Herbivore Trophic Dynamics:

Potential Influences of Climate Warming

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Attributes of Herbivore Forage

- Quantity
  - g/m^2
- Quality
  - digestibility, N content, C:N ratio
- Morphology
  - potential bite size (interacts with herbivore morphology)
- Accessibility
  - growth initiation and cessation
  - snow depth and snow characteristics

Attributes of Herbivore Foraging

- Herbivore morphology/behavior
  - Maximum *bite size* and *biting rate* limits intake
    - intake asymptotic at some forage density (g/m^2)
    - variable among species, size classes

- Herbivore food processing rate (gut passage)
  - rate inversely related to forage quality
  - if processing is too slow, and time constrained

    >> intake quantity may be limited

Warming Effects on Herbivore Forage

- Quantity
  - Greater at a given date and at peak biomass
- Quality
  - Reduced at peak biomass, perhaps earlier
  - Earlier senescence may reduce relative quality in fall
- Morphology
  - Larger bites available from some plant species
- Accessibility
  - Earlier in spring
  - Snow - depends on interaction of temperature and precipitation
    - Deeper/shallower or harder/softer snow
    - Earlier lake melt; later lake freeze

Warming Effects on Herbivore Foraging

- Herbivore Morphology
  - biomass limiting for a shorter time
    - Higher biomass earlier
- Herbivore food processing
  - enhanced/inhibited depending on season
    - Enhanced early; Inhibited later

Global Observations

Parmesan and Yohe. 2003. Nature 421:37-42

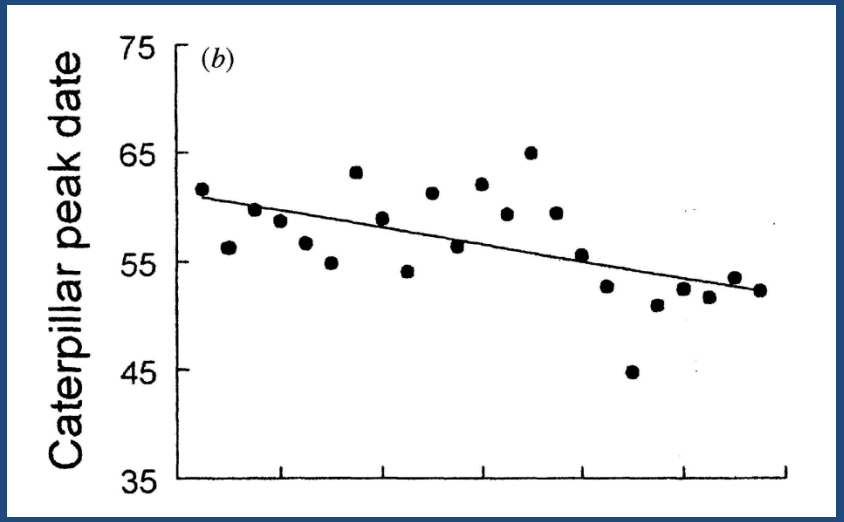
- Phenology
  - 677 species
    - 62% advanced,
    - 9% delayed,
    - 27% no trends,
    - 87% of shifts in expected direction
  - 172 species
    - ~2.3 days/decade earlier

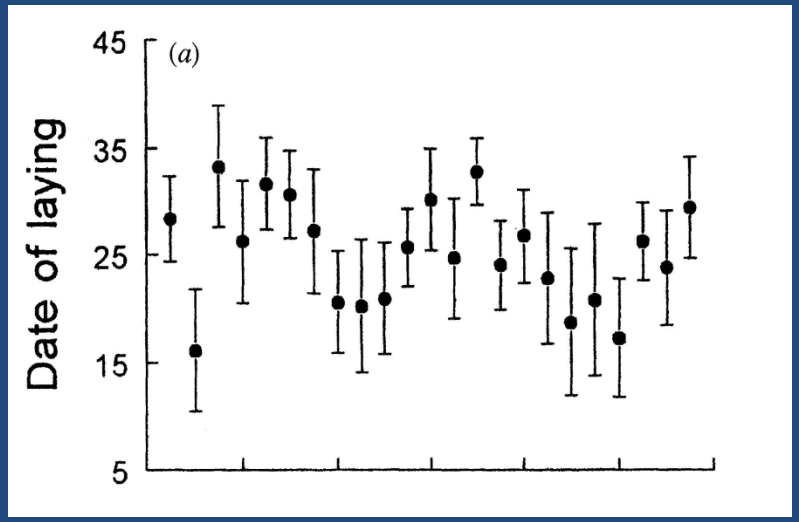
Trophic Mismatch

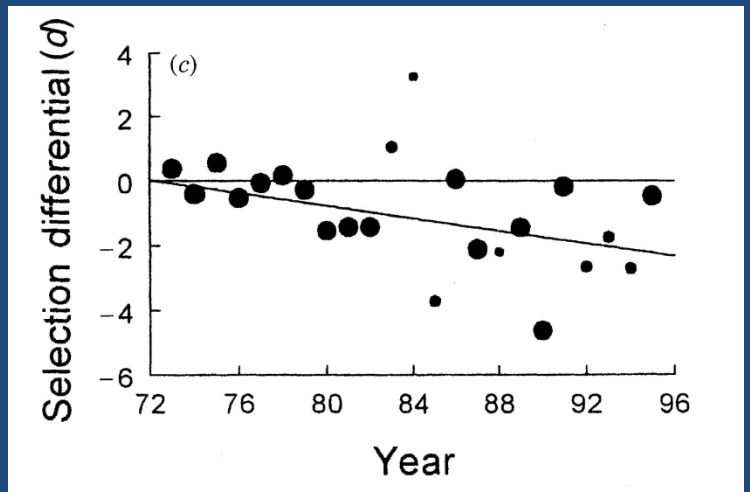
- Decoupling of forage need and availability
  - Forage item available too late
  - Forage item available too early
  - Suitable/adequate alternate forage not available
- Demonstrable demographic consequences
  - Reduced fecundity, survival, etc.
- Enhanced trophic match possible

Early Example of Trophic Mismatch

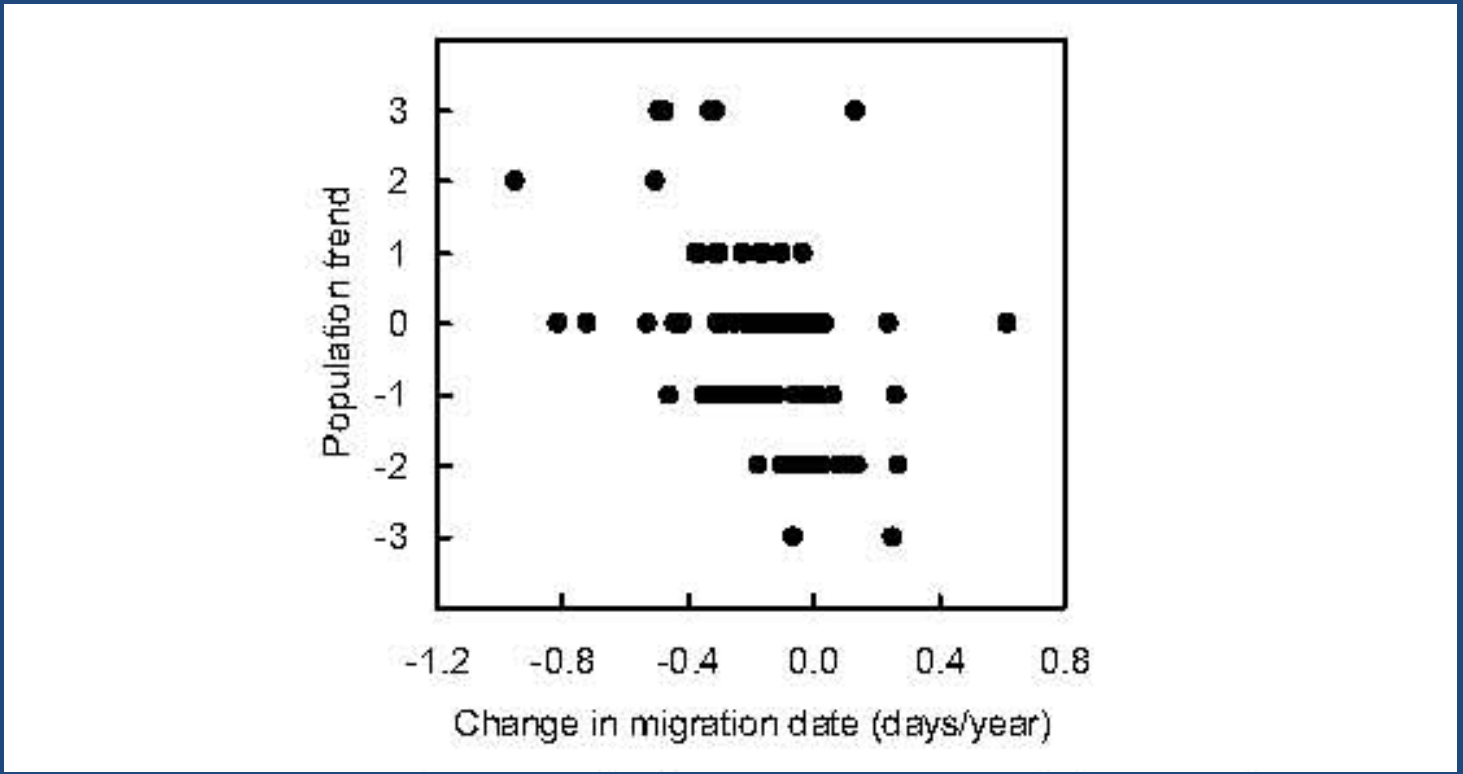
Visser et al. 1998. Warmer springs lead to mistimed reproduction in great tits (*Parus major*). Proc. Royal Soc. Lond. B 265:1867-1870.







Multi-species Trophic Mismatch



100 European bird species; 1990-2000.

Relationship not present 1970-1990; other habitat attributes associated with declines.

Moeller et al. 2008, PNAS 105:16195-16200.

“Wishful” Example of Trophic Mismatch

“..a rapidly developing mismatch between caribou reproduction and the timing of the availability of their forage (figure 2).”

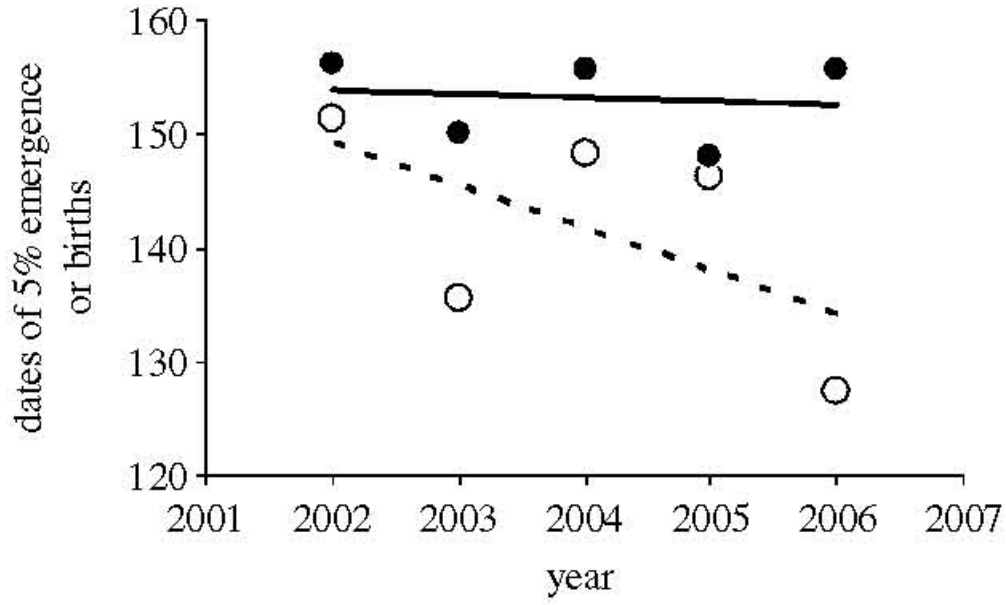


Figure 2. Dates (in day of year) of emergence of 5% of forage species (open circles, dashed line) and of 5% of caribou births (filled circles, solid line) at the study site in Kangerlussuaq, West Greenland, during the period of continuous annual data collection from 2002 to 2006. Fitted lines are linear regressions.

Post and Forschammer. 2008. Climate change reduces reproductive success of an Arctic herbivore through trophic mismatch. Phil. Trans. Royal Soc. Lond. B 363:2369-2375.

Mismatch Likely

- Different mechanisms for
  - Timing of life history event and food availability, e.g.
    - conception/migration affected by photoperiod
    - forage availability affected by temperature
- Income breeder
- Forage specialist
- Slow adaptation to different foods
- Little spatial heterogeneity in food availability
- Herbivore has limited mobility
- Short “life cycle” of forage item
- Alternate forage items not available

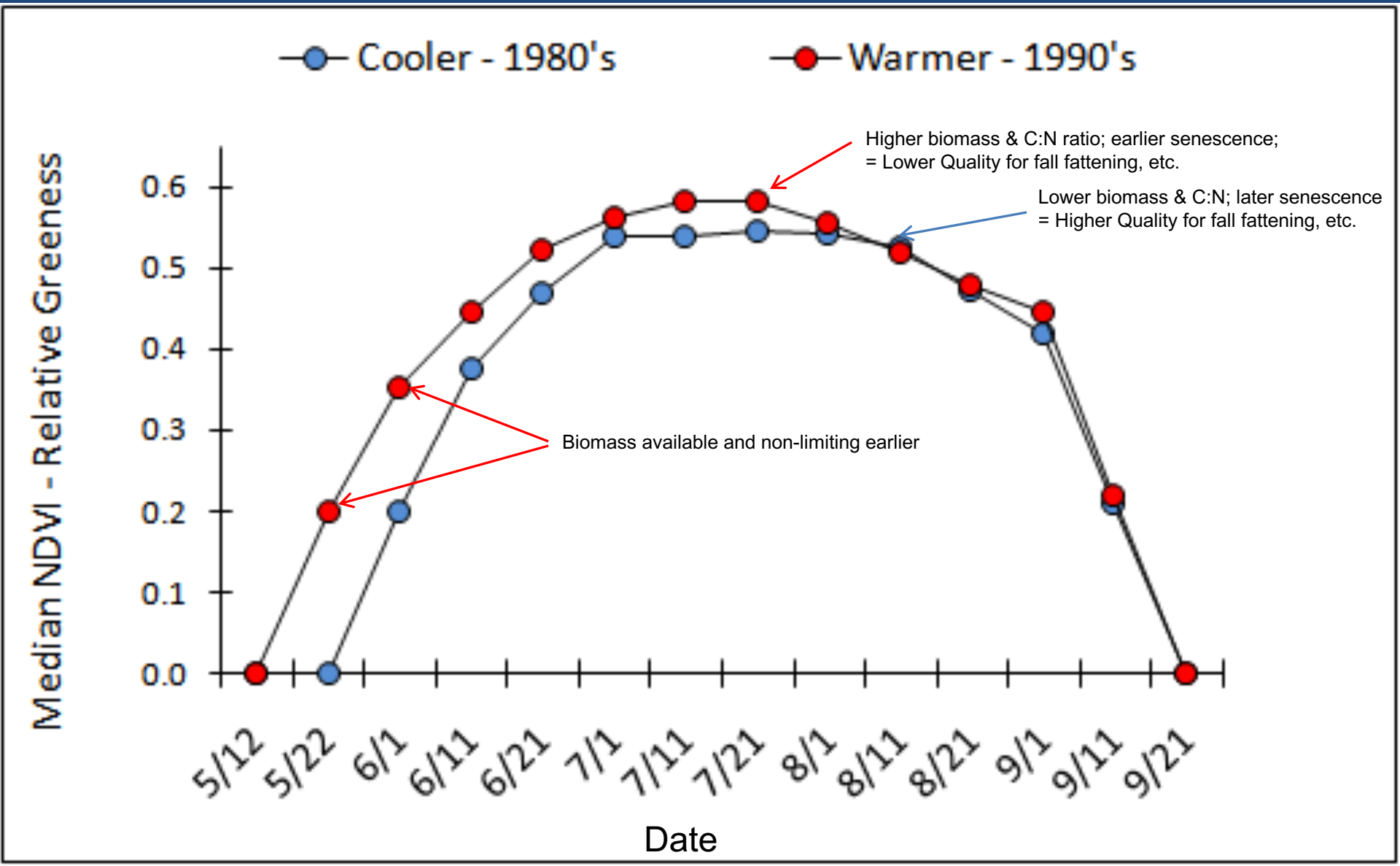
Mismatch Unlikely

- Forage generalist
- Capital breeder
- Rapid adaptation to different foods
- Much spatial heterogeneity in food availability
- Herbivore has substantial mobility
- Long “life cycle” of forage item
- Alternate forage items available

Complete annual and/or multi-annual analyses required

- Seasonal apparent trophic mismatch may be
  - Compensated (partial or full), e.g.
    - Mismatch in fall followed by
    - Enhanced match in spring
  - Magnified, e.g.
    - Mismatch in multiple seasons
    - Enhanced match in multiple seasons

Relative forage biomass (NDVI) in a warmer decade compared to a cooler decade, Arctic coastal plain, AK and YT



Requirements for Understanding Climate Effects on Mammals

(Krebs and Berteaux 2006. Clim Research 32:143-149

- Simple, explicit, mechanistic hypotheses
- Observational “experiments”
- Relatively long time series
- Minimize explicit prediction (Fairy Tales)