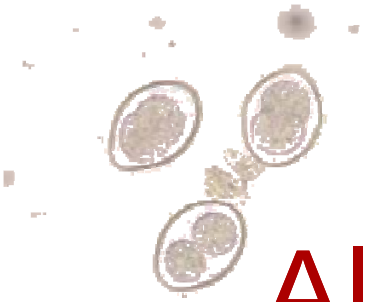

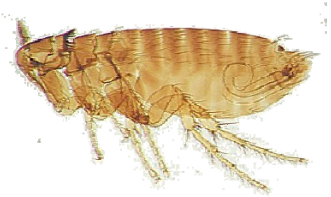

Alien squirrels & diseases: implications and threats

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Alien species & parasites

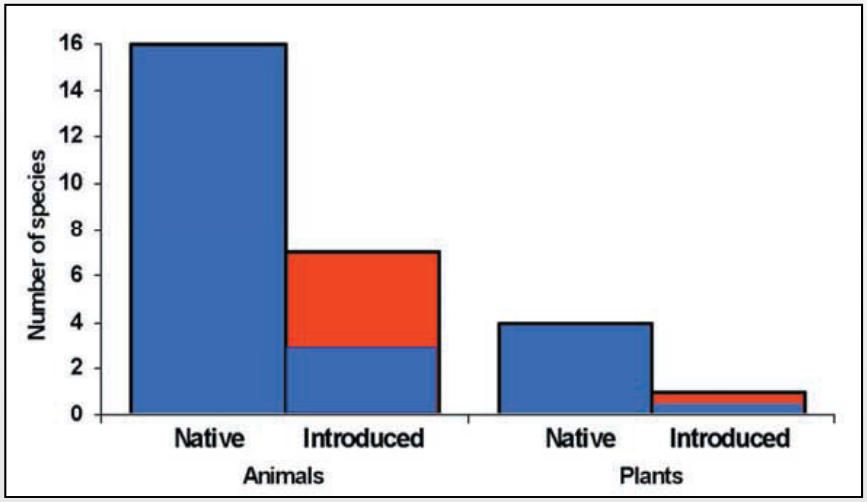
1. PARASITE LOSS

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



(Torchin & Mitchell, Front Ecol Environ, 2004)

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Alien species & parasites

2. ALIEN PARASITE INTRODUCTION

3. LOCAL PARASITE ACQUISITION

spillover to naive native species

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

competition mediated by shared natural enemies

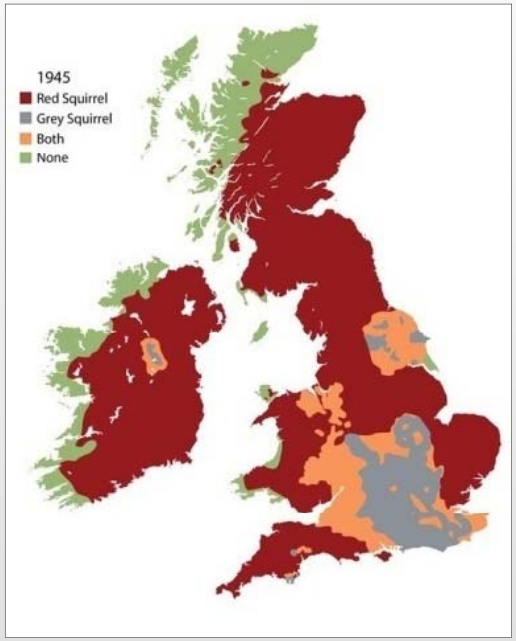
APPARENT COMPETITION

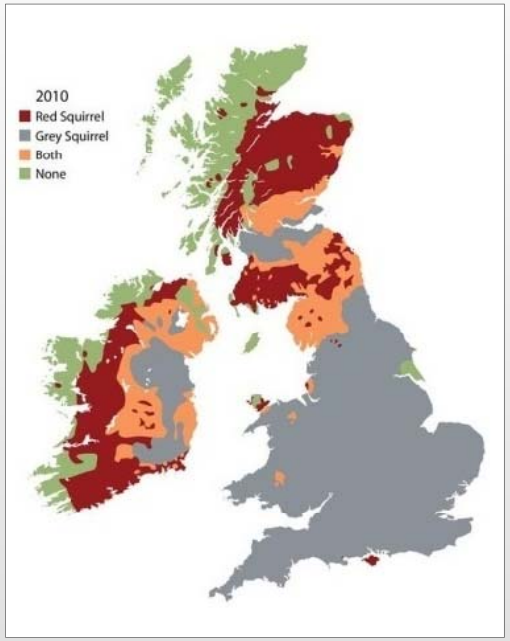
Alien squirrels & parasites

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





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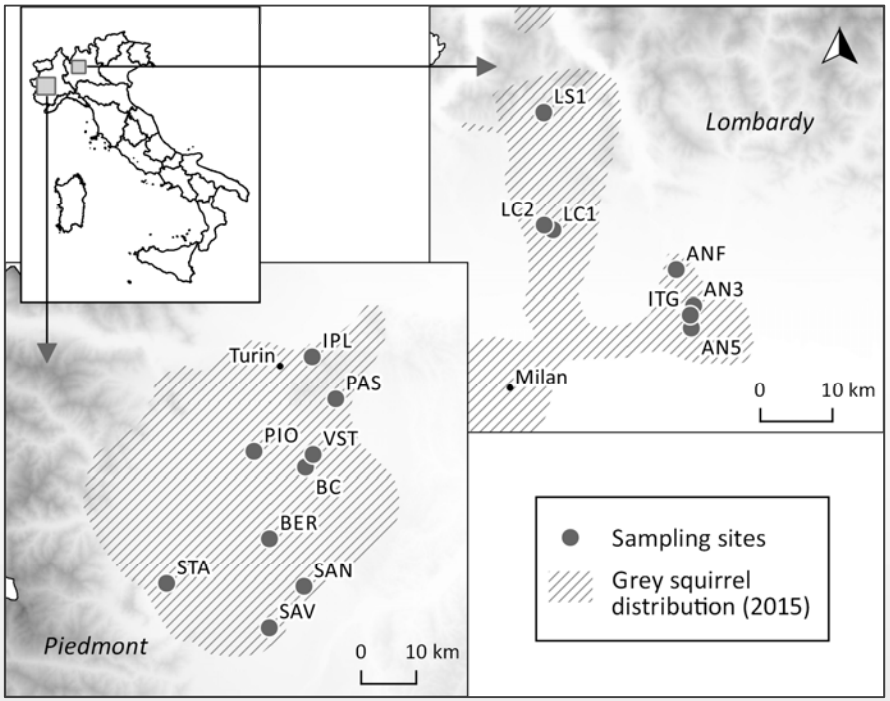
Squirrelpoxvirus in Italy?

- **Serology** (n=285) + **molecular** (n=66) (2011-2014)

- ELISA: 4 positive reactors (cross-reactions!)
- PCR: all negative



No evidence of SQPV in Italian grey squirrel populations

however, **passive surveillance** is recommended

(Romeo et al., An Cons, under review)

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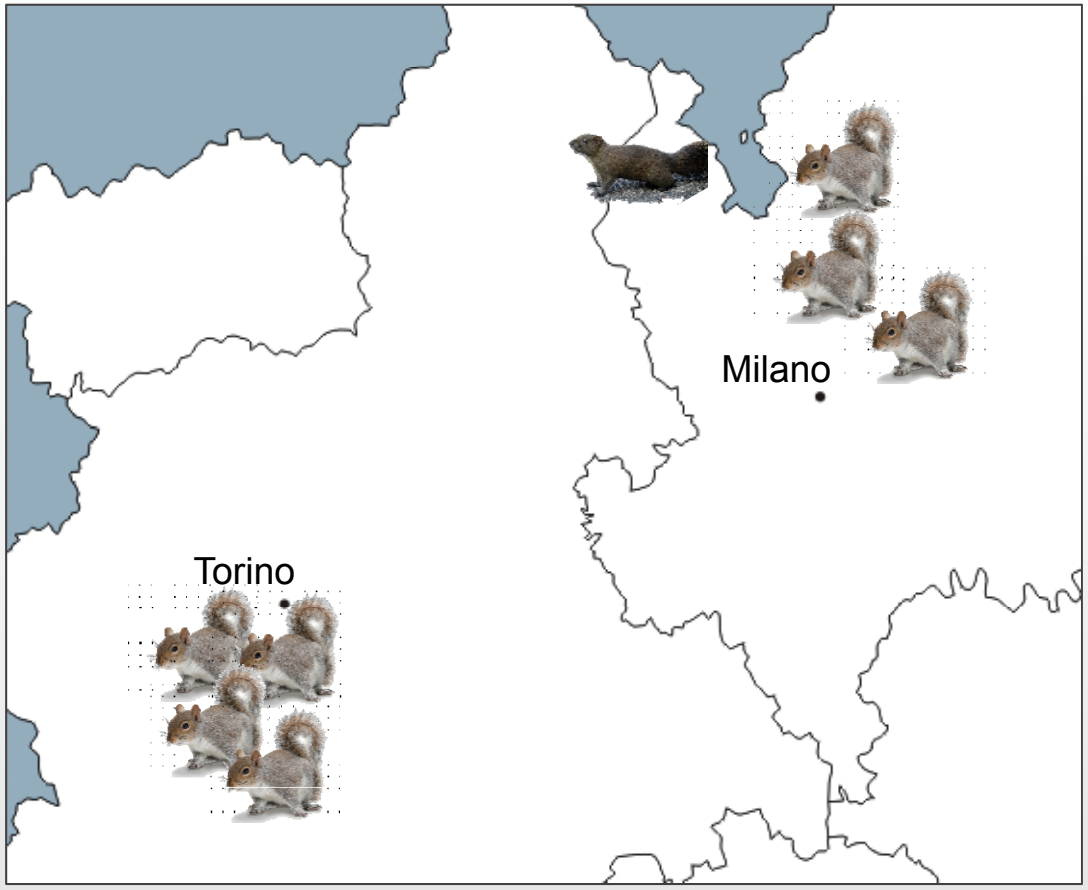
Alien squirrels & parasites

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

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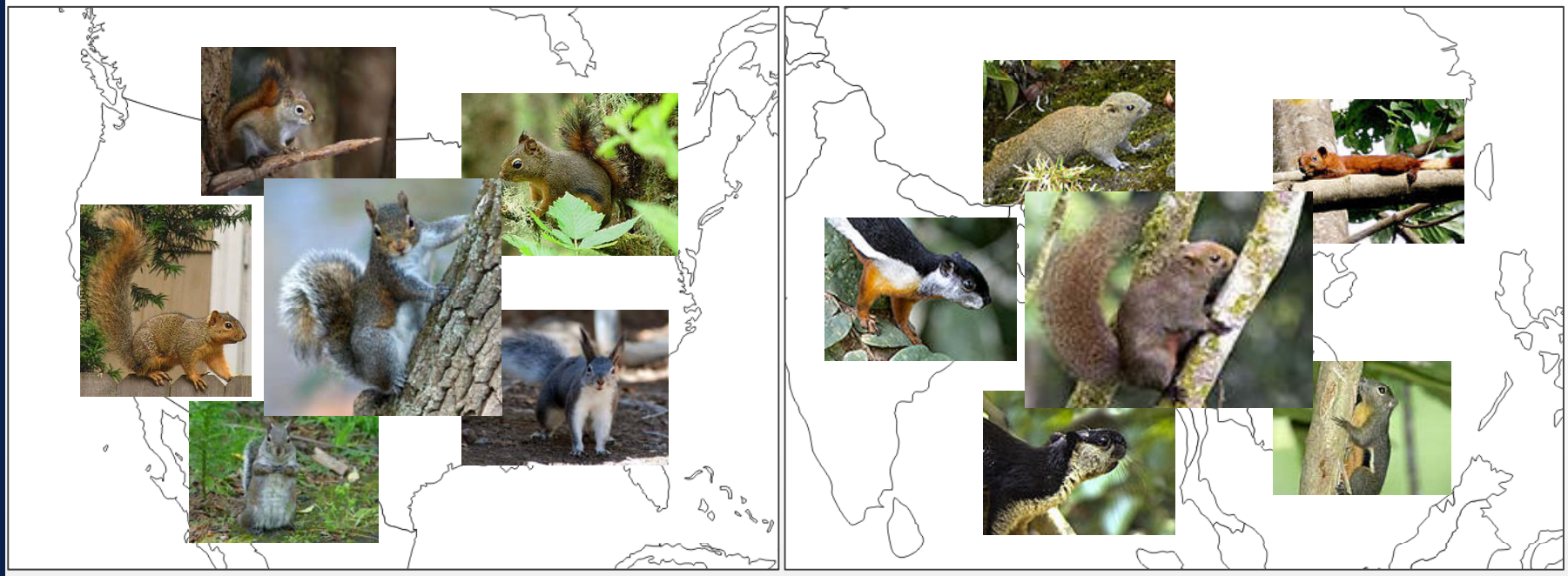
Alien squirrels & parasites



Rich Host Community = **Rich Parasite Community**

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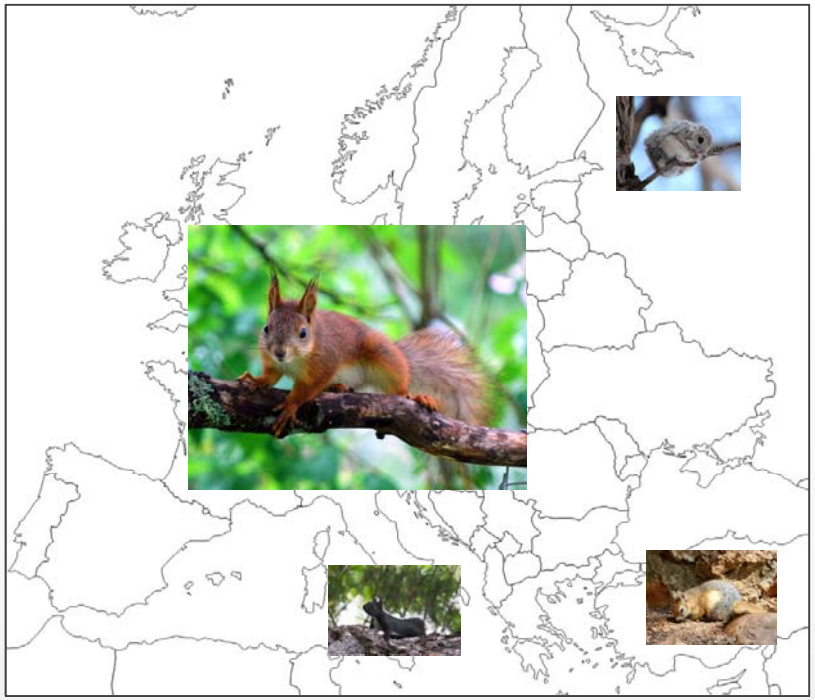
Alien squirrels & parasites



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*

n=262

Taxon	Prevalence	Mean Intensity
Strongyloides robustus	56.5%	16.9 ± 2.1
Trichostrongylus calcaratus	6.5%	1.9 ± 0.3
Trichuris muris	4.2%	1.3 ± 0.2
Trypanoxyuris sciuri	1.9%	80 ± 2.5
Aonchotheca annulosa	1.5%	2.2 ± 0.6

(Romeo et al., PloS ONE 2014)

n=73

Taxon	Prevalence	Mean Intensity
Trypanoxyuris sciuri	5.5%	2.3 ± 1.3
Trichuris muris	5.5%	1
Strongyloides callosciureus	2.7%	1

(Mazzamuto et al., Ann Zool Fenn 2016)

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Endoparasites – *Helminths*

Both species harbour **poor helminth communities**

→ POTENTIAL FOR ENEMY-RELEASE

Grey squirrels successfully **introduced** the nematode ***S. robustus***

→ **SPILLOVER TO NATIVE SPECIES?**

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

→ SPILL-BACK UNLIKELY

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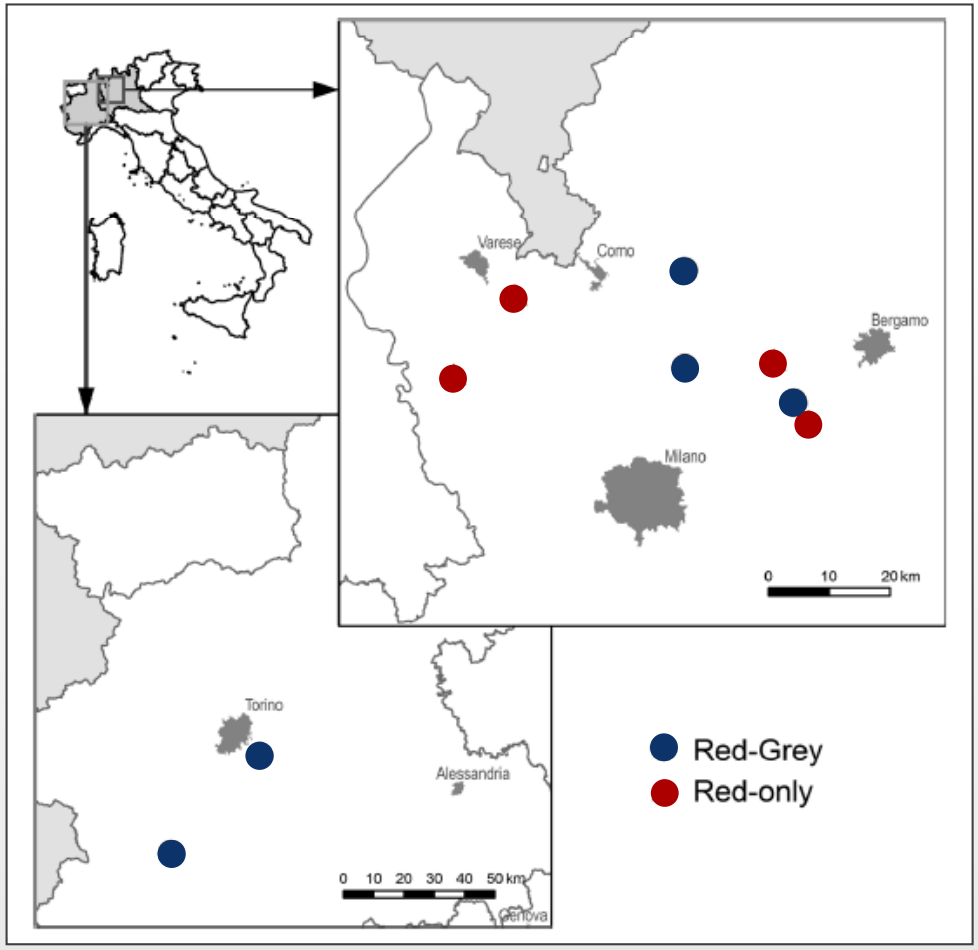
Endoparasites – *Helminths*



- 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)

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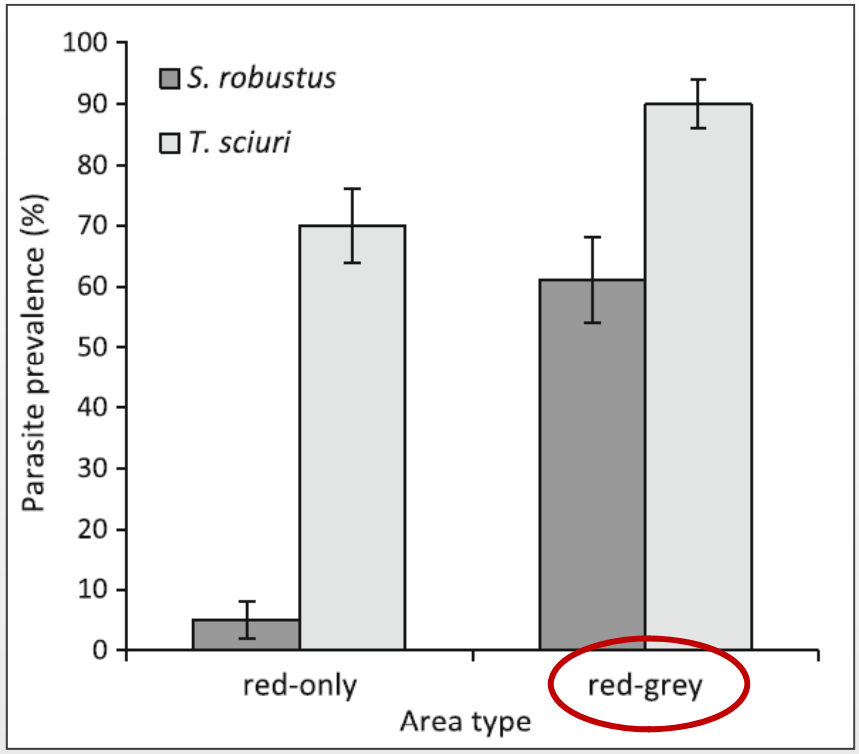
Endoparasites – *Helminths*

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



S. robustus egg

T. sciuri egg

(Romeo et al., Parasitol Res 2015)

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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?

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Endoparasites – *Coccidia*

Eimeria morphotypes	OPG	Prevalence (%)	
E1	102 - 79 394	7.8	SV
E2	116 - 66 550	95.6	SV
	112 - 115 833	95.7	SC
	$<10^2$ -1 068	4.1	CE
E3	$<10^2$	20.9	SV
	$<10^2$	34.8	SC

- 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)

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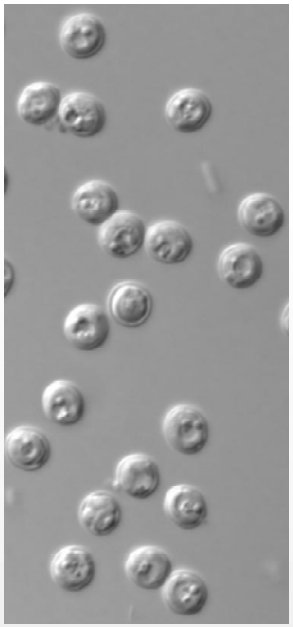
Endoparasites – *Cryptosporidium*

Squirrel species	Prevalence	*Taxa*
RED *(n=123)*	10.7%	Ferret genotype
GREY *(n=162)*	3.7%	Chipmunk genotype I Skunk genotype *C. ubiquitum*
PALLAS' *(n=72)*	2.8%	Chipmunk genotype I



DATA SUGGEST NO INTERSPECIFIC TRANSMISSION

(Prediger et al., Eu J Protistol, 2017)

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Ectoparasites

n=231

Taxon	Prevalence	Mean Intensity
Ceratophyllus sciurorum	26.5%	2.7 ± 0.3
Neaohaemathopinus sciuri	17.7%	3.6 ± 0.8
Ixodes acuminatus	1.7%	1
Ctenocephalides felis	0.4%	1

(Romeo et al., PloS ONE 2014)

n=135

Taxon	Prevalence	Mean Intensity
Ceratophyllus sciurorum	50%	1.0 ± 0.1
Ixodes ricinus	47%	3.0± 0.7

(Mazzamuto et al., Ann Zool Fenn 2016)

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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?**

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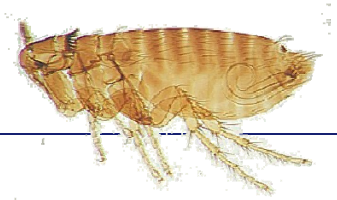
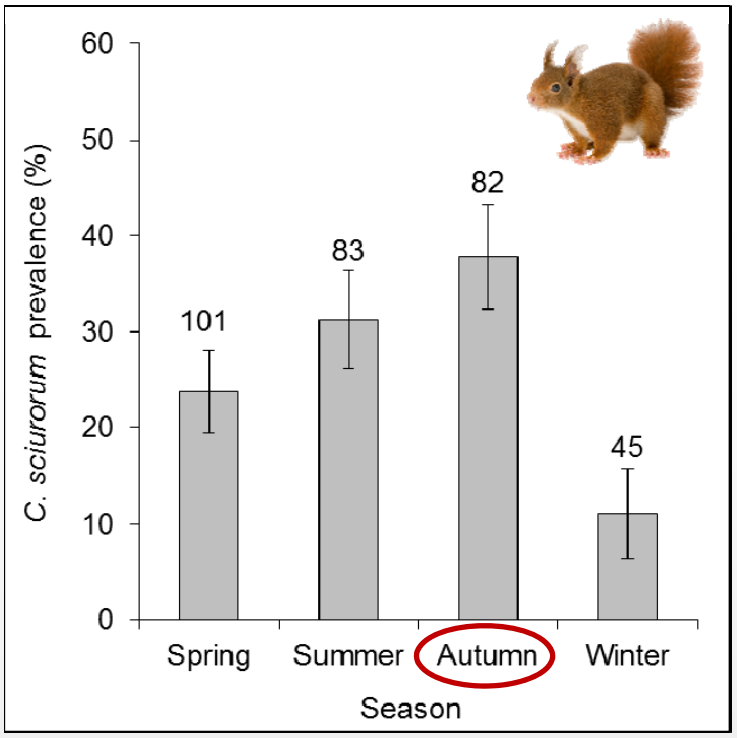
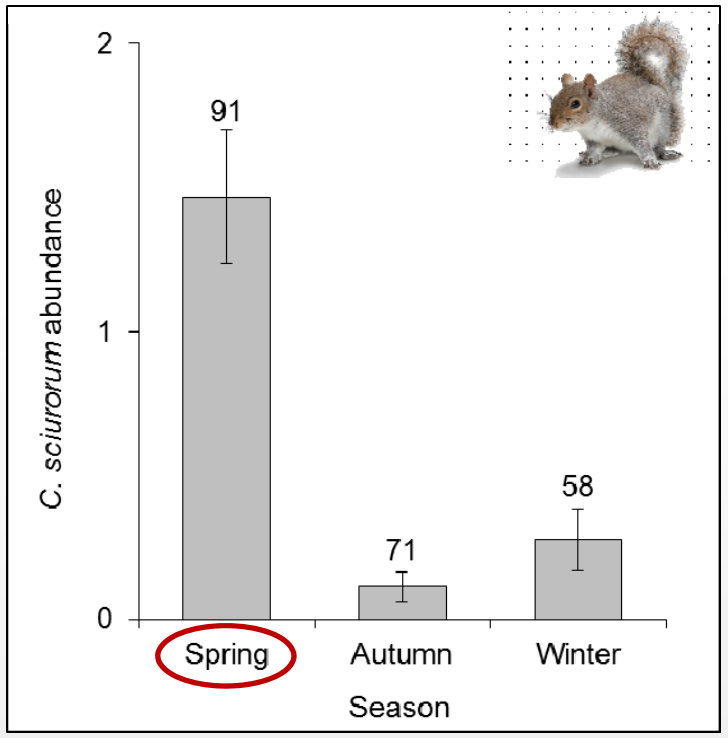
Ectoparasites







Potential alteration of
***C. sciurorum* seasonal distribution** in areas
co-inhabited by grey squirrels

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Ectoparasites

Pallas' squirrels are frequently infected by the hard tick ***I. ricinus***

→ ALTERATION OF TICK-BORNE PATHOGENS DISTRIBUTION?

OPEN ACCESS Freely available online

PLOS | ONE

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

Maud Marsot[1,2], Jean-Louis Chapuis[2], Patrick Gasqui[1], Anne Dozières[2], Sébastien Masséglia[1], Benoit Pisanu[2], Elisabeth Ferquel[3], Gwenaël Vourc'h[1]*

→ POTENTIAL SANITARY THREAT

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Conclusions & future perspectives

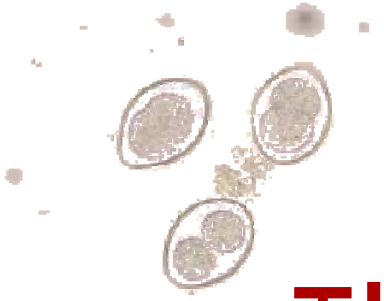
1. **No Squirrelpox virus** in Italy → GOOD NEWS, BUT WE NEED TO REMAIN VIGILANT!

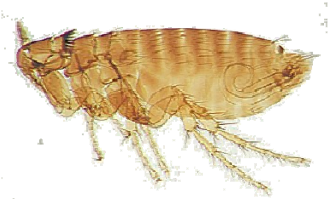
2. **Parasite loss** in both alien squirrel species → ENEMY-RELEASE?

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!