Monitoring and Managing California Endemic Large Branchiopods

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Who are the Endemics?

- Vernal pool fairy shrimp (VPFS, *Branchinecta lynchi*)
- Conservancy fairy shrimp (COFS, *B. conservatio*)
- Longhorn fairy shrimp (LFS, *B. longiantenna*)
- Midvalley fairy shrimp (MFS, *B. mesovallensis*)
- California fairy shrimp (CFS, *Linderiella occidentalis*)
- Mono Lake brine shrimp (*Artemia monica*)
- San Francisco brine shrimp (*A. franciscana*)
- San Diego fairy shrimp (SDFS, *B. sandiegonensis*)
- San Rosa Plateau fairy shrimp (SRPFS, *L. santarosae*)
- Riverside fairy shrimp (RFS, *Streptocephalus woottoni*)
- California clam shrimp (CCS, *Cyzicus californicus*)
- Vernal pool tadpole shrimp (VPFS, *Lepidurus packardi*)

Goals and Objectives

- What is the 

  - To maintain or increase endemic large branchiopod occurrences and abundances?
- How do we reach the goal?
  - Objectives
    - The "who, what, when, where, and how" of reaching the goals

Objectives

- First
  - Monitor vernal pools large branchiopods
- Second
  - The results of the monitoring will dictate what maintenance and management activities are needed. Right?
- Wait !
  - Need to know the life histories of targeted species
  - The parameters that influencing their occurrences and abundances

Life History

Table 1. Endemic Large Branchiopod Habitat "Preferences"

Large Branciopod Species	Ponding																	
	Depth (in inches)						Duration (in days)						Area (in acres)					
	1-2	2-4	4-6	6-8	8-10	>12	<14	14-30	30-60	60-90	90-120	> 120	<0.0005	0.0005 - 0.005	0.005 - 0.05	0.05 - 0.5	0.5 - 5.0	> 5.0
San Diego Fairy Shrimp	X	X	X	X	X	X	X	X	X				X	X	X			
Midvalley Fairy Shrimp	X	X	X	X			X	X	X				X	X	X			
Vernal Pool Fairy Shrimp	X	X	X	X	X	X		X	X	X	X		X	X	X	X	X	
Longhorn Fairy Shrimp		X	X	X	X			X	X	X	X		X	X	X	X	X	
California Fairy Shrimp		X	X	X	X	X		X	X	X	X	X	X	X	X	X	X	
Santa Rosa Plateau Fairy Shrimp			X	X	X	X			X	X	X					X	X	X
Vernal Pool Tadpole Shrimp		X	X	X	X	X		X	X	X	X	X		X	X	X	X	X
California Clam Shrimp			X	X	X	X			X	X	X	X			X	X	X	X
Conservancy Fairy Shrimp			X	X	X	X			X	X	X	X			X	X	X	X
Riverside Fairy Shrimp						X			X	X	X			X	X	X	X	X

Life History

- San Diego fairy shrimp (SDFS)
  - Very fast life cycle
    - Can mature in 7 days
    - Max longevity = 45 days
  - Inhabits very flashy pools and deep turbid road ruts (Trump Pools)
  - Co-occurs and hybridizes with the versatile fairy shrimp (*B. lindahli*)

Life History

- Midvalley fairy shrimp (MFS)
  - Fast maturing
    - Can mature in 16 days
    - Max longevity = 143 days
  - Inhabits flashy grassy pools (dominated by facultative grasses)
  - Often overlooked or assumed to be VPFS

Life History

- Vernal pool fairy shrimp (VPFS)
  - Fast maturing
    - Can mature in 14 days
    - Max longevity = 139 days
  - Susceptible to low DO and warm waters
  - Highest densities occur in clear water pools with low growing vegetation with highly fluctuating hydroperiods with no other LB
  - Found in the most diverse habitats

Life History

- Longhorn fairy shrimp (LFS)
  - Moderate maturing time
    - Can mature in 23 days
    - Max longevity = 147 days
  - Occupies tiny rock out crop pools and moderate to large alkaline playa pools
  - Highest densities are in rock out crop vernal pools with no other LB
  - Densities are low in turbid playa pools
  - Generally disappear long before habitat dries

Life History

- California fairy shrimp (CFS)
  - Moderate maturing time
    - Can mature in 21 days
    - Max longevity = 168 days
  - Can tolerate
    - high water temperatures
    - low DO (for a fairy shrimp)
    - thatch

  - Densities are significantly decreased in ungrazed pools
  - Strict mid-water column filter feeders and tend to "hover" in non vegetated areas
  - Will seek lower water temperatures in the bottom cattle hoof prints
  - Mating instinct in males is strong and they remain "clasped" to females for extended periods even when removed from water

Life History

- Vernal pool tadpole shrimp (VPTS)
  - Slow maturing
    - Can mature in 35 days
    - Max longevity = 168 days
  - Can tolerate
    - High levels of poaching

      = livestock trampling creating punch and pot-marks
    - Low DO
    - Warm water
  - Greatest densities are in turbid pools
  - Can create turbidity by bioturbation activities that uproot young plants
  - Adults can move into swales and drainages (ephemeral and intermittent drainages) but young are poor swimmers and are swept downstream

Life History

- California calm shrimp (CCS)
  - Can tolerate
    - High levels of poaching
    - The lowest DO
    - High water temperatures
  - Greatest densities are in turbid pools
  - Can tolerate ungrazed pools since they can swim up and down in the water column
  - Occur in ponds and other deep semi-permanent habitats

Life History

- Conservancy fairy shrimp (COFS)
  - Moderate maturation time
    - Can mature in 19 days
    - Max longevity = 154 days
  - Always found in turbid waters
  - Prefers playa pools
  - Moderately tolerant to DO and warm water
  - Very fragile (soft) until after maturity
  - Generally disappears long before habitat dries
  - Generally co-occurs with VPTS

Life History

- Riverside Fairy Shrimp (RFS)
  - Very slow maturing
    - It takes 45 days to mature
    - Max longevity = 120 days
  - Needs
    - Warm water to hatch
    - Deep pools
      - Size is not as important as depth so long as ponding duration is adequate
  - Fastest swimmer of the endemic LB
  - Perhaps the most tolerate high water temperatures and low DO of the endemic fairy shrimp
    - Often coming to surface for oxygen

What is the most important factor influencing vernal pools?

Parameters Influencing LB Occurrences

- Δ in hydroperiod (inundation duration) - the most important factor influencing vernal pools
  - Δ in depth
- Δ in water quality
  - Pollutants
  - ↓ in dissolved oxygen (DO)
  - ↓ in pH
  - Δ in turbidity

Parameters Influencing LB Occurrences(cont.)

- ↑ predators and competitors
- Δ in food availability
- Δ in stimuli that break cyst dormancy
  - DO, pH, water temperature, cold “snap”, pre-saturation, barometric pressure

Parameters Influencing LB Occurrences(cont.)

- Dr. Jamie Kneitel *et al* (2017) study of four CA endemic LB responses to hydroperiod, plant thatch, and nutrients in mesocosms
  - Four Species
    - Vernal pool fairy shrimp (VPFS)
    - Vernal pool tadpole shrimp (VPTS)
    - California clam shrimp (CCS)
    - California fairy shrimp (CFS)

Parameters Influencing LB Occurrences(cont.)

- Kneitel *et al* (2017) (cont.)
  - Hydroperiod Results
    - CFS densities were not affected by hydroperiod
    - VPFS density ↑ when hydroperiod stability ↓
    - CCS & VPTS densities ↓ when hydroperiod stability ↓
      - Why? These species hatch later and have longer maturation rates
    - Unstable hydroperiod ↑ DO and turbidity

Parameters Influencing LB Occurrences(cont.)

- Kneitel *et al* (2017) (cont.)
  - Thatch Results
    - ↑ thatch (native or non native) ↓ VPFS, CFS and VPTS densities
    - CCS no response to thatch
  - Water Quality Results
    - DO positively correlated with VPFS but negatively with VPTS and CCS
    - Conductivity negatively correlated with VPFS and CFS
    - Turbidity positively correlated with VPTS and CCS
    - Chlorophyll-a positively correlated with all LB's

Monitoring

- Design
- Techniques
- Timing

Monitoring

- Design
  - How many pools?
    - More is better
  - Which pools?
    - Stratify by:
      - Soil types
      - Pastures (paddocks)
      - Pool sizes/depths
  - How often - frequency?
  - Same pools each time?

Monitoring

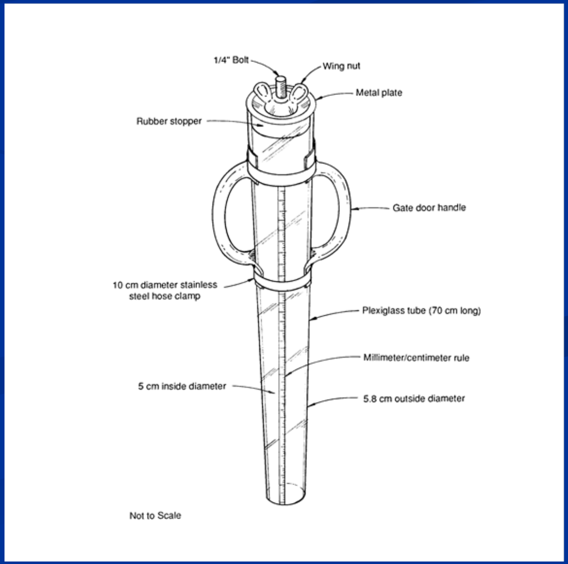
- Techniques
  - Two Methods (not including eDNA)

Monitoring

- Techniques
  - Limitations
    - Dry
      - Only cysts presence. Not if they are hatching, maturating and reproducing
      - What if inoculum was used?
      - May not be able to tell different species of *Branchinecta*
    - Wet
      - Presence is determined by seasonal environmental conditions
        - Rainfall
        - Cues to break cyst dormancy

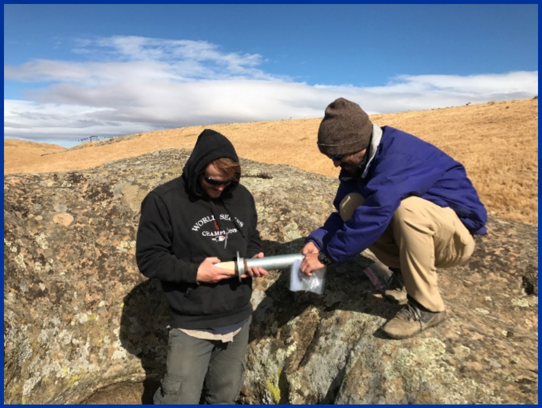
Monitoring

- Techniques
  - Wet
    - Qualitative – Present or absent
    - Semi-quantitative
      - Densities (number of individuals per volume)
      - Volume = Net aperture x distance
    - Quantitative
      - Tube sampler
        - Water column
        - Soil – disruptive to pool bottom



Monitoring

- Techniques
  - Dry
    - Qualitative – Present or absent
      - Consolidate sub-samples
    - Semi-quantitative
      - Measure volume of consolidated sample
    - Quantitative
      - Soil Core



Monitoring

- Techniques
  - Other Wet-season Monitoring Parameters
    - Biological Parameters
      - Wildlife
        - Other macroscopic aquatic invertebrates
          - Mosquito and midge fly larvae
        - Amphibians
        - Waterfowl/shorebirds/wading birds
      - Vegetation
        - Vascular plants
          - Invasive weeds
        - Non-vascular plants
          - filamentous algae

Monitoring

- Techniques (cont.)
  - Other Wet-season Monitoring Parameters (cont.)
    - Chemical Parameters
      - Water quality (pH, DO, etc.)
        - Standardize timing
    - Physical Parameters
      - Inundation (Ponding)
        - Depths
          - Average
          - Maximum
        - Area
        - Duration
      - Amount of poaching or other disturbances

Monitoring

- Timing
  - Dependent on:
    - Method(s) used
    - Targeted species
    - Local weather
      - Rainfall patterns
      - Ambient temperatures between storm events
        - Air /Water
      - Winds

Monitoring

- Timing (cont.)
  - Dependent on:
    - Habitat Types
      - Hydrology Inputs
        - Direct inception
        - Surface flow
        - Subsurface flow
      - Depth of soil over impervious layer
        - Rock outcrop pool vs Northern hardpan vernal pool
  - <u>Bottom Line</u> – You can't set a date in advance

Management

- How to maintain hydroperiods?
  - Livestock Grazing
    - Liacos (1962) Heavy grazed site (> 35 years)
      - ↑ soil density and shallow soil ↑ water yield
    - Blackburn (1975)
      - ↑ vegetation ↓ runoff
    - Barry (1975)
      - ↑ thatch ↓ net moisture
        - From evaporation and soaking into dry plant matter

Management

- Maintaining hydroperiods (cont.)
  - Livestock Grazing
    - Gifford and Hawkins (1978)
      - ↑ grazing ↓ soil infiltration
    - Marty (2015)
      - Ungrazed pools ↓ hydroperiod (50-80%)
        - Slower to fill and faster to dry down
  - <u>Bottom line</u> - grazing increases hydroperiods by removing phytomass and increasing soil "Cowpaction"

Management

- Livestock Grazing
  - Different types of livestock
    - Sheep
    - Goats
    - Horses
    - Cattle

  - Picking the correct livestock starts with knowing your goals
    - What do you expect your grazers to do?
    - Different types of livestock graze differently and therefore will impact each site differently

Management

- Alien Invasion
  - Predators
    - Bullfrogs
    - Fish
  - Weeds
    - Always Mediterranean barely (*Hordeum marinum subsp. gussoneanum*) and Italian ryegrass (*Festuca perennis* aka *Lolium*)
    - Waxy manna grass (*Glyceria declinata*)
      - Invades pools with moderate depths but minimum surface areas that are not directly exposed to winds
      - Long floating leaves reduces amount surface water
      - Increases thatch contributing to BOD
        - Which can attract mosquitoes


Waxy manna grass (*Glyceria declinata*)

Management

- When the Natives take over
  - Common spikerush (*Eleocharis macrostachya*)
    - Minimizes movement of LB
    - Serves as attachment locations for filamentous algae
    - Quite palatable to livestock and water fowl

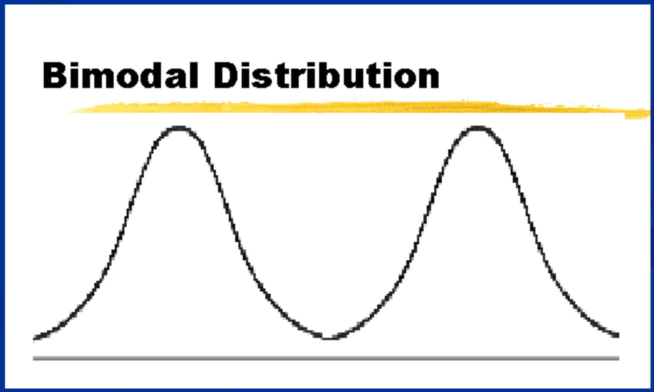
Conclusion

- There is no one recipe for monitoring or managing LB
  - Every site is unique
- The land manager has to really understand the site's ecology and the life histories of the targeted species

Discussion

- Current Threats
  - Besides residential, commercial , and agricultural development?

1. Climate change
   - Drought
     - Bimodal rainy season?



Discussion

- Bimodal Seasonal Rain
  - Early and late rains with none to little in the middle
    - Early rains
      - False starts - LB hatch but can't complete their life cycle
        - If occurs frequently can extirpate species due to cyst bank depletion
    - Late rains
      - Warm temperatures
      - Low DO
      - False starts
      - More grasses = greater phytomass (BOD)
      - Possibly C_4 metabolism plant invaders

Discussion

- Bimodal Seasonal Rain (cont.)
  - Which LB species are going to be impacted the greatest by Global Warming?
    - Southern California populations, especially those with long maturation periods
      - Riverside fairy shrimp
      - Santa Rosa Plateau fairy shrimp
      - Longhorn fairy shrimp (Playa Pool)
      - Conservancy fairy Shrimp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Citations and Suggested Reading

- Eriksen, C. H., and D. Belk. 1999. Fairy shrimps of California's puddles, pools, and playas. Mad River Press, Inc. Eureka, California. 196 pp.
- Helm, B. P. 1998. Biogeography of eight large branchiopods endemic to California. Pages 124-139 *in*: C. W. Witham, E. T. Bauder, D. Belk, W.R. Ferren Jr., and R. Ornduff (eds.). Ecology, conservation, and management of vernal pool ecosystems – proceeding from a 1996 conference. California Native Plant Society, Sacramento, California. 285 pp.

- Holland and Jain (1984)
  - ↑ frequency and abundance of upland ruderal species in VP margins during drought
- C_3 vs C_4 photosynthetic pathways
  - C_3 temperate climates with winter precipitation
  - C_4 tropical environments with fall/summer precipiations
- C4 weeds
  - bermuda grass (*Cynodon dactylon*)
  - barnyard grass (*Echinocloa* spp.)
  - Johnson grass (*Sorghum halepense*)
  - common purslane (*Portulaca oleracea*)
  - crabgrass (*Digitaria sanguinalis*)

- C4 Weeds (continued)
  - Several species of pigweed (*Amaranthus* spp.),
  - Russian thistle (*Salsola kali*)
  - *Cyperus*
  - *Euphorbia*
  - *Hydrila*
  - *Egeria*
  - *Mollugo*
  - *Portulaca*
  - *Paspalum*
  - *Echiniochloa*
  - *Tribulus*