Why worry about mutualisms and climate change?

- Ecologically and economically important
  - Mutualisms = interactions benefit both participants (+, +)
  - Pollination, seed dispersal, plant protection, etc.
- Climate change affecting many species
  - Many are mutualists
- Mutualistic interactions often tightly linked
  - Specter of co-extinctions
    - Loss of one species result in loss of many others that depend it
  - “4th horseman” of main drivers of extinction - *Diamond 1989*
Pollination and seed dispersal are best studied mutualistic interactions.

From Bronstein et al. 1998.
Why pollination and dispersal mutualisms are important

- Some plants need animals to reproduce
  - Movement of pollen (gene flow)
  - Dispersal of seeds to ‘safe sites’
- Some animals need plants to survive and reproduce
  - Provision of food: pollen, nectar and ‘fruits’
  - Diversity of animal taxa involved in plant mutualisms
    - Invertebrates: butterflies, moths, bees, beetles, ants, etc.
    - Vertebrates: mostly birds, small mammals
Overview

• Evidence for climate change impacts on species
• Possible effects of climate change on mutualisms
• Conservation of mutualisms in the Laguna in the face of climate change
Overview

• Evidence for climate change impacts on species
• Possible effects of climate change on mutualisms
• Conservation of mutualisms in the Laguna in the face of climate change
Many species being affected by climate change *(Parmesan and Yohe 2003)*

<table>
<thead>
<tr>
<th>Type of change</th>
<th>Climate change prediction</th>
<th>Change as predicted</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Phenology</strong></td>
<td>Earlier timing of spring events</td>
<td>87%</td>
</tr>
<tr>
<td><strong>Distribution</strong></td>
<td>Poleward or upward range shifts</td>
<td>81%</td>
</tr>
<tr>
<td><strong>Community composition</strong></td>
<td>Increase in warm-adapted species and decrease in cold-adapted species</td>
<td>85%</td>
</tr>
</tbody>
</table>

Based on meta-analysis involving 944 species representing multiple taxa – plants and animals
Overview

• Evidence for climate change impacts on species
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The problem of altered synchrony: mismatches between mutualists

**Scenarios:** Temporal mismatches (phenology)
- Animal mutualists emerge earlier (or later) than plant partners
- Plant mutualists emerge earlier (or later) than animal partners
- Plants respond to warming, but mutualists respond to other cues (and *visa versa*) — *i.e.* photoperiod

Central Valley butterflies emerging earlier (average 21 days earlier)  
*Forister and Shapiro 2003*
Mismatches between mutualists, cont.

**Scenarios: Spatial mismatch (distribution)**

- When range shifts out of synch
  - Plant mutualists shift/contract range, mutualist partners do not
  - Animals mutualists shift/contract range, plant partners do not
- Plants and animal mutualists shift ranges together in lock step

~ $\frac{1}{3}$ of CA flora predicted to experience dramatic range reductions within next century (Loarie et al. 2008) – what will happen to mutualist partners?
Consequences of mismatches

Climate warming

Plants
- Phenology
- Distribution
- Visitation numbers
- Pollen deposition
- Reproductive success
- Population dynamics

Pollinators
- Phenology
- Distribution
- Nectar/pollen amounts
- Food availability
- Reproductive success/survival
- Population dynamics

From Hegland et al. 2009
Mismatched mutualisms – the evidence (or lack thereof)

- **Empirical data:**
  - Data are slim, speculation is ample (e.g. Visser and Both 2005)
  - Mutualistic interactions weakened by climate change
    - Based on recent synthesis of 688 studies (Tylianakis et al. 2008)
  - Fossil/pollen record shows community disassembly during periods of climate change (Davis and Shaw 2001)

- **Simulation data:**
  - Co-extinctions of mutualists should be common (Memmett et al. 2007, Dunn et al. 2009)
    - Not well-supported by empirical data
The evidence paradox: why don’t model predictions match the empirical data?

• Insufficient research?
• Other drivers of global environmental change (GEC) may mask effects of climate change
  – N deposition, habitat loss and fragmentation, biological invasions, etc.
  – Higher order effects of GEC drivers rarely studied
• Plant-animal mutualistic networks may buffer effects of GEC (Memmet et al. 2004 and Bascompte et al. 2006)
  – Whole interaction networks rarely studied (empirically)
    • Problem of looking only at pair-wise interactions
  – Mutualist networks heterogenous, asymmetrical, with weak linkages
Example of plant-pollinator network

- From Zackenberg Arctic Tundra, Greenland

*From Bascompte and Jordano, 2007*
Do mutualisms matter?

- Which mutualist species are threatened by climate change impacts and in what systems?
- Which traits predict vulnerability?
Predicting which plants are vulnerable

- Probability of mutualism failing
  - Generalist vs. specialist
  - Degree of redundancy
    - Few partners vs. network of mutualist partners
- Degree of reproductive dependence
  - Obligate vs. facultative
- Degree of demographic importance of seeds
  - Importance of seeds to population dynamics

From Bond 1995
Overview

• Evidence for impacts of climate change on species interactions
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Which special-status plants are at greatest risk in the Laguna watershed?

<table>
<thead>
<tr>
<th>Common Name</th>
<th>Scientific Name</th>
<th>Feder</th>
<th>State</th>
<th>CNPS</th>
<th>RMP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Burke's goldfields</td>
<td>Lasthenia burkei</td>
<td>FE</td>
<td>SE</td>
<td>1B.1</td>
<td>YES</td>
</tr>
<tr>
<td>Calistoga popcorn-flower</td>
<td>Plagiobothrys strictus</td>
<td>FE</td>
<td>ST</td>
<td>1B.1</td>
<td>NO</td>
</tr>
<tr>
<td>Clara Hunt's milk-vetch</td>
<td>Astragalus claranus</td>
<td>FE</td>
<td>ST</td>
<td>1B.1</td>
<td>NO</td>
</tr>
<tr>
<td>Hickman's cinquefoil</td>
<td>Potentilla hickmanii</td>
<td>FE</td>
<td>SE</td>
<td>1B.1</td>
<td>YES</td>
</tr>
<tr>
<td>Kenwood Marsh checkerbloom</td>
<td>Sidalcea oregana ssp. valida</td>
<td>FE</td>
<td>SE</td>
<td>1B.1</td>
<td>NO</td>
</tr>
<tr>
<td>Loch Lomond button-celery</td>
<td>Eryngium constancei</td>
<td>FE</td>
<td>SE</td>
<td>1B.1</td>
<td>NO</td>
</tr>
<tr>
<td>Napa blue grass</td>
<td>Poa napensis</td>
<td>FE</td>
<td>SE</td>
<td>1B.1</td>
<td>NO</td>
</tr>
<tr>
<td>Pitkin Marsh lily</td>
<td>Lilium pardalinum ssp. pitkinense</td>
<td>FE</td>
<td>SE</td>
<td>1B.1</td>
<td>YES</td>
</tr>
<tr>
<td>Sebastopol meadowfoam</td>
<td>Limnanthes vinculans</td>
<td>FE</td>
<td>SE</td>
<td>1B.1</td>
<td>YES</td>
</tr>
<tr>
<td>Showy indian clover</td>
<td>Trifolium amoenum</td>
<td>FE</td>
<td>1B.1</td>
<td>YES</td>
<td></td>
</tr>
<tr>
<td>Sonoma alopecurus</td>
<td>Alopecurus aequalis var.</td>
<td>FE</td>
<td>1B.1</td>
<td>YES</td>
<td></td>
</tr>
<tr>
<td>Sonoma spineflower</td>
<td>Chorizanthe valida</td>
<td>FE</td>
<td>SE</td>
<td>1B.1</td>
<td>YES</td>
</tr>
<tr>
<td>Sonoma sunshine</td>
<td>Blennosperma bakeri</td>
<td>FE</td>
<td>SE</td>
<td>1B.1</td>
<td>YES</td>
</tr>
<tr>
<td>Vine Hill clarkia</td>
<td>Clarkia imbricata</td>
<td>FE</td>
<td>SE</td>
<td>1B.1</td>
<td>YES</td>
</tr>
<tr>
<td>White sedge</td>
<td>Carex albida</td>
<td>FE</td>
<td>SE</td>
<td>1B.1</td>
<td>YES</td>
</tr>
<tr>
<td>Yellow larkspur</td>
<td>Delphinium luteum</td>
<td>FE</td>
<td>1B.1</td>
<td>NO</td>
<td></td>
</tr>
</tbody>
</table>
What about the animal pollinators?

- How will changes in plant phenology and distributions influence animal mutualists?
  - Many vernal pool bees specialize on collecting pollen from one or few plant species
    - i.e. Andrenid bees

*Andrena limnanthus* on *Limnanthes douglasi* ssp. *rosea*

*Nests of vernal pool solitary bees*

*Andrena blennospermatis* on *Blennosperma nanum*
Preserving mutualisms in Laguna Watershed

Recommendations:

- Protect more land (i.e. habitat).
  - Last of the least, best of the rest
  - Assume range contractions norm for most species of concern

- Maintain habitat connectivity at different scales

- Manage other drivers of GEC
  - Especially invasives
Preserving mutualisms in the watershed, cont.

• Prioritize species at greatest risk to co-extinction/extirpation
  – i.e. traits analysis

• Provide surrogate mutualist services
  – Hand-pollination, seed dispersal for species threatened by loss or decline of mutualist partners

• Develop systematic conservation plan for County
  – i.e. Upland Goals Project approach
Conclusions

• Climate change affecting many mutualists
• Little data on how these changes affect mutualistic interactions
• Mutualistic interaction networks likely to buffer impacts of climate change – to a point
• Need to understand which mutualist species most vulnerable to disruption
Future responses to mismatches?

Mismatch dampened by adaptation

Current ‘trend’ continues

From Hegland et al. 2009