Monitoring and Managing California Endemic Large Branchiopods

By
Brent Helm, Ph.D.
Tansley Team, Inc.
(dba Helm Biological Consulting)
(530) 633-0220
bhelm69485@aol.com
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 goal?
  - 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>
<thead>
<tr>
<th>Large Branchiopod Species</th>
<th>Depth (in inches)</th>
<th>Duration (in days)</th>
<th>Area (in acres)</th>
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<tbody>
<tr>
<td>San Diego Fairy Shrimp</td>
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<td>Midvalley Fairy Shrimp</td>
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<td>Vernal Pool Fairy Shrimp</td>
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<td>Longhorn Fairy Shrimp</td>
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<td>California Fairy Shrimp</td>
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<td>Santa Rosa Plateau Fairy Shrimp</td>
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<td>Vernal Pool Tadpole Shrimp</td>
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<td>California Clam Shrimp</td>
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<td>Conservancy Fairy Shrimp</td>
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</table>
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)
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 tolerant 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

- $\Delta$ in hydroperiod (inundation duration) - the most important factor influencing vernal pools
  - $\Delta$ in depth
- $\Delta$ in water quality
  - Pollutants
  - $\downarrow$ in dissolved oxygen (DO)
  - $\downarrow$ in pH
  - $\Delta$ 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 $\uparrow$ when hydroperiod stability $\downarrow$
    - CCS & VPTS densities $\downarrow$ when hydroperiod stability $\downarrow$
    - Why? These species hatch later and have longer maturation rates
    - Unstable hydroperiod $\uparrow$ 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)

Wet-season sampling

Dry-season sampling
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
    - **Bottom Line** – You can’t set a date in advance
Management

How to maintain hydroperiods?

Livestock Grazing

- Liacos (1962) Heavy grazed site (> 35 years)
  - \( \uparrow \) soil density and shallow soil \( \uparrow \) water yield

- Blackburn (1975)
  - \( \uparrow \) vegetation \( \downarrow \) runoff

- Barry (1975)
  - \( \uparrow \) thatch \( \downarrow \) 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
  - Bottom line - 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 C₄ 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
El Fin
Citations and Suggested Reading


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 precipitations

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*