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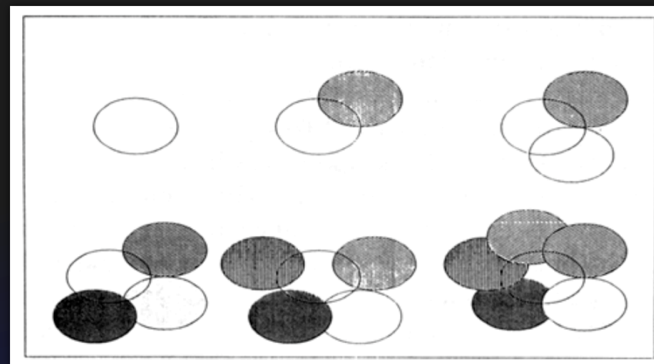
1. Social structure and genetic connectivity in mule deer

2. Vernal pool functional evaluation, conservation and management, with special focus on the endangered San Diego fairy shrimp

Social Structure and Genetic Connectivity in the Southern Mule Deer: Implications for Management

Mule deer
- Polygamous
- Male-biased dispersal
- Female site fidelity
- Rose-petal hypothesis: *Porter et al. 1991*



MSCP monitoring
- Mule deer thought to be resilient to intense urbanization …
  … but no regional mark-recapture studies*
  … and tracking data that indicate habitat use may not translate to dispersal through an area.

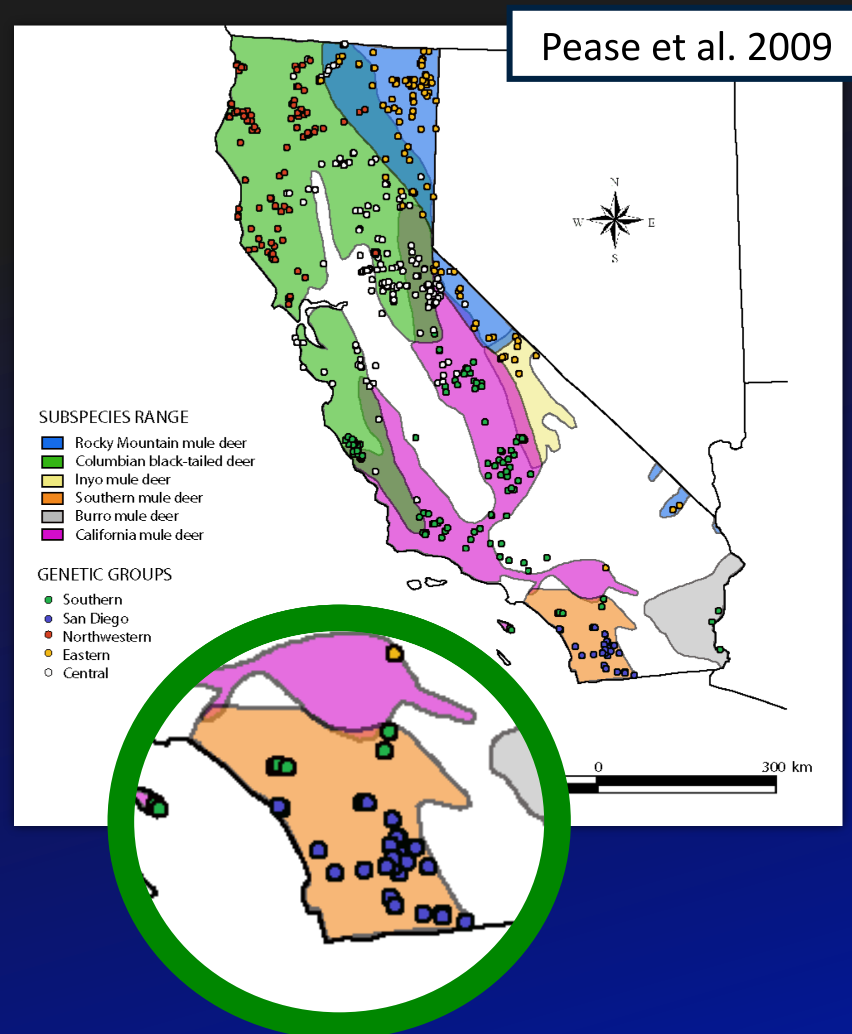
Social Structure and Genetic Connectivity in the Southern Mule Deer: Implications for Management

Six California mule deer subspecies

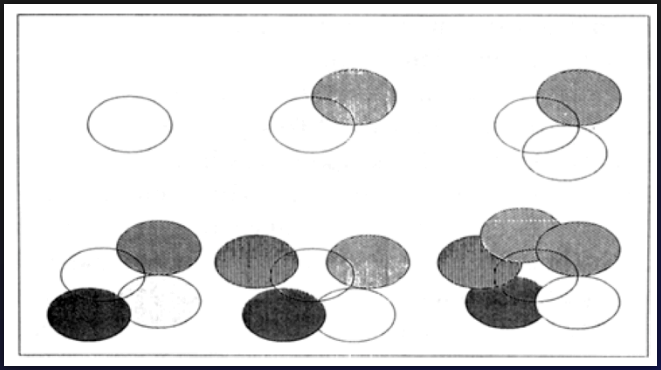
- 5 genetically distinct units
- San Diego County is genetically unique, even from “Southern Mule Deer” in Orange County

San Diego herd

- Non-migratory
- Rut/breeding: peak in late Nov-late Dec
- Fawning: late Jun-early Jul
- “Stable to slightly declining” CDFG, 2009

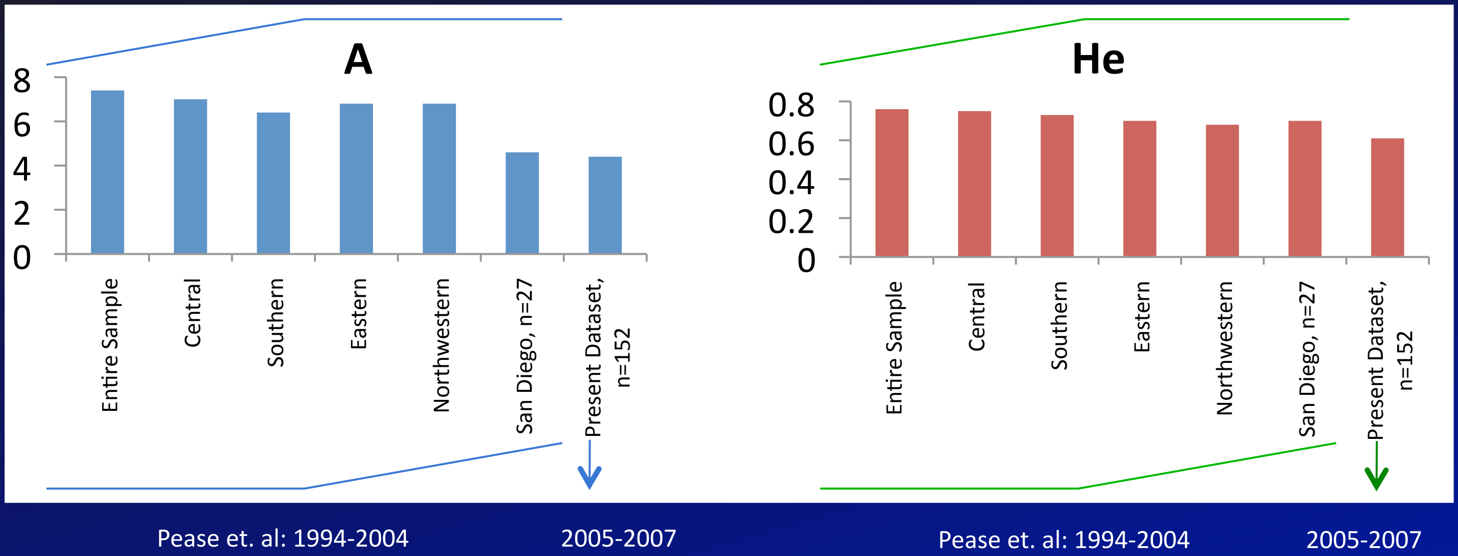


Social Structure and Genetic Connectivity in the Southern Mule Deer: Implications for Management



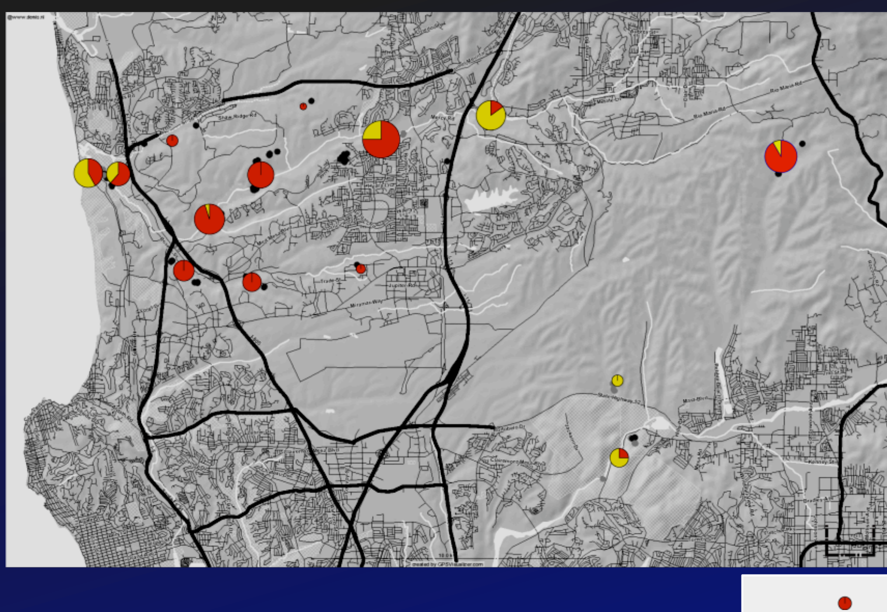
Mitelberg (2010) MS thesis

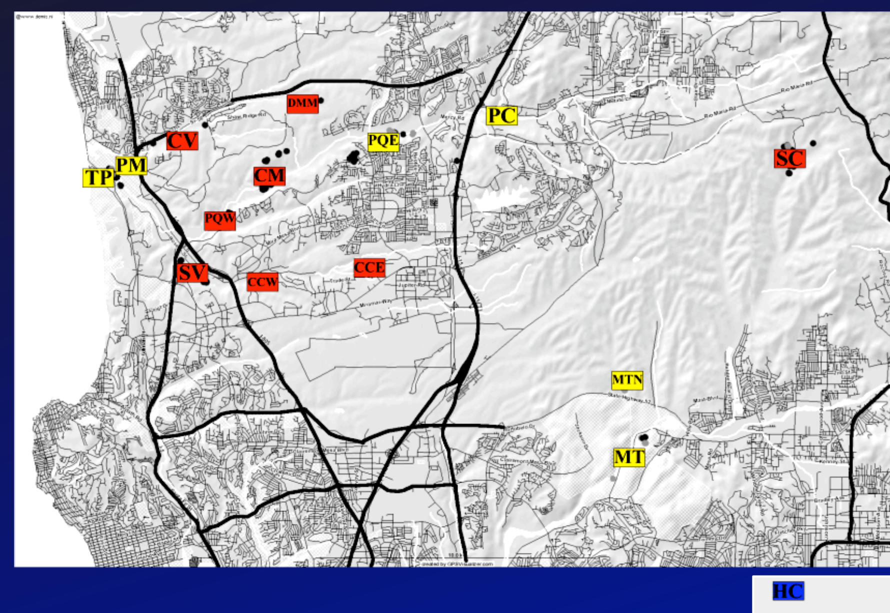
– Genetic sex-ID marker + 4-6 microsatellite markers/analysis
– Individual DNA fingerprints obtained for 184 scat piles = 152 individuals
– Almost no movement over 2 years
– Lower genetic diversity in San Diego than elsewhere in the state



Social Structure and Genetic Connectivity in the Southern Mule Deer: Implications for Management

- At least 2 regional gene pools
- High divergence across I-5
- Additional analyses suggest role of major freeways in limiting male dispersal.

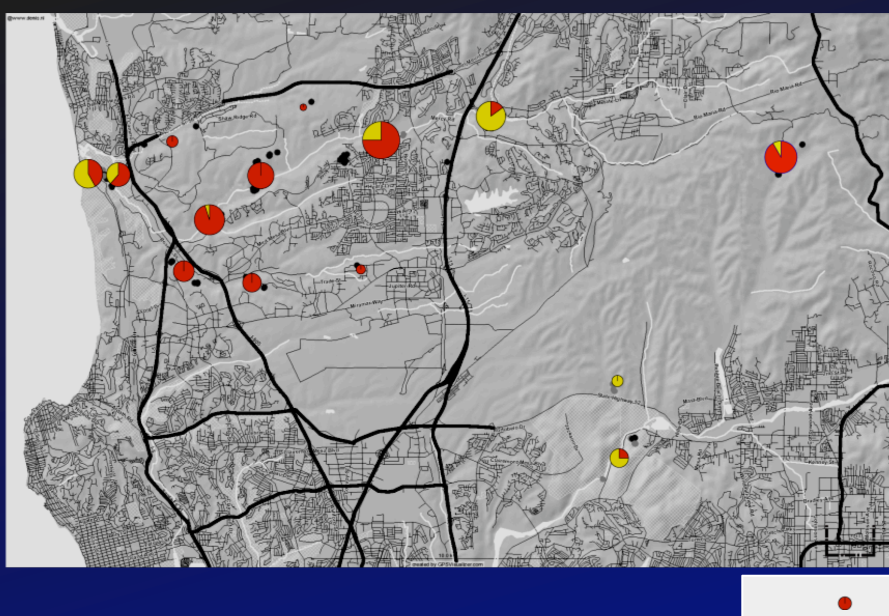


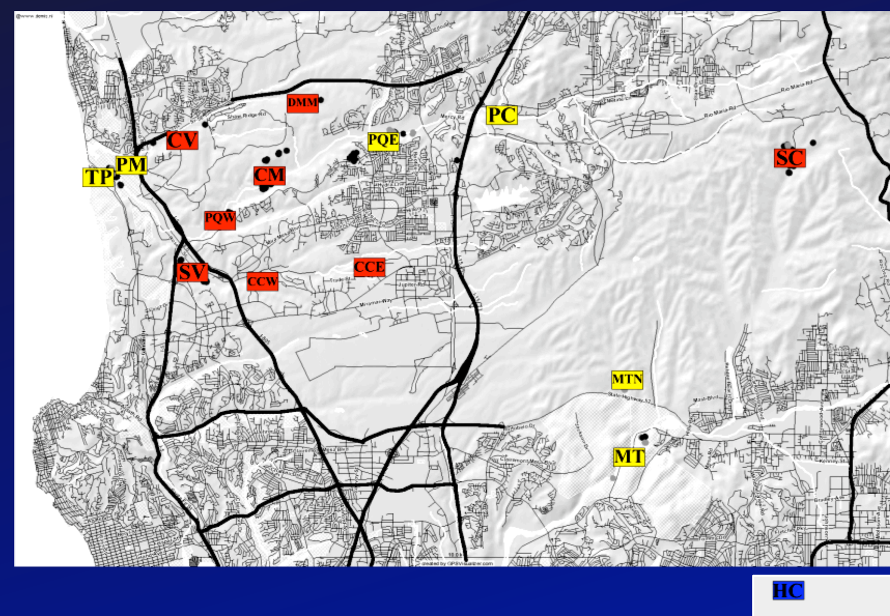


Social Structure and Genetic Connectivity in the Southern Mule Deer: Implications for Management

Genetic monitoring of mule deer scat: Implementation

- Likely costs of $25-$40/sample + labor + field collection
- Possible sampling regime: rotate high intensity sampling among gene pools in the county, returning every 3-5 years
- Information on: residency, regional movement, genetic diversity, family structure/inbreeding

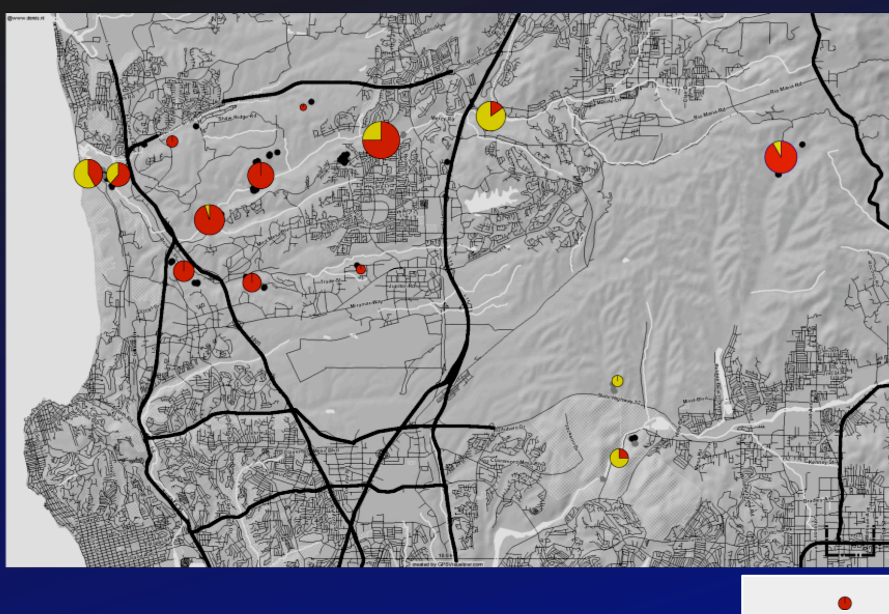


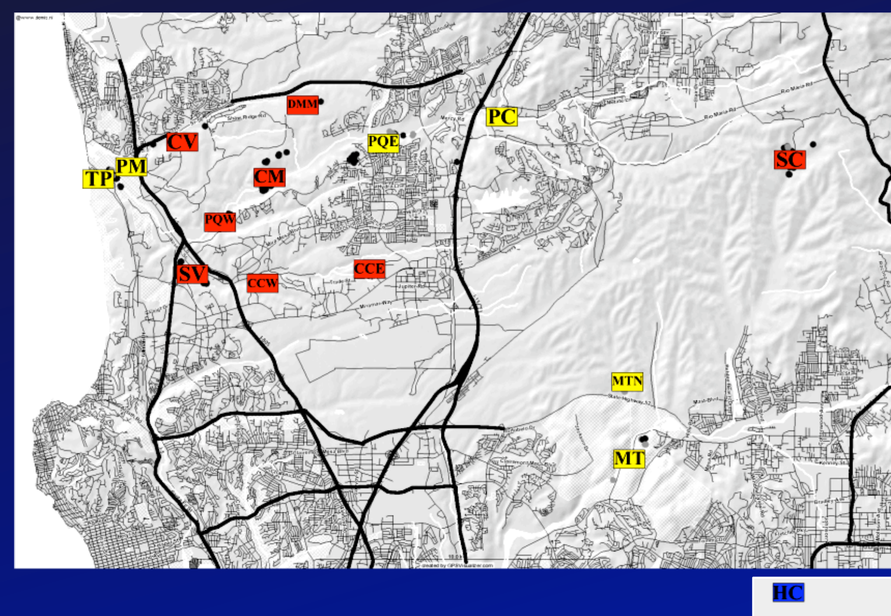


Social Structure and Genetic Connectivity in the Southern Mule Deer: Implications for Management

Genetic monitoring of mule deer scat: Protocol development

– Increase the number of microsatellite markers from 6 to 15.
– Reanalyze ca. 100 previously collected samples with 15 markers.
– Pilot study across the county, to demonstrate utility and cost-effectiveness as a monitoring strategy.





Vernal pools

- Specialized flora and fauna (≈ 20 spp. federally listed).
- Vernal pool losses in southern CA estimated to be >95% (e.g., Bauder 1998).
- At this time, regulatory protection in southern California is primarily focused on endangered species and MSCP

Wetland assessment methods

- 40+ wetland assessment methods have been developed nationally
- HGM (Hydrogeomorphic) approach developed by US Army Corps of Engineers (1995-1996), initially for the Clean Water Act (Section 404 Regulatory Program permit review)
- Bauder et al. (2009) guidebook overseen and primarily funded by US Environmental Protection Agency

Environmental Assessment Terms (Bohonak and Bauder)

Y variables:

a priori FCI: Functional Capacity Index est. from best expert opinion / disturbance history, scaled 0 to 1

Y_F: FCI scaled 0 to 1, estimated from field data

X variables:

X_{Direct}: Variables directly related to function, but often costly in terms of time, money and/or expertise

$X_{Indirect}$: Variables rapid to assess, but only indirectly related to functional capacity

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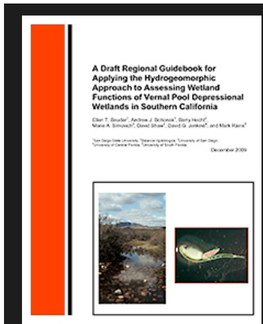
Direct FCI: $Y_F = f\ (X_{Direct})$

Indirect FCI: $Y_F = f\ (X_{Indirect})$

} accuracy inferred from correlations between Direct FCI, Indirect FCI, and *a priori* FCI



Southern California vernal pool HGM functions

Function	Direct FCI development	Indirect FCI development
Surface and Sub-surface Water Storage	45 pools	61 pools
Hydrologic Networks	3 networks	3 networks
Maintenance of the Characteristic Plant Community	61 pools	61 pools
Maintenance of the Characteristic Faunal Community	28 pools	61 pools

Bauder et al. 2009
Bohonak and Bauder *in revision*
Bohonak and Bauder *in review*

Faunal Direct FCI (depth > 0.07 m)

Index conditions	Index
{ ($V_{CRUSTSPP}$ > 10) and ($V_{FAUNIND}$ ≥ 0.6) and (V_{SDFS} = 1) and (V_{LFS} = 0) } or { ($V_{MAXDEPTH}$ < 0.15) and (V_{SDFS} = 1) and (V_{LFS} = 0) }	1.00
($V_{FAUNIND}$ ≥ 0.5) and (V_{SDFS} = 1) and (V_{LFS} = 0)	0.75
[{ ($V_{FAUNIND}$ ≥ 0.5) or (V_{SDFS} = 1) } and (V_{LFS} = 0)]	0.65
($V_{FAUNIND}$ > 0.0)	0.25
($V_{CRUSTSPP}$ > 0)	0.10
($V_{CRUSTSPP}$ = 0)	0.00

$V_{MAXDEPTH}$ = maximum pool depth in meters

$V_{CRUSTSPP}$ = total number of crustacean species

V_{SDFS} = (0,1) indicator for the San Diego fairy shrimp *B. sandiegonensis*

V_{LFS} = (0,1) indicator for the fairy shrimp *B. lindahli*

$V_{FAUNIND}$ = proportion of $V_{CRUSTSPP}$ found in a list of 14 "Faunal Indicators"

Faunal Indirect FCI

If $(0.07\ m \leq V_{MAXDEPTH} < 0.15\ m)$, $FCI_{INDIRECT}$ =

$$0.40 + 0.50 \times (V_{INLETMOD} = 0) + (0.33 \times \log(V_{CATCHAREA})) + 0.20 \times (V_{COBBLESBA} > 10)$$

If $(V_{MAXDEPTH} \geq 0.15\ m)$, $FCI_{INDIRECT}$ =

$$0.40 + 0.30 \times (V_{INLETMOD} = 0) + (0.15 \times \log(V_{CATCHAREA})) + 0.20 \times (V_{MOUNDPRES}) + 0.20 \times (V_{SURFCRACKS} > 1) + (0.75 \times \log(V_{MXDEPTH}))$$

$V_{INLETMOD}$ = Discernible modification to inlet? 0=no, 1=raised, 2=lowered

$V_{CATCHAREA}$ = catchment area (est.) in acres

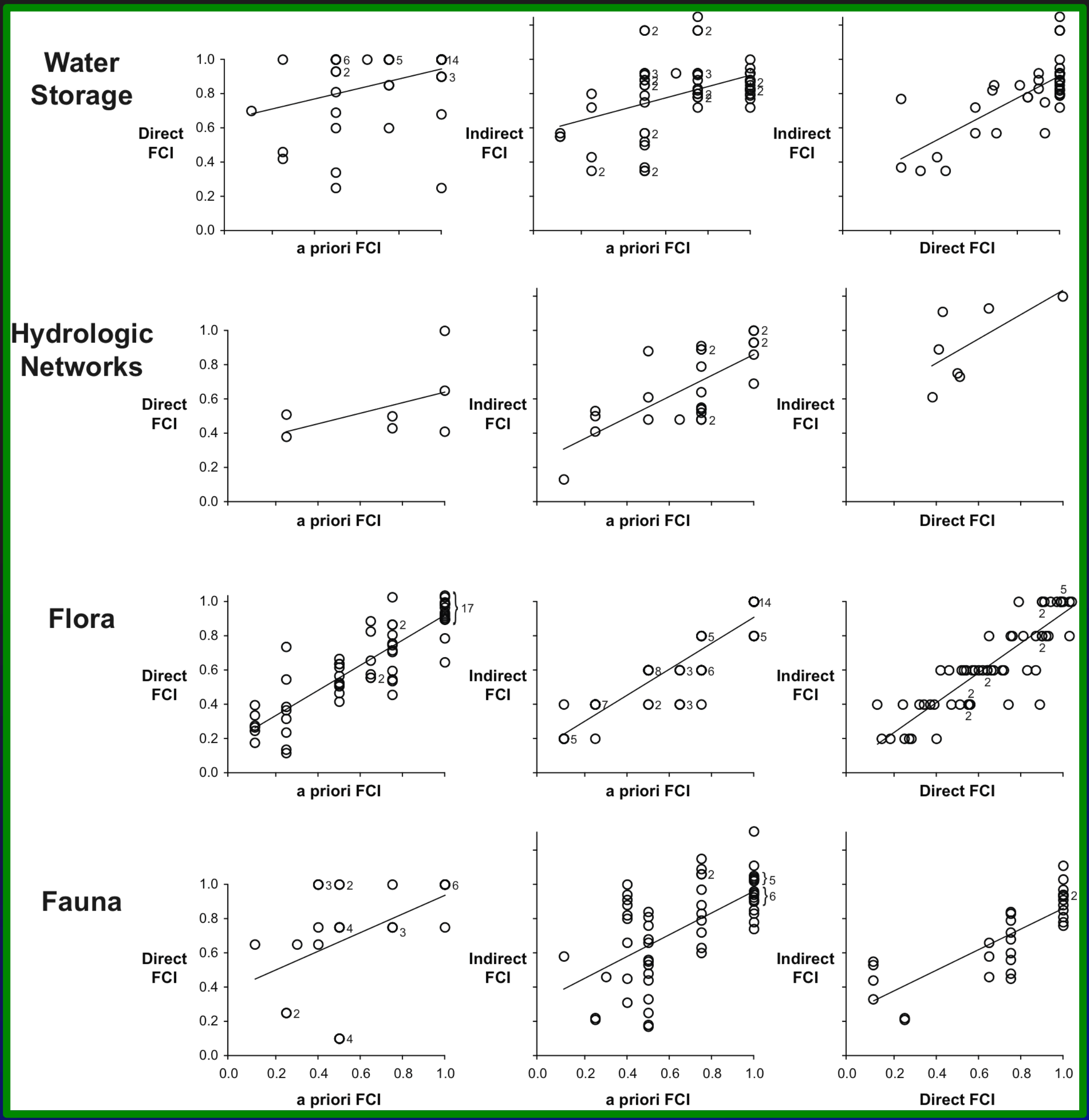
$V_{COBBLESBA}$ = 100 X (% of basin covered with pebbles or cobbles)

$V_{MOUNDPRES}$ = Mounds present?: 0=no, 1=yes

$V_{SURFCRACKS}$ = Surface cracks? 0=no, 1=shallow, 2=deep

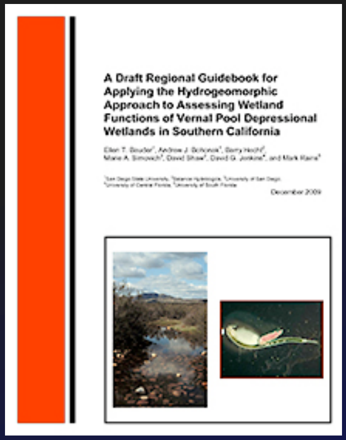
$V_{MAXDEPTH}$ = maximum depth in meters

Accuracy of HGM Assessment



Bohonak and Bauder *in review*

Vernal pool functional assessment



Available at http://tinyurl.com/vernalpool

- Conceptually identical to CRAM, but calibrated in San Diego County using direct measures of function
- In peer review by ACOE, also 2 manuscripts in review / in revision

Vernal pool functional assessment

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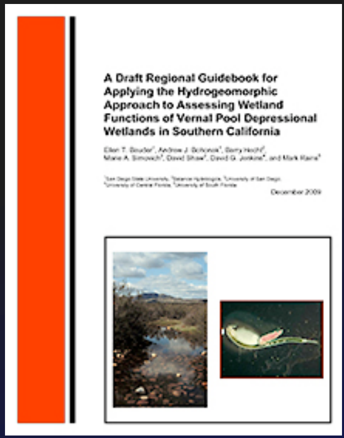


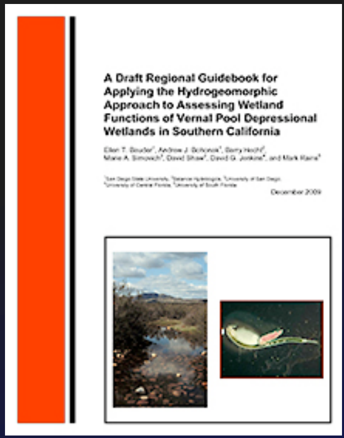
- Conceptually identical to CRAM, but calibrated in San Diego County using direct measures of function
- In peer review by ACOE, also 2 manuscripts in review / in revision

HGM assessment of vernal pools: Implementation

- Field time: 0.25-0.5 hours/pool for team of 2, plus travel time
- Possible frequency: Direct FCI every 7-10 years
  Indirect FCI every 3-5 years
  Site visit for new damage/disturbance every 1-2 years

Vernal pool functional assessment

Available at http://tinyurl.com/vernalpool



- Conceptually identical to CRAM, but calibrated in San Diego County using direct measures of function
- In peer review by ACOE, also 2 manuscripts in review / in revision

HGM assessment of vernal pools: Protocol development

– Largely complete
– Training and information session?
– Periodic model revisions with new pools / long-term data

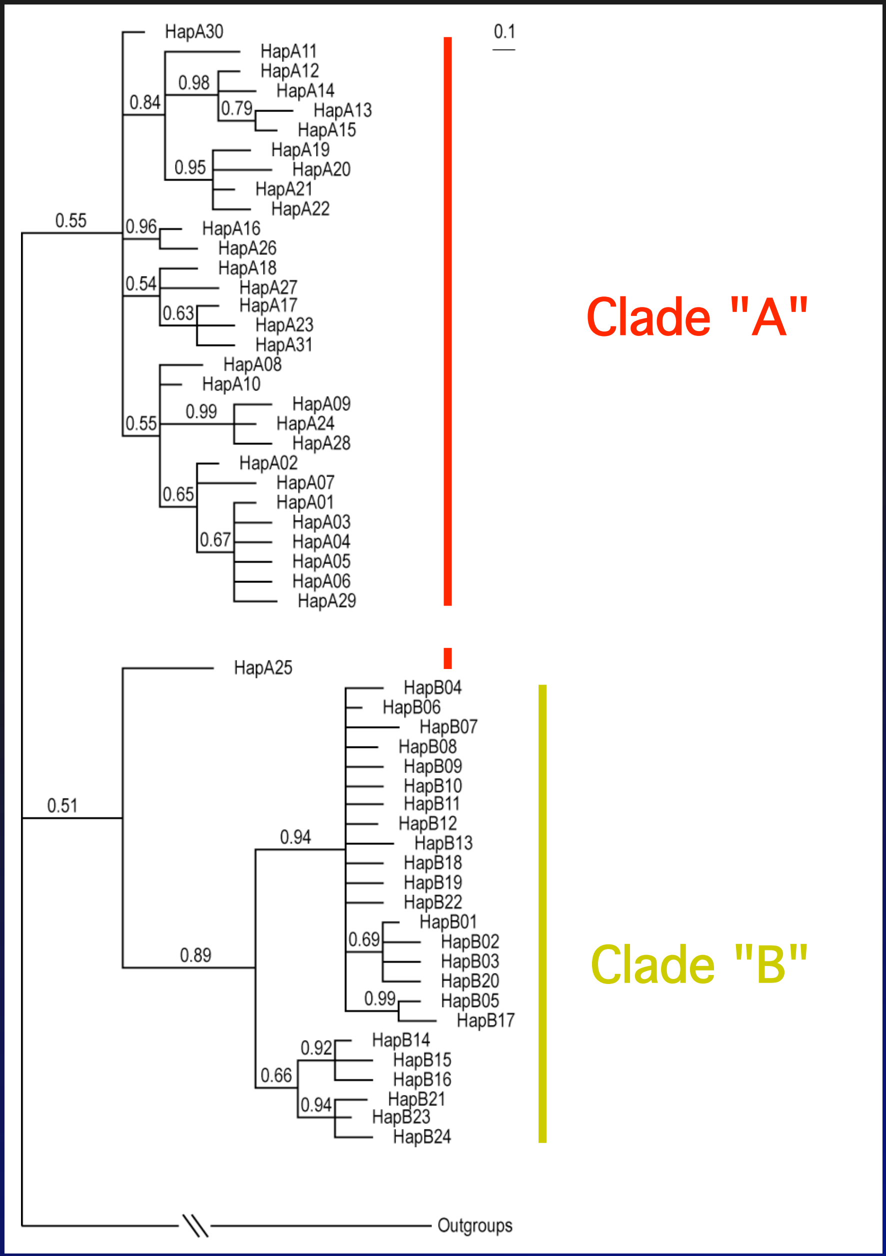
San Diego fairy shrimp: *Branchinecta sandiegonensis* (Fugate, 1993)

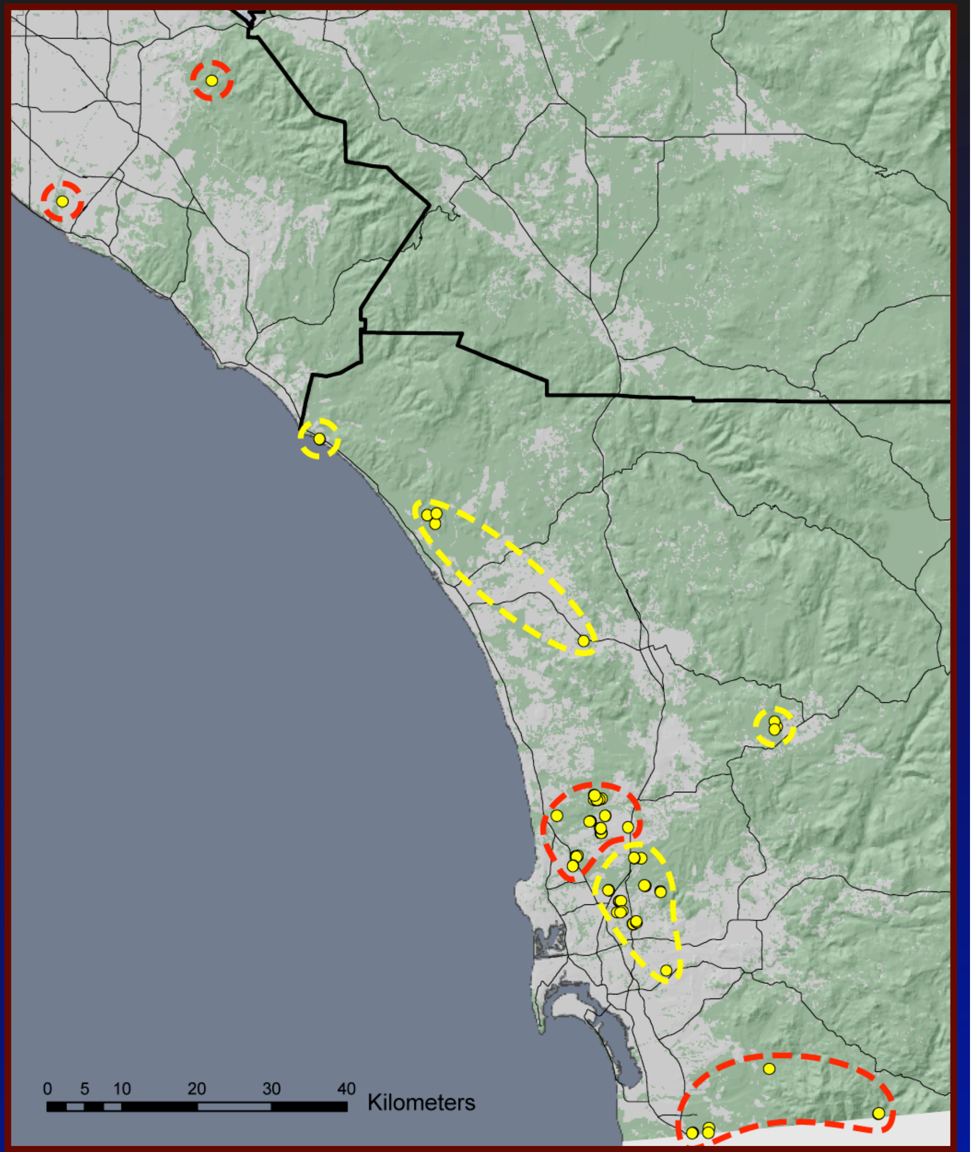
- Federally listed as endangered in 1997
- Narrowly endemic, primarily in San Diego County
- Desiccation resistant cysts (encysted embryos)
- Cysts are not indestructible (vehicles: Hathaway et al. 1996; age: Vandergast et al. unpublished)

San Diego fairy shrimp:
Branchinecta sandiegonensis (Fugate, 1993)

- Downlisting or delisting difficult due to persistent threats (most importantly, habitat loss)
- Conservation efforts tend to focus on maintenance and restoration of current pools, and sometimes creation of new pools

Genetic study for City of San Diego

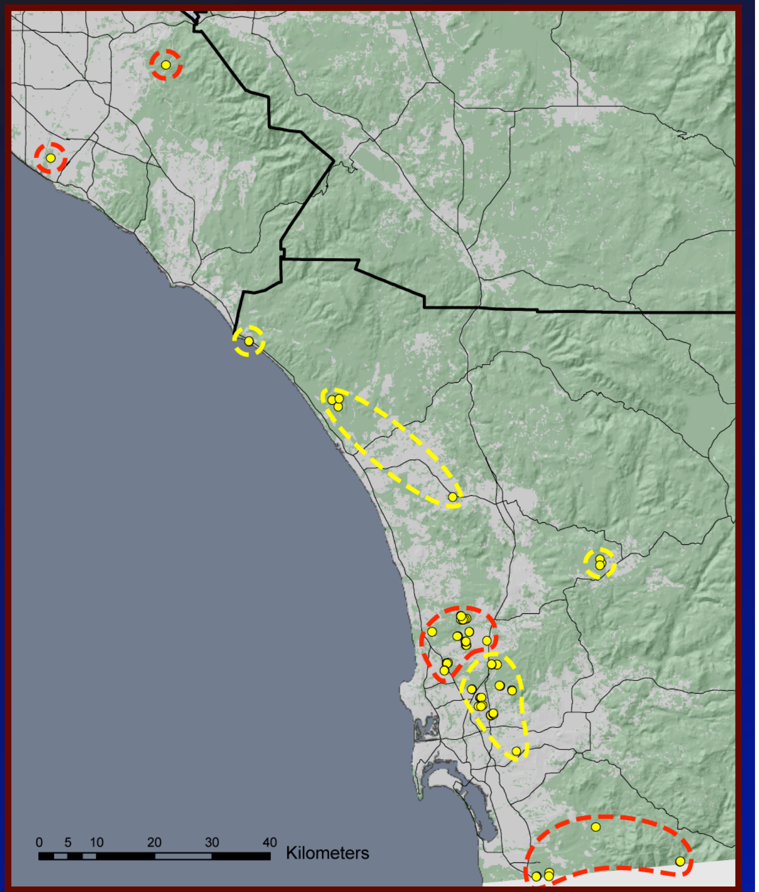




			Haplotype																												
Region	**Complex**	**Pond**	**A07**	**A08**	**A10**	**A01**	**A02**	**A21**	**A22**	**A12**	**A14**	**A20**	**A11**	**A04**	**A19**	**A13**	**A15**	**A06**	**A03**	**A29**	**A05**	**A25**	**A16**	**A26**	**A09**	**A24**	**A27**	**A18**	**A23**	**A28**	**A17**
Nobel drive	Nobel drive	1	1	1		1	7																								
		2					4																								
		3			1		2																								
	Eastgate	1				1		1		1																					
		2					4																								
		4					2																								
Del Mar	Bowtie	1				1		2	1	1																					
		2						2	2																						
		3						1		2	1																				
	Del Mar Mesa North	1				1		1				1																			
		2				1		1																							
		3				2		2																							
	Del Mar Mesa East	2					1			1																					
		3								1																					
		4											3	1																	
		5								2			1	1																	
		RR1				1		1	1	1					1																
Mira Mesa	Cousins	1				5																									
	Mesa Verde	1					4																								
		2				1	3																								
		3				5																									
	Winterwood	1				3										2															
		2					1			1			1																		
		3				1											1														
		4								2																					
		5				2										1		2													
	Brown	1				1							2																		
		2				3																									
		3				1							1						2												
	Maddox	1				17														1	1										
		2				3				1																					
		4				3																									
		7				1															3										
Carmel Mountain	Carmel Mountain	1				5																									
Costa Mesa	Costa Mesa	D																					2		1						
Irvine	Irvine	1																				2									
Otay Lakes	Otay Lakes	1																					7	1							
Otay Mesa	Snake Cholla	1																						2							
		2																					5		1						
	Arnie's Point	1																								3	2				
		2																										2	1		
	J16-18	1																								1		1		2	
	Goat Mesa	2																										5			
Marron Valley	Marron Valley	3																													5
		5																													5

San Diego fairy shrimp

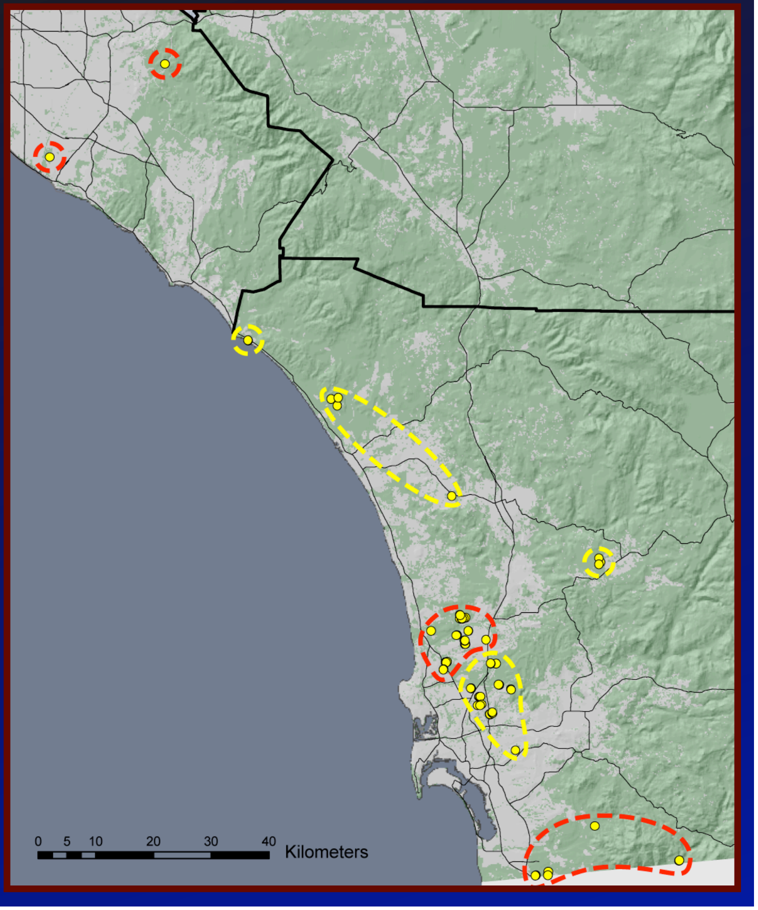
- Genetic studies suggest that local pool complexes were historically isolated; currently homogenized in high use sites
- To maximize the likelihood of success, new mitigation pools should probably be “stocked” from a very local source.
- Genetic tools used to develop rapid diagnostics for identifying individual cysts to species (Vandergast et al. 2009).
- High genetic divergence also seen among tadpole shrimp *L. packardi* populations (N. Cal.) but not *B. lynchi* (statewide)
- mtDNA variation in *B. lindahli* and *S. woottoni* in S. Calif. is too low for definitive conclusions from similar analyses



San Diego fairy shrimp

<u>Genetic monitoring of San Diego fairy shrimp: Implementation</u>

- Diagnostics for species and hybrid identification
- Periodic long term monitoring for changes in genetic diversity patterns (baseline data set available)



San Diego fairy shrimp

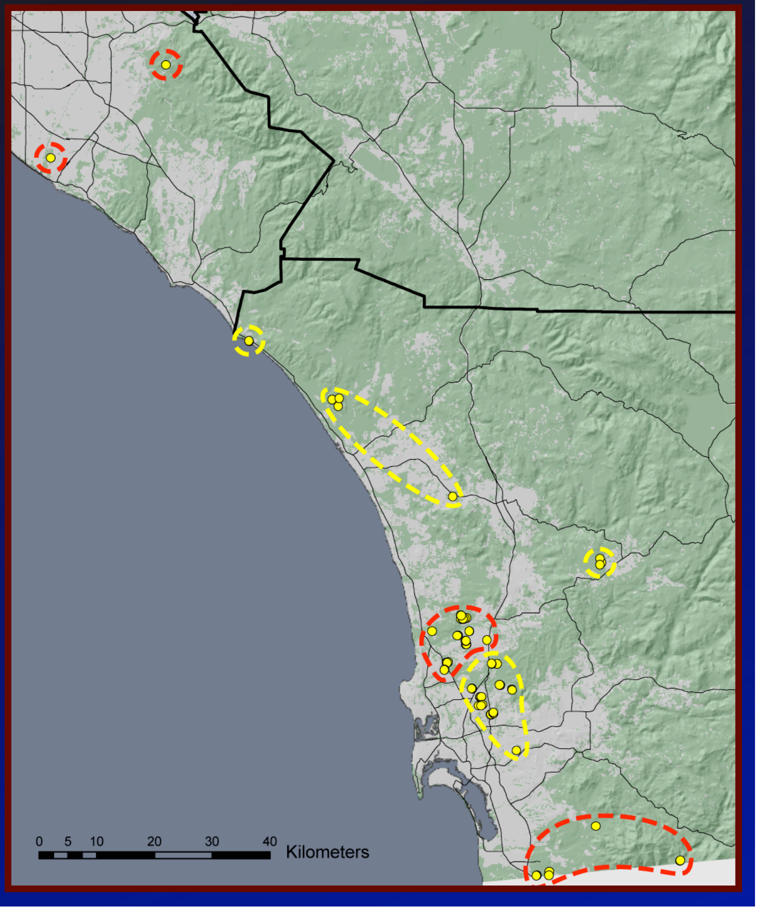
Genetic research on San Diego fairy shrimp: Protocol development

- Development of microsatellite markers
- Microsatellite study of *B. sandiegonensis*
- Does anthropogenic homogenization translate to real differences in hatching rates or individual survival?

  -> studies of local adaptation
- Does this homogenization lead to hybridization between endangered and non-endangered fairy shrimp?

  -> hybridization studies

  -> nature of speciation / reproductive isolation in this genus



Hybridization?

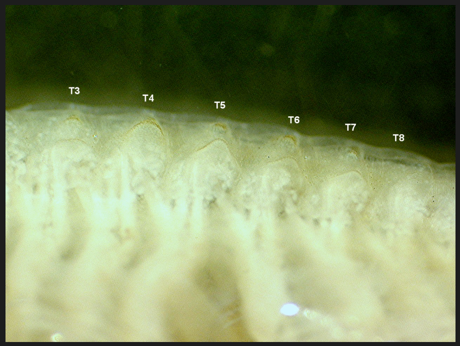
B. lindahli - widespread species

- Widely distributed across western states
- Playas and disturbed ephemeral wetlands
- Wide temperature and chemistry tolerance

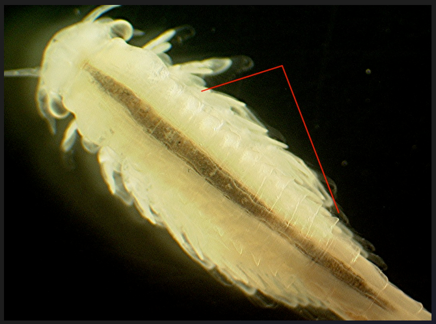
B. sandiegonensis - endangered species

- Narrow endemic – Coastal San Diego Co. +
- Undisturbed/mildly disturbed vernal pools
- Limited temperature and water chemistry tolerance

B. lindahli female



B. sandiegonensis female



Possible hybrid female

Hybridization suspected in the field because:

- Can hybridize in the lab
  (Fugate 1998, Shanney prelim. unpub.)
- Apparent morphological intermediates found in nature
  (Simovich et al. *in prep*: n=203 including 55 putative hybrids)

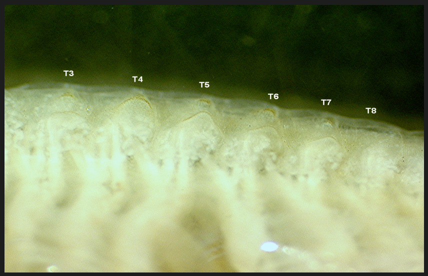
  Females with characters from both species (spination patterns and ovary position), but female mtDNA and male morphology represent a single species.

Gynandromorph

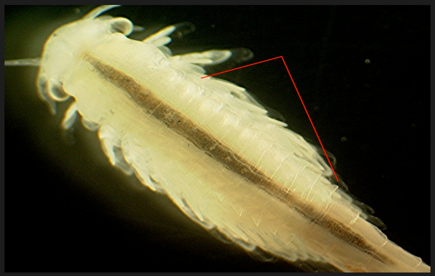
Parasites provide a possible mechanism

- *B. lindahli* harbors a feminizing parasite (possibly *Wolbachia*, which is widespread in arthropods)
- Transmitted mother to offspring, converts genetic males to females (Sassaman and Fugate 1997, Krumm 2006)
- Female-biased sex ratios and gynandromorphs (incompletely transformed males) found by numerous researchers/consultants

B. lindahli female



B. sandiegonensis female



Possible hybrid female

Gynandromorph

Genetic monitoring of San Diego fairy shrimp: Implementation

- Diagnostics for hybrid identification

San Diego fairy shrimp: Protocol development

- Morphological hybrid index developed for females (Simovich et al. *in prep*)
- Genetic hybrid index with microsatellites may be possible
- Genetic verification and identification of feminizing parasite