Movement, Migration and Ecological Plasticity in Deer Species:
Facts and Consequences in a Changing European Landscape

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Migration plasticity in Deer species: 
Facts and consequences in a changing European landscape

1. Animal movement & ecosystems

2. Is there evidence of *seasonal movement plasticity* in European deer species?

3. What are the *causes* of seasonal movement plasticity in European deer species?

4. What are the *consequences* of seasonal movement variability?
Theoretical Framework(s) for Animal movement

1. Animal movement and ecosystems

- POPULATION DISTRIBUTION
- MOVEMENT PATTERNS
- INDIVIDUAL MECHANISMS
- EXTERNAL CONTEXT

Cagnacci et al. 2016, JAnE

Drake et al. 1995
Mueller & Fagan 2008
Nathan et al. 2008

Migration arena
Natural selection
Migration syndrome
Genetic complex
Landscape structure/dynamic resources
External factors & Dynamics

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Theoretical Framework(s) for Animal movement and spatial distribution

- Movement emerges on heterogeneous landscapes, in space and time (context of movement)- directly linked to habitat selection.

- Movement is a multi-scale phenomenon:
  Movement behavior = applies to individuals (physiological, behavioral, genetic- movement process and pattern)
  Movement ecology = applies to populations (ecological, evolutionary- movement outcome)
Seasonal Species Distribution and Ecosystem functions

Bauer & Hoye
2015, Science
49 study areas, ranging 63°N-38°N 0-2000m a.s.l.

33 partners, 15 countries
> 2500 individual tracks
> 8 million GPS locations
TOTALLY BOTTOM-UP AND COLLABORATIVE
How to study this across Europe? The EURODEER collaborative project!

Feeding Type
- Red Deer: Mixed Feeder
- Roe Deer: Browser

Body Size
- Male Red Deer: 108-160 kg
- Female Red Deer: 27-28 kg
- Male Roe Deer: Low sexual size dimorphism

Social Behavior
- Red Deer: Mainly gregarious, Males hold harems
- Roe Deer: Mainly solitary, Male territoriality

IUCN

Maps showing the distribution of Red Deer and Roe Deer across Europe.
Nathan Ranc, 4pm Thursday 09.08!
Behavioural and Spatial response of Roe deer to Supplemental Feeding Management
Migration plasticity across roe deer populations

Migration rate and migration distance differ
(or: it is not only a matter of migrating, but how you do it)
Migration plasticity across deer species, and populations:

Migration distance

Migration distance: red deer migrate farther, red deer males migrate farther than red deer female.

Roe deer: 10 populations, $N_{roe} = 273$; Red deer: 12 populations Red deer: $N_{red} = 264$
Maximal residence time in summer and winter ranges:

Individual migratory behaviour

Constraint line: $\text{win} + \text{sum} = 1$

Red shapes: females
Blue shapes: males
Different shapes $\rightarrow$ different areas

Cagnacci et al. 2011, Oikos EURODEER # 1
Migration plasticity in European deer species: migration rate and residence time

Cagnacci et al. 2016, JAnE EURODEER # 4
1. **MRSA**: Stochastic mechanistic movement model to estimate (simplified, circular) home ranging area

2. Estimate of the **initiation and duration of transitional movements** while accounting for the autocorrelation

3. Likelihood-based evaluation to quantify ‘**significant’ shifts’.

*Gurarie, Cagnacci et al. 2017, JAnE*
Home range size and distance of migration

Range Shift Index (RSI): ratio distance/diameter of ranging area → EFFECT SIZE OR INDEX OF MIGRATORINESS

RSI = 0.67 (p<0.001)

RSI = 7.19 (p<0.001)
Migration plasticity across deer species, and populations: onset of migration

Spring migration timing: Females migrate sooner, and are more synchronized. Roe deer migrate sooner.

Fall Migration timing: Roe deer males migrate later.

Roe deer: 10 populations, $N_{roe} = 273$
Red deer: 12 populations Red deer: $N_{red} = 264$
Phenotypic ‘ecological’ plasticity: phenotypic differences among individuals of the same genotype that occur in response to an environmental cue.

**Plasticity at individual level** = Behavioral plasticity (facultative migration/distance-timing-duration of migration)

**Plasticity at population level** = Partial migration
Bridging patterns and causes: determinants of the Migratory continuum

- Animals living in environments with the *scarcest* resources travel *farther* and have the *largest HR*

- Animals travel *farther* in environments with *broader scales* of resource variability.

Mueller et al. 2011, GEB; Teitelbaum et al. 2015
**Phenotypic plasticity**: phenotypic differences among individuals of the same genotype that occur in response to an environmental cue.

- **Plasticity at individual level** = Behavioral plasticity (facultative migration/distance-timing-duration of migration)
- **Plasticity at population level** = Partial migration
The Migration Niche: Migration across an Ecological Distance

Common definitions:
1. Spatial separation between home-ranges
2. Temporal separation between home-ranges
3. Spatial and temporal variability in resources

Peters et al. 2017 Ecol Monog EURODEER #6
What are the factors affecting the seasonal spatial distribution of ungulates in Europe?

3. Causes of seasonal movements
3. Causes of seasonal movements

Single population analysis of forage: fine scale use (shrubs)

Migrants: are summer ranges better than winter ranges?

Are resident ranges better than migrant ranges, if they staid?

Are summer migrant ranges better than resident summer ranges?

P<0.01

n.s.

P<0.01

Zini et al. in prep.
Single population analysis of winter selection: cover and snow depth

3. Causes of seasonal movements

<table>
<thead>
<tr>
<th>Factor</th>
<th>Effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>Forest cover</td>
<td>+ +</td>
</tr>
<tr>
<td>Snow Depth</td>
<td>- -</td>
</tr>
<tr>
<td>Distance from Feeding sites</td>
<td>-</td>
</tr>
</tbody>
</table>

Ossi et al. 2015 EJWR.
3. Causes of seasonal movements

Multi-population/Multi-species: productivity vs probability and timing of migration

Peters et al.
In revision
EURODEER #10
3. Causes of seasonal movements

Multi-population/Multi-species: spatio-temporal variability vs migration

* Time-varying covariates
§ Site specific covariates

Contingency: intra-annual variability (seasonality)
Constancy: inter-annual variability (predictability)
Are the determinants of seasonal movements currently changing?

4. Consequences of seasonal movements

- Temperature is increasing across altitudinal and latitudinal ranges → snowline and snow-depth
- Growing season is changing (phenology, duration)
Winter habitat selection of roe deer across decades

Winter distribution of roe deer changed across an inter-decadal period, but is also more variable in recent years than it used to be.

Bright-Ross et al. submitted
Fast-changing seasonal distribution of deer species in Europe?

1. We found evidence of *seasonal movement plasticity* in European deer species, at the individual and population level. However, responses are species-specific.

2. Seasonal movement plasticity is affected by *spatio-temporal variability of productivity and winter severity*, and thus (also) by abiotic factors.

3. Abiotic factors are fast changing, especially at the latitudinal and altitudinal edges of Europe. We have some evidence of how this may affect seasonal ungulate distribution.
4. Consequences of seasonal movements

Fast-changing seasonal distribution of deer species in Europe?

Effects on:
• Nutrient cycle
• Seedling
• Browsing pressure
• Trampling/scraping
• Disease transmission
• ..... 

Animal movement might be the fastest source of variation in forest ecosystem dynamics and services
Thank you! Questions?

Mark Hebblewhite, University of Montana
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Paul Moorcroft, Harvard University
Julius Bright-Ross, Harvard University & Oxford University
Elie Gurarie, University of Maryland
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All my other students and co-authors
All EURODEERERS....

...and the Euroungulates sponsor