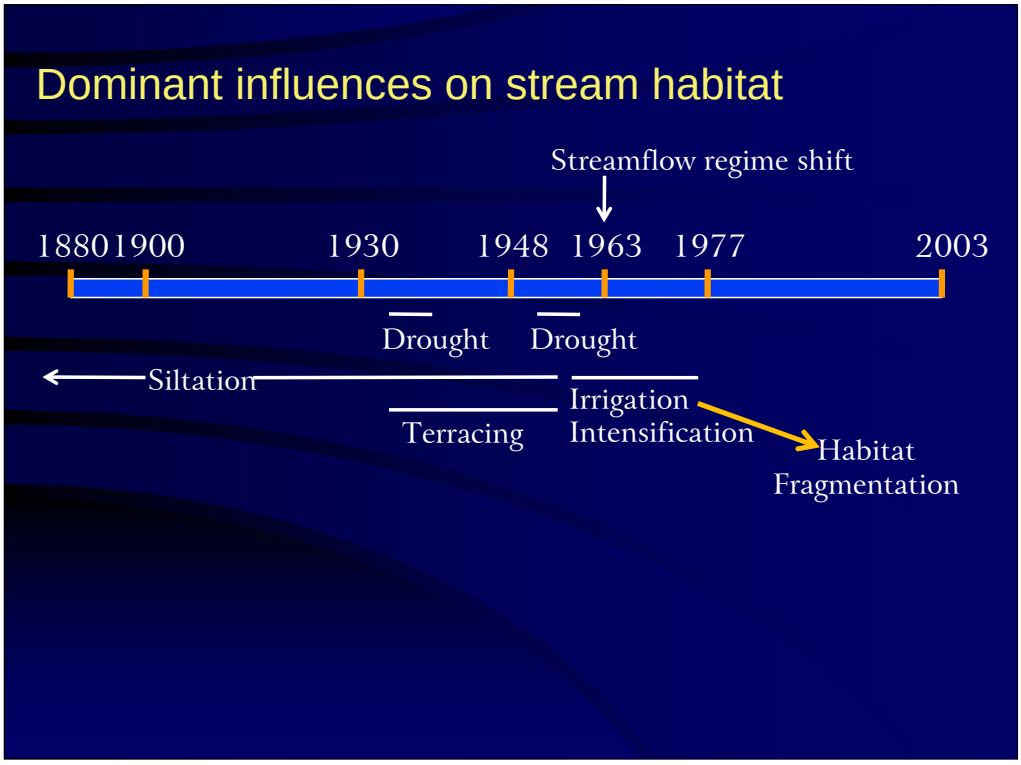
As the number of groundwater extraction wells increases, the amount of refugia decreases.


Modeled fish habitat declines
1990
Groundwater extraction well
Groundwater monitoring well
Channel network
Potential refugia
Ogallala aquifer
El Cuartelejo pueblo c1650
Rose Creek
0 5 10 20 40 miles
Modeled area of Kansas

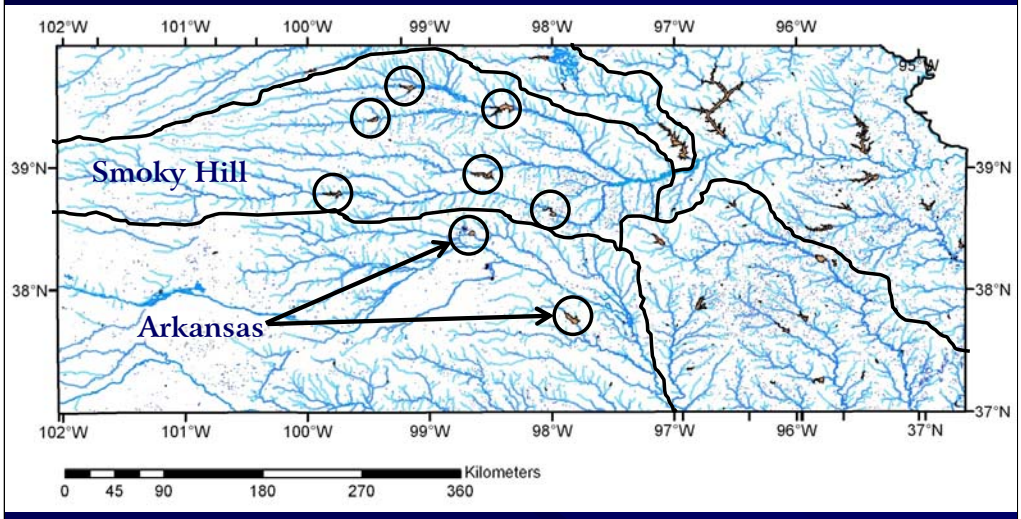

Modeled fish habitat declines
2000
Groundwater extraction well
Groundwater monitoring well
Channel network
Potential refugia
Ogallala aquifer
El Cuartelejo pueblo c1650
Rose Creek
0 5 10 20 40 miles
Modeled area of Kansas



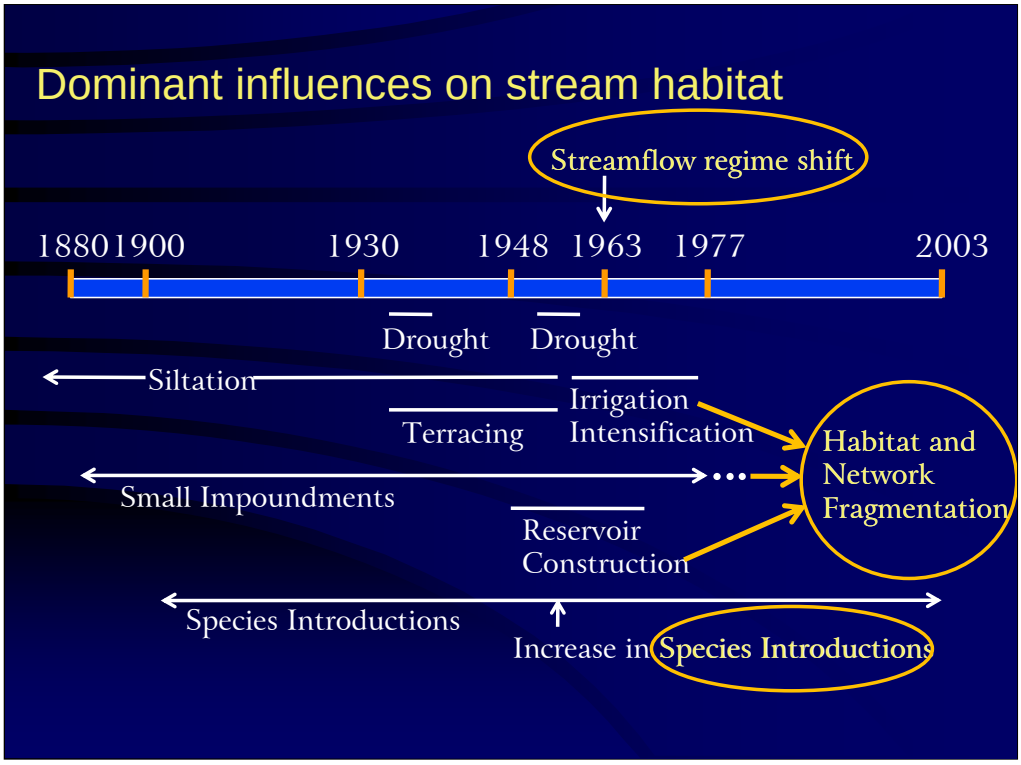
Irrigation intensification also has led to fragmentation.


Dominant influences on stream habitat
Streamflow regime shift
1880
1900
1930
1948
1963
1977
2003
Drought
Drought
Siltation
Irrigation
Intensification
Terracing
Habitat
Fragmentation

Fragmentation - Impoundments



Fragmentation has also been caused by impoundments. There are a number of large impoundments in the Smoky Hill basin, whereas there are only two large impoundments in the Arkansas basin.



Large reservoir construction began in the late 1940s. Species introductions coincide with the introduction of these large impoundments.

There are three major thresholds: streamflow regime shift, habitat and network fragmentation, and species introduction.

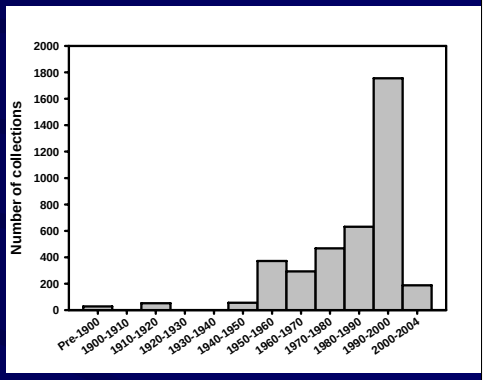
Outline

- Land use and precipitation
- Thresholds in streamflow
- Fish habitat changes
- **Detecting changes in historical data**
- Thresholds of fish community structure

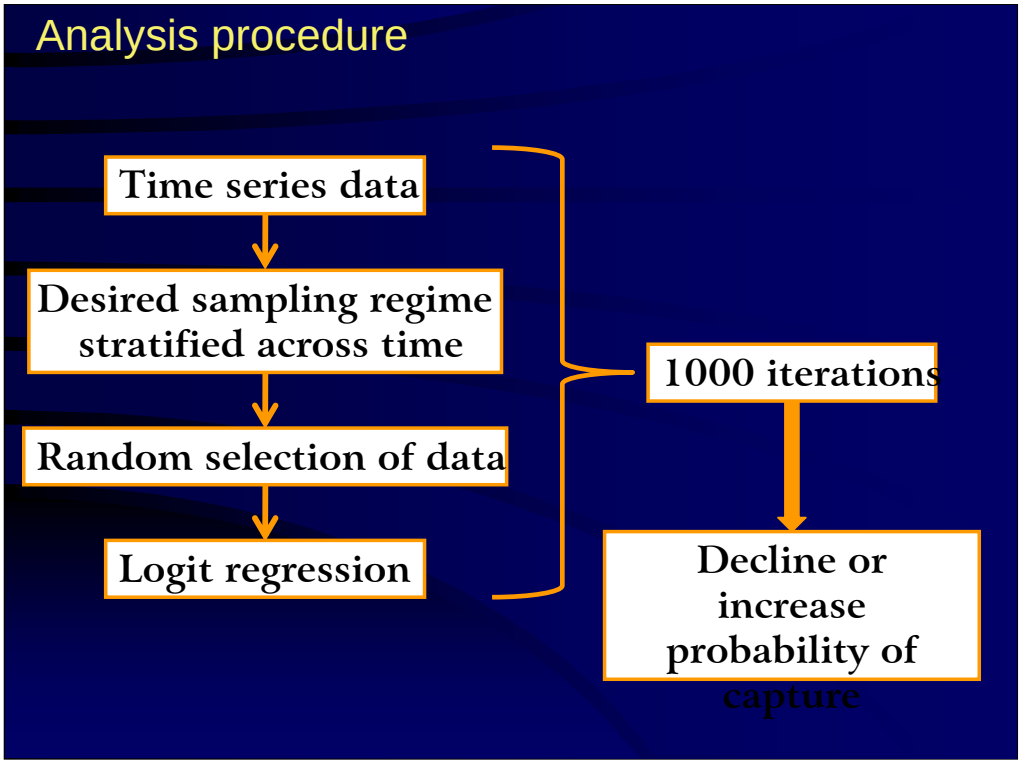
Detecting changes in presence/absence data

- Problems detecting changes:
  - Variable sampling effort
  - Targeted sampling
  - Parametric approach invalid for presence/absence data
- Solution:
  - Monte Carlo iterative resampling
  - Logit Regression (populations)

  or Jaccard's Similarity (communities)



This graph shows the number of collections over time. Collection was sporadic in the beginning.


Analysis procedure
Time series data
Desired sampling regime stratified across time
Random selection of data
Logit regression
1000 iterations
Decline or increase probability of capture

Outline

- Land use and precipitation
- Thresholds in streamflow
- Fish habitat changes
- Detecting changes in historical data
- **Thresholds of fish community structure**

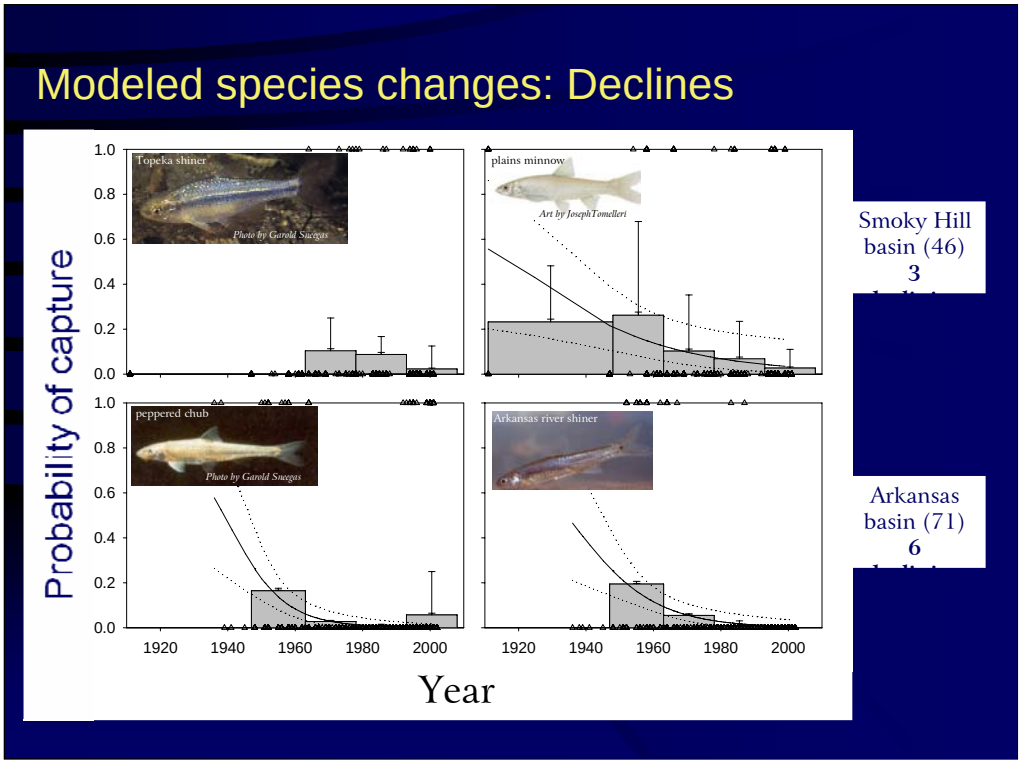
Species increases: sportfish dominated

Smoky Hill

- No non-native fish in streams prior to reservoir construction (1948)
- 3 new species of centrarchids found in streams (1966)
- 1 more centrarchid species found (1983)

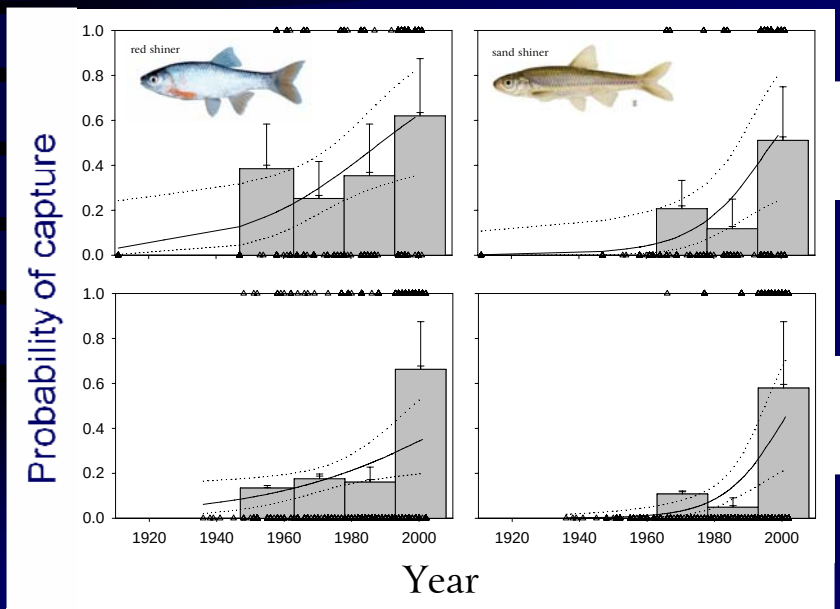
Arkansas

- Only western mosquitofish predates (1941) reservoir construction
- Same 3, plus 1 other species of centrarchids found (1948-1969)
- 3 more centrarchid species found (1995-2000)



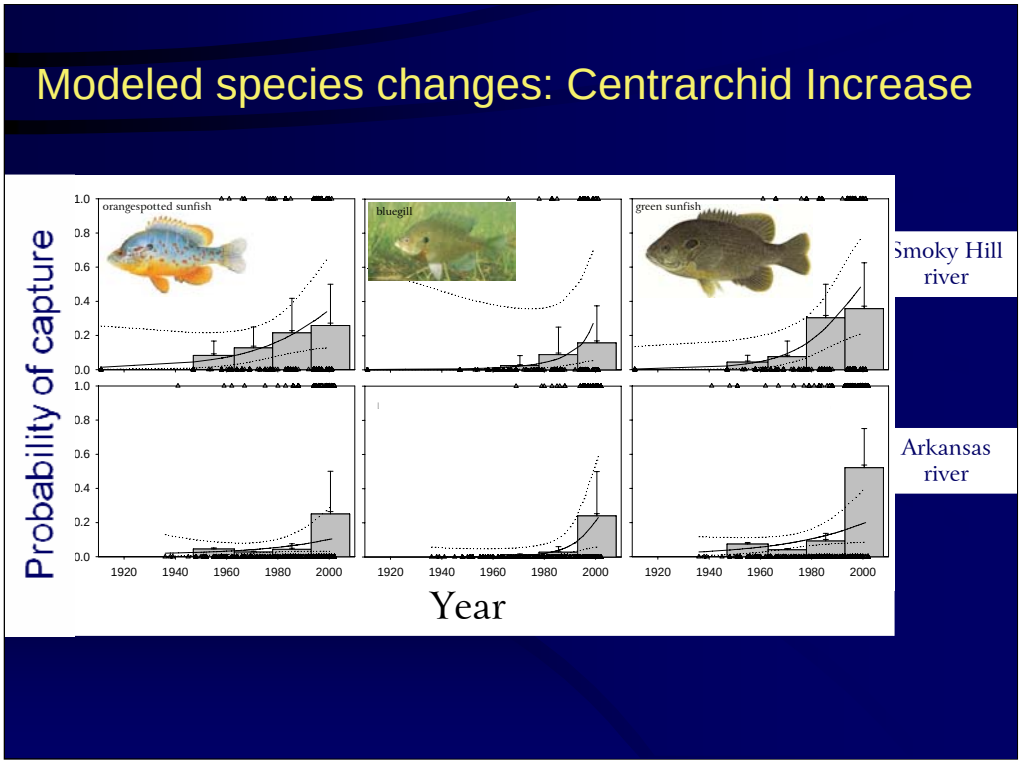
The bars represent the mean from the 1,000 iterations performed for each time period. The bar width represents the different thresholds. The bar height represents the mean probability of occurrence and the standard deviation from the 1,000 iterations. During each iteration, logit regression was performed. The lines represent the error of that regression.

Modeled species changes: Increases



Smoky Hill
(46)
15 increasing
53% lentic

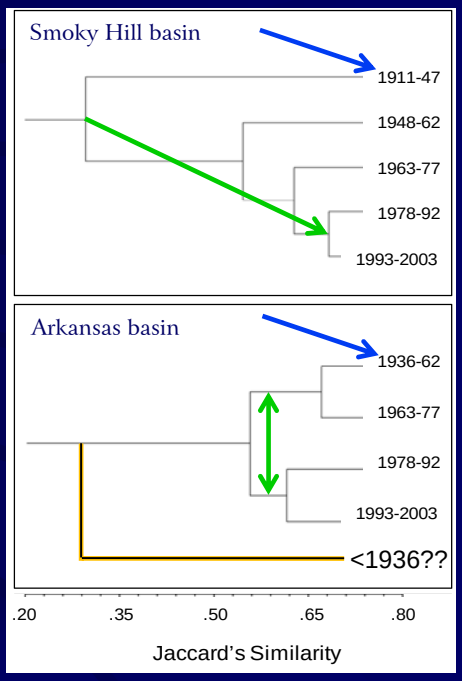
Arkansas
(71)
14 increasing
50% lentic



There has been a gradual increase in these species in the Smoky Hill River basin and an abrupt increase in the Arkansas River basin. The Smoky Hill River basin is more heavily impounded than the Arkansas River basin.

Native fish changes

- Longer-term record for Smoky Hill basin
- Directional change, with increasing impoundments
- Shift in composition, lag time after streamflow declines

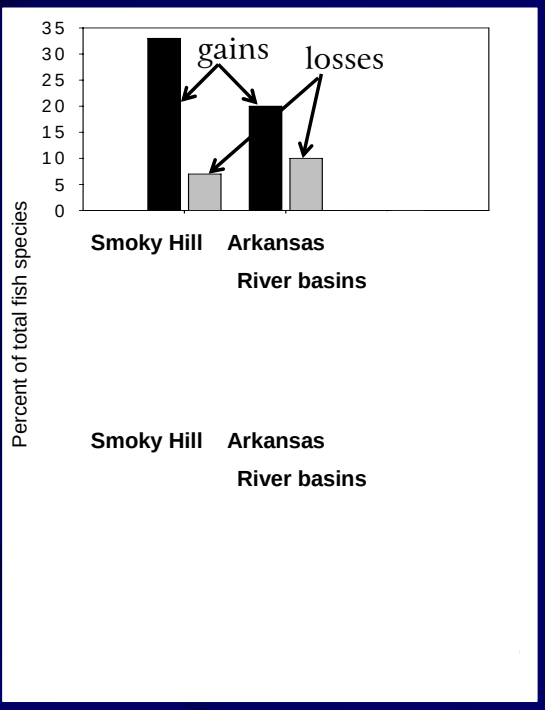


Species changes:

All species

Centrarchids

Cyprinids



d) Surprising results

- Fish species increases outweighs declines:
- Species introductions and range extensions of introduced and native species are driving observed patterns of biotic homogenization.
- Current resiliency of the current fish community may be a result of historical losses of sensitive fish species: several remaining species show patterns of range extension.

- Interaction between streamflow regime and non-native species:
- Biotic state-change identified from species composition patterns.
- Large-scale switch in both the Kansas and Arkansas basins:
- Historical community = stream-fish adapted to summer flowing-water refugia.
- New community = lake/pond-fish adapted to non-flowing/pool refugia.

- New predictive capabilities:
- Restoring streamflow quantity may be more important to limiting the loss of native species than removing barriers created by reservoirs.

e) Management to improve system resilience

- Regime shift of stream biota due to:
  1) Siltation of streams
  2) Loss of connectivity in stream network
  3) Reduction and loss of streamflow
  4) Species losses coupled with range expansions of others
  5) Species introductions

- New method to detect change in historical presence-absence data:

1) Resilient to uneven sampling, both temporally and spatially
2) Applicable to quantify and identify species changes

- Preventing future regime shifts:

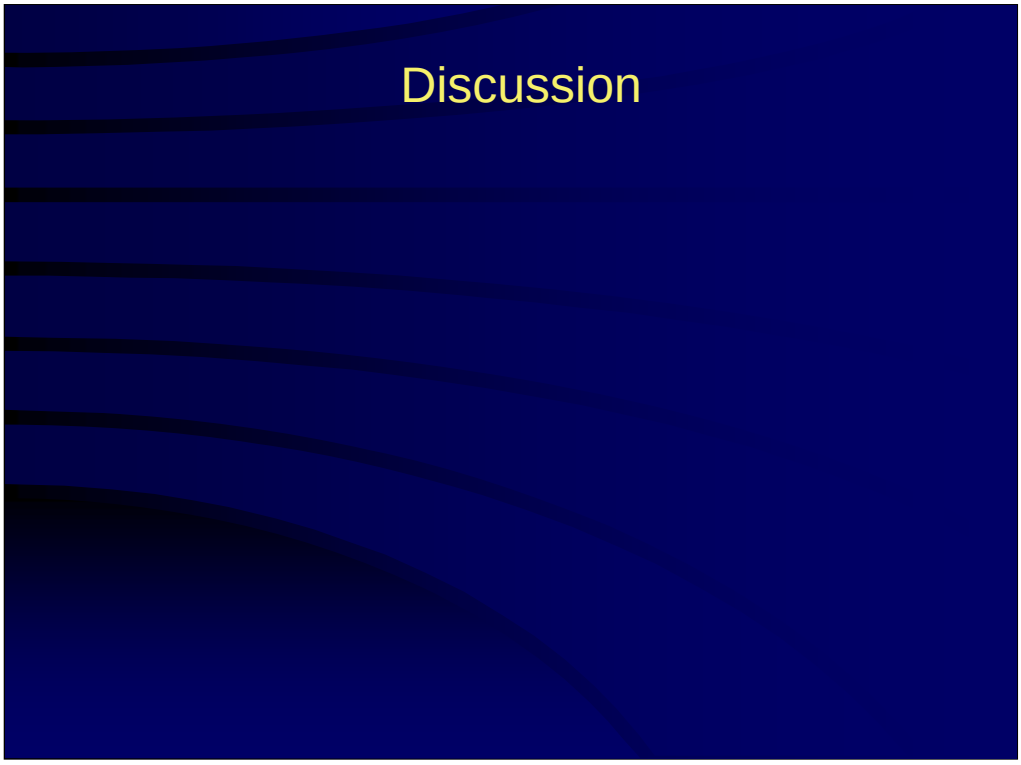
1) Aquifer mining for irrigation associated with losses of native species
2) Reservoir construction and stocking is associated with increased biotic homogenization

f) Collaboration and new connections

- Collaboration with:
  - M. Eberle (Fort Hays State University)
  - Ecoforcasting project (M. Evans-White, D. Hoeinghaus, Kansas State University)
  - D. Chandler (Kansas State University)

- Kansas Department of Wildlife and Parks – effects of global warming and increased ethanol biofuel production on aquatic resources

- Discussions and possible collaboration with C. Damgaard – (NERI, Terrestrial Ecology, Denmark) on mathematics of threshold effects



A participant asked if potential water management adjustments can be incorporated into the analysis. Dr. Gido responded that he and his colleagues are hoping to explore these types of questions in the future. The participant pointed out that Dr. Gido and his colleagues potentially could approach the issue from a flow recovery perspective.

Another participant asked if timelines were important for identifying which stressors were causing the changes. Dr. Gido reminded the participants that groundwater mining was intense in the Arkansas River basin. The major changes seen in the late 1970s might be a time lag effect from that disturbance.

Another participant asked if any hybridization of species was occurring. Dr. Gido responded that he and his colleagues have not seen hybridization in the two study sites.