



# Population ecology

Importance of biotic and climatic interactions

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**Wednesday**  
0900-1045am: Lecture 1 - Deer responses to global environmental change.  
1100-1230pm: Lecture 2 - TSA in ecology.  
0130-0230pm: Preparing paper presentations.  
0230-0500pm: Paper presentations and discussions.

**Thursday**  
0900-1100am: TSA exercises in R.  
1130-1230pm: Guest Lecture - Long-term ecosystem dynamics: case study Zackenberg.



# Deer responses to global environmental changes



by Mads C. Forchhammer

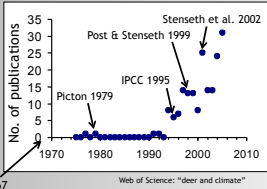
Aarhus University  
Department of Bioscience  
Denmark



# Deer responses to global environmental changes

Prologue

Googling "deer and climate":  
**5,110,000 hits**

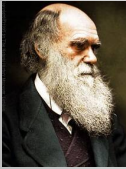


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## Deer responses to global environmental changes

### Prologue



"In one sense the conditions of life may be said, not only to cause variability, either directly or indirectly, but likewise to include natural selection, for the conditions determine whether this or that variety survive."

Charles Darwin (On the Origin of Species, 1859)

In my presentation  
conditions = climate

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## Deer responses to global environmental changes

### Prologue

This not a "DID or DID-not" presentation, that is ...



whether density independent (DID) factors are most important or ...

Andriewartha & Birch 1954



... density dependent (DD) factors are most important!

Nicholson 1954



The conditions are important, that is, DD/DID work together simultaneously!

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## Deer responses to global environmental changes

### Prologue

Defining global environmental changes

A global change index: the NAO

How do global changes affect deer?

Deer responses I: cohort and life history

Deer responses II: population dynamics

Deer responses III: community context

### Epilogue

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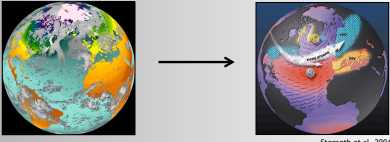
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## Deer responses to global environmental changes

### Defining global environmental changes

A transformation that occurs on a worldwide scale

Transformations in large-scale climate



Stenseth et al. 2004

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## Deer responses to global environmental changes

### Defining global environmental changes

**Climate**

Climate is the weather averaged over space and long periods of time

"Climate is what you expect, weather is what you get!"

**Ecosystem**



**Weather**

Weather is the specific condition of the atmosphere at a particular place and time

**Individual**



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## Deer responses to global environmental changes

### Defining global environmental changes

Climate → Pattern → Ecosystem

Weather → Process → Individual

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## Deer responses to global environmental changes

### Defining global environmental changes

Why use large-scale climate indices?

Short answer: "... animals [deer] are physiological weather integrators ..." Peterson 1984

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## Deer responses to global environmental changes

### Defining global environmental changes

Why use large-scale climate indices?

1. Integration in time

Year 1 (+)  
Year 2 (+)  
Year 3 (-)  
Year 4 (+)  
Year 5 (-)

December January February March

Scale of the NAO

NAO=North Atlantic Oscillation

Stenseth & Mysterud 2005  
Hallett et al. 2004

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## Deer responses to global environmental changes

### Defining global environmental changes

Why use large-scale climate indices?

2. Integration in space

Winter

Low NAO index  
- Low temperatures  
- Little precipitation

High NAO index  
- High temperatures  
- Much precipitation

Seasonal migration

Winter range

Summer range

Scale of the NAO

NAO=North Atlantic Oscillation

Stenseth & Mysterud 2005  
Hallett et al. 2004

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## Deer responses to global environmental changes

### Defining global environmental changes

Why use large-scale climate indices?

3. Integration of weather variables

Extreme cold

Severe rainfall

Strong winds

Year 1 (+)  
Year 2 (+)  
Year 3 (-)  
Year 4 (+)  
Year 5 (-)

December January February March

Scale of the NAO

NAO=North Atlantic Oscillation

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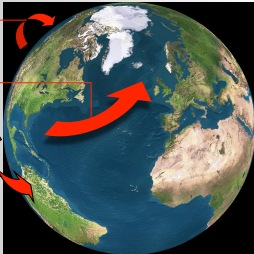
## Deer responses to global environmental changes

### A global change index: the NAO

North Pacific Oscillation

North Atlantic Oscillation (NAO)

El Niño Oscillation



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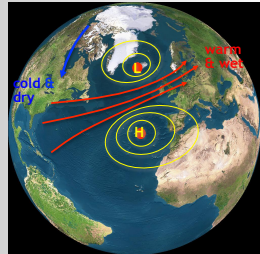
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## Deer responses to global environmental changes

### A global change index: the NAO

The North Atlantic Oscillation (NAO): a meridional oscillation in atmospheric mass

high NAO



Forchhammer 2001

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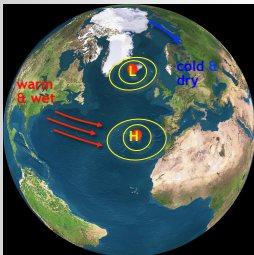
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### A global change index: the NAO

The North Atlantic Oscillation (NAO): a meridional oscillation in atmospheric mass

low NAO

The NAO captures variations in winter temperature and precipitation throughout the Northern Hemisphere



Forchhammer 2001

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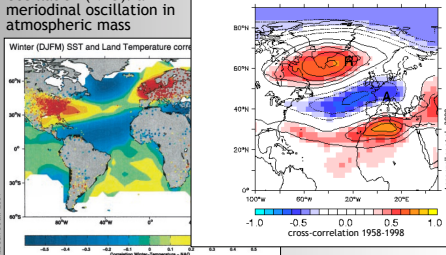
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### A global change index: the NAO

The North Atlantic Oscillation (NAO): a meridional oscillation in atmospheric mass

NAO modulates the Earth's ozone shield

Winter (DJFM) SST and Land Temperature correlation



Webster et al. 2001

Agnew et al. 2000

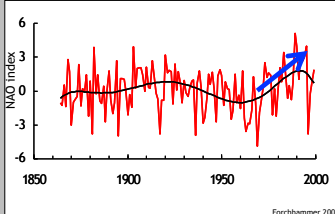
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Forchhammer 2001

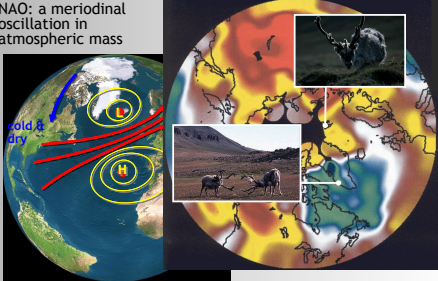
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NAO: a meridional oscillation in atmospheric mass



Forchhammer 2001

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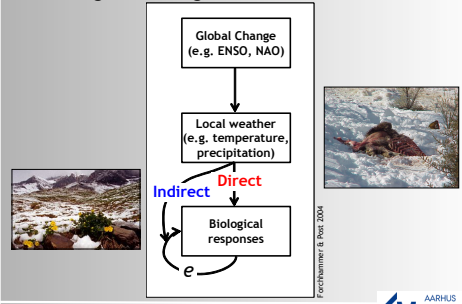
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How do global changes affect deer?

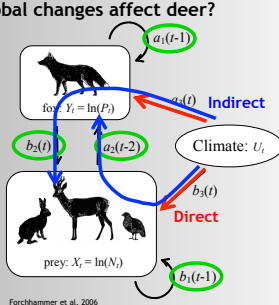


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## Deer responses to global environmental changes

How do global changes affect deer?



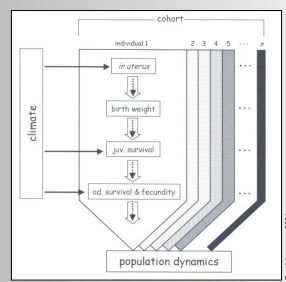
Forchhammer et al. 2006

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How do global changes affect deer?



Forchhammer 2001

by Mads C. Forchhammer



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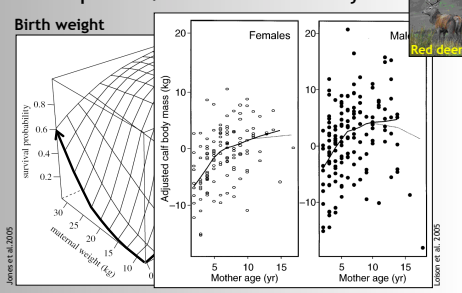
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## Deer responses to global environmental changes

Deer responses I: cohort and life history

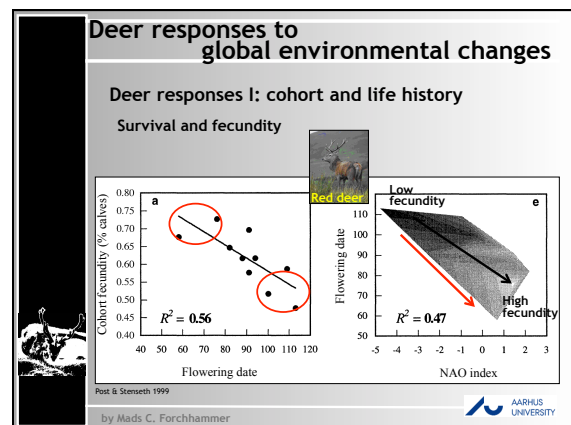
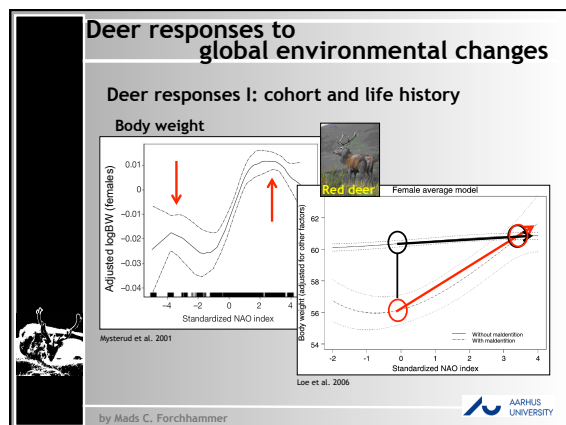
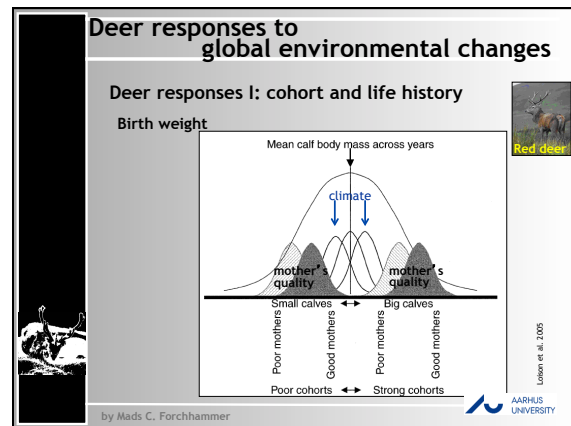
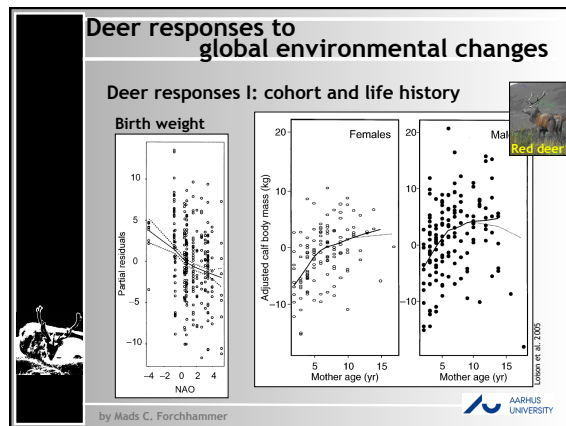
Birth weight



Forchhammer et al. 2005

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## Deer responses to global environmental changes

### Deer responses II: population dynamics

(i)  $N_t = f(N_{t-1}, NAO_t)$   
(simultaneous effects, interactions)

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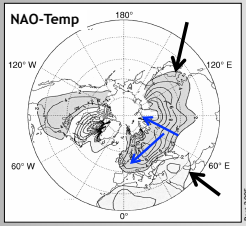
## Deer responses to global environmental changes

### Deer responses II: population dynamics

(i)  $N_t = f(N_{t-1}, NAO_t)$   
(simultaneous effects, interactions)

(ii) Large spatial variation in NAO/local weather relationships

NAO-Temp



Post 2005

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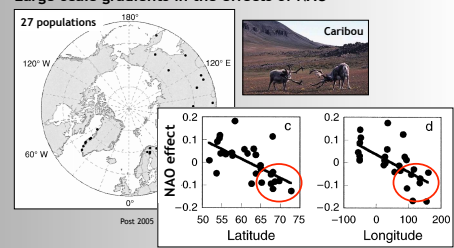
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## Deer responses to global environmental changes

### Deer responses II: population dynamics

#### Large-scale gradients in the effects of NAO

27 populations



Caribou

NAO effect

Latitude

Longitude

Post 2005

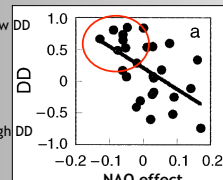
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## Deer responses to global environmental changes

### Deer responses II: population dynamics

#### Large-scale gradients in the effects of NAO



low DD

high DD

NAO effect

Post 2005

Caribou

- Caribou/reindeer populations limited mainly by abiotic factors may be prevented from reaching densities at which DD factors limit growth.
- The more similar the effect of the NAO, the more synchronized population dynamics!

Post 2005

Not only to correct for DD but also to consider interactions of DD and climate!

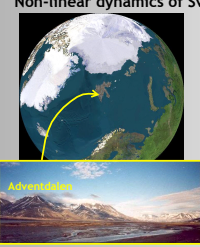
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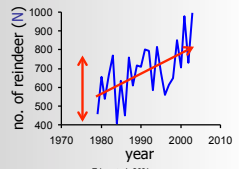
## Deer responses to global environmental changes

### Deer responses II: population dynamics

#### Non-linear dynamics of Svalbard reindeer



Svalbard reindeer



no. of reindeer (N)

year

1970 1980 1990 2000 2010

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## Deer responses to global environmental changes

### Deer responses II: population dynamics

Non-linear dynamics of Svalbard reindeer

Traditional linear approach:  
 $N_t = N_{t-1} + \text{weather}_t$



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Tyler et al. 2007

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Tyler et al. 2007

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## Deer responses to global environmental changes

### Deer responses II: population dynamics

Non-linear dynamics of Svalbard reindeer

Traditional linear approach:  
 $N_t = N_{t-1} + \text{ablation}_t$

Non-linear (phase-dependent) approach:

$$N_t = \begin{cases} \text{growth} > 0: N_{t-1} + \text{ablation}_t \\ \text{growth} \leq 0: N_{t-1} + \text{ablation}_t \end{cases}$$


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Tyler et al. 2007

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## Deer responses to global environmental changes

### Deer responses II: population dynamics

Non-linear dynamics of Svalbard reindeer

Traditional linear approach:  
 $N_t = N_{t-1} + \text{ablation}_t$

Non-linear (phase-dependent) approach:

$$N_t = \begin{cases} \text{high NAO: } N_{t-1} + \text{ablation}_t \\ \text{low NAO: } N_{t-1} + \text{ablation}_t \end{cases}$$


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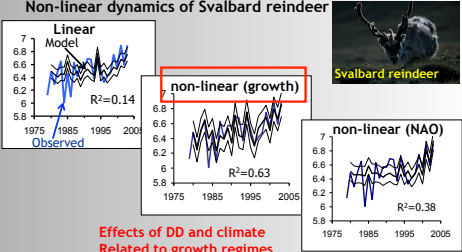
Tyler et al. 2007

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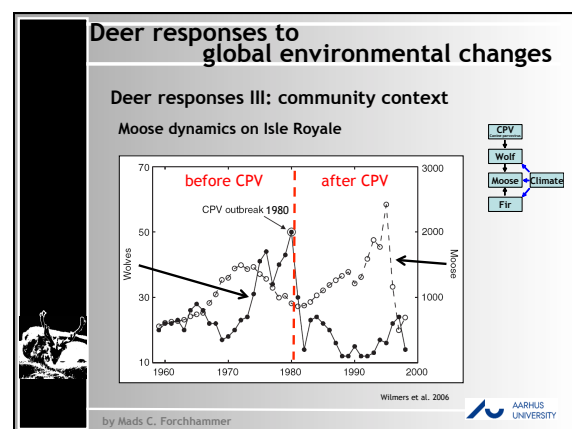
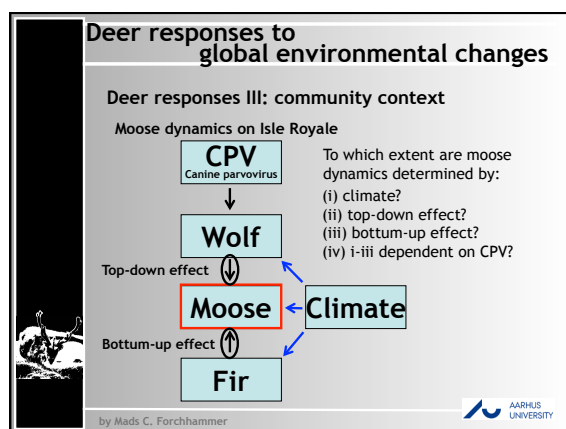
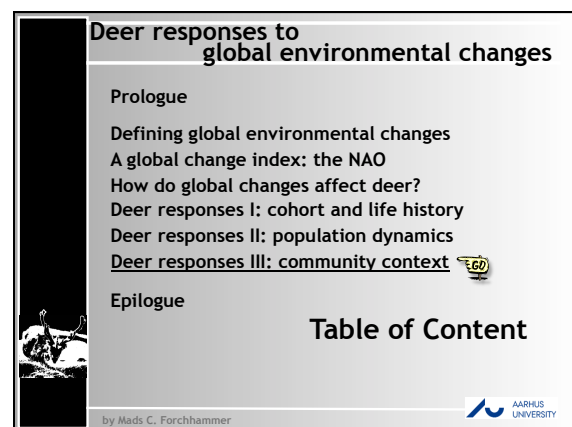
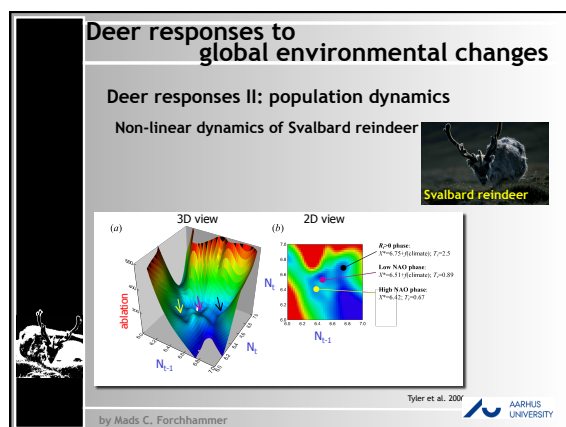
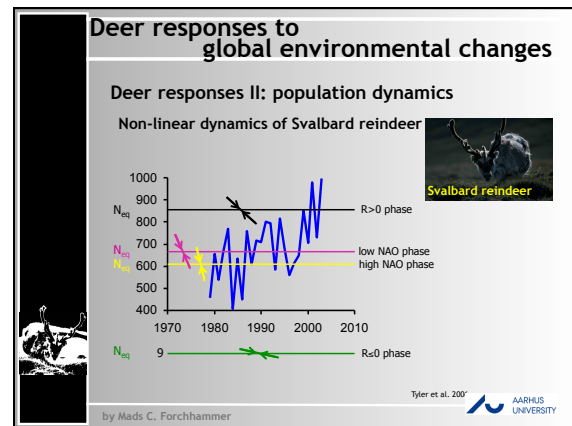
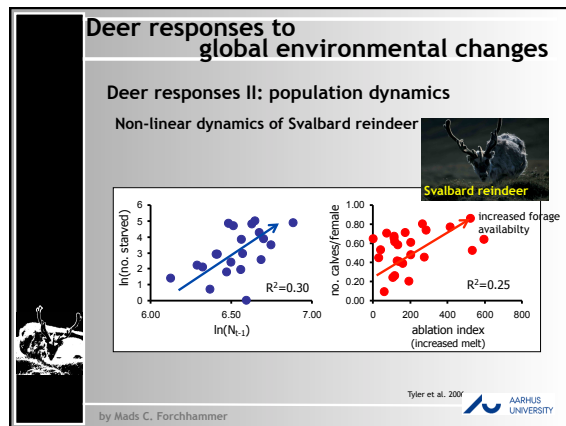


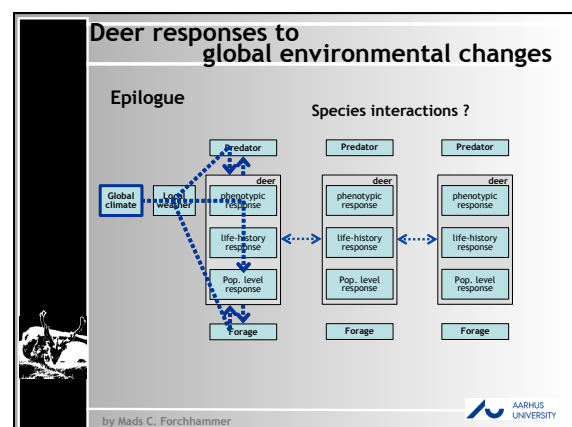
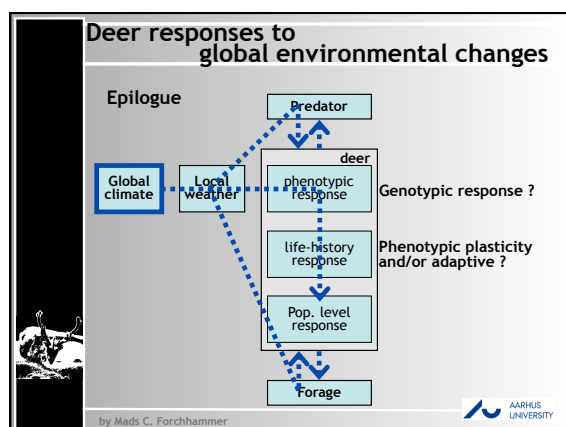
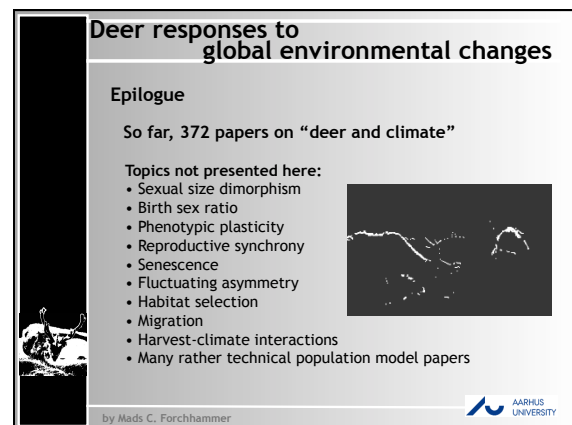
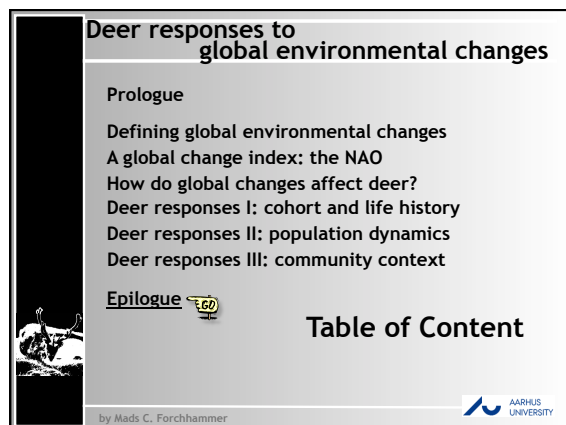
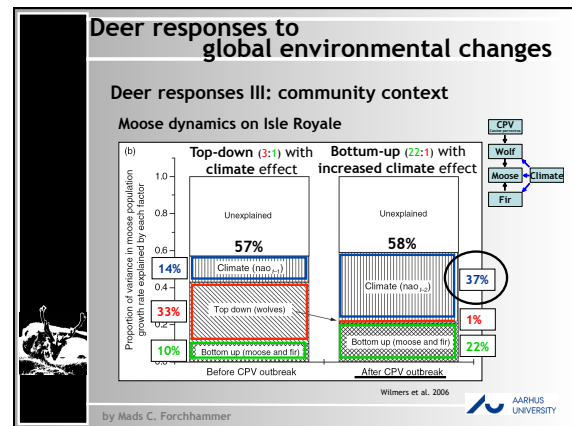
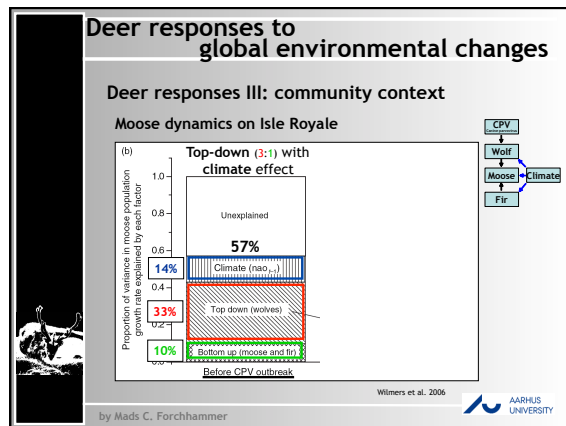
Effects of DD and climate Related to growth regimes

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Tyler et al. 2007

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The diagram illustrates the flow of information from external climate to internal ecosystem memory. On the left, a box labeled 'External climate' has a dashed arrow pointing to a 'Memory' box. This 'Memory' box is connected to a 'Vegetation indices' box, which in turn connects to a 'Life history response' box. Below these are 'Phys. stress response' and 'Vegetation' boxes. To the right, there are two identical vertical stacks of boxes, each labeled 'Production' at the top. Each stack contains 'physiological response', 'life history response', 'Phys. stress response', and 'Vegetation' boxes. Horizontal dashed arrows connect the 'Vegetation indices' box to the 'life history response' boxes in both production stacks. Vertical dashed arrows connect the 'Vegetation indices' box to the 'Phys. stress response' boxes in both production stacks. Vertical dashed arrows also connect the 'Life history response' boxes to the 'Phys. stress response' boxes within each production stack. Finally, vertical dashed arrows connect the 'Phys. stress response' boxes to the 'Vegetation' boxes within each production stack.

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**Zackenberg Basin**

**GeoBasis**

**ClimateBasis**

**BioBasis**

**MarineBasis**

**UrbanBasis**



Individual-based  
Modeling and  
Ecology

VOLKER GRIMM AND STEVEN F. RAILSBACK

by Mads C. Forchhammer

