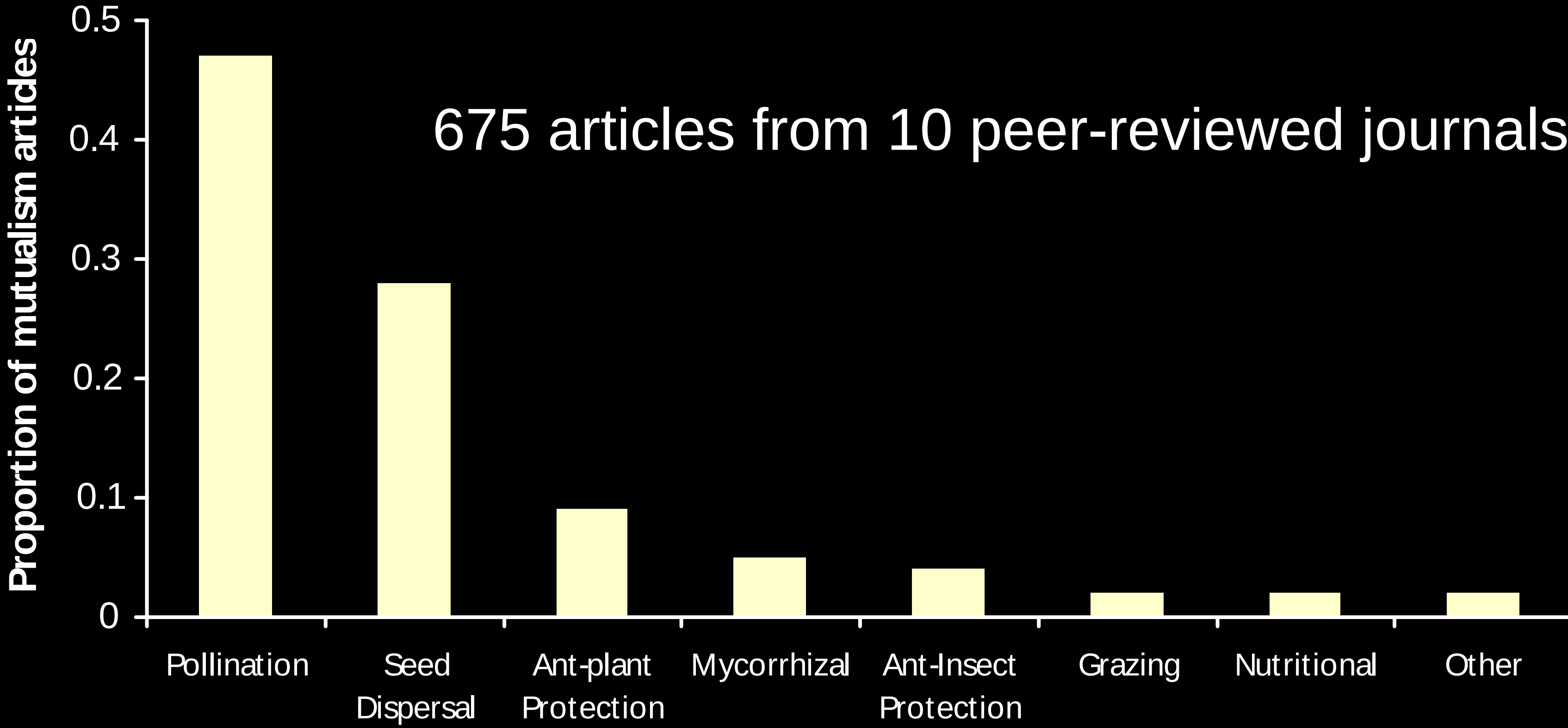
Why worry about mutualisms and climate change?

- 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

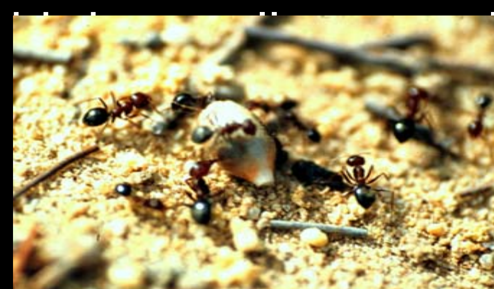
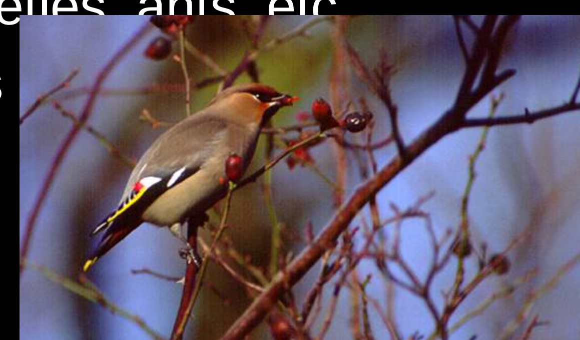


From Bronstein et al. 1998

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
    - Verte … y … s



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

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Many species being affected by climate change *(Parmesan and Yohe 2003)*

Type of change	Climate change prediction	Change as predicted
Phenology	Earlier timing of spring events	87%
Distribution	Poleward or upward range shifts	81%
Community composition	Increase in warm-adapted species and decrease in cold-adapted species	85%

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

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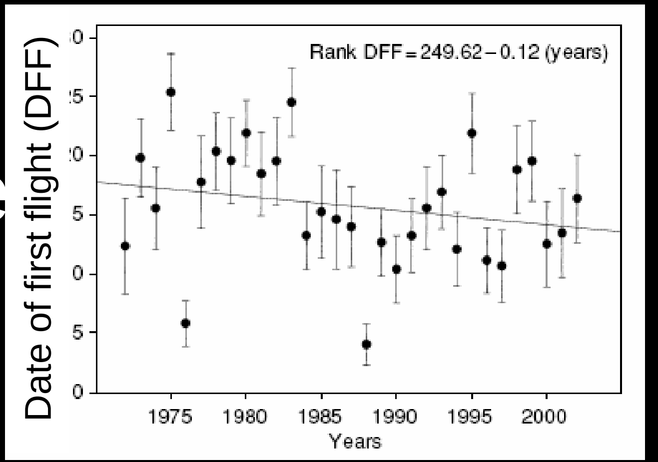
The problem of altered synchrony: mismatches between mutualists

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



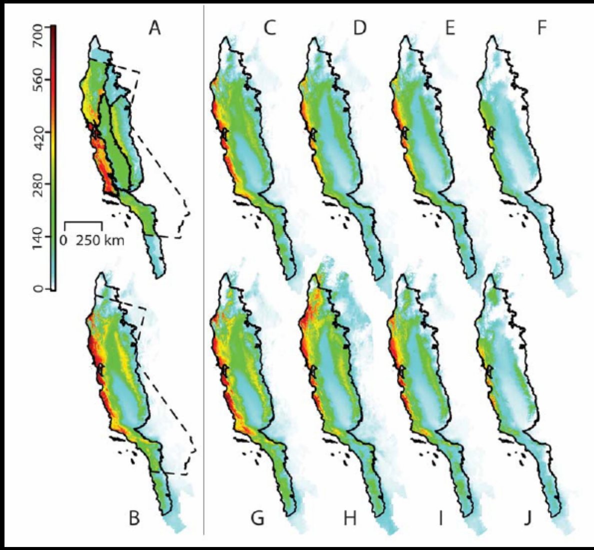
Central Valley butterflies emerging earlier (average 21 days earlier)

Forister and Shapiro 2003

Mismatches between mutualists, cont.

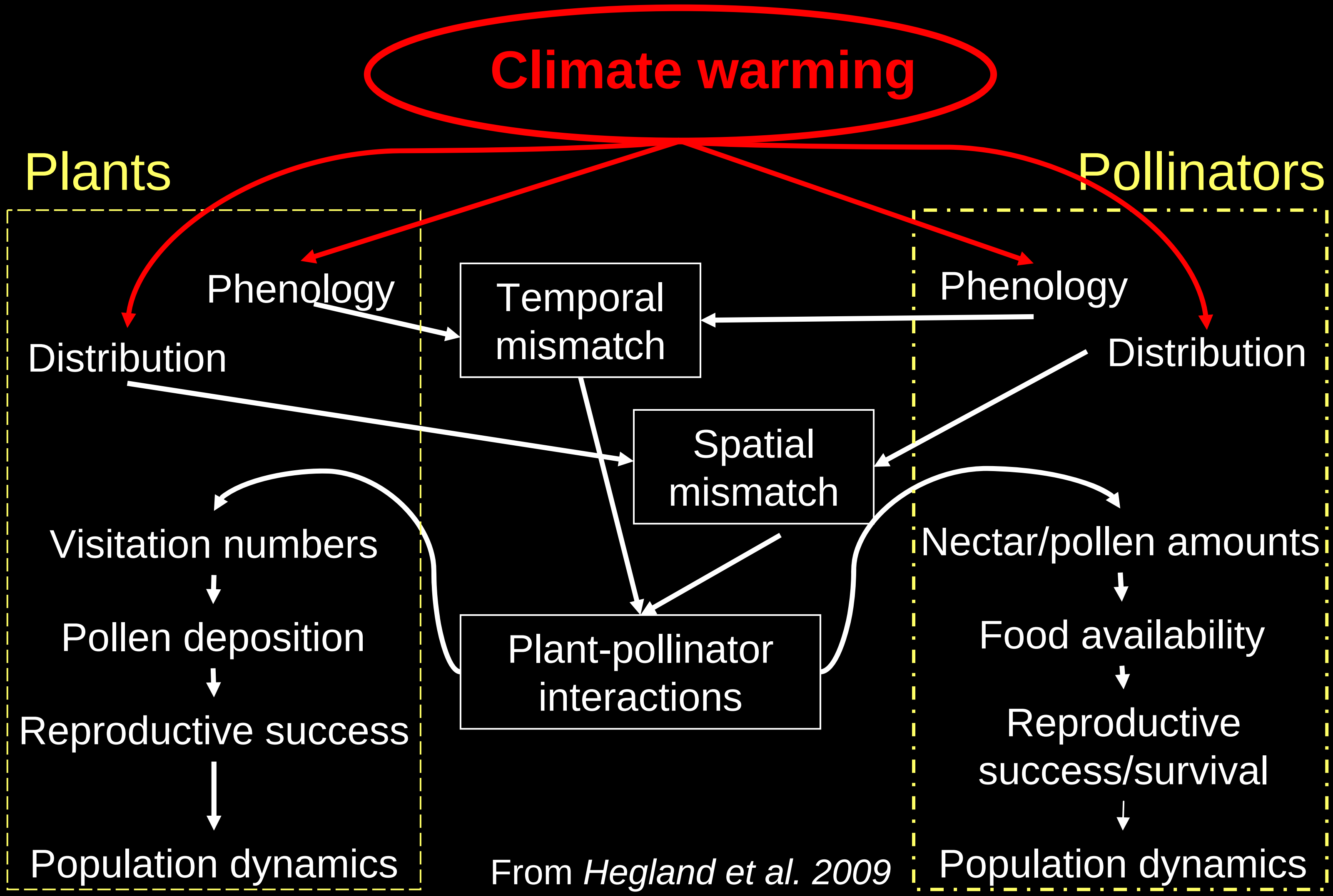
<u>Scenarios</u>: Spatial mismatch (distribution)

- 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



~ 1/3rd 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



From *Hegland et al. 2009*

Mismatched mutualisms – the evidence (or lack thereof)

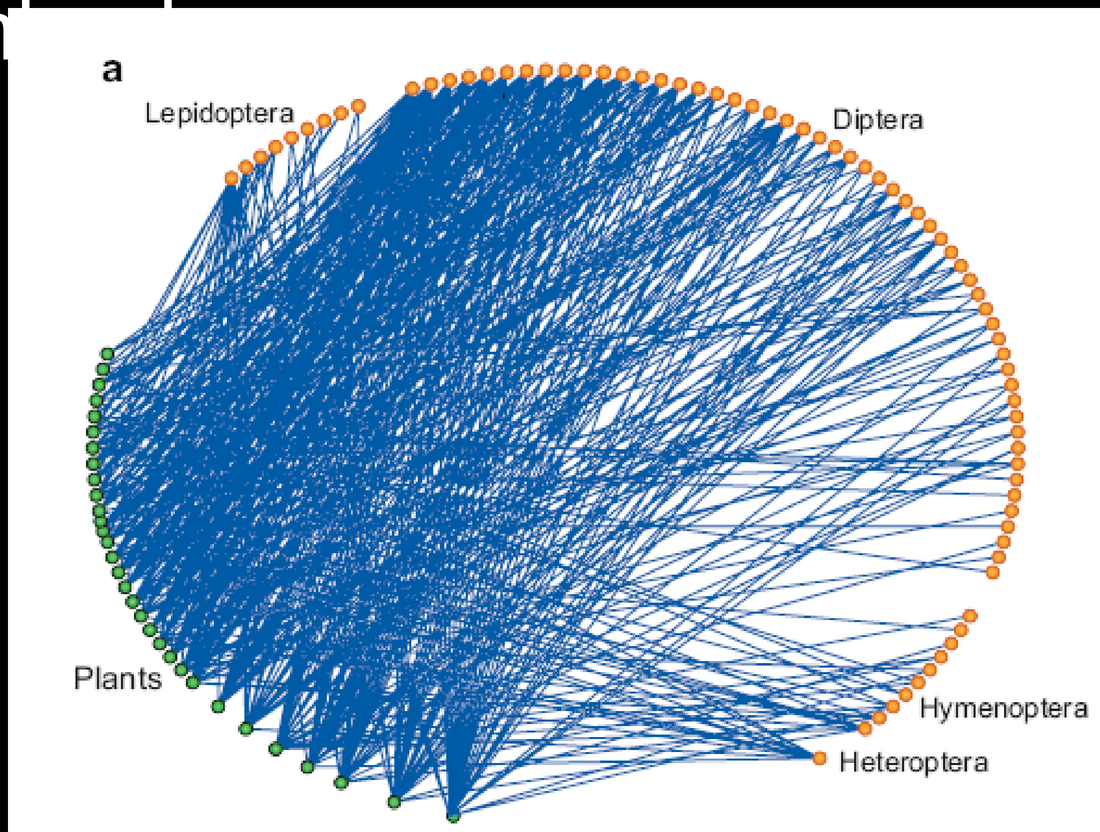
- Empirical data:
  - Data are slim, speculation is ample (e.g. *Visser and Both 2005*)
  - Mutualistic interactions weakened by climate change
    - Based on recent synthesis of 688 studies (*Tylianakis et al. 2008*)
  - Fossil/pollen record shows community disassembly during periods of climate change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

Example of plant-pollinator network

- From Zackenberg Arctic Tundra, Green



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

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Which special-status plants are at greatest risk in the Laguna watershed?

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

What about the animal pollinators?

- How will changes in plant phenology and 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

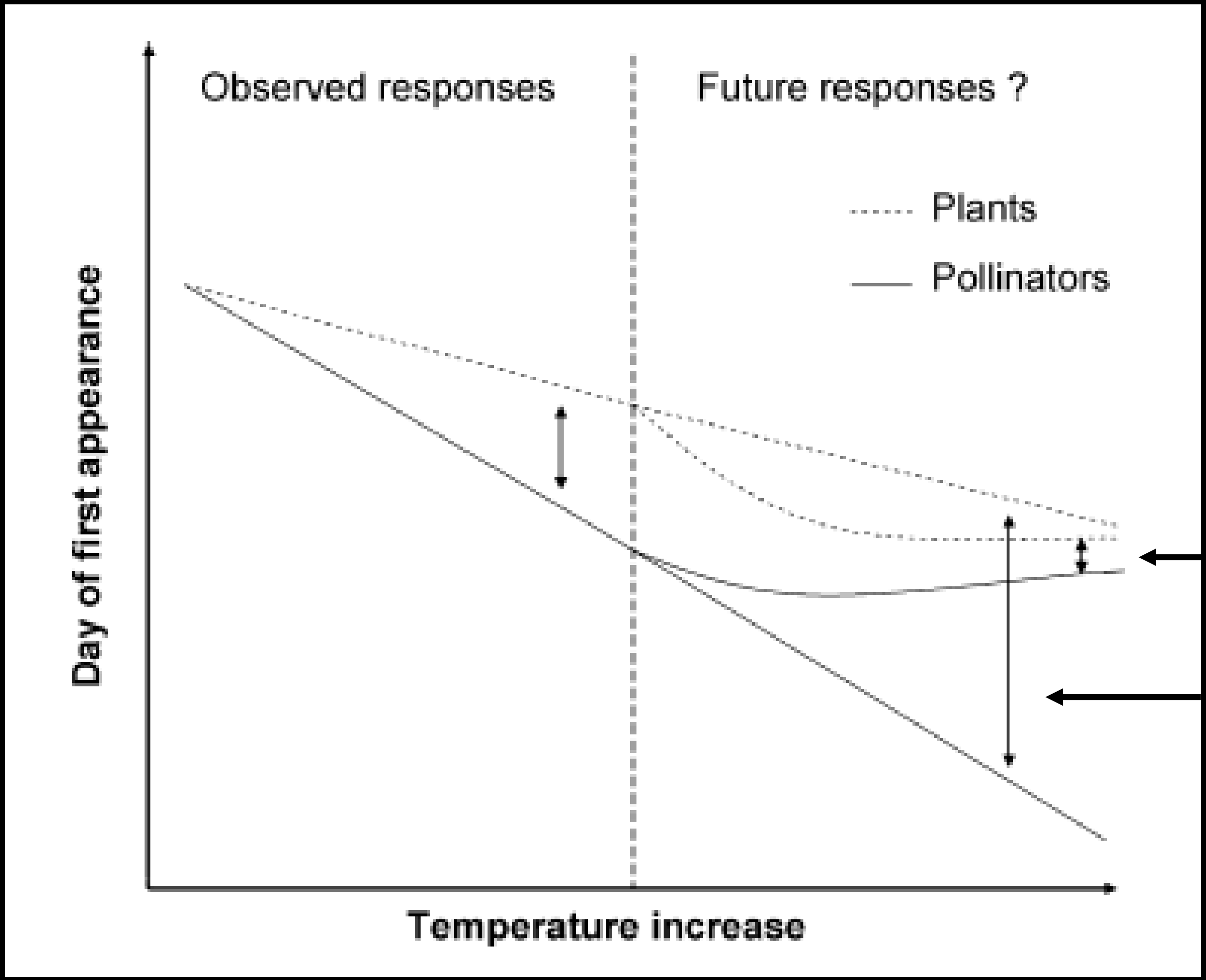
Preserving mutualisms in the watershed, cont.

- 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*