Alien squirrels & diseases: implications and threats

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1. PARASITE LOSS

Invaders often lose part of their parasite community during invasion (e.g. founder effect, drugs during captivity, no intermediate hosts, etc.)

They will benefit from this loss in terms of fitness

Improved performances in the new range compared to the native range

**ENEMY-RELEASE HYPOTHESIS**

Alien species & parasites

2. ALIEN PARASITE INTRODUCTION

- spillover to naive native species

3. LOCAL PARASITE ACQUISITION

- alteration of pre-existent epidemiology
  and spill-back to native species

competition mediated by shared natural enemies

APPARENT COMPETITION
Alien squirrels & parasites

**SQUIRRELPOX VIRUS** mediates the competition between red & grey squirrels in Great Britain & Ireland

- **Grey squirrel:** healthy carrier (prevalence ~60%)
- **Red squirrel:** lethal in most cases
- Replacement accelerated up to ~ 25 times

Photo credit: Sarah McNeil
Squirrelpoxvirus in Italy?

- **Serology** (n=285) + **molecular** (n=66) (2011-2014)
  
  - ELISA: 4 positive reactors (cross-reactions!)
  - PCR: all negative

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No evidence of SQPV in Italian grey squirrel populations

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However, **passive surveillance** is recommended

(Romeo et al., An Cons, under review)
Did alien squirrel introduced to Italy lose, acquire or carry along any parasite species?

- **Grey squirrel:**
  - 7 sites
  - (2011-2013)

- **Pallas’ squirrel:**
  - 1 site
  - (2011-2014)

Direct parasitological survey through PM examination of carcasses
Alien squirrels & parasites

Rich Host Community = Rich Parasite Community
Alien squirrels & parasites

**POOR PARASITE COMMUNITY**
e.g. a single gastro-intestinal, scarcely pathogenic helminth species: *Trypanoxyuris sciuri* (>80% prevalence)

Vulnerability to **Spillover**?

(Romeo et al., Parasitol Res, 2013)
## Endoparasites – Helminths

<table>
<thead>
<tr>
<th>Taxon</th>
<th>Prevalence</th>
<th>Mean Intensity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strongyloides robustus</td>
<td>56.5%</td>
<td>16.9 ± 2.1</td>
</tr>
<tr>
<td>Trichostrongylus calcaratus</td>
<td>6.5%</td>
<td>1.9 ± 0.3</td>
</tr>
<tr>
<td>Trichuris muris</td>
<td>4.2%</td>
<td>1.3 ± 0.2</td>
</tr>
<tr>
<td>Trypanoxyuris sciuri</td>
<td>1.9%</td>
<td>80 ± 2.5</td>
</tr>
<tr>
<td>Aonchotheca annulosa</td>
<td>1.5%</td>
<td>2.2 ± 0.6</td>
</tr>
</tbody>
</table>

*(Romeo et al., PloS ONE 2014)*

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<tr>
<th>Taxon</th>
<th>Prevalence</th>
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</thead>
<tbody>
<tr>
<td>Trypanoxyuris sciuri</td>
<td>5.5%</td>
<td>2.3 ± 1.3</td>
</tr>
<tr>
<td>Trichuris muris</td>
<td>5.5%</td>
<td>1</td>
</tr>
<tr>
<td>Strongyloides callosciureus</td>
<td>2.7%</td>
<td>1</td>
</tr>
</tbody>
</table>

*(Mazzamuto et al., Ann Zool Fenn 2016)*

n=262
Endoparasites - Helminths

Both species harbour poor helminth communities

Grey squirrels successfully introduced the nematode *S. robustus*

Grey and Pallas’ squirrels rarely acquire red squirrels’ *T. sciuri*

Potential for enemy-release

Spillover to native species?

Spill-back unlikely
Endoparasites – Helminths

- 4 red-only sites (n=60)
- 5 red-grey sites (n=49)

- Extensive live-trapping (2011-2013)

- Faecal examination for S. robustus + tape tests for T. sciuri

(Romeo et al., Parasitol Res 2015)
In areas co-inhabited by grey squirrels, red squirrels have a *higher* probability of being infected by both *S. robustus* and *T. sciuri* ($p<0.05$)

(Romeo et al., *Parasitol Res* 2015)
Endoparasites - Helminths

Spillover of *S. robustus* from grey to red squirrels

**WHAT IS THE IMPACT ON RED SQUIRRELS?**

*S. robustus* has high prevalence in red squirrels which shed **viable eggs**

**RED SQUIRRELS ACT AS COMPETENT HOSTS**

In the presence of grey squirrels, red squirrels also suffer **increased infection by T. sciuri**

**STRESS-MEDIATED EFFECTS ON IMMUNE RESPONSE?**
Endoparasites – Coccidia

• Most of red & grey squirrels are infected by coccidian (e.g. E2 > 90%)

• Pallas’ squirrels likely lost their coccidian parasites

Molecular analysis revealed that E2 are actually two distinct species: E. sciurorum in red squirrels and N. American E. lancasterensis in grey squirrels

DATA SUGGEST NO INTERSPECIFIC TRANSMISSION

(Hofmannová et al., Eu J Protistol, 2016)
## Endoparasites - Cryptosporidium

<table>
<thead>
<tr>
<th>Squirrel species</th>
<th>Prevalence</th>
<th>Taxa</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>RED</strong> (n=123)</td>
<td>10.7%</td>
<td>Ferret genotype</td>
</tr>
<tr>
<td><strong>GREY</strong> (n=162)</td>
<td>3.7%</td>
<td>Chipmunk genotype I, Skunk genotype, C. ubiquitum</td>
</tr>
<tr>
<td><strong>PALLAS</strong> (n=72)</td>
<td>2.8%</td>
<td>Chipmunk genotype I</td>
</tr>
</tbody>
</table>

Data suggest no interspecific transmission (Prediger et al., Eu J Protistol, 2017)
Ectoparasites

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<tr>
<th>Taxon</th>
<th>Prevalence</th>
<th>Mean Intensity</th>
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</thead>
<tbody>
<tr>
<td><em>Ceratophyllus sciurorum</em></td>
<td>26.5%</td>
<td>2.7 ± 0.3</td>
</tr>
<tr>
<td><em>Neaohaemathopinus sciuri</em></td>
<td>17.7%</td>
<td>3.6 ± 0.8</td>
</tr>
<tr>
<td><em>Ixodes acuminatus</em></td>
<td>1.7%</td>
<td>1</td>
</tr>
<tr>
<td><em>Ctenocephalides felis</em></td>
<td>0.4%</td>
<td>1</td>
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(Romeo et al., PloS ONE 2014)

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<tbody>
<tr>
<td><em>Ceratophyllus sciurorum</em></td>
<td>50%</td>
<td>1.0 ± 0.1</td>
</tr>
<tr>
<td><em>Ixodes ricinus</em></td>
<td>47%</td>
<td>3.0 ± 0.7</td>
</tr>
</tbody>
</table>

(Mazzamuto et al., Ann Zool Fenn 2016)
Ectoparasites

Both species harbour poor helminth communities → POTENTIAL FOR ENEMY-RELEASE

Neither grey nor Pallas’ squirrels introduced any alien parasites → NO SPILLOVER

Both squirrel species successfully acquired local parasites → SPILL-BACK TO NATIVE SPECIES?
Ectoparasites

Potential alteration of *C. sciurorum* seasonal distribution in areas co-inhabited by grey squirrels
Pallas’ squirrels are frequently infected by the hard tick *I. ricinus*

**ALTERATION OF TICK-BORNE PATHOGENS DISTRIBUTION?**

**OPEN ACCESS** Freely available online

**Introduced Siberian Chipmunks (Tamias sibiricus barberi) Contribute More to Lyme Borreliosis Risk than Native Reservoir Rodents**

Maud Marsot¹,², Jean-Louis Chapuis³, Patrick Gasqui⁴, Anne Dozières⁵, Sébastien Masséglia⁵, Benoît Pisanu², Elisabeth Ferquel³, Gwenaël Vourc’h¹

**POTENTIAL SANITARY THREAT**
Conclusions & future perspectives

1. No Squirrelpox virus in Italy

GOOD NEWS, BUT WE NEED TO REMAIN VIGILANT!

2. Parasite loss in both alien squirrel species

ENEMY-RELEASE?

3. Introduction of S. robustus by grey squirrels with spillover to red squirrels

WHAT IS THE IMPACT ON NATIVE SPECIES?

4. Acquisition of the flea C. sciurorum by both alien squirrel species

SPILL-BACK TO NATIVE SPECIES?

5. Acquisition of the tick I. ricinus by Pallas’ squirrels

SANITARY RISK?
Thank you for your attention!