Long Term Monitoring of Arroyo Toads: Multi-Year Trend Analysis and Program Evaluation

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Arroyo Toad (*Anaxyrus californicus*)

- **Federally Endangered**
  - Monterey County to northern Baja
  - Occupies 25% of former habitat

- **Habitat Specialist**
  - Low gradient streams/rivers
  - Sandy substrates
  - Breeding- low flow shallow pools

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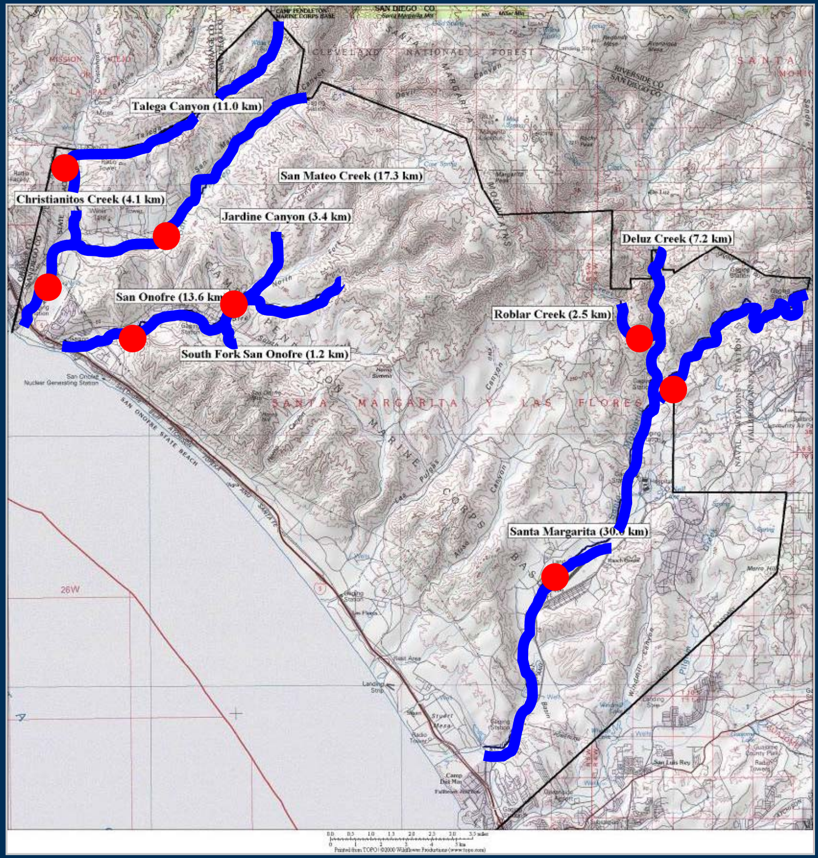
MCBCP Arroyo Toad Monitoring: Camp Pendleton

- Coastal southern California-northern San Diego County
- 125,000 acres
- 3 major watersheds
- 87 km arroyo toad habitat



● Holland 1 km transects 1996-2000

MCBCP Arroyo Toad Monitoring: Program Goals 2003

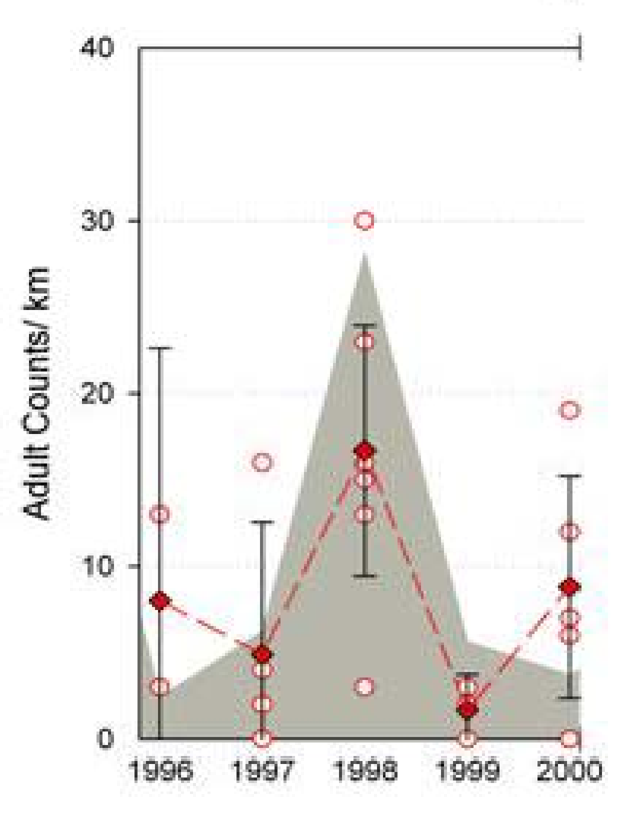
- Track trends in breeding populations within 3 occupied drainages (87 km)
- Long term monitoring metric least affected by short term fluctuations
- Recommend management actions & evaluate effectiveness of actions
- Cost effective
- Scientifically rigorous

AT Monitoring: 1996-2001

- 8- 1km transects - Selectively placed
- Night Counts of Toads- ~ 4X year
- Counts = x*Abundance + y*Activity + z*Detectability...... (x,y,z?)

Results:

- Highly Variable (survey, site)
- Don't know what it is telling us about toad populations.
- Cannot infer results across species on Base



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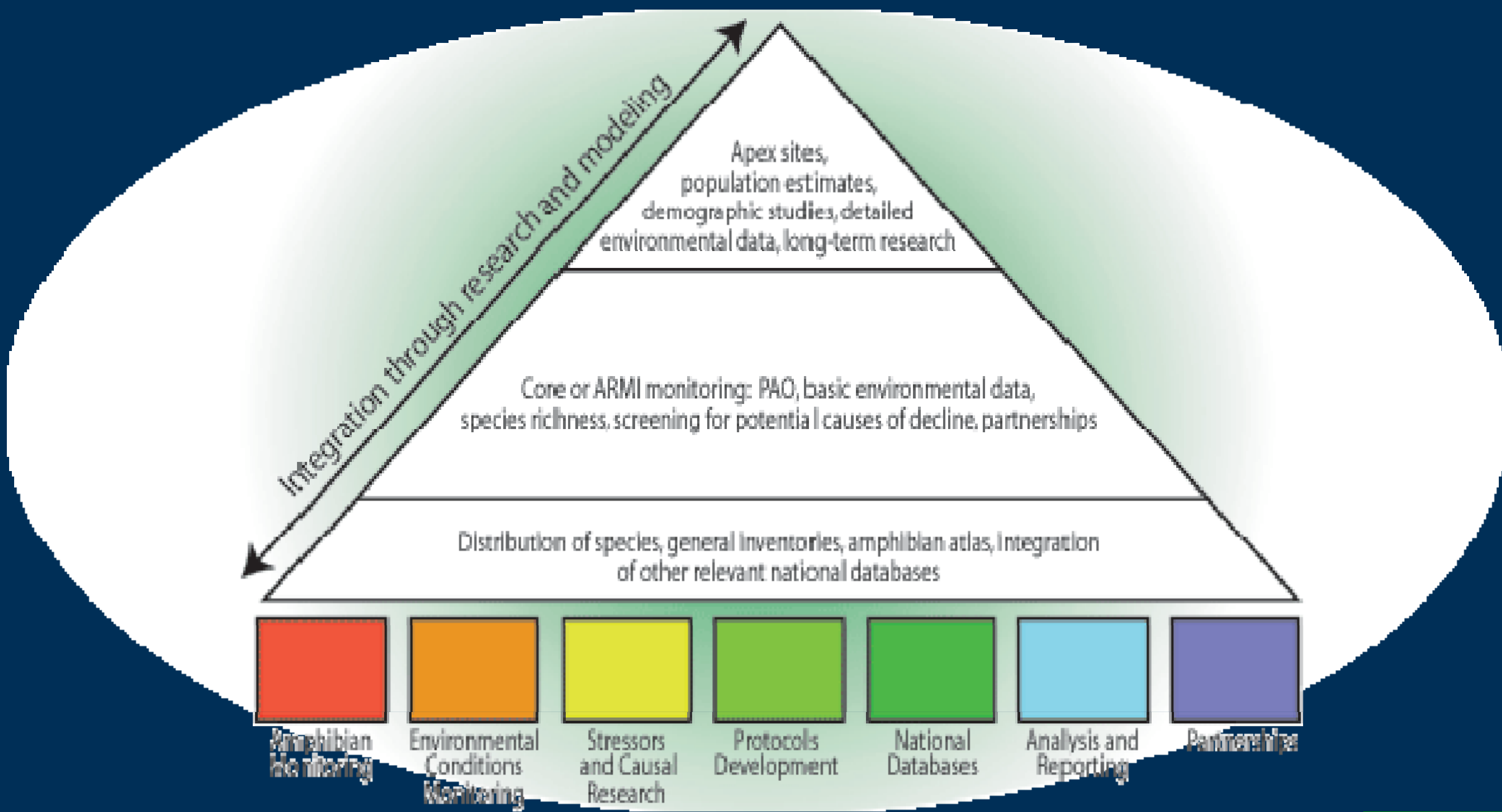
Amphibian Research and Monitoring Initiative



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ARMI

MCBCP Arroyo Toad Monitoring: Multi-agency task force

- U.S. Geological Survey
- Fish and Wildlife Service
- MCB Camp Pendleton
- U.S. Forest Service
- Outside Independent scientists
  - Brad Shaffer
  - Ted Case, UCSD
  - Norm Scott

Figure 6. Arroyo Toad Conceptual Model*

Possible Management Actions

•Protect and maintain breeding habitat and connectivity with upland habitats. Maintain sandy soil next to rivers.
•Manage natural hydrology and sediment supply to extent possible to allow natural creation and maintenance of toad habitat. Maintain flushing flows during winter and avoid unseasonal floods during spring
•Control invasive predators such as bullfrogs, African clawed frogs, non-native fish in and around breeding areas. Control invasive plants in and around breeding areas (arundo, tamarisk, water cress). Control beavers.
•Avoid disturbance, crushing, & siltation of breeding areas by vehicles/humans/livestock during breeding season
•Minimize contaminants

Breeding Adult Stage Characteristics

Breeding is nocturnal in spring after water temperatures reach at least 14 °C and water levels (<30 cm deep) and speed (<5 cm/sec) are appropriate for breeding; females assumed to lay only one egg mass, males may mate with multiple females; prefer darker nights

Habitat Conditions

Clear still to slow-moving water with shallow, exposed clean, sandy bottom and open canopy [see influencing factors]

Risk Factors (Stressors)

Breeding habitat loss due to urbanization; lack of flushing flows and sediment supply causes habitat loss due to natural plant plant succession • Breeding habitat quality degradation and loss due to exotic plants (arundo, tamarisk) or to native plants (water cress) • Lack of water in pools due to low annual rainfall, excessive water diversions and/or groundwater pumping • roadkill / crushing by vehicles, people, livestock • predation by raccoons,crows,bullfrogs, bass, crayfish, fire ants, Argentine ants? • light pollution • noise pollution does not appear to affect calling males but may have an effect on female response • aquatic contaminants (sewage effluent, pesticides) • aerial contaminants? fire retardant? • disease?

Influencing Factors

Episodic flushing flows & floods are needed to naturally disturb riparian habitat, clear vegetation on sandy terraces and maintain toad habitat; • Variability in climate, amount of rainfall, and timing of rainfall strongly affect available habitat and breeding. Breeding is limited or may not occur at all in drier years • Water diversions, and groundwater pumping can reduce flows • Dams alter the amount and timing of flushing flows and sediment supply • Beaver dams block sediment supply and alter river and stream hydrology • Excessive urban runoff can increase peak flows and contain contaminants • Weeds like arundo can slow flows and increase siltation • Ephemeral water habitats that are occasionally dry have lower concentrations of non-native fish and bullfrogs and perennial habitats have higher concentration • Erosion after fires can cause siltation of breeding habitat

Adult Life Stage Characteristics (limited knowledge)

Lifespan about 5 years (?); Favor nights for activity, burrow in sand during day; typically do not go more than 0.5-0.75 miles from breeding pools but may travel over 1 mile, distance influenced by topgraphy and microclimate; very dispersed; feed on native ants and other invertebrates

Habitat Conditions

Coastal Sage Scrub, Chapparal, oak woodland, but not grasslands (may travel thru grasslands); Require friable soils & permeable plant understory for burrowing.

Risk Factors (Stressors)

Habitat loss • Lack of connectivity between breeding habitat and uplands • Roadkill / crushing by vehicles • Non-native ants (argentine & fire ants) • Predation-native and house cats • Fire • Pesticides • drought (starvation)

Females mature: 2-3 years
Males: 1-2 years

ADULTS
Uplands

BREEDING
Jan – Early July**

EGGS
Feb-Early July**

12-20 days

TADPOLES
March-July**

65-85 days

METAMORPHS
(10-17mm)
May-August**

JUVENILES
Uplands

Egg Life Stage Characteristics

Strings of 2,000-10,000 eggs on sand, gravel, cobble or mud along pool margins away from vegetation

Habitat Conditions

Same as breeding habitat; require lack of sediment/turbidity (but can tolerate it for a few days)

Risk Factors (stressors)

Desiccation due to lack of rainfall, ground water pumping, and water diversions • *Disturbance/Siltation* due to humans, vehicles, livestock, floods, run-off, fires • Unseasonal flooding can wash eggs downstream • *Predation*: exotic fishes, crayfish, invertebrates • disease? • *Contaminants*: pesticides, heavy metals, treated effluent

Juvenile Life Stage Characteristics (limited knowledge)

Assume moving into upland but may remain by pools for up to 6 months, more dispersed than metamorphs, nocturnal, assume eat native ants & beetles; upland movement is close and parallel to stream and influenced by topography and availability of suitable microhabitat

Habitat Conditions & Risk Factors

Similar to adults

Metamorph Life Stage Characteristics

Active during day on sandy benches; still fairly clustered together; feed on native ants and possibly other invertebrates;

Habitat Conditions

Soft, exposed, sand and moist sandy benches with partial shading adjacent to pools

Risk Factors (stressors)

Crushing from vehicles and humans (when still clustered they are especially vulnerable) • Fire ants and Argentina ant displacing native ants • Predation from garter snakes, bullfrogs, birds (killdeer, herons) • Contaminants: pesticides, heavy metals, urban runoff, etc. • Habitat loss (arundo) • compaction of sand prevents metamorph burrowing

Tadpole Life Stage Characteristics (65-85 days)

Active during day; very cryptic; can disperse downstream

Habitat Conditions

Similar to breeding habitat, also need detritus, moss, periphyton

Risk Factors (stressors)

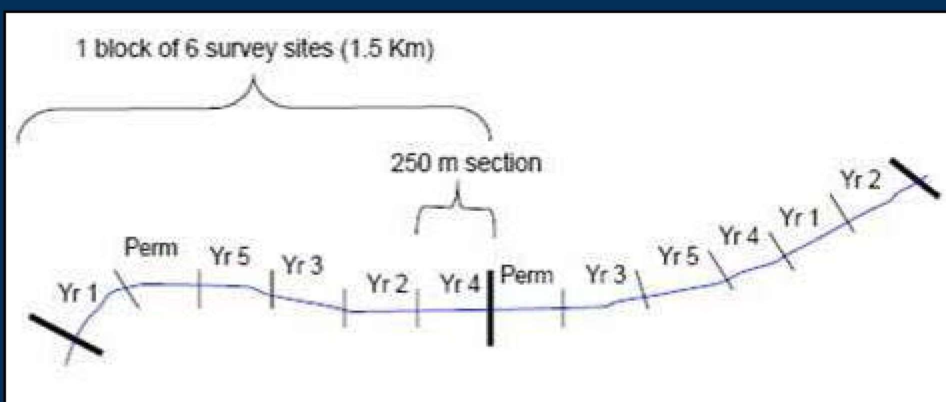
Predation: exotic fishes, garter snakes,birds,bullfrogs,etc. • Crushing, disturbance, & siltation from humans vehicles, livestock (bison)• Poorly timed flushing events can wash tadpoles downstream into poor habitats • Desiccation due to lack of rainfall, ground water pumping, and water diversions • Disease? • Contaminants: pesticides, heavy metals, treated effluent, urban runoff, etc.

* For details see arroyo toad recovery plan (USFWS, 1999)

** These dates may shift in some years depending on rainfall. Dates also shift in montane or inland desert areas.

MCBCP Arroyo Toad Monitoring: Design

- **Spatial Approach** (Proportion Area Occupied-MacKenzie et al. 2002, 2003)
- **357 survey transects** (250m each)
- **Rotating Panel Design**



Atkinson et al. 2003

5-Year Rotation pattern among groups of sites

Group	**# Sites**	2003	2004	2005	2006	2007	2008	2009
					Year			
Perm (all yrs)	50	X	X	X	X	X	X	X
A=Year 1	50	X					X	
B=Year 2	50		X					X
C=Year 3	50			X				
D=Year 4	50				X			
E=Year 5	50					X		

MCBCP Arroyo Toad Monitoring: Design

- **Spatial Approach** (Proportion Area Occupied- MacKenzie et al. 2002, 2003)
- **357 survey transects** (250m each)
- **Rotating Panel Design**
- **Survey for AT tadpoles**

DP: 0.85 vs. 0.45
(2003 USGS data)

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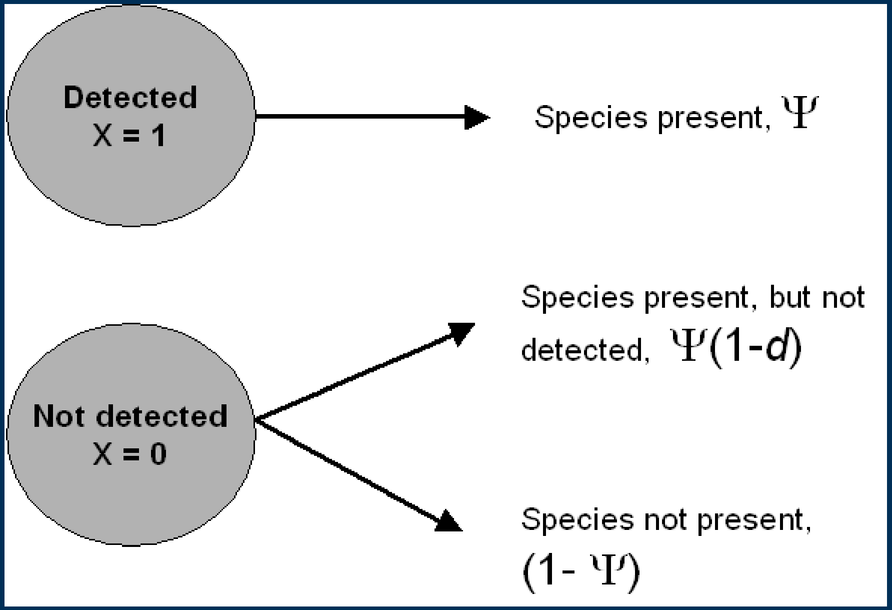
Intro to Occupancy Monitoring

Spatial

- Proportion Area Occupied/Used
- Detection probability < 1
- Relationship to Abundance



Questions that can be asked (single season):

- Are perceived differences in occupancy due to differences in ability to detect species?
- What makes habitat suitable?

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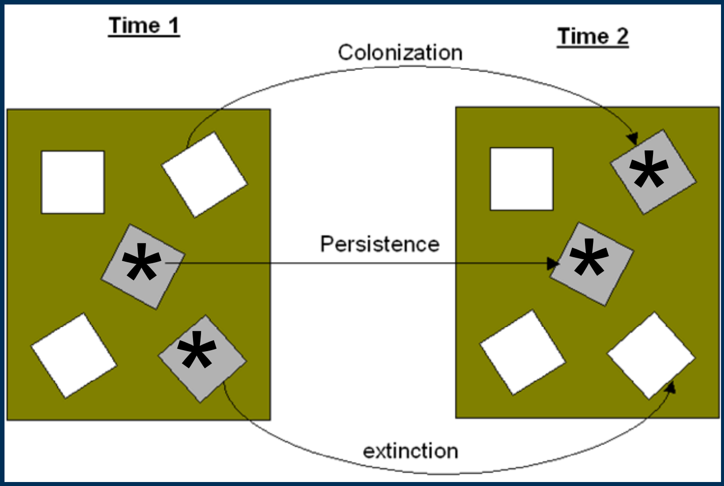
Intro to Occupancy Monitoring

Temporal

- Colonization and Extinction

  (γ) & (ε)



Questions that can be asked (multiple seasons).....

- What factors cause populations to increase/decrease over time?-- *covariates*
- Are military activities contributing to population increases/declines?
- Is my management working?

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MCBCP Arroyo Toad Monitoring:

Parameters

- **Initial occupancy** (ψ)
- **Probability of detection** (ρ)
- **Colonization/ extinction** (γ, ε)

Covariates

- **Entrenchment ratio** (ψ, γ, ε)
- **Sand cover** (ψ, γ, ε)
- **Aquatic veg. cover** (ψ, γ,, ρ)
- **Disturbance level** (ψ, γ, ε)
  - Artillery, troops, heavy equipment
- **Hydroperiod** (ψ, γ, ε)
  - Ephemeral/ perennial
- **Pres. of predators/competitors** (ψ, γ, ρ)
  - Bullfrog, crayfish, mosquitofish, lg pred fish
  - Non-native Index (0-4): Total 1st four above
- **Pres. of low flow shallow water** (ρ)
  - Index (0-5): [0, 1-10%], 11-25%, 26-50%, 51-75%, >75%

MCBCP Arroyo Toad Monitoring:

Multi-year Occupancy

Top Model- 100% AIC weight

γ, ε (t, ephemeral/perennial)

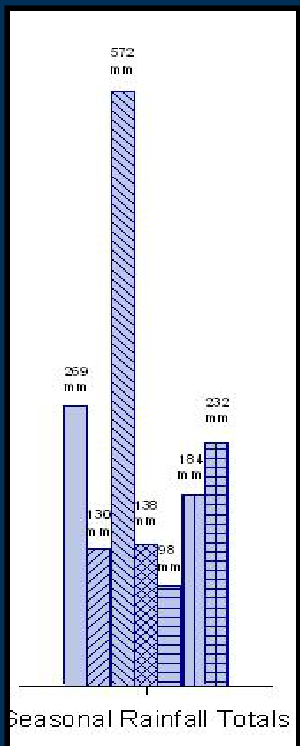
ρ (low flow index, non-native index)

Model	AIC	ΔAIC	AIC wgt	No.Par.	(-2*LogLike)	
psi,gamma(Year*Hydroperiod),eps(Year*Hydroperiod),p(LowFlow, Year*NNI)	697.04	0.00	0.99	19	659.04	*best model*
psi,gamma(Year),eps(Year),p(LowFlow, Year*NNI)	707.1	10.06	0.01	14	679.1	
psi,gamma(Year),eps(Year),p(LowFlow)	721.81	24.77	0.00	8	705.81	
psi,gamma(Year),eps(Year),p(Year*NNI)	761.88	64.84	0.00	13	735.88	
psi,gamma(Year),eps(Year),p(Year)	763.55	66.51	0.00	12	739.55	
psi,gamma(Year),eps(Year),p(NNI)	767.42	70.38	0.00	8	751.42	
psi,gamma(Year),eps(Year),p(AqVeg)	774.67	77.63	0.00	8	758.67	
psi,gamma(.),eps(.),p(LowFlowWater)	778.16	81.12	0.00	5	768.16	
psi,gamma(Year),eps(Year),p(.)	783.92	86.88	0.00	7	769.92	
psi,gamma(Year),eps(Year),p(RACA)	784.29	87.25	0.00	8	768.29	
psi,gamma(.),eps(.),p(Year)	788.2	91.16	0.00	9	770.2	
psi,gamma(Hydroperiod),eps(Hydroperiod),p(Year)	796.78	99.74	0.00	11	774.78	
psi,gamma(.),eps(.),p(NNI)	833.62	136.58	0.00	5	823.62	
psi,gam(.),eps=1-gam,p()	855.53	158.49	0.00	3	849.53	
psi,gamma(.),eps(.),p(.)	857.09	160.05	0.00	4	849.09	*null model*
psi (NNI),gamma(Year*NNI),eps(Year*NNI),p(LowFlow)	86494.18	85797.14	0.00	11	86472.18	
psi (sand),gamma(Year*Sand),eps(Year*Sand),p(LowFlow*NNI)	87634.78	86937.74	0.00	17	87600.78	

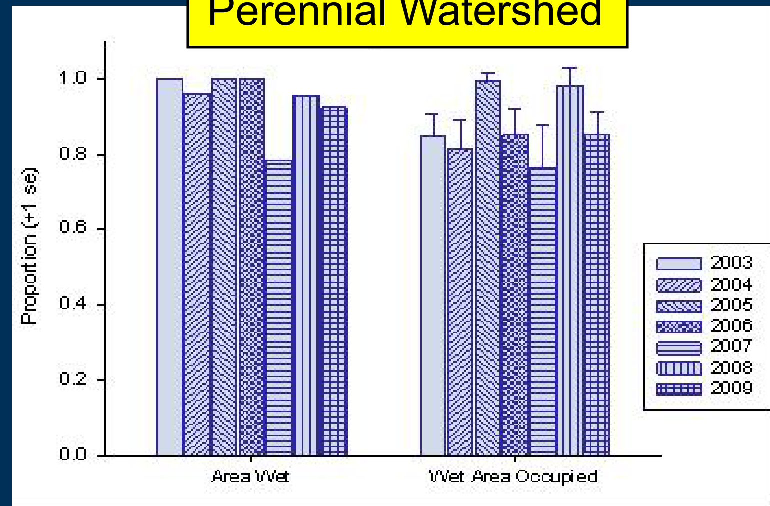
Note: Covariates tested for psi included Aquatic Emergent Vegetation Index (AEV), Bullfrog presence (RACA), Crayfish presence (PRCL), Hydroperiod (Ephem/Peren), Low Flow Shallow Water Index (LowFlow), Non-Native Index (NNI), Predatory fish presence (PredFish), and Sand Cover Index (SandCover). (*) denotes an interactive effect was tested between two variables and model parameter estimate. Models are not shown when there is evidence of poor fit (convergence <5 significant digits, no covariance matrix, standard errors>parameter estimates).

Colonization, Extinction (γ,ε)

- Hydrology
- Year

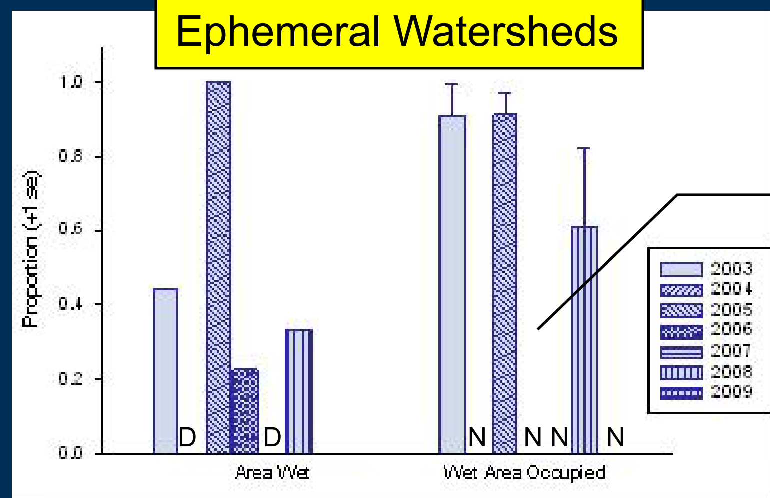


Perennial Watershed



0 < ε < 0.4
$0 < \gamma < 0.9$

Ephemeral Watersheds



0 < ε < 0.9
0 < γ < 0.8

Scouring Event

Probability of detecting arroyo toads (ρ)

- ↑ Low Flow Shallow water Index
  - 1.9X more likely to detect AT for each level of index
  - Cumulative 13X
- ↓ Non-native index (0-4) **: Association varied by year** - Peak 2007
  - Mosquitofish, bullfrogs, crayfish, predatory fish
  - 4.1X less likely per species/group
  - Cumulative 71X

  - Multistate models (David Miller, Jim Nichols, Jim Hines)

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Non-native species- Direct effects: 2008 Bullfrog Study

2008 Estimate: 125 arroyo toads consumed/ km /month

Feedback Loop to Management
Removal of Invasive Aquatic Species

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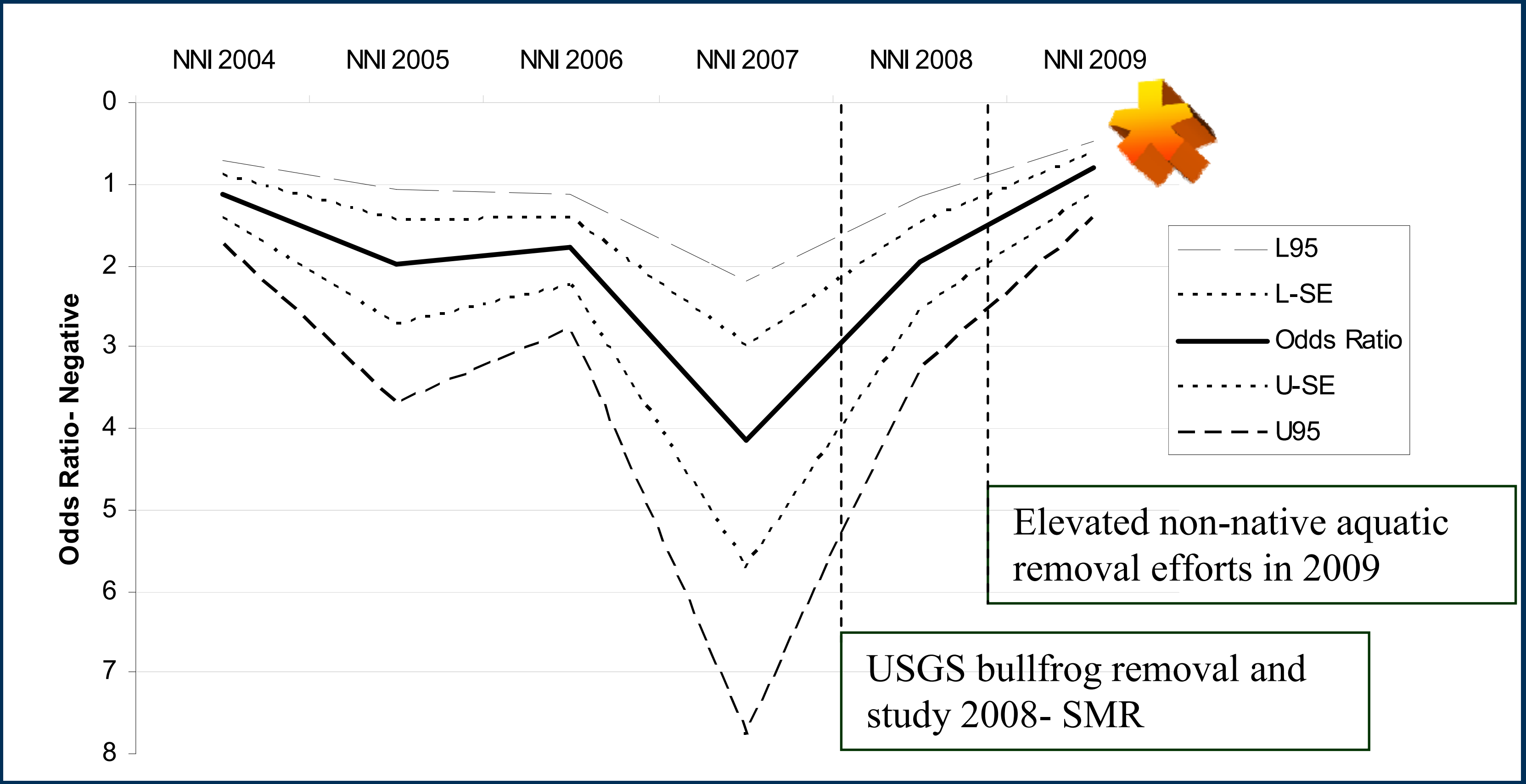
Feedback Loop to Management Removal of Invasive Aquatic Species



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Non-native Species Management Removal vs. Hydrology

Mgmt of non-natives

Perennial: many $\varepsilon = 0$

Ephemeral: few $\varepsilon = 1$ in dry years

(Miller et al. in review)

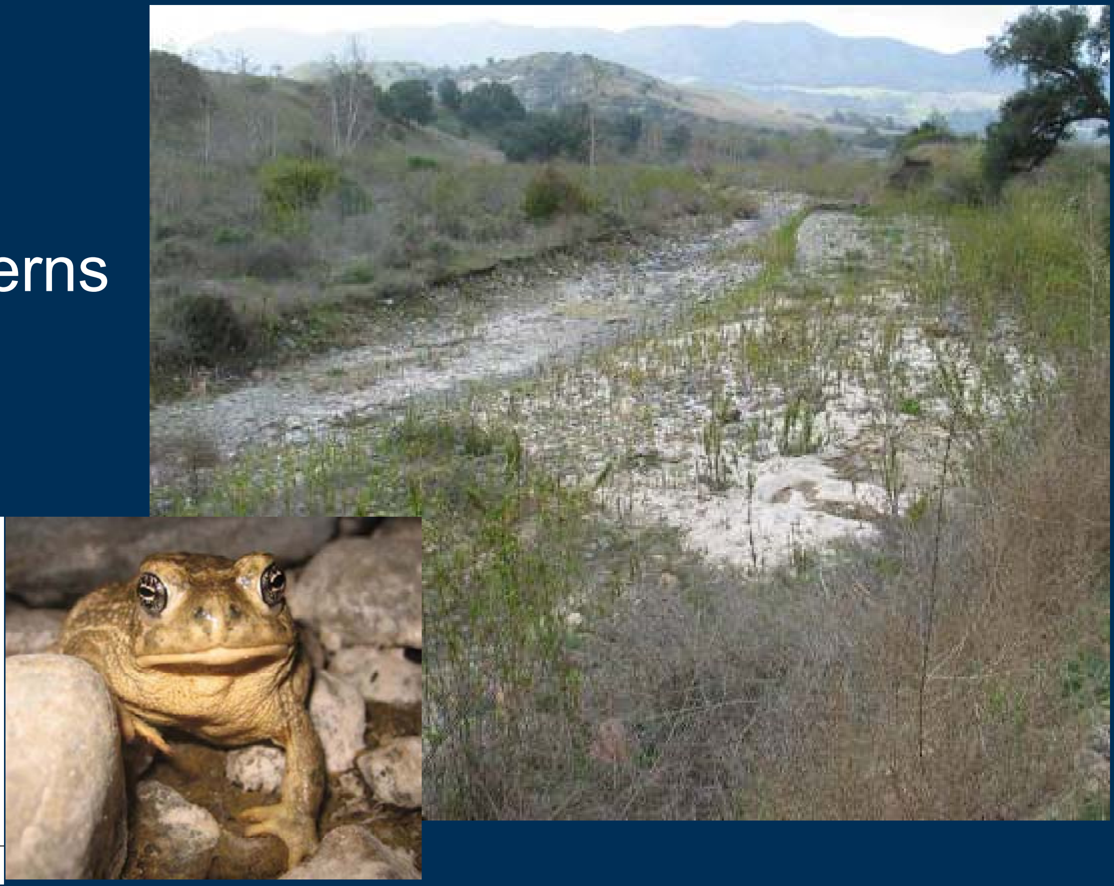
Santa Margarita River:

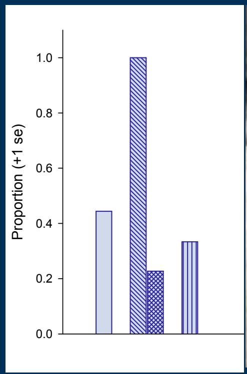
- **Upper basin- Discharge of 3cfs guaranteed**
  - **Cooperative Water Resources Management Agreement (CWRMA 2002).**
- **Aseasonal flow from agriculture**

Natural drying cycles or NNAq removal in perpetuity

Ephemeral Creeks: AT Population Dynamics

- Drought- Stochastic
- Climate Change Concerns





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MCBCP Arroyo Toad Monitoring: Program Review

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MCBCP Arroyo Toad Monitoring: Program Review

Target- Detect 20% decline

Evaluate 4 sampling scenarios

- Current Design: 60 permanent + 60 5-yr rotation
- Alternate 1: same effort: 120 permanent sites
- Alternate 2: reduced effort: 60 permanent sites
- Alternate 3: reduced effort: Current design- sampled every other year

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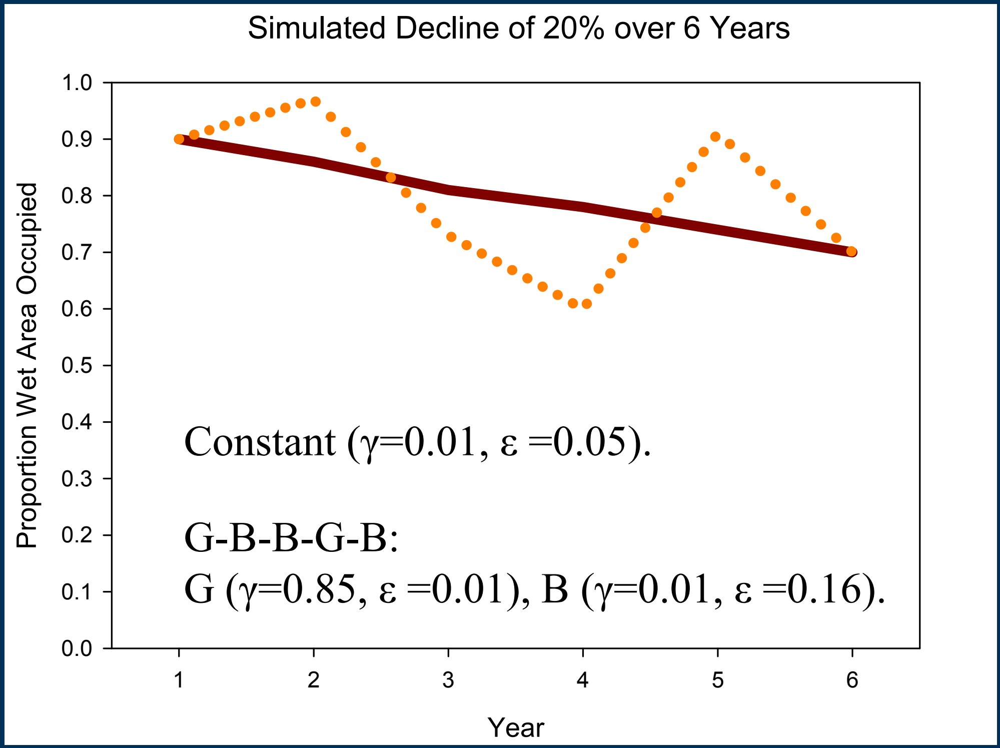
Power Analysis

Data simulated: 20% decline over 6 years

- Perennial: Constant slow decline
- Ephemeral sites: Variable declines/ increases (good & bad years)



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Power Analysis

"Power is probability a study will find a significant effect if it exists"

Model Comparisons

- Likelihood Ratio Tests (True model vs. Null hypothesis)
- Power from non-central chi-square distribution (α= 0.05)

(Burnham et al. 1987, Bailey et al., 2007, Mattfeldt et al. 2009)

Bias, Precision, Power t-test (Year 1 vs. Year 6)

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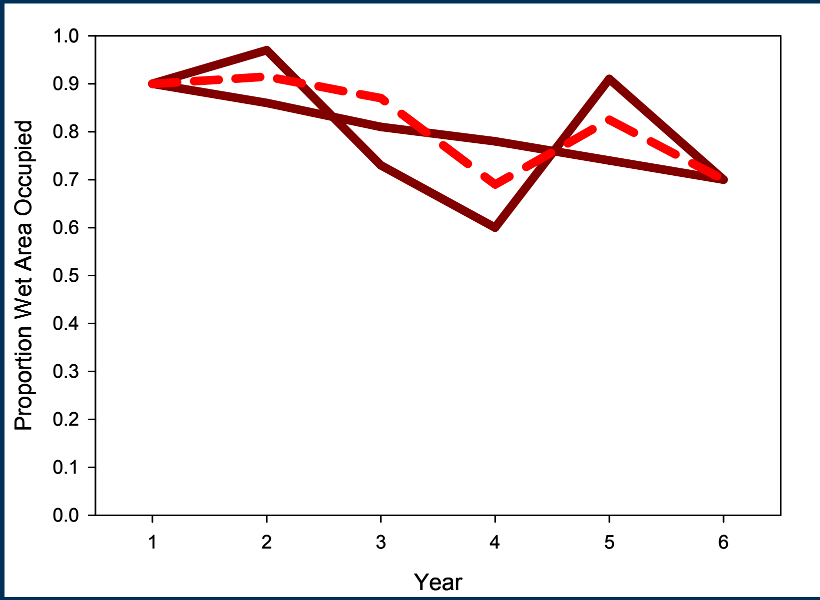
Data simulated: 20% decline over 6 years

Power to Distinguish Groups



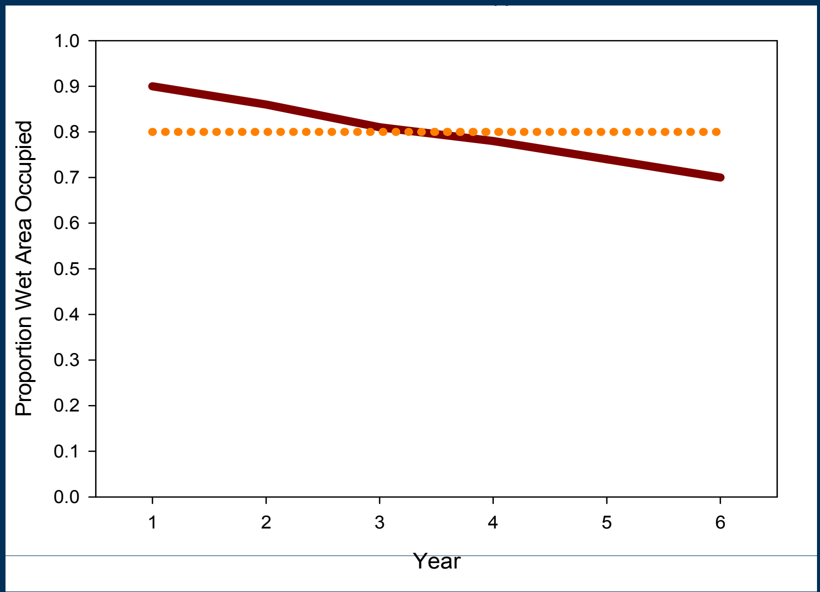
Ψ, γ (t*eph, per), ε (t*eph, per), ρ (.) "true"

Ψ, γ (t), ε (t), ρ (.)

	Sample Designs			
	Current Design: 60 Sites Permanent & 60 Sites Rotation	120 Sites Permanent	60 Sites Permanent	60 Sites Permanent & 60 Sites Rotation sampled every other year
Model/ Test	Same effort	Same effort	Reduced effort	Reduced effort
Power α=0.05	100%	100%	99%	87%

Data simulated: 20% decline over 6 years

Perennial system: decline vs. no decline



Ψ (.), ε (.), ρ (.)

Ψ, γ (.), ε (.), ρ (.) "true"

	Sample Designs			
	Current Design: 60 Sites Permanent & 60 Sites Rotation	120 Sites Permanent	60 Sites Permanent	60 Sites Permanent & 60 Sites Rotation sampled every other year
Model/ Test	Same effort	Same effort	Reduced effort	Reduced effort
Power α=0.05	91%	97%	68%	81%

Per: Yr 6 = Yr 1	72%	62%	25%	64%
Per: ε = 0	87%	89%	60%	80%

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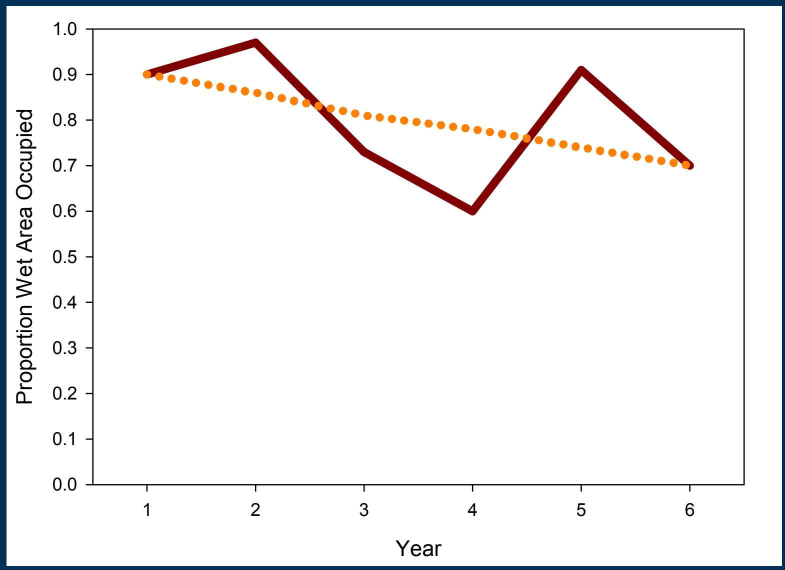
Data simulated: 20% decline over 6 years

Ephemeral system: variable decline vs. constant decline



Ψ, γ (t), ε (t), ρ (.) "true"

Ψ, γ (.), ε (.), ρ (.)

	Sample Designs			
	Current Design: 60 Sites Permanent & 60 Sites Rotation	120 Sites Permanent	60 Sites Permanent	60 Sites Permanent & 60 Sites Rotation sampled every other year
Model/ Test	Same effort	Same effort	Reduced effort	Reduced effort
Power α=0.05	100%	100%	100%	100%
Eph: Yr 6 = Yr 1	89%	82%	60%	97%

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MCBCP Arroyo Toad Monitoring Program Review : Conclusions & Recommendations

- **Current and alternate sampling strategies evaluated all have high power to detect:**
  - Differing patterns of decline among watersheds
  - Annual fluctuations
  - Long-term gradual decline

Recommended Strategies:

- Trends over time = 120 permanent sites
- Coverage of entire Base over time = current program (60 perm+60 rotation)
- Reduced effort = 60 permanent sites
  - Sampling every other year not recommended due to importance of wet year for assessing status of populations in ephemeral systems.

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Current/ Recent Arroyo Toad Studies

- Monitoring in San Diego County- Post-fire
- Life Span/ Age distributions: Skeletochronology
- Upland Movement- MCBCP Telemetry Studies

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