Impacts of Climate Change: Understanding Current Responses and Implications for the Future

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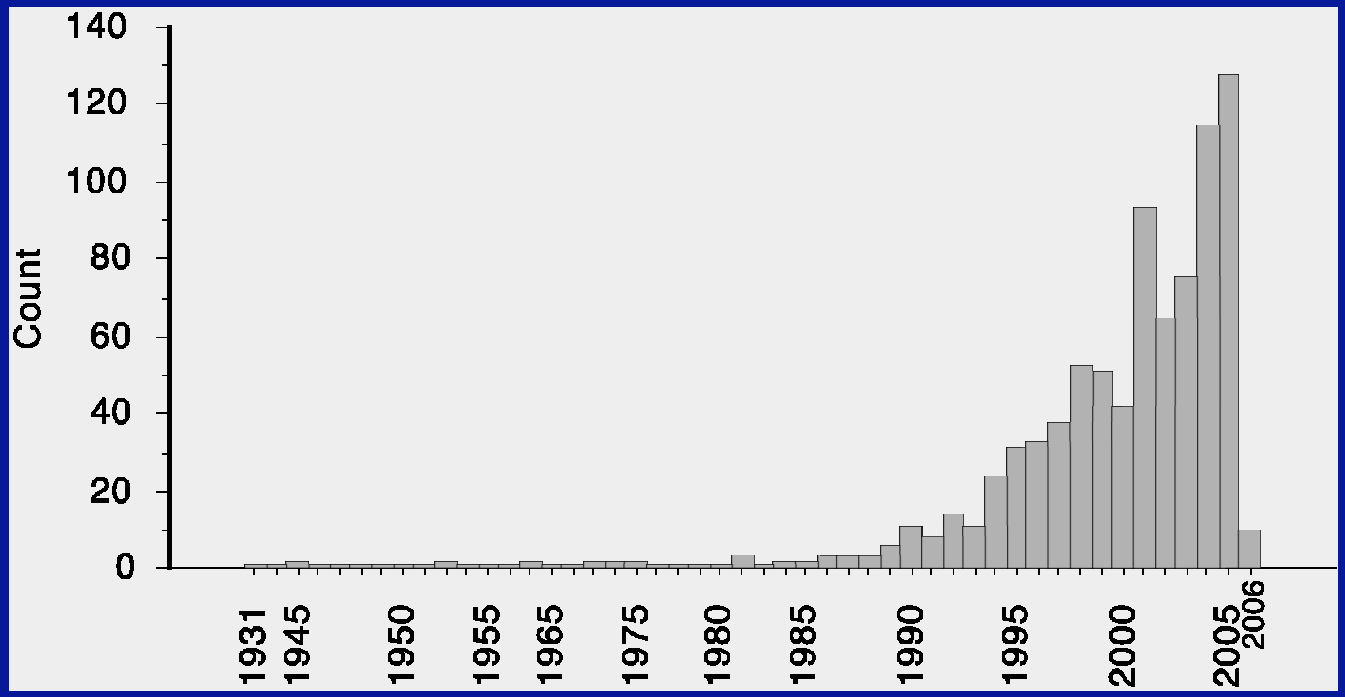
Royal Society workshop, London June 2007

2006 review of global biological impacts

#publications = 866

#species = several thousand



Number of publications documenting a response of a species, community or system to recent climate change
(up to Jan. 2006)

Parmesan 2006, Annual Reviews Ecology Evolution and Systematics

Overriding Questions:

1) Which are the most sensitive species and systems?

2) What do observed responses tell us about relative importance of ecological *vs*. evolutionary responses to climate change?

3) What do current responses tell us about future responses?

   i) Projections for individual species?

   ii) Projections for biodiversity more generally?

What we already know: Observed responses to recent climate change

- 50% of species studied worldwide show measurable response
- Every major group studied has been affected, and impacts have occurred on every major continent and in every major ocean
- Northward range shifts from 30 - 600 miles, and upward shifts of 300 - 2,000 feet (snow line) have occurred
- Almost everywhere, spring earlier & fall later, all taxa
- Parasites and their vectors have also shifted northward, some of these affect human health as well as wildlife

Parmesan & Yohe *Nature* 2003; Parmesan *AREES* 2006; IPCC 2007; Parmesan & Martens in press

Estimated: More than Half of Wild Species have Responded to 20th c. Climate Change

(>1700 species; ~ 1598 datapoints)

Type of Analysis	Changed as predicted (n)	Changed opposite to prediction (n)	P
Phenological N = 484 / (678)	87 %	13 %	$< .1 \times 10^{-12}$
Distributional changes: At poleward/upper range boundaries At equatorial/lower range boundaries	81 % 75 %	19 % 25 %	
Community (abundance) changes: Cold-adapted species Warm-adapted species	74 % 91 %	26 % 9%	
N = 460 / (920)	81 %	19 %	$< .1 \times 10^{-12}$
Meta-analysis Range-boundaries (n=99) Phenologies (n=172)	6.1 km-m/decade northward/upward shift 2.3 d/decade advancement		.013 < 0.05

Diverse species of: trees, herbs, shrubs, reptiles, amphibians, fish, marine zooplankton, marine invertebrates, mammals, birds butterflies

(Parmesan & Yohe, *Nature* 2003)

What we already know:
Most negatively affected species / systems

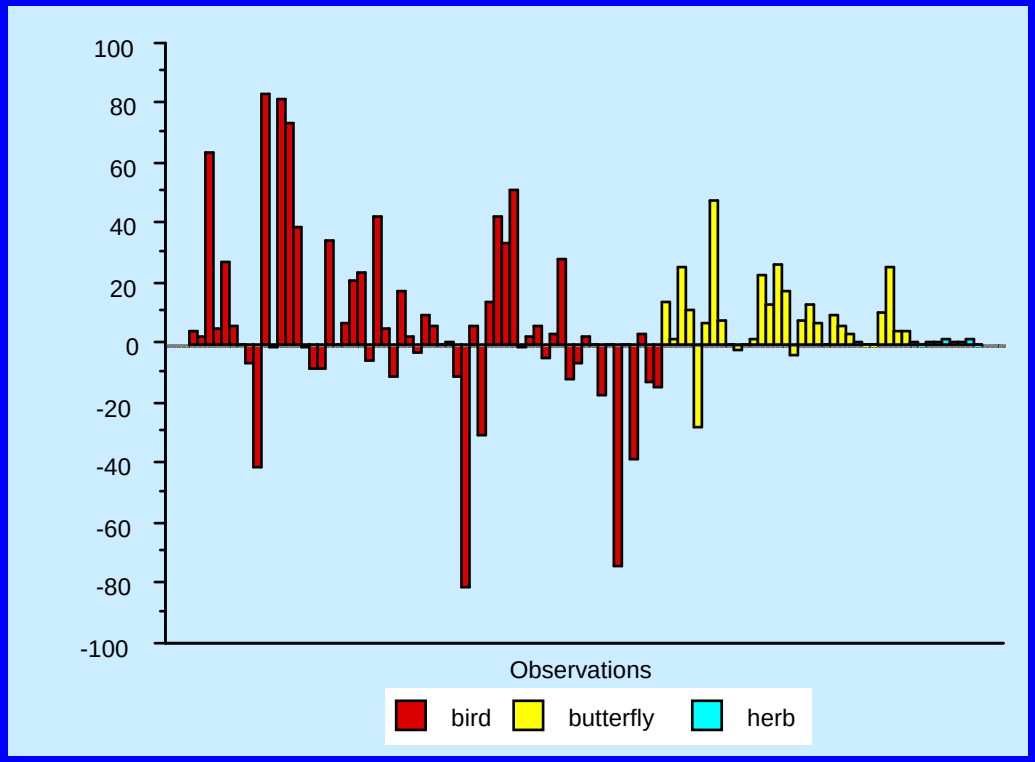
- Cold-adapted and severely range-restricted species have lost habitat and are reaching "endangered" status because of loss of climatically-suitable space.
    - sea-ice habitats (polar bears, ringed seals, Adelie and emperor penguins)
    - montane habitats (Harlequin frogs, pikas, Alpine butterflies)
- Species extinctions have already occurred:
    - 74 species of highland cloud forest frogs gone
    - ~ 30% of tropical coral reefs gone = ?? Species

Pounds *et al.* 2006, Descimon *et al.* 2006, Ainley *et al.* 2003, Croxall *et al.* 2002, Smith *et al.* 1999, Wilson et al. 2001, Barbraud & Weimerskirch 2001, Emslie et al. 1998, Fraser et al. 1992, Hoegh-Guldberg 1999, 2005; Wilkinson 2000, Stirling et al. 1999, Derocher et al. 2004, Ferguson et al. 2005, IPCC 2007

Changes in Northern / Upper Range Limits among Temperate Species

north / upslope

south / downslope



mean 6.1 km-m /decade

taxa ns different

Parmesan & Yohe, *Nature* 2003

Variation of Response - unclear why: *e.g.* congeneric butterflies

Species	N-boundary	Habitat	Host	Response?
Lassiomata				
maera	C Sweden	dry rocky	*Poaceae*	stable
magera	S Sweden	meadows	sps	expanding
Heodes				
alciphron	N France	flowery	*Rumex*	stable
tityrus	Dk, Estonia	meadows	*acetosa*	expanding
Coenonympha				
glycerion	CE Finland	flowery	*Poaceae*	stable
arcania	C Sweden	meadows	sps	expanding

Parmesan *et al*. *Nature*, 1999 and unpublished

AGCI / QUEST workshop
"Biodiversity in a Changing Climate: Assessing Uncertainties

Aspen, July 2005

Camille Parmesan & John **Katzenberger,** Chairs

Gerry Meehl

Dave Easterling

Gary Yohe

Osvaldo Sala

Resit Akcakaya

Jorge Soberon

Miguel Araujo

Richard Pearson

Josh Lawler

Linking changes in wild species to human health

1. Basic thermal ecology of pathogens largely correlational
   a) 8 % increase diarrhea in Lima, Peru with each 1°C temperature rise[1]
   b) 60 % variation *Vibrio vulnificus* bacteria in oysters explained by temperature, 30-48% of humans die
   c) Abundances of *Vibrio cholerae* bacteria in Bangladesh positively correlated with SST and copepod abundances[3]
2. Need for expansion of research on thermal ecology of pathogens
3. Need for experimental research

[1] Checkley *et al.* 2000; [2] Motes *et al.* 1998, Shapiro *et al.* 1998; [3] Colwell 1996

Vector-borne diseases

1. For common diseases with epidemics linked to climate, 67 % are transmitted by a wild animal vector, or are dependent on wild animals as resevoirs for some life history stage[1]
2. Few studies of population dynamics of human pathogens in the wild[2]
3. Few studies of vectors/resevoirs of human pathogens in the wild[2]
4. VERY few studies of complete systems - from pathogen to vector to human disease[2]

[1]Cleveland *et al*. 2001; [2]Gubler 2001, WHO 2003, 2004, Parmesan & Martens in press

Vector-borne diseases, continued…..

1. Well-documented studies in SW USA desert: El Niño years = wet = increased rodent densities = plague and hanta virus outbreaks in humans[1]
2. Need for increased monitoring of human pathogens and their vectors / resevoirs in the wild
3. Need for more studies which make explicit, quantitative links from wild state of pathogen to vector ecology to human disease outbreaks

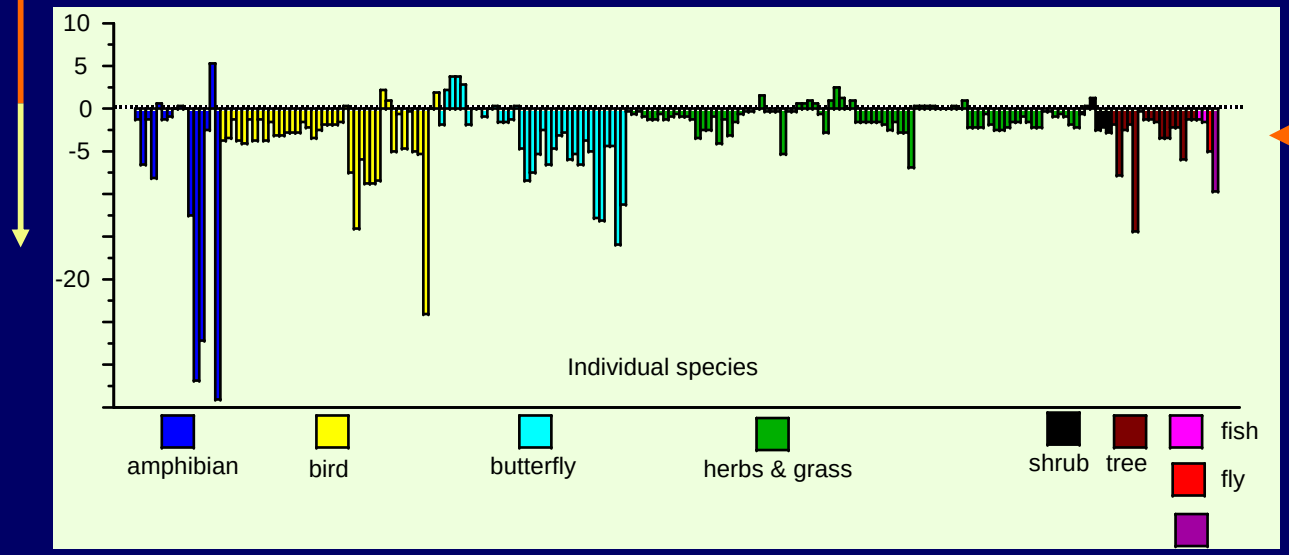
[1] Engelthaler *et al.* 1999, Parmenter *et al.* 1999, Glass *et al.* 2000, Gulber *et al.* 2001

What we already know: Observed phenological responses

- Spring events are earlier by 2 weeks on average since 1970, with some frogs breeding a month earlier per decade[1]
- Warmer winters, northward ranges shifts of moths and beetles, and extended growing seasons have resulted in increased pest outbreaks, tree deaths, and associated loss of productivity in forests across the lower USA, Alaska, Canada and Russia[2]

[1]Parmesan & Yohe 2003, Root *et al.* 2003, Parmesan in press
[2] IPCC 2001, Logan *et al.* 2003, Battisti *et al.* 2005,

Trends in timing of spring events among northern temperate species



mean 2.8 days/ decade advance

n = 203

timespan = 17 - 99 years

Parmesan (2007) *Global Change Biology*

Phenological changes drive range shifts

----- Warming Causes Asynchrony

- 2° C experimental warming causes timing mismatch
- Host plants dry up 3-7 days earlier,
- caterpillars starve

Singer 1972,
Weiss *et al.* 1997,
Parmesan 2003

Phenological Responses

- Some evidence for asymmetry of response across trophic levels
- Very few quantitative studies of specific interacting species-pairs
- Need for quantitative research and monitoring of key species' interactions
    - Flowering plants / pollinators
    - Insects / host plants
    - Predator / prey

Visser & Both 2005, Parmesan 2007

Conclusions

- Mass responses to recent climate change:
  - ~ 50 % of species
- Large variation in magnitude of responses
  - Confounding factors (land use change, urbanization)
  - Different aspects of climate as driving mechanisms
    - Among species
    - Different boundaries of same species
- Mysteries remain
  - Species with similar geographic distributions, ‘niches’ & life histories showing different responses
  - Subsequent impacts on human health?

- Microevolution may facilitate species' persistence
  - Selection for high dispersal phenotypes improves changes of range shifts keeping pace with climate change
  - Species with variation of climate-adapted genotypes contain genetic flexibility to cope in situ
- No evidence for macroevolution (emergence of novel adaptive traits within species)
- High end of climate change projections problematic:
  - Some habitats completely lost (tundra, alpine, coral reefs?)
  - outside of evolutionary history of many species
  - Unlikely for existing genetic variation to be sufficient

Parmesan, *AREES* 2006