The *Myodes glareolus* invasion in Ireland as a model system to study parasite dynamics and immunogenetics of invaders and natives

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- Irish depauperate fauna
  (60 mammal species, 7 rodents)

- Red squirrel (*Sciurus vulgaris*)
- Grey squirrel (*Sciurus carolinensis*)
- Wood mouse (*Apodemus sylvaticus*)
- House mouse (*Mus musculus*)
- Black rat (*Rattus rattus*)
- Brown rat (*Rattus norvegicus*)
- Bank vole (*Myodes glareolus*)
- Hazel dormouse (*Muscardinus avellanarius*)

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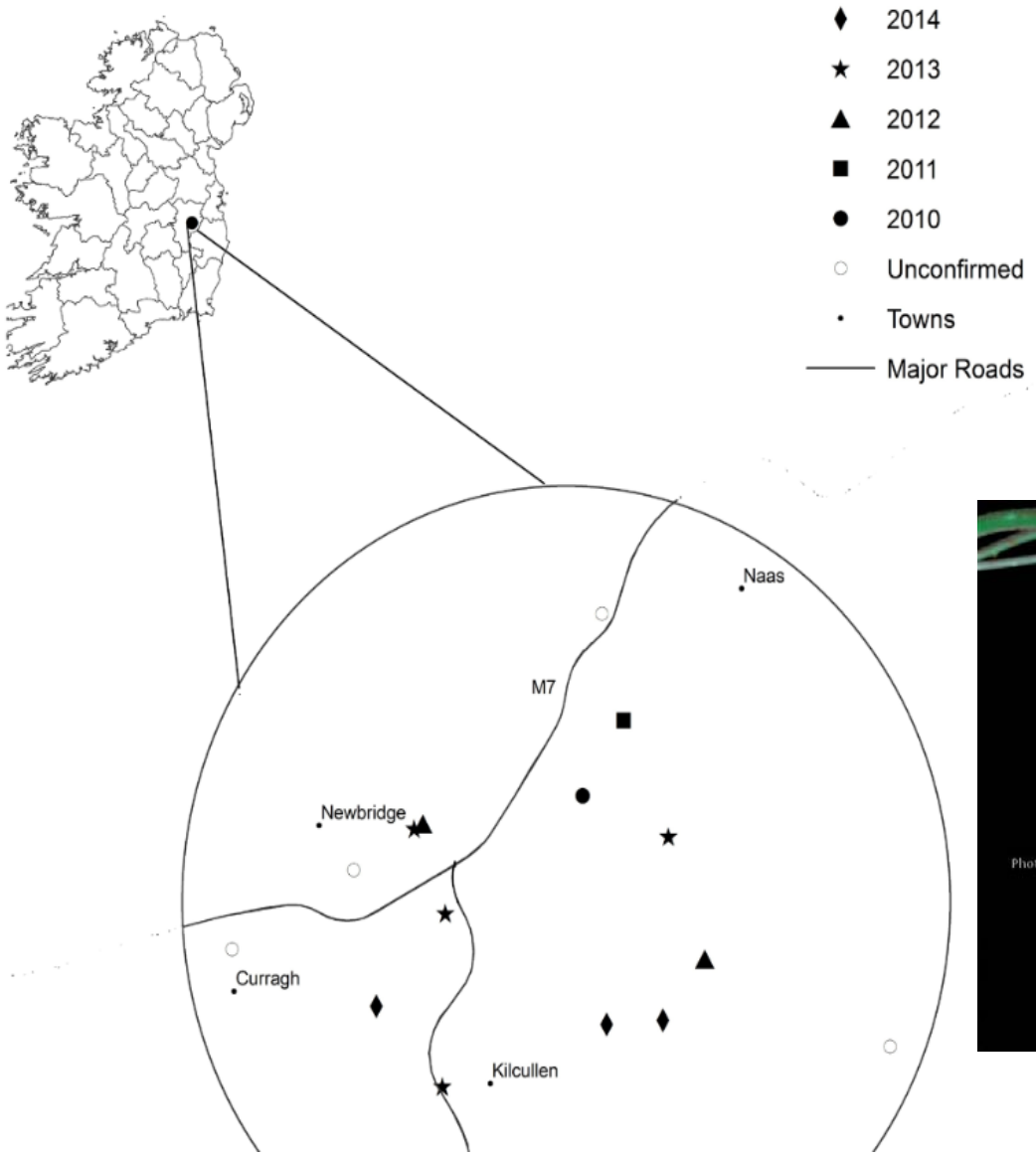

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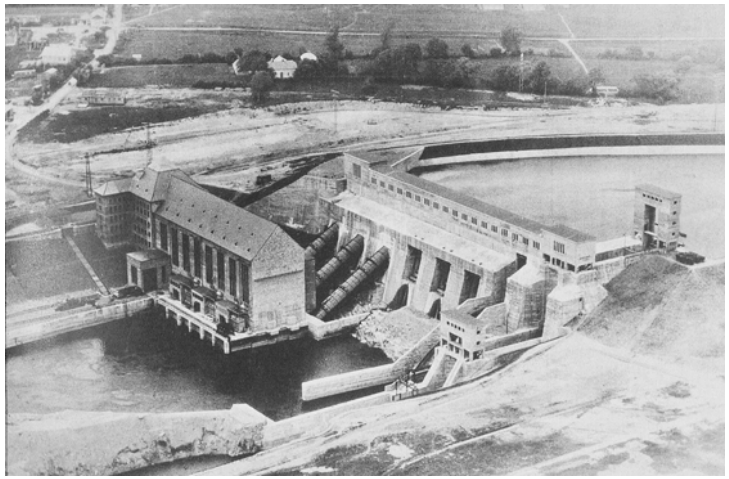
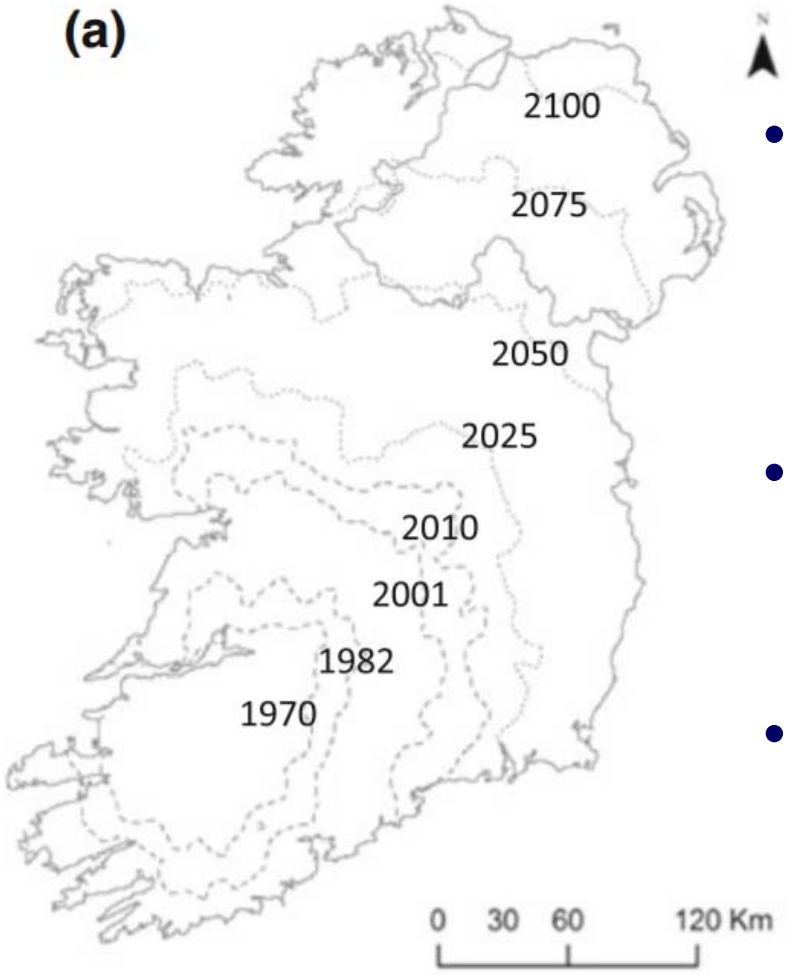
Origin



- Introduction of the bank vole (*Myodes glareolus*), via Germany in the 1920's (Stuart *et al*. 2007)
- Small founder population

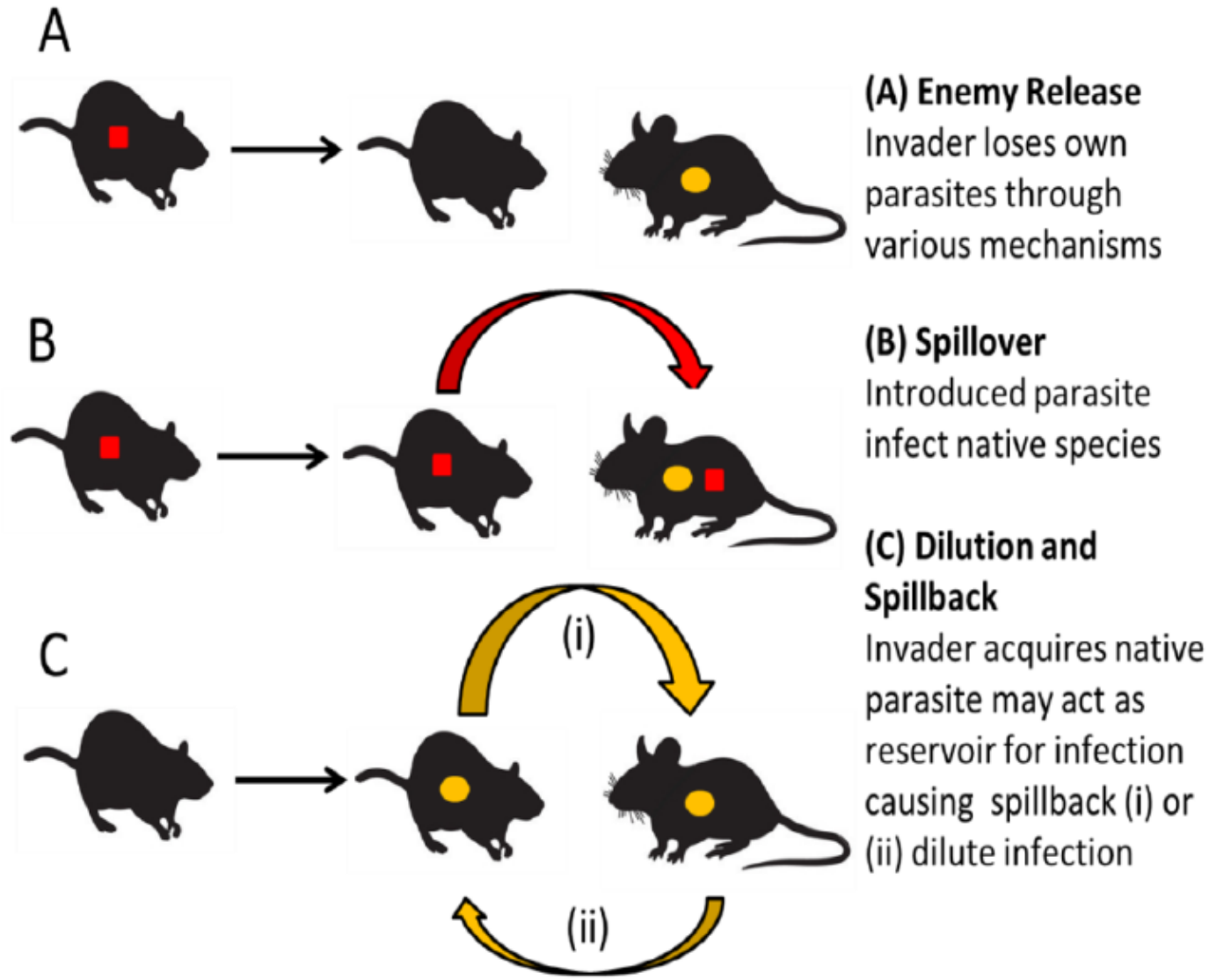
Study System



White *et al.* 2012

- No eradication programme in Ireland and several empirical studies
- Steady rate of expansion after an initial lag (White *et al.* 2012)
- Rate of expansion about 2.5km a year
- Ireland presents a large natural perturbation experiment

Hypotheses



(A) Enemy Release
Invader loses own parasites through various mechanisms

(B) Spillover
Introduced parasite infect native species

(C) Dilution and Spillback
Invader acquires native parasite may act as reservoir for infection causing spillback (i) or (ii) dilute infection

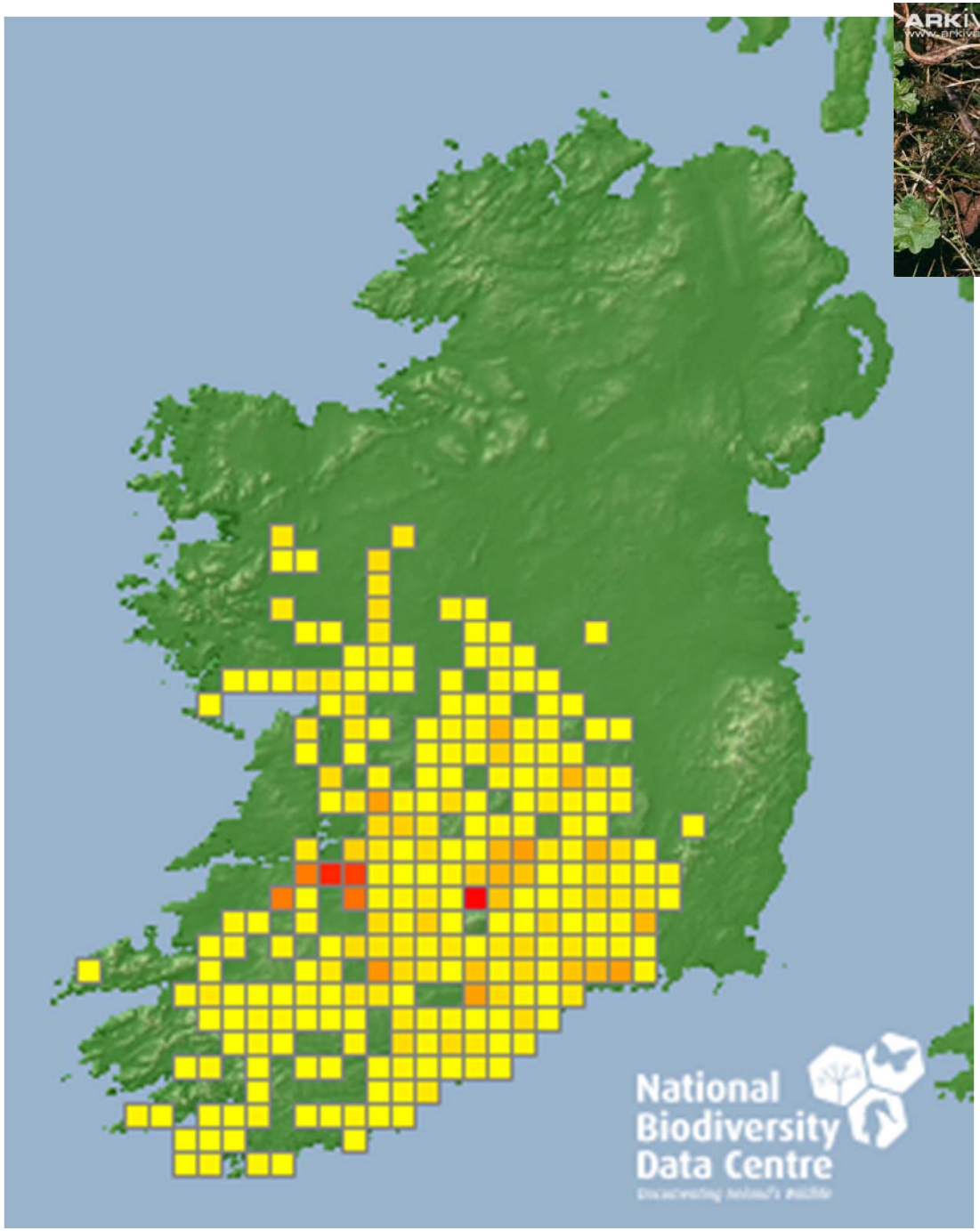
Myodes glareolus 12-35g

Apodemus sylvaticus 13-27g

Ground dwelling

Prefer heavy vegetation

M. glareolus has intermediate food preferences between insectivourous/granivorous murine and herbivourous arvicoline species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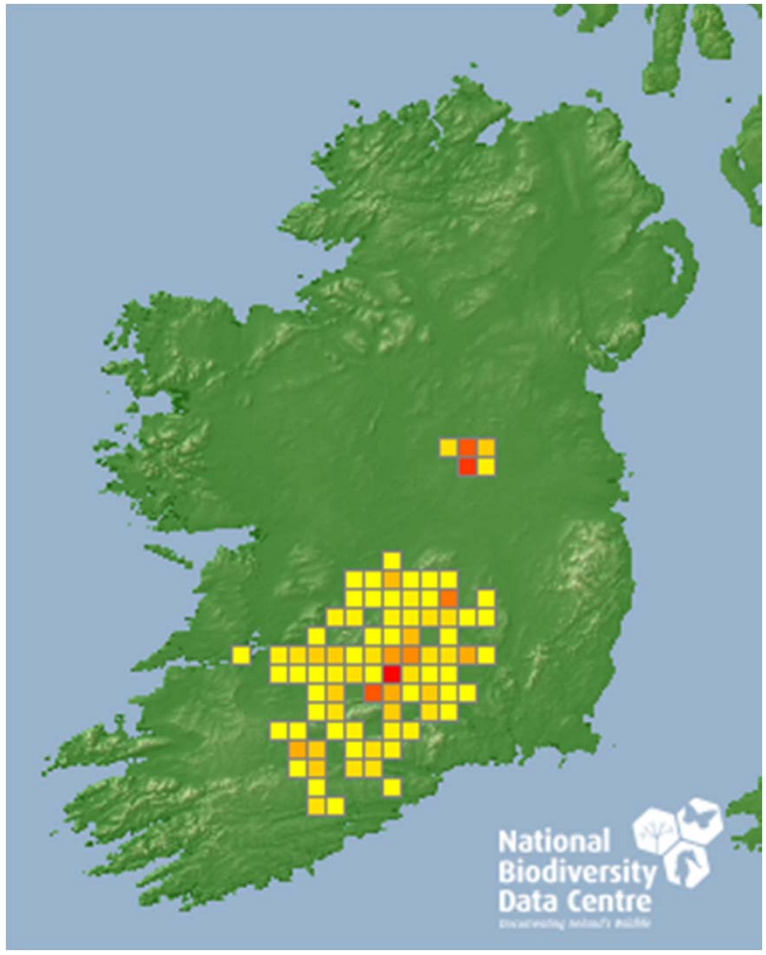
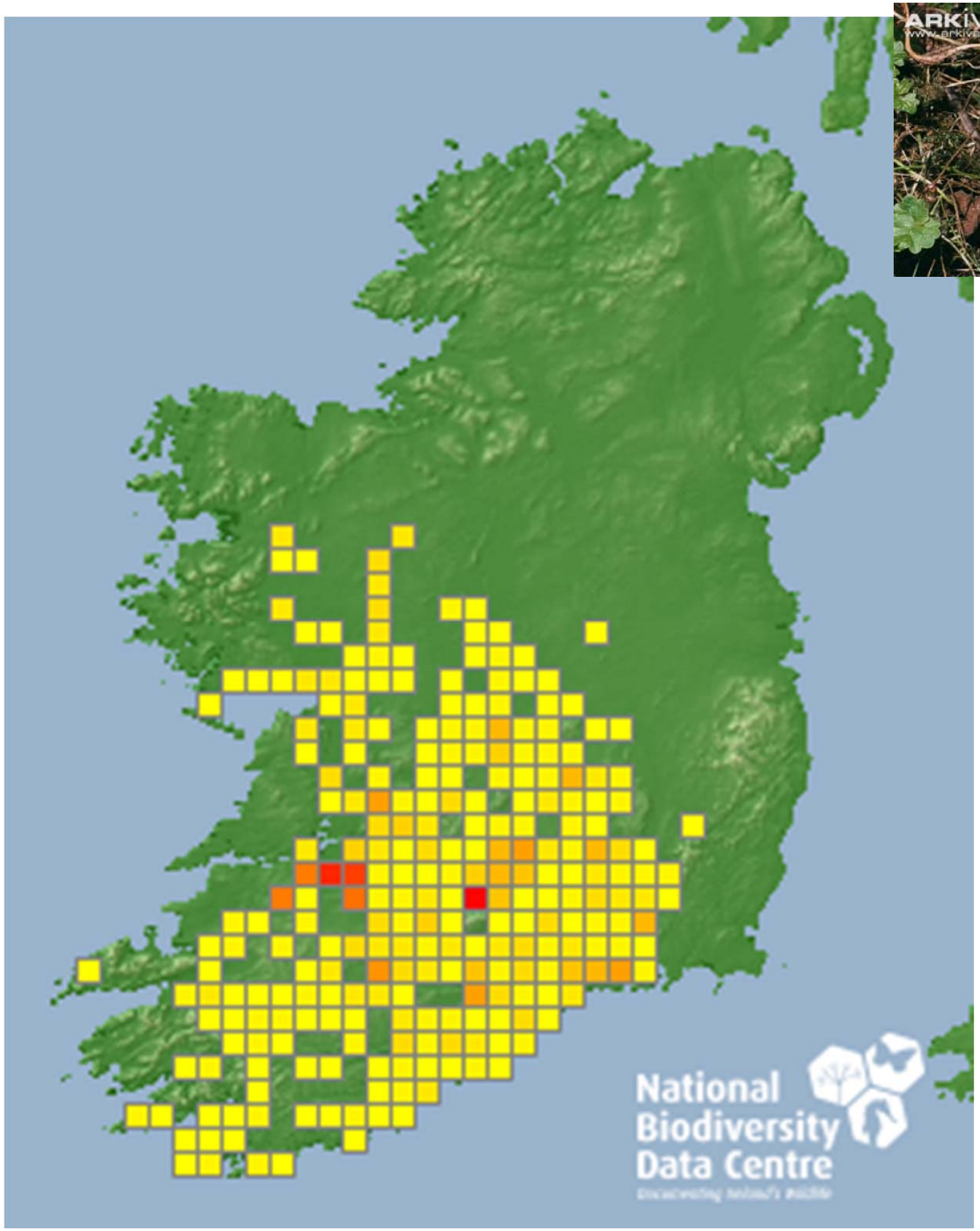
Greater White-toothed Shrew (*Crocidura russula*)



Sorex minutus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Hypotheses

- Hypothesis 1. Due to lower encounter rates with infected hosts, bank voles at the wave front of the expansion, will have lower levels of directly-transmitted parasites, than those from established populations.

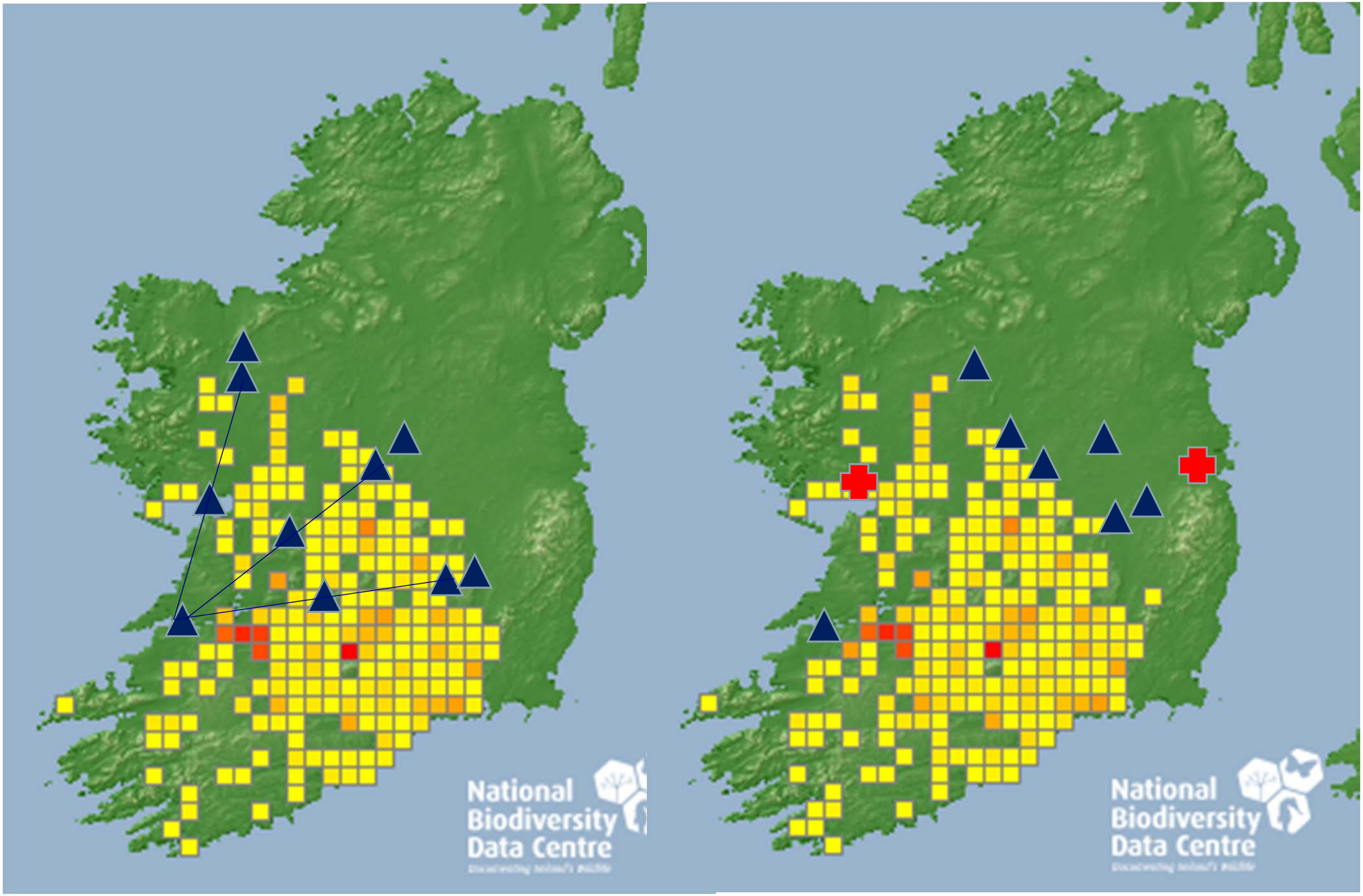
- Hypothesis 2. Due to their release from parasites, bank voles at the wave front of expansion invest less energy in immune function and more in dispersal, growth and reproduction. Therefore lower expression levels of costly immune genes will be observed and higher levels of fecundity.

Hypotheses

- Hypothesis 3. Greater variation in the (a) parasite dynamics and (b) immune gene expression between the established populations and the wave front will be observed during the breeding season of the bank voles.

- Hypothesis 4. Bank voles have a dilution effect on the parasites of the native woodmouse. Therefore, where bank voles have now become established, woodmice will have lower expression levels of immune genes.

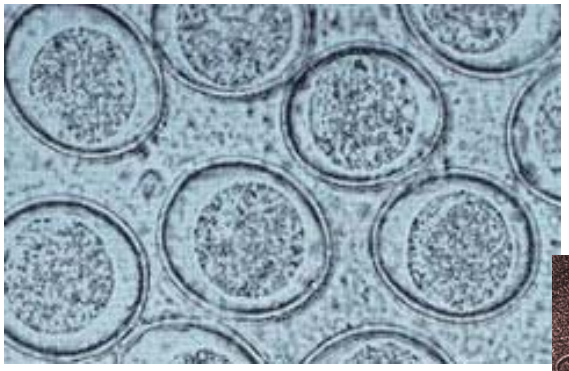
Methodology

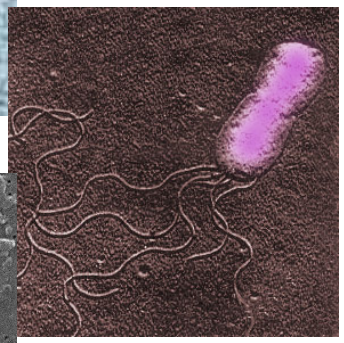


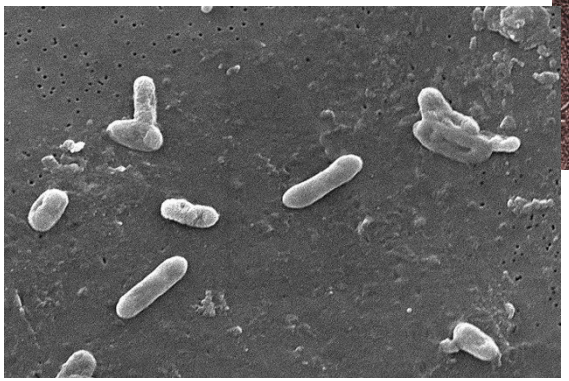
Methodology

- Host: Weight, length, sex, body condition, reproductive status and age
- Macroparasites
- Ecto-parasites: fleas, ticks and mites. Brushed out
- Helminths: Nematodes and Cestoda (tapeworms). Dissection

Methodology

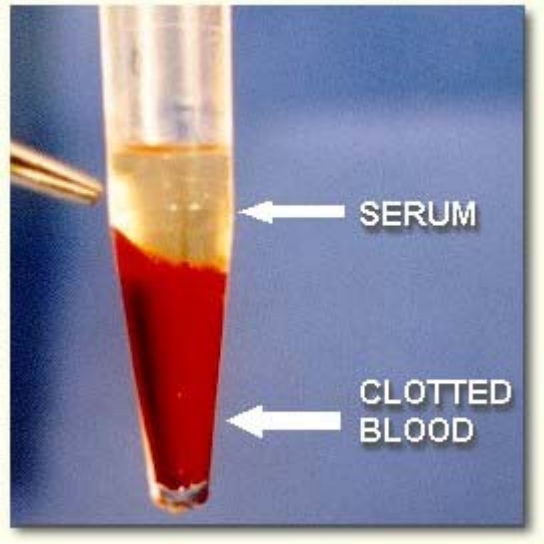






- Microparasites
- *Eimeria.* Floatations from faeces
- *Bartonella*: Culture then PCR
- *Bordetella:* Culture then PCR
- *Borrelia* : PCR
- 16s metagenomics

Sample bank



- Spleen in RNAlater
- Liver in RNAlater
- Lung samples frozen
- Faecal samples frozen
- Red blood cells and serum
- Ectoparasites
- Body

Enemy release

Parasite species	Origin	Edge
Nematoda	*Aspiculuris tianjinensis*	Direct
	Aonchotheca murrissylvatici	Direct
Cestoda	*Taenia martis*	Indirect
	Taenia polyachanta	Indirect

Enemy release

Table 5
Prevalence (%) and mean intensity/abundance (in brackets) of intestinal helminth parasites in bank voles throughout their native range in Europe.

Location	Sample size	All helminths	Total species[a]	Reference[b]
Ireland	177	77.4% (29.9[c]) (23.7[d])	3	Present study
Southern Norway	398	29.4% (3.2[c])	8	Tenora et al., 1979
Poland (3 sites)	40	95% (109.9[d])	9	Behnke et al., 2001
	41	68.3% (129.9[d])	6	
	58	91.4% (16.1[d])	9	
Germany	29	69.0% (26.2[d])	3	Klimpel et al., 2007a
Poland (3 sites)	112	89.3% (52.1[d])	13	Behnke et al., 2008
	114	73.8% (52.3[d])	10	
	132	81.1% (12.9[d])	10	
Spain (2 sites)	271	72.3%	14	Ribas et al., 2009
	105	51.42%	10	
Serbia	588	Nematodes	14	Bjelić-Čabrilo et al., 2011
		60.2% (20.8[c])		
		Cestodes		
		20.7% (3.67[c])		
Poland (3 sites)	304	85.% (23.8[d])	–	Grzybek et al., 2015
	209	77.9% (31.8[d])	–	
	328	75.0% (10.0[d])	–	

[a] Total species includes juvenile and adult cestodes.
[b] References are listed according to the date the study was under taken.
[c] Intensity.
[d] Abundance.

(Loxton *et al.* 2016)

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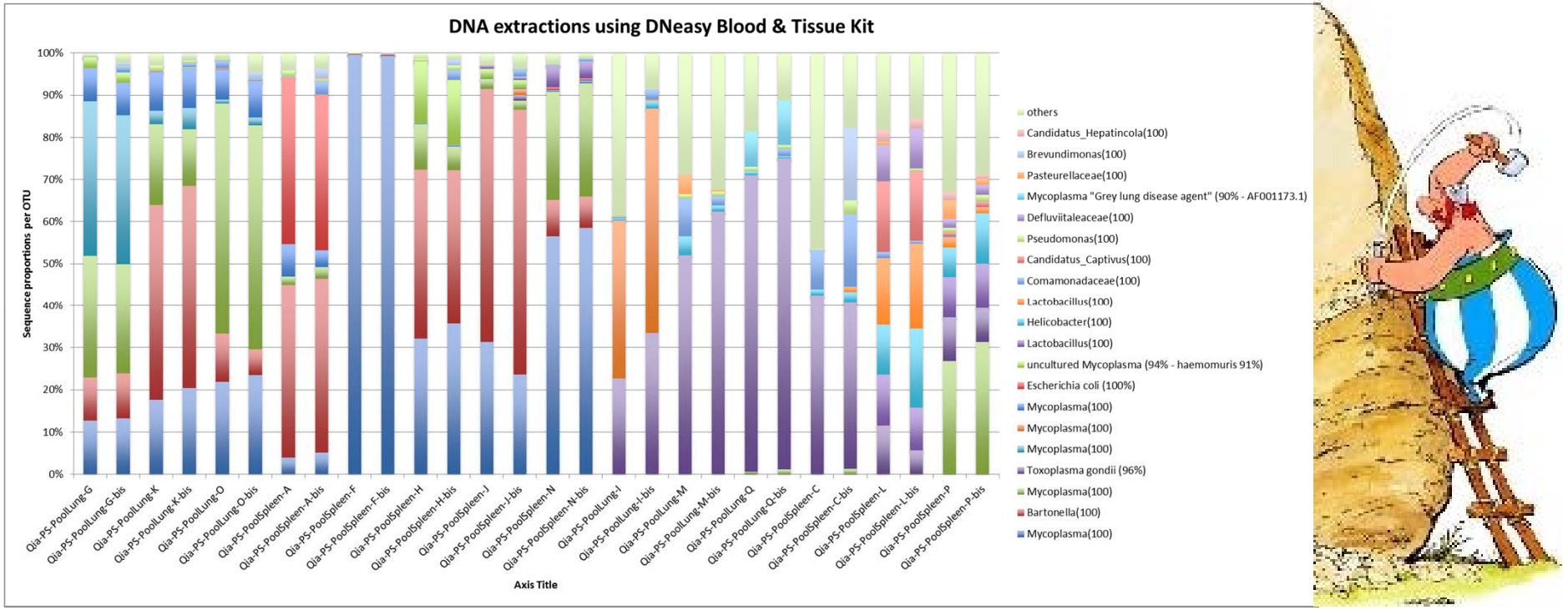
Enemy release

Taxon	Species	Life-cycle
Nematoda	*Syphacia stroma*	Direct
	Aonchotheca murissylvatici	Direct
	Trichuris muris	Direct
	Heligosomoides polygyrus	Direct
Cestoda	*Hymenolepis hibernia*	Indirect
	Rodentolepis sp.	Indirect
	Catenotaenia lobata	Indirect
	Taenia martis	Indirect
	Taenia taeniaeformis	Indirect
	Taenia polyachanta	
Trematoda	*Brachylaemus recurvum*	Indirect
	Corrigia vitta	Indirect

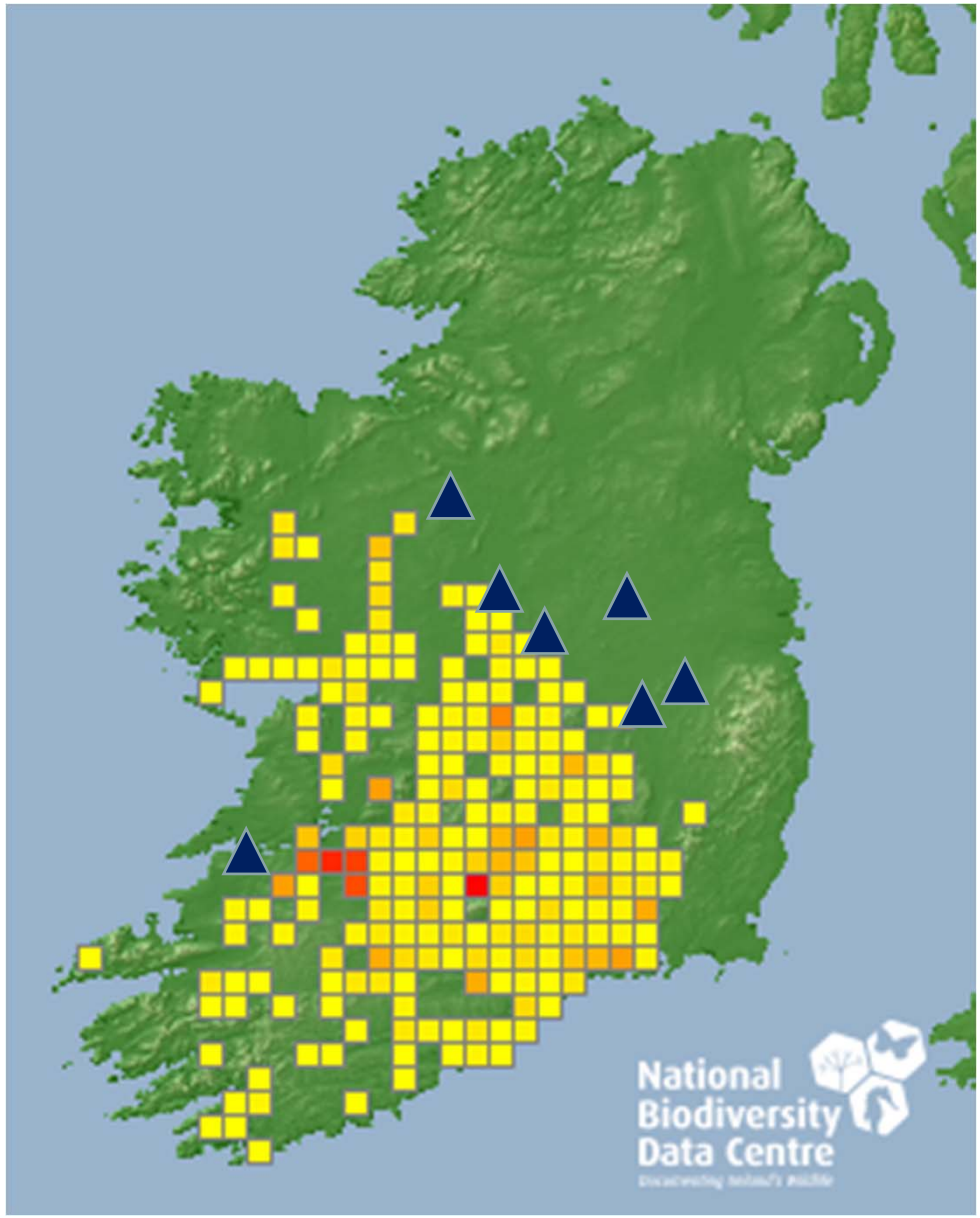
Enemy release



Spillover

- Probable that *Myodes* brought *Aspiculuris tianjinensis* as not present in *Apodemus*
- Appears *Myodes* also brought fleas
- Microparasites?

Future work

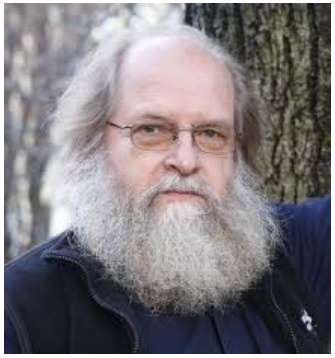


White *et al.* Mol Ecol. (2013) **22**, 2971–2985

Conclusions

- The continuing range expansion of the bank vole within Ireland presents a unique natural large-scale perturbation experiment.
- Enemy release, spillback and dilution of pathogens is occurring.
- Variations in the intensity of these processes can be expected to be observed across the range of *Myodes* expansion

Acknowledgements



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