Welcome to the Conservation Lecture Series

www.dfg.ca.gov/habcon/lectures

Questions? Contact margaret.mantor@wildlife.ca.gov
Lecture Schedule

- **White Abalone, Dr. Kristin Aquilino**
  July 22, 1:00-3:00, Sacramento

- **Rearing Salmon in the Yolo Bypass, Carson Jeffres**
  August 25, 1:00-3:00, Sacramento

- **California Red-Legged Frog, Jeff Alvarez**
  September 9, 1:00-3:00, Sacramento

- **Townsend’s Big-Eared Bat, Dr. Dave Johnston**
  October 7, 1:00-3:00, Sacramento
Conservation challenges for the critically endangered Amargosa vole

or

Demography, population dynamics, and habitat selection of the Amargosa vole: implications of short and long-term stressors on an endangered wetland-dependent mammal that lives in a very dry place

Janet Foley, UC Davis School of Veterinary Medicine

and

Robert Klinger, USGS Western Ecological Research Center

Photography courtesy of Caitlin Ott-Conn, Deana Clifford, Judy Palmer
History of the Amargosa vole

- End of the Pleistocene, the vole begins to be cut off from other vole populations.
- The T&T railroad is constructed, fragmenting and protecting marshes from floods.
- The vole is rediscovered near Tecopa.
- The state of California lists the vole as an endangered species.
- The "Amargosa Vole Recovery Plan" is published.
- The first demography study on the vole begins.

- 9687 BC
- 1900
- 1906
- 1917
- 1936
- 1967
- 1980
- 1984
- 1998
- 2010
- 2011
- 2013

- The Amargosa vole is first described in Shoshone, CA.
- The vole population in Shoshone goes extinct.
- The "Borehole" is dug, creating new habitat for voles.
- USFWS lists the vole as a federally endangered species.
- An orange mite is discovered on the vole.
- Demography, disease, occupancy, and predation studies continue.

Endangered Species Act

North American Fauna No. 41
Amargosa vole natural history: a subspecies of California vole (*Microtus californicus*)

*M. californicus scirpensis*

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

- Mojave Ecoregion
  - 152,000 km$^2$
  - 95,000 miles$^2$
  - Tecopa is located in the central Mojave

The vole lives about here

Image courtesy of Randy McKinley USGS-EROS
Amargosa voles were differentiated from California voles because of isolation.

After Pleistocene water receded, isolated to small pools and river stretches with riparian vegetation sometimes only meters wide.

First description:
- narrow zygomatic arch
- light colored pelage
We see:
Large California vole (75-100g)
Relatively docile
Lives, nests, burrows, and feeds in bulrush
“Mouse-brown” color with a white mustache
Status of species

• Only 80 ha true habitat in small, disjunct marshes
• No known marsh hosts sustainable subpopulation
• 50-500 *Amargosa voles* left
• Intense predation pressure, very short (months) life span
• All in a single watershed (Tecopa) vulnerable to drought, fire, disease, catastrophes that can end species existence *in days*
Life within a subpopulation

Disjunct pools, downstream spillover

Lack of true migration fails to promote metapopulation

Each subpopulation far below Allee threshold

Great recruitment, extremely high mortality
Biotic associations

- woodrats, house mice, cactus mice
- voles and harvest mice
Pathogens can contribute to extinction:

If they cause disease
Deterministically (no chance involved)
  – Frequency-dependent transmission
  – Apparent competition/overlap with maintenance species

Stochastically
  – Demographic stochasticity in host population growth
  – Catastrophic epidemics
Biotic associations with parasites: Disease in Am voles and sympatric small mammals

*Toxoplasma gondii* prevalence 13%

*Bartonella* spp. 24%

*Borrelia burgdorferi* sensu lato spp. 21%

*Anaplasma phagocytophilum* 2.6%

*Rickettsia* spp. 13%,

Relapsing fever *Borrelia* 3.9%

**Ticks**

**Fleas**, so far generalist fleas

**Mites** (chiggers)

Hantavirus, *Yersinia pestis, Francisella tularenisis*– none yet

*Leptospira* – in progress
Chigger mite-associated Gross Lesions

Common on voles and harvest mice but disease only in voles
Inflammation
Complete loss of tissue
Necrosis

Photos by Judy Palmer and Caitlin Ott-Conn
Description of Mites

Morphological description from electron micrographs
Genetic analysis (18S rRNA gene)

*Neotrombicula microti* (larva or chigger)
Histological Assessment of Lesions

Inflammation and necrosis

Heightened reaction surrounding stylostome

No noted secondary infections

Why are voles so severely affected?

Photo by Leslie Woods
Diagram by http://en.wikipedia.org/wiki/Trombiculidae
Irritant, reduced feeding, increased grooming?

Anal mites and impaired breeding?

Disease transmission?

Impact of mite on the vole
The *Toxoplasma gondii* life cycle

*Expert Reviews in Molecular Medicine ©2001 Cambridge University Press*
Behavior response to *Toxoplasma gondii* infection in rodents (Vyas 2007 PNAS 104: 6442)

Encysts in the brain
Learning capacity in infected hosts inversely related to parasite load
Infected mice were more active and attracted to novel stimulation
Infected rats did not avoid cat areas and in some cases preferred them
Ticks on some of the voles
Ticks and tick-borne pathogens from Tecopa, autumn 2011-spring 2013

• 62 infested Amargosa voles (many recaptures), 15 harvest mice, 11 house mice
• All ticks confirmed as *I. minor*
• 99% identity of 16S to *I.*
  91% with (*I. muris*)
• 98% identity to calreticulun to *I. minor calreticulin*, 88% *pacificus*.
• 13 adults (9 female, 4 male), 3 larvae, and 5 nymphs
• February, March, and April
3730 Chromatogram

Ixodes minor 16S ribosomal RNA gene, partial sequence; mitochondrial gene for mitochondrial product

Sequence ID: gb|AF549841.1  Length: 482  Number of Matches: 1

Range 1: 120 to 393

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Ecology of *Ixodes minor*

- First described in 1902 from Guatemalan “Hesperomys” (possibly *Calomys* sp.)
- Considered an invalid species in 1945, lack of corroborating data
- Rediscovered in Georgia as *I. bishoppi*, synonymized with *I. minor* 1961
- Well-documented now from Florida to Virginia, range expansion!
- Feeds in all stages on small mammals, ground-feeding, sometimes migratory birds
Ixodes minor- transmitted *Borrelia* species

- *Borrelia burgdorferi* sensu lato screening by real-time PCR
- Sequencing of *flagellin, ITS, 16S* genes,
- 23% Amargosa ticks positive, 24.2% voles, 27% house mice, and 7% harvest mice
- All informative genes had highest match to *B. carolinensis*
Species phylogeny based on concatenated sequences of five genomic loci of control Borrelia species available from databases and obtained in this study.

This disease work raises important questions

- How will patch connectivity affect pathogens and vole?
- Does disease regulate population size or are losses compensatory (e.g. via predation)?
- Assuming vole numbers < Allee threshold and heritable disease resistance is impaired, how does disease contribute to extinction vortex?
- How do we manage for disease during captive propagation and translocation?
Genetic structure of Amargosa vole populations

• Origin of the subspecies:
  • Mitochondrial DNA ties Am voles to southern California clade.
  • But nuclear DNA (microsats) and skull structure tie Am voles to eastern Sierra Nevada and northern Cal clade

• Present genetic status:
  • 5 of 12 microsats show no variation
  • Virtually no variability in any loci at Marsh 1
  • No power to detect population substructure

• Loci under selection: disease resistance? Other important?
Ecological Setting
Overview

Environment is:

• Isolated
• Extreme
• Variable
  – Seasonally
  – Interannually

• Isolated + Extreme + Variable ≠ Closed
  – Wetlands depend on water from outside sources
    • Large-scale precipitation patterns
    • Recharges by runoff from distant mountain ranges
Ecological Setting

- Mojave Ecoregion
  - 152,000 km²
  - 95,000 miles²
- Tecopa is located in the central Mojave
Ecological Setting
Spatial Pattern of Precipitation

- Four major precipitation zones in the Mojave ecoregion

(Tagestad et al in prep)

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

The vole lives about here
Ecological Setting
Temporal Variation in Precipitation Regime

- Recent analysis
  - Monthly time series 1950 – 2012
    - N = 29 stations parsed to 14 with near complete annual records
    - All within ecoregional boundary

High variability but NO trend
(Multivariate Autoregressive State-Space Model: MARSS)
Ecological Setting
Strong Seasonality In Habitat Conditions

January 2012

May 2012
A Starting Point
Distribution, Abundance, Habitat Selection, and Scale
A Conceptual Framework
Distribution In Geographic and Environmental Space

- Implications of pattern
  - Relatively unsusceptible to habitat degradation
  - Could find suitable habitat in other locations
  - Disease transmission enhanced
Distribution In Geographic and Environmental Space

- **Implications of pattern**
  - Susceptible to habitat degradation
  - Could find suitable habitat in other locations
  - Disease transmission enhanced
Distribution In Geographic and Environmental Space

• **Implications of pattern**
  - Susceptible to habitat degradation
  - Could find suitable habitat in other locations
    • **Dispersal critical**
  - Disease transmission reduced
    • **Dispersal critical**
Distribution In Geographic and Environmental Space

• Implications of pattern
  – More resilient to habitat degradation
  – Unlikely to find suitable habitat in other locations
  – Disease transmission enhanced
Distribution In Geographic and Environmental Space

**Implications of pattern**
- Resilient to habitat degradation
- Unlikely to find suitable habitat in other locations
  - Dispersal critical
- Disease transmission reduced
  - Dispersal critical
Distribution In Geographic and Environmental Space

- Implications of pattern
  - Highly susceptible to habitat degradation
  - Unlikely to find suitable habitat in other locations
  - Disease transmission enhanced
Main Questions
What Is Its Habitat?
What Condition Is Its Habitat In?
How Is Its Population Structured In Space?
What are its temporal dynamics?
What Stressors Are On The Population?
Demographic Component of Study

• What are relative contributions of survival, recruitment and dispersal to vole population dynamics?
  – Question of temporal dynamics
  – Objectives
    • Estimate abundance
    • Estimate survival
    • Estimate movement

• What is the distribution of abundance in the population?
  – Question of geographic space
  – Objectives
    • Estimate abundance in multiple geographic areas

• What is the relationship between disease and demography?
  – Question of resilience
  – Objectives
    • Estimate proportion of infected individuals in population
    • Estimate survival and recruitment among uninfected and infected individuals
Habitat Component of Study

• How closely tied are voles to *Schoenoplectus* dominated vegetation?
  – Question of environmental space
  – Objectives
    • Quantify vegetation structure at multiple scales
    • Relate captures to vegetation structure *and* composition

• What is vole habitat?
  – Question of environmental space
  Objective
    • Estimate parameters for key structural and composition components of vole habitat

• Where is vole habitat?
  – Question of environmental *and* geographic space
  – Objective
    • Map environmental space onto geographic space
Study Design

**Spatial component**
- Six 1 ha trapping grids
- Random origin
- Linear distance ≈ 1.3 km
- Inter-grid distance 75-250 m
- Includes multiple vegetation assemblages
  - Avoid bias towards *Schoenoplectus* dominated vegetation (self-fulfilling prophecy)
Study Design

- **Demographic component**
  - January – May 2012
  - 108 live traps per grid (1 ha)
  - 12 subgrids per grid (0.0225 ha)
  - 9 traps per subgrid
  - Each grid trapped for 5 consecutive days every 4 weeks (robust design)
Study Design

- **Habitat component**
  - Quantify habitat structure and vegetation composition at trap, subgrid and grid scales
    - Vegetation, bare ground, litter depth, soil moisture, soil pH, soil temperature, standing water depth
  - Collect data in winter (January/February) and late spring (May/June)
Study Design

• Habitat map
  – Major vegetation formations
  – NAIP imagery
    • 1 square meter resolution
    • 2012 imagery
  – Classification based on maximum likelihood and resampling methods
  – Validate with “blind” ground-truthing
    • January – February 2013
    • N = 600 randomly selected points
Very Powerful Design

- Avoids bias in habitat evaluation
- Quantify temporal dynamics
  - Abundance
  - Demography
  - Habitat use
- Quantify spatial dynamics
  - Abundance
  - Demography
  - Habitat use, structure, and composition at multiple scales
  - Movements within and among grids
- Estimate monthly total population size
- Can link temporal and spatial dynamics
### Abundance
- Great spatial variability
  - $N = 166$ individuals
  - Animals caught at 4 of the 6 grids
  - $\approx 86\%$ of animals occur in one grid

![Short-term Population Dynamics Graph](image)

**Legend:**
- Grid 1
- Grid 2
- Grid 4
- Grid 6

**Pradel reverse-time/Huggin's N-mixture closed population with heterogeneity model**
Short-term Population Dynamics

- Abundance
  - Rapid increases
  - Less extreme decrease

![Graph showing population dynamics with Pradel reverse-time/Huggin's N-mixture closed population with heterogeneity model](image-url)
Relationship Between Abundance & *Schoenoplectus* Cover

- **Mean *Schoenoplectus* cover**
  - No voles in grids with < 50% *Schoenoplectus* cover
- **Variation in *Schoenoplectus* cover**
  - Density greater with less variation in cover (i.e. less patchiness)
  - Caution because of certain amount of statistical artefact
- **Patterns constant across seasons**
Demographics

- **Sex and age structure**
  - Even sex ratio
  - ≈ 85% of population adult age class
Demographics

- Recruitment
  - Variable per capita recruitment
  - Shows same pattern as lambda!

Pradel reverse-time/Huggin’s N-mixture closed population w/heterogeneity model
Demographics

- **Dispersal**
  - ** Movements**
    - Mean maximum $\approx 25$ m (both sexes)
  - **Spatial pattern**
    - 60% occurred in one subgrid
    - 32% occurred in two subgrids
    - 8% occurred in three subgrids
  - **No intergrid dispersal**
Demographics

- Breeding & survival
  - Variable monthly breeding
  - Constant but *low* monthly survival
    - $\Phi = 0.342 \pm 0.040$ (95% CI = 0.268 – 0.424)
Demographics & Disease

- Low infection rates
  - Numbers too small for meaningful statistical analysis

- Qualitative patterns
  - Proportion infected low and decreasing
    - 13.9% January – February
    - 6.6% March - June
  - Persistence of infected individuals similar to or greater as uninfected individuals
  - Only one infected individual “got worse”
Demographics

- **Demographics & Disease**
  - Low infection rates
    - Numbers too small for meaningful statistical analysis
  - Qualitative patterns
    - Proportion infected low and decreasing
      - 13.9% January – February
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*First key pieces of information on population dynamics*
Survival influencing *levels* of abundance
Recruitment influencing *rates of change* in abundance
Dispersal has a negligible effect on population dynamics
Population dynamics are occurring at a *local scale*
Role Of Density Dependence In Population Dynamics

Evidence of density-dependence on reproduction
Evidence of density-dependence on population rate of change

$$\lambda = 1 \approx 30 - 35 \text{ voles ha}^{-1}$$
Occupancy

- Grid scale (1 ha)
  - Mean proportion of area occupied $= 0.501 \pm 0.146$ SE
  - Monthly colonization ($0.091 \pm 0.087$ SE) and extinction ($0.077 \pm 0.074$ SE) rates similar
  - Grids < 50% cover of bulrush were not occupied

Dynamic occupancy models
Occupancy

- Subgrid scale (225 m²)
  - ≈ 21% of habitat occupied
    - Large proportion of habitat is unoccupied
Occupancy

- Subgrid scale (225 m²)
  - Probability of patch occupancy increases dramatically as cover of *Schoenoplectus* increases
Linking Occupancy, Abundance & Habitat Structure

- **Grid scale**
  - Very high heterogeneity among grids
    - Schoenoplectus/Distichlis ratio
    - Proportion of bare ground and salt flat
    - Litter density and depth
    - Vegetation height
  - Very high heterogeneity within grids
    - Schoenoplectus/Distichlis ratio
    - Proportion of bare ground and salt flat
    - Litter density and depth
    - Vegetation height

  Grid 1
  - 86% of population

  Grid 2
  - 5% of population

  Grid 3
  - No captures

  Grid 4
  - 6% of population

  Grid 5
  - No captures

  Grid 6
  - 3% of population

Universal kriging
Habitat Selection

- Number of individuals captured
  - Subgrid scale
    - CV *Schoenoplectus* stronger predictor than mean *Schoenoplectus* cover
  - Trap scale
    - Mean *Schoenoplectus* cover very strong predictor
    - Mean cover of litter weak predictor

Generalized linear mixed models
Habitat Use & Selection

- **Subgrid scale**
  - Habitat structure
    - Separated along axes of vegetation height and litter depth (Axis 1) and vegetation cover (Axis 2)
  - Vegetation composition
    - Separated along axis of *Schoenoplectus* and *Distichlis* cover
  - Habitat use
    - Most voles occurred in subgrids dominated by *Schoenoplectus*
    - **Many subgrids with suitable habitat unoccupied or have few voles**
    - Occasionally occur in mixed *Distichlis/Juncus* patches
    - **DO NOT PERSIST** in these patches
  - Habitat structure voles like
    - Tall, dense, homogeneous stands of *Schoenoplectus* with deep dense litter layer
    - Lots of captures in this stuff!

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Redundancy Analysis

N for SU’s = 72 subgrids
Veg species cover (Hellinger transformed); N = 12 species
6 vegetation structure variables and 2 physical structure variables
58% of unconstrained variation accounted for by constraints (habitat structure variables)
98% of constrained variation accounted for by habitat structure variables
Habitat Use & Selection

- A less technical way of looking at things

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Here are the voles!
Habitat Use & Selection

- A less technical way of looking at things

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Here are where the voles aren’t
Habitat Use & Selection

- A less technical way of looking at things

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Here are the voles!
Habitat Use & Selection

- A less technical way of looking at things

Redundancy Analysis

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6 vegetation structure variables and 2 physical structure variables
58% of unconstrained variation accounted for by constraints (habitat structure variables)
98% of constrained variation accounted for by habitat structure variables
Habitat Mapping

- Very accurate map
- Overall confusion matrix statistics
  - Accuracy = 0.904 (95% CI’s 0.881 – 0.929)
  - Cohen’s Kappa = 0.856
- Confusion matrix statistics for *Schoenoplectus*
  - Sensitivity = 0.942
  - Specificity = 0.941
  - Positive Predicted value = 0.916
  - Negative Predicted value = 0.960
Habitat Mapping

- Key pieces of information
  - 107 hectares of wetland habitat
  - Only 30 hectares of bulrush vegetation
    - Many < 0.1 ha
  - Original recovery plan estimated 20 km² of “critical habitat”
Distribution In Geographic and Environmental Space

- **Implications of patterns**
  - Highly susceptible to habitat degradation
  - Could find suitable habitat in other locations
  - **Dispersal critical**
Now What Could We Do With This Information?

- Estimate overall population size
  - Baseline for continued monitoring
  - Benchmark for evaluating success of management actions
- Develop a population model
  - Explanatory component
  - Forecasting component (PVA)
- Outline preliminary conservation/management actions
  - Hypothesis driven
  - Short-term and long-term actions
An Initial Population Model

• Stage-based (Lefkovitch matrix)

• Explanatory component
  – Identify sex-age class and demographic parameters primarily responsible for population change

• Structure
  – Four main subpopulations
  – \( K = 35 \) voles ha\(^{-1} \)
  – 2-sex model
  – 3-stages
  – Monthly timesteps
  – 20 year runs (240 months)
  – Demographic stochasticity
    • From variance in survival and recruitment
  – Environmental stochasticity
    • Variance in estimate of \( K \)
  – Density-dependence
  – Allee effects
  – Low dispersal
  – 25% chance of flood every five years

\( N = 1000 \) runs
An Initial Population Model

- **Main patterns**
  - Model-based density-dependence very similar to the observed pattern
    - Evidence model specifications are reasonable
    - Shows some subpopulations will not reach positive growth rates
      - Sink populations
      - Depend on rescue effects
      - But dispersal rates are *LOW*
An Initial Population Model

• Main patterns
  – Model-based density-dependence very similar to the observed pattern
    • Evidence model specifications are reasonable
    • Shows some subpopulations will not reach positive growth rates
      – Sink populations
      – Depend on rescue effects
      – But dispersal rates are LOW
  – Three parameters had approximately equal importance
    • Juvenile → subadult transition
    • Subadult → adult transition
    • Fecundity
Some Lingering (and important) Questions

Why the extreme habitat specialization?
What were the main mortality factors?
Were these related?
Some Lingering (and important) Questions

Why the extreme habitat specialization?
   Microclimate?
   Food Resources?
Some Lingering (and important) Questions

Why the extreme habitat specialization?

Food Resources?
Competition?
Lack of access to alternative habitats?
Predation?
The Development Of A Hypothesis

• Top-down effects
  – Everyone wants a furry burrito
  – About 2 dozen potential predators

• Hypothesis:
  – Habitat selection influenced *primarily* by top-down effects
  – Population dynamics influenced *primarily* by bottom-up effects
    • Food quality
    • Predictability of food resources?
  – Variation of Chutes & Ladders concept
Road Map To Another Years Activities
(The best laid plans…)

• Section 6 funding came through
  – Study top-down effects
  – Find evidence of how many patches of habitat were or **had been** occupied
    • Scat
    • Runways
    • Hair
  – Continue trapping at population center (Borehole Marsh)

• Continue habitat sampling
  – Quantify inter-annual variation in habitat structure
  – Relationships between Schoenoplectus, Distichlis, and physical factors (soil and water variables)
Then The Scat Hit The Fan…

Borehole June 2012

Borehole June 2013

Virtually no emergence of new Schoenoplectus in 2013
Low statured but green marsh was now low statured and brown
Translated to MUCH lower abundance of voles
Then The Scat Hit The Fan…

- Vole abundance at the Borehole was estimated at 8 individuals in November 2013
  - All were captured in a narrow band along the creek where there was denser, green *Schoenoplectus*
- Optimistic population “pseudoestimate” was around 36 individuals
- All evidence indicated a major collapse in *Schoenoplectus* cover between 2012 and 2013 in the vole’s core population habitat
- *WHY?*
Two Critical Factors For *Schoenoplectus* Growth

- Warm soil temperatures
  - $\approx 16^\circ - 17^\circ$ C
  - No significant shift in pattern of seasonal soil temperatures
- Standing water
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Two Critical Factors For *Schoenoplectus* Growth

- **Warm soil temperatures**
  - ≈ 16° - 17 °C
  - No significant shift in pattern of seasonal soil temperatures

- **Standing water**
  - Starting somewhere around late spring of 2012 recharge into the majority of the Borehole marsh dramatically slowed
  - *Schoenoplectus* no longer had enough reserves to push through extremely thick organic litter
Distribution In Geographic and Environmental Space

- Implications of patterns
  - Highly susceptible to habitat degradation
  - Could find suitable habitat in other locations
    - **Dispersal critical**
Some Implications and Transitioning Thoughts

- Immediate concerns
  - Situation had quickly gone from precarious to dire
  - The core population was now likely a sink population confined to a VERY narrow strip of habitat
  - Narrow window for habitat restoration to be successful
  - The Amargosa vole may now be the most endangered mammal in the United States
Some Implications and Transitioning Thoughts

• Longer-term concerns
  – The marsh and the vole are strongly linked
  – Situation at Borehole had human and natural causes
  – Evidence other patches of marsh were also drying
  – Suggested a relationship with larger-scale climate patterns
Population status and viability: stochastic time series

\[ T_e(n_0) = 2n_0(k-n_0/2)/v_r \]

- \( T_e \): time to extinction
- \( n_0 \) is \( \ln(\text{initial N}) \)
- \( k \) is \( \ln(K) \), lowest annual \( K \)
- \( v_r \) is variance in \( r \) due to environmental stochasticity
- \( r \) is the per capita growth rate

(Foley 1997, Extinction models for local populations)

Model predicts \( T_e \) from 16-35 years and 10% chance of extinction in 2014.
Two scenarios for Lefkovich matrix projections

- Main goal was to estimate times to extinction
- Conditions for 20 years remained similar to those in 2012
- Deterioration in habitat quality at Borehole as observed in 2014
  - Expressed as deterministic reduction in $K$ at Borehole
  - $K$ in other subpopulations same as 2012

$N = 1000$ runs
Predictions For Patch Occupancy

- If conditions remained similar to 2012
  - Population likely to persist
- Habitat loss not reversed
  - Population will likely be extinct by 2017
Predictions For Borehole Population

- If conditions remained similar to 2012
  - Population likely to persist
- Habitat loss not reversed
  - Population will likely be extinct by 2017
Predictions For Entire Population

- If conditions remained similar to 2012
  - 41% chance likely to go extinct within 20 years

- Habitat loss not reversed
  - 97% chance likely to go extinct within 20 years
Predictions For Lingering Populations

• If conditions remained similar to 2012
  – 54% chance likely to go extinct within 20 years
• Habitat loss not reversed
  – 100% chance likely to go extinct within 20 years
Am vole management
Implementing 1997 Recovery Plan recommendations

Learn
- Document genetic structure of population
- Understand basic biology of the species
- Describe the extent of occupied habitat, determine habitat requirements, and determine habitat quality
- Determine population size
- Outside the scope: Survey pathogens and parasites, determine impact on population health

Manage
- Acquire land
- Improve or recreate habitat
- Assist translocation (supplemental or reintroduction)
- Perform captive breeding (manage for alleles and disease)
What Kinds Of Transitions In Remaining Vole Habitat Are We To Expect In The Future?

From this… …to this?

How resistant and how variable will the Amargosa wetland complex be to ongoing shifts in climate?
Some Implications and Transitioning Thoughts

• Some reason for optimism
  – Rapid and positive multi-agency and multi-institutional response to incorporate the new scientific evidence into on-the-ground management actions
    • Brian Croft (FWS)
    • Erin Norden (FWS)
    • Chris Otahal (BLM)
    • Scott Osborn (CDFW)
    • Steve Parmenter (CDFW)
    • Susan Sorrels (Shoshone Village)

• Some glimmers of frustration
  – Ecological and conservation needs are moving faster than bureaucratic processes

• Some glimmers of hope
  – The Amargosa wetlands and the vole have persisted for millenia
  – May be able to continue to do so with a little timely help
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  - For hanging in there

It's STILL my marsh!!