# The Vole In The Climatic Coal Mine

How One Of The Rarest Mammals In North America Can Be A Key Element In Management And Restoration Of One Of The Largest Remnant Wetlands In The Mojave Desert


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# Where I Am Going

- **Put relationships between Amargosa vole population dynamics and habitat in a climatic context**

- **Describe how and why the vole is a key, but not only element, in conserving a very important and uncommon wet system in the Mojave Desert**

# Ecological Setting

- Mojave Ecoregion
  - Tecopa is located in the central Mojave

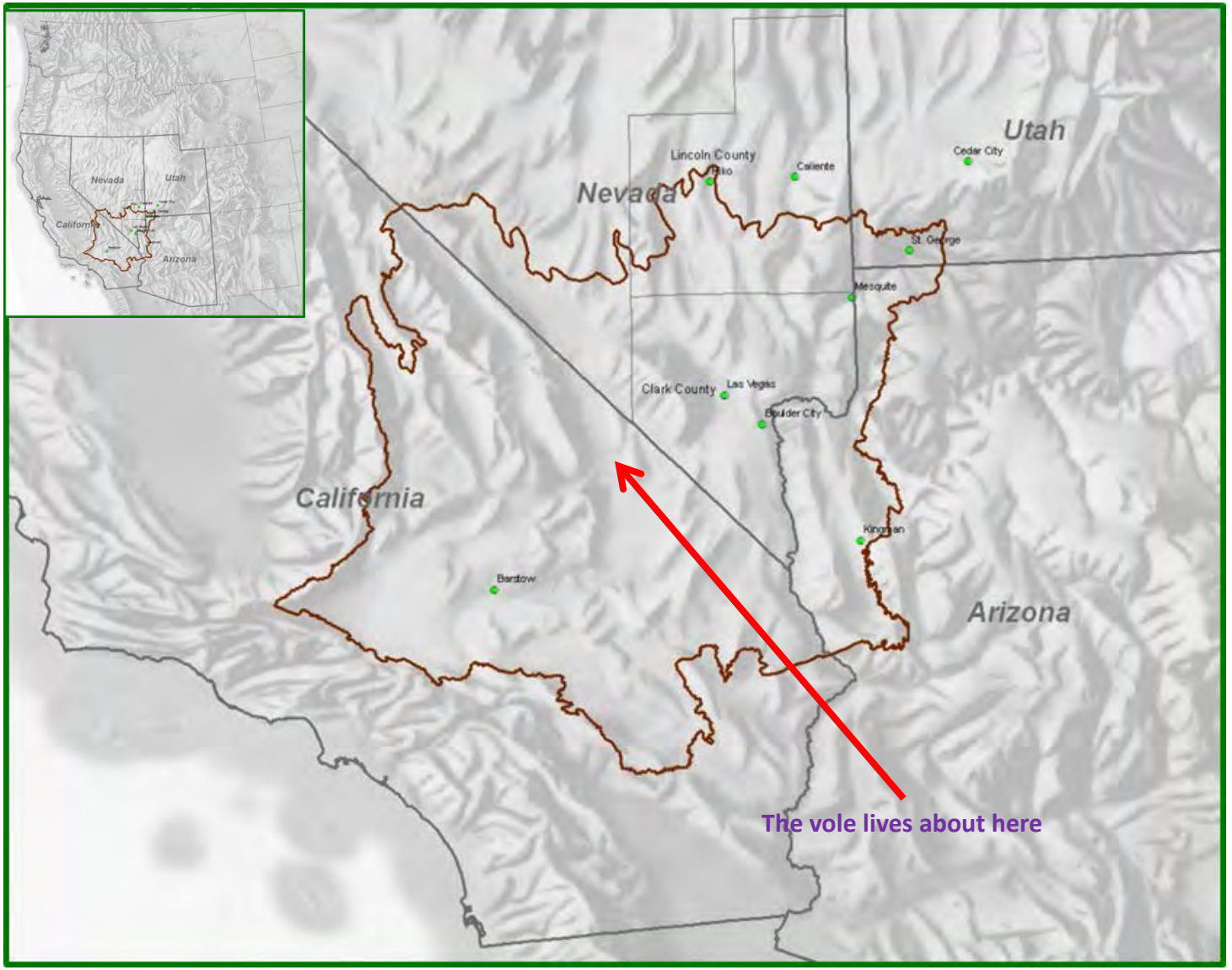



Image courtesy of Randy McKinley USGS-EROS

# Ecological Setting
# The Amargosa River


**One of four rivers in the Mojave ecoregion (≈ 300 km in length)**

**One of two with headwaters and mouth entirely within the ecoregion**

**Approximately 30 km (10%) flows aboveground**

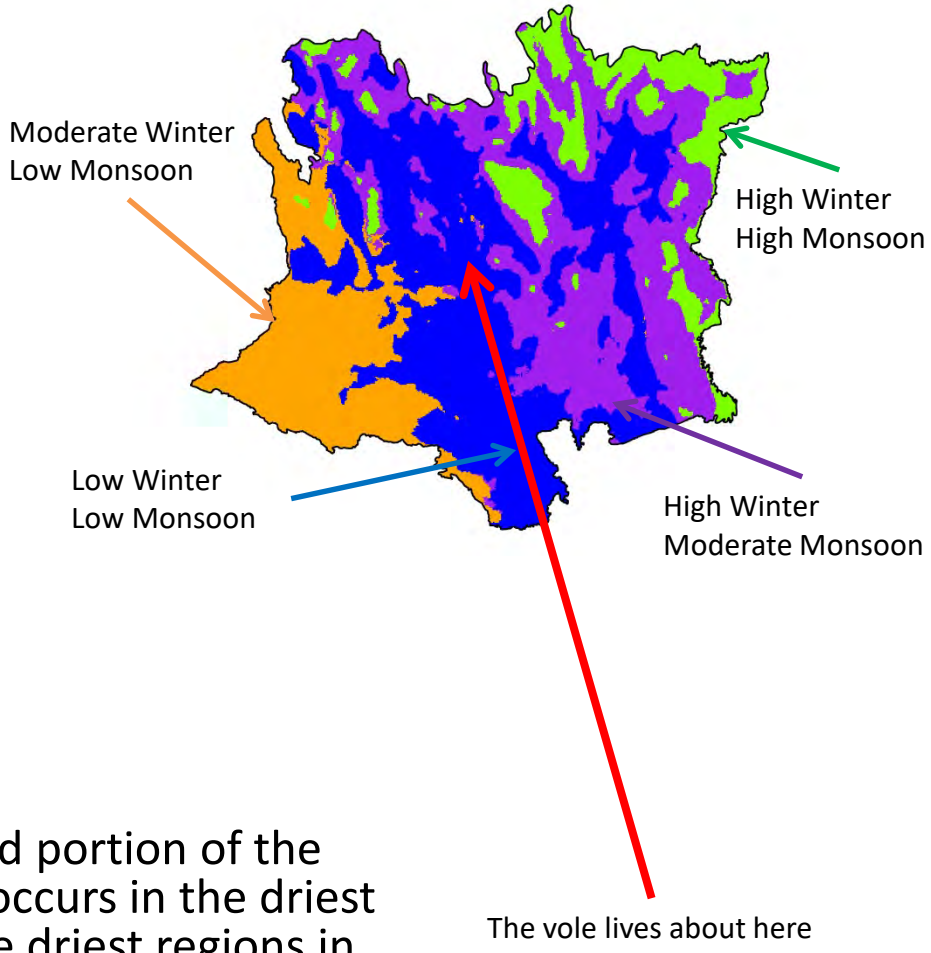
**Local recharge from springs, regional recharge from groundwater (Spring Mountains in Nevada)**

# Ecological Setting

## Spatial Pattern of Precipitation

- Four major precipitation zones in the Mojave ecoregion

(*Tagestad et al 2015*)




- The above ground portion of the Amargosa River occurs in the driest part of one of the driest regions in North America

# Say Hello To The Amargosa Vole

- 75-100 g rodent
- Subspecies of garden variety California vole
- Evolutionary significant unit!
  - Cut off from other subspecies ≈ 10,000 – 250,000 years
  - Multiple lines of origin
- Predisposes itself to extinction
  - EXTREMELY restricted range
    - 1 $km^2$ of fragmented ***wetlands***
  - Small and variable population size
  - Habitat specialist!
    - Tied to patches of bulrush

Possibly the most endangered mammal in North America (Klinger et al. 2015; Global Ecology & Conservation)

# Ecological Setting

## Bulrush and Voles

- Food (bottom-up process)!
  - Bulrush stands are almost monocultures
  - VERY low quality forage
  - Recruitment and abundance strongly related to bulrush quality

- Predators (top-down process)!
  - Two dozen predators
  - Can be a very strong force
    - Population mortality-limited in some years (predation)

# Ecological Setting

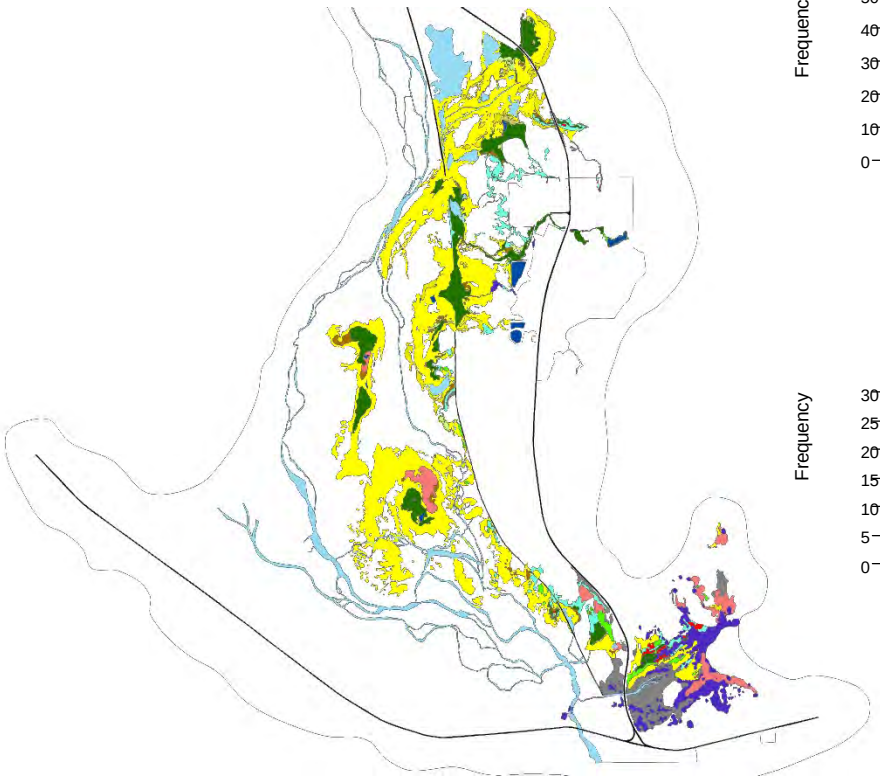
## Strong Seasonality In Habitat Conditions

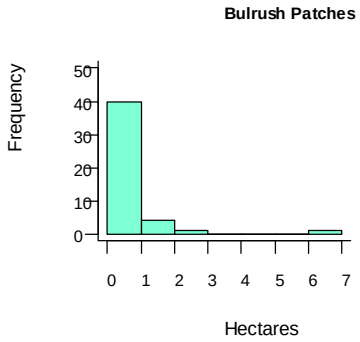
**January**

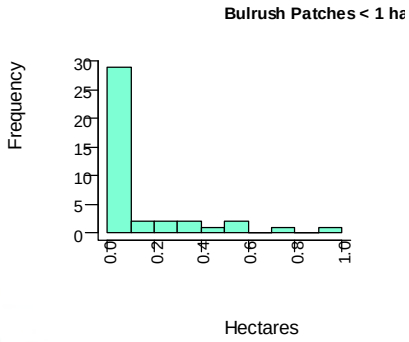
**May**

# Ecological Setting

## Very Patchy Habitat Conditions



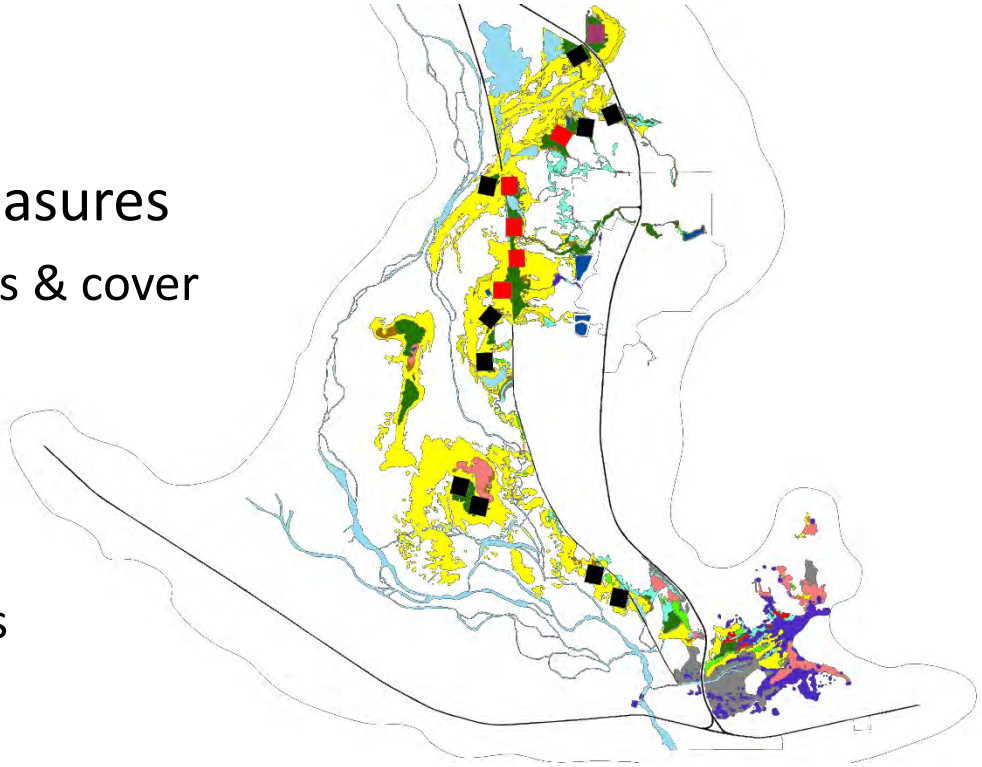


# An Overview of What Has Been Done On The Ground

## Population Dynamics & Habitat

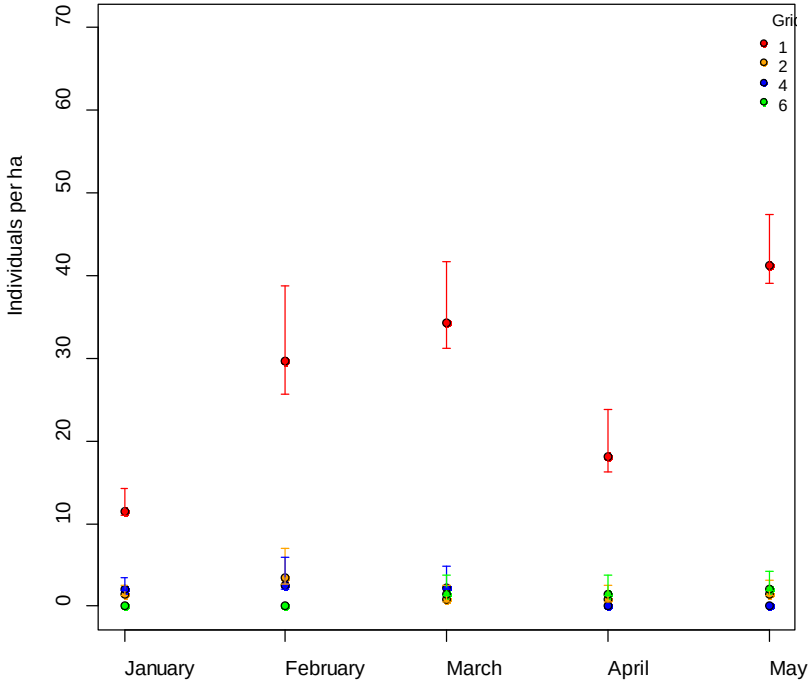
- Lots of trapping
  - January 2012 – November 2016
    - N = 6 - 16 grids
  - Mark-recapture
- Lots of habitat measures
  - Vegetation species & cover
  - Bulrush
    - Cover
    - Stem density
    - Biomass
  - Physical measures
    - Water depth
    - Soil moisture



# So What Did We Learn?

**January 2012 – November 2013**

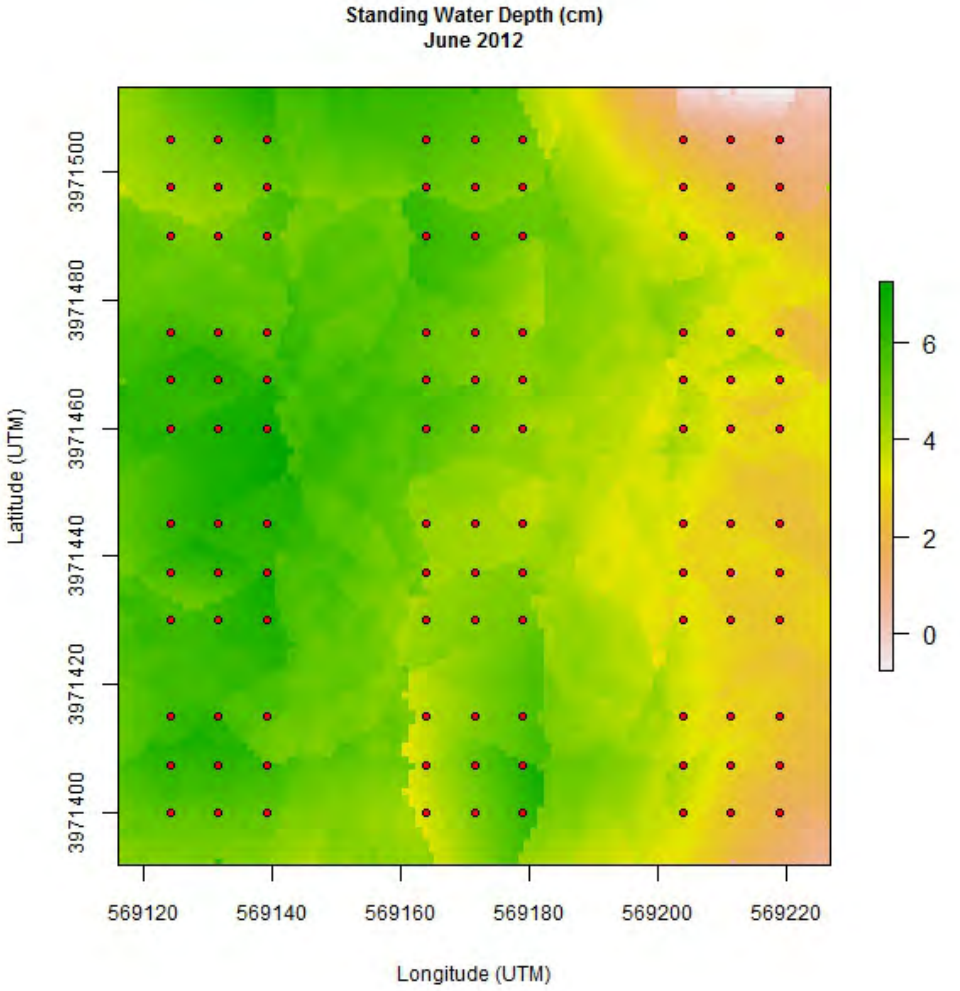
- Abundance
  - Strong seasonal dynamics
    - **≈ 300-400 during the summer**
    - **≈ 70-90 during the winter**
  - Great spatial variability
    - **≈ 86% of animals occurred in one grid**
- Demography
  - They don't move far (≈ 20 – 30 m)
  - Decent recruitment ( ≈ 1.25 per adult)
  - Low monthly survival (≈ 0.33)
    - ***Predation***



# An Unexpected & Unwanted Object Lesson…

## An Unnatural Field Experiment

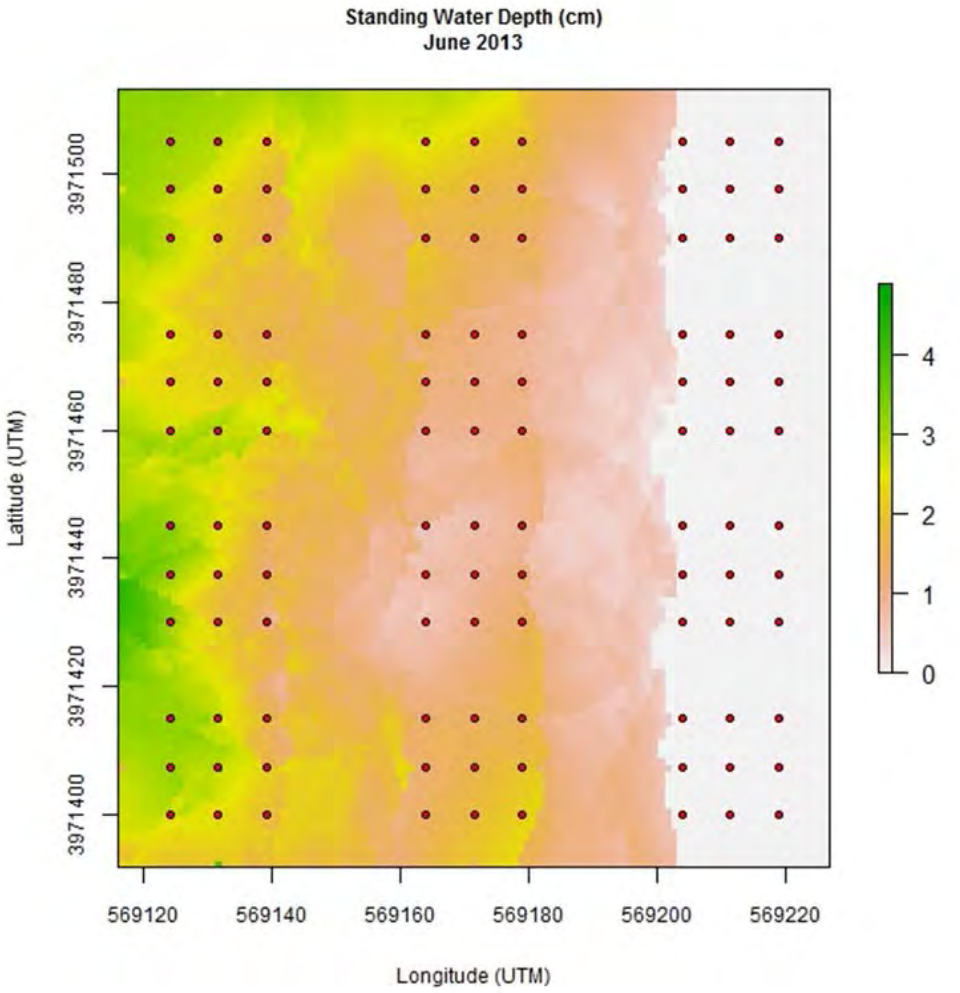
- The “Borehole”
  - In 2012 85% - 90% of the vole population occurred in a 2.5 ha wetland at the northern end of the vole’s current range
    - ≈ 1.50 ha dominated by bulrush
    - ≈ 25-35 voles $ha^{-1}$
  - Mean bulrush cover ≈ 92%
  - There was standing water throughout most of the grid



# An Unexpected & Unwanted Object Lesson…

## An Unnatural Field Experiment

- The “Borehole”
  - Mean bulrush cover in 2013 ≈ 8%
    - ≈ 0.15 ha dominated by bulrush
  - There was very little standing water in most of the grid
  - ≈ 5-6 voles in November 2013
  - What happened!?
    - A flood control project resulted in the marsh being drained



# Habitat Suitability Can Rapidly Change

**Borehole June 2012**

**Borehole June 2013**

**Clear window into potential drier future conditions and long-term degradation of bulrush stands**

# Threats

- Intrinsic
  - Restricted range, isolation, small population, variable population, habitat specialist, patchy habitat, limited dispersal, low recruitment rates
    - Can't do too much about these
- Extrinsic
  - Predation
    - Can't do too much about this
  - Disease
    - Can do a little bit about this
  - Drying of the wetlands
    - Climate
    - Human activities
    - *Can we do something about these?*

# Water Availability, Bulrush & Voles

- **Only ≈ 1 km$^2$ of wetland vegetation in the Lower Amargosa**
- **Only *≈ 25 ha* of bulrush dominated vegetation**
- **Long-term reduction in condition and/or extent of bulrush dominated vegetation would likely lead to extinction of the vole**

# Human Activities

- Modern solar arrays can have major impacts on water table
  - Impacts can be detected 100 km or more away
- Local water use
  - Pahrump and Las Vegas (Nevada)
  - Tecopa Hot Springs
- Concern with the vole and the wetlands is synergistic effect of human-driven lowering of the water table and ongoing climate shifts
  - The “ultimate offsite effect”

“ The $2.2 billion bird-scorching solar project”
Wall Street Journal February 12, 2014

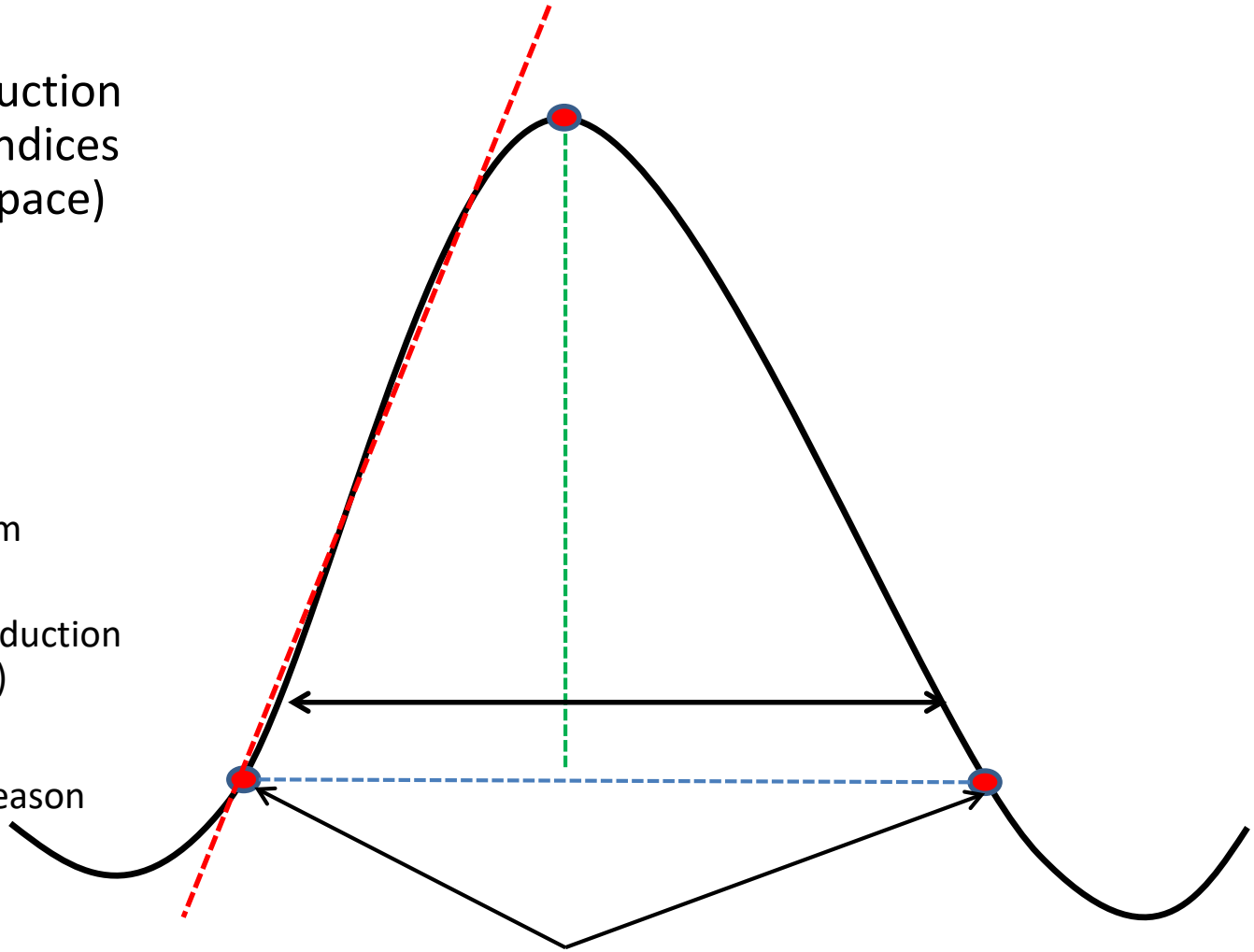
# Relationship Between Bulrush Dynamics & Climate

- Monthly precipitation
  - 1949 – present
  - N = 30 stations
- Bulrush condition (production/productivity)
  - Time series of satellite data
  - Normalized Difference Vegetation Index (NDVI)

# A Word On NDVI

## Monthly & Derived Data

- Monthly data as covariate in population analyses
- Derived annual production and temporal NDVI indices from MARSS (state-space) models for bulrush production analyses
  - Production
    - Base level
    - Amplitude
    - Annual maximum
    - Rate of increase
    - Total annual production ("large integral")
  - Temporal
    - Start & end of season
    - Duration



# Relationship Between Bulrush Dynamics & Climate

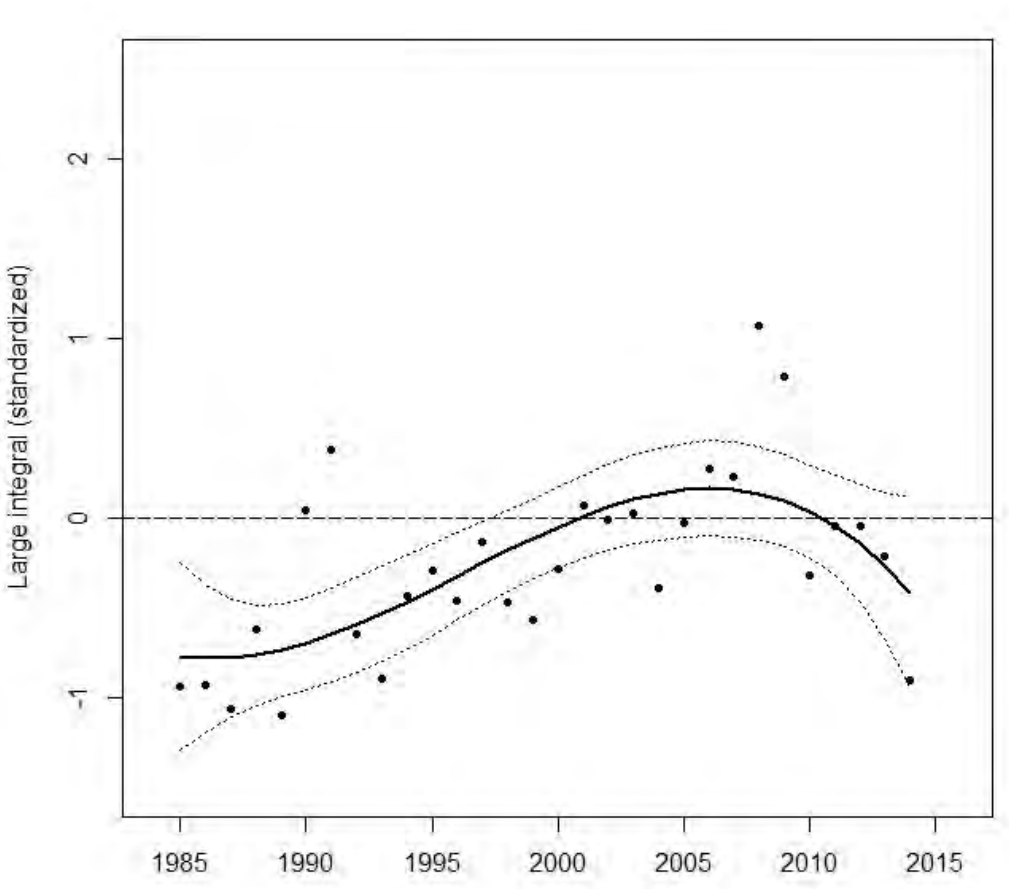
- Model relationships between precipitation, bulrush performance (cover, stem density, and biomass), NDVI and vole abundance
  - Predict bulrush biomass from NDVI
  - Link bulrush - NDVI relationship to large-scale forecasts of vole population dynamics

# Relationship Between Climate and Bulrush Dynamics

NDVI and Precipitation

- Precipitation consistently improves model predictions for several production variables:
  - Amplitude, total production, and rate of production
    - ΔAICc ≥ 26
- General increase in bulrush production from 1985 to 2008 followed by decrease
  - Self-thinning

**Total Annual Production & Precipitation**

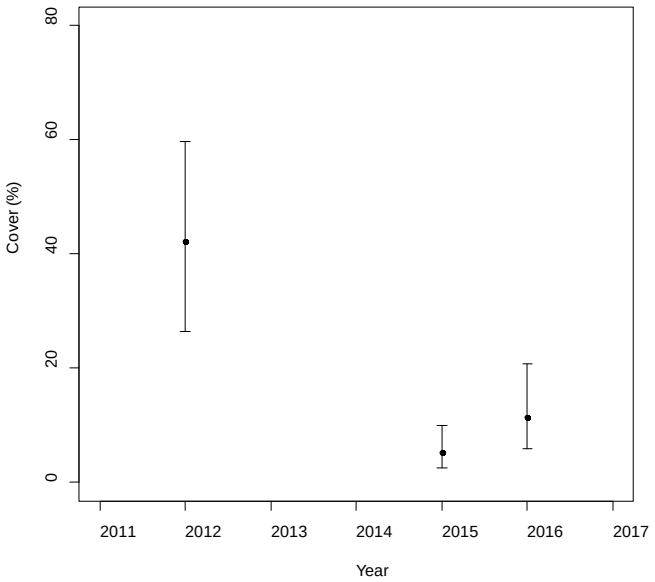


# Relationship between climate and wetland vegetation dynamics

**Mean Annual Maximum NDVI**


**Comparison between 2012 and 2015**

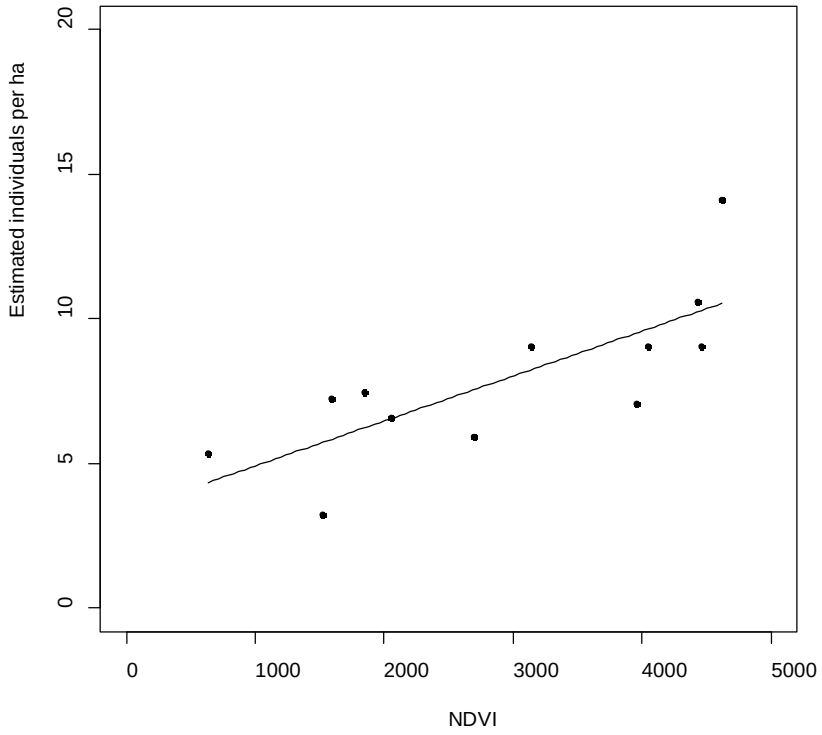
**ΔMean bulrush cover = -17% to -90%**




Strong signature of recent drought (2012 – 2015)

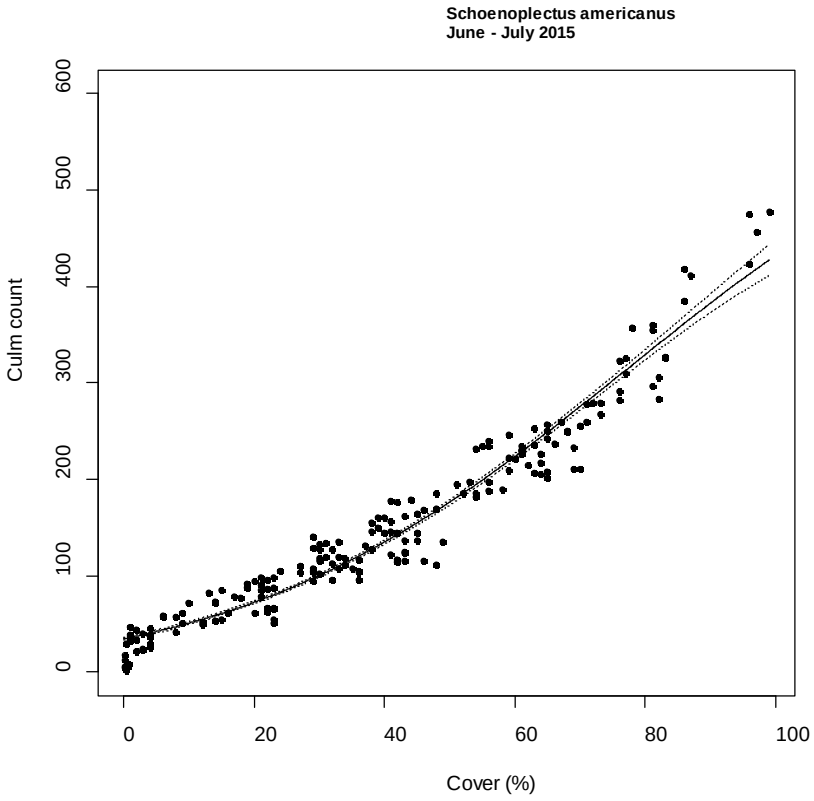
# Relationship Between Vole Population Dynamics and Bulrush Production

- Strong *temporal* relationship between abundance and bulrush production

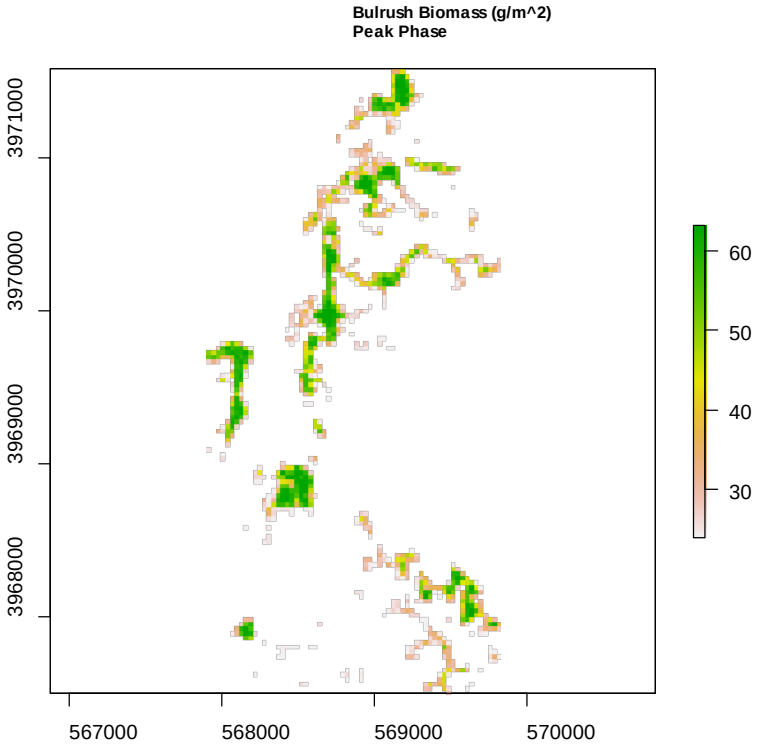


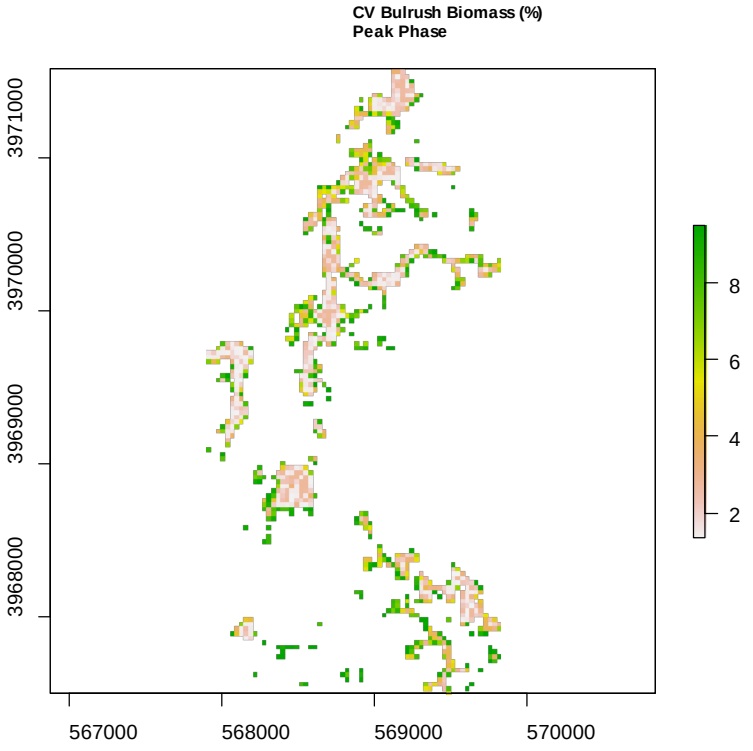
# Simulating Changes To Bulrush Production & Modeling Vole Population Persistence

- 4- step process
  1. Estimate bulrush biomass from cover-stem density-stem weight relationships
  2. Relate bulrush biomass to NDVI
  3. Relate NDVI to precipitation patterns (current and future)
  4. Relate vole carrying capacity (K) to NDVI



# Predicted Changes In Bulrush Production

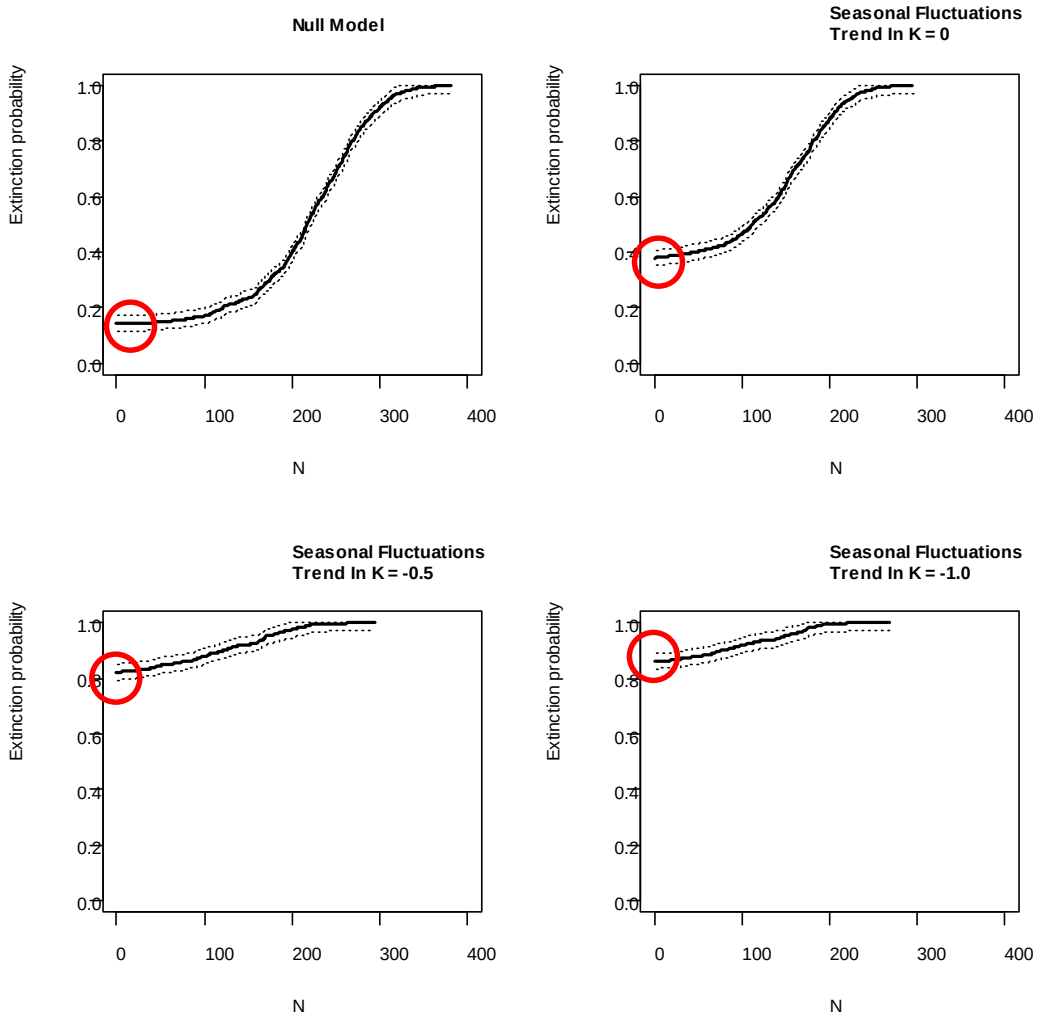


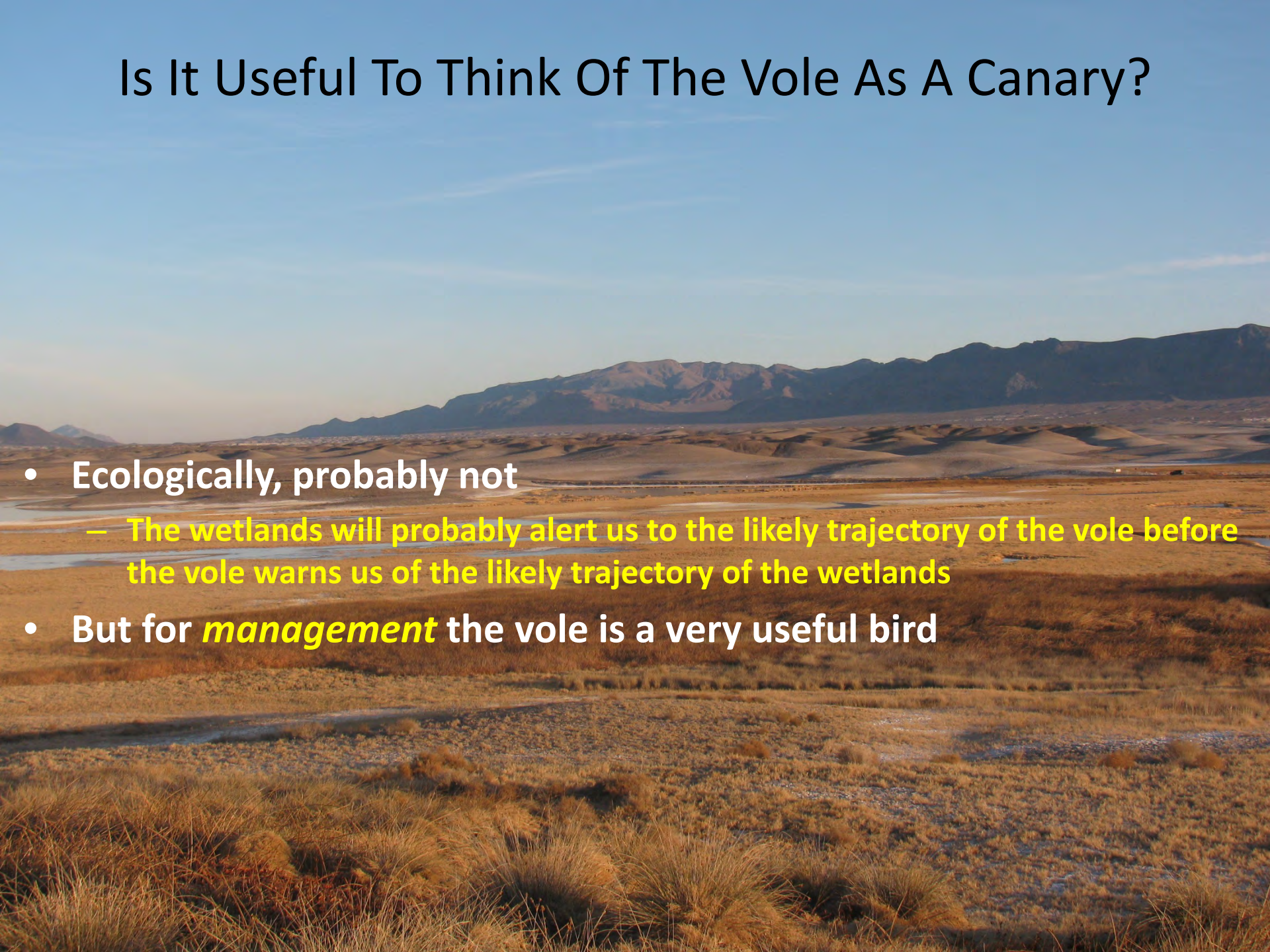

- **Greater spatial and temporal variability in NDVI (= bulrush biomass)**
- **Loss of ≈ 5 ha of bulrush**
- **Decrease in NDVI to levels ≈ to current mid-spring levels**

# Population Modeling

- **Transient dynamics models indicate ≈ 85% chance of extinction in next 20 years if K changes ≈ 20% (*Klinger et al in review*)**



# Is It Useful To Think Of The Vole As A Canary?



- **Ecologically, probably not**
  - **The wetlands will probably alert us to the likely trajectory of the vole before the vole warns us of the likely trajectory of the wetlands**
- **But for *management* the vole is a very useful bird**

# Measurable Conservation Actions

## What Is Working

- Tremendously successful collaboration
  - Three federal agencies, two universities, one state agency, two NGO's
  - High profile success story (so far)
- Highly integrated science driven management
  - Population and habitat monitoring
  - Field and mesocosm experiments
  - Restoration
  - Captive breeding
  - Translocations
- *Moving from deterministic vole-o-centric management perspective to wetland protection based on stochastic dynamics*

## What Could Be Improved

- Socio-economic perceptions
  - Extremely low human population density
  - Tiny local economy
- Long-term planning
  - Likely a conservation-dependent species
- Water management strategy
  - How to provide water to wetlands in a system with high variability and high uncertainty

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