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Ecology of ticks & *B. burgdorferi*

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The British tick fauna

Ixodes ricinus

Dermacentor reticulatus

22 species recorded

19 Hard ticks (Ixodid)

- 15 *Ixodes* species
- *Dermacentor reticulatus*
- *Haemaphysalis punctata*
- *Hyalomma marginatum* – (imported by migrant birds)
- *Rhipicephalus sanguineus* (imported by pets, not native)

3 Soft ticks (Argasid)

- 2 *Argas/Carios*
- 1 *Ornithodoros* – rarely imported on seabirds

Carios vespertilionis

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Hard ticks (Ixodid ticks)

- Live outdoors, some are nidiculous (i.e. nest-dwelling); arduous lifestyle, require a chance meeting with animals.
- Once attached, they engorge slowly, dispersed by their hosts - long distances on migratory birds
- Spend most of their time ‘questing’ for blood hosts and attached to their hosts - high mortality rates due to host grooming, predation and environmental factors
- Hard sclerotised plate (scutum), forward-projecting capitulum.
- Except in male, all stages have a small scutum to allow them to engorge
- In the male the scutum completely covers its body. It does not engorge. It has armoured plates, to retain moisture levels.

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Ixodes – specialist parasites of wildlife

7 species are principally bird ticks:

Ixodes arboricola
Tree-hole nesting birds

Ixodes caledonicus
Cliff nesting birds

Ixodes frontalis
Passerine birds

Ixodes lividus
Sand martins

Ixodes rothschildi
Burrow nesting birds

Ixodes unicavatus
Coastal birds

Ixodes uriae
Cliff colony birds

Humans are rarely bitten, only as accidental hosts

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Ixodes – specialist parasites of wildlife

6 species are principally mammal ticks:

Ixodes acuminatus
Small mammals

Ixodes apronophorus
Wetland mammals

Ixodes canisuga
Fox tick

Ixodes ventalloi
Rabbit tick

Ixodes trianguliceps
Burrowing small mammals

Ixodes vespertilionis
Horseshoe bats

Humans are rarely bitten, only as accidental hosts

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Ixodes – parasites of humans

2 species are mammal ticks but do bite humans:

Ixodes hexagonus
Hedgehog tick

Humans are occasional hosts

Ixodes ricinus
Deer/Sheep/Pasture/Caster bean tick

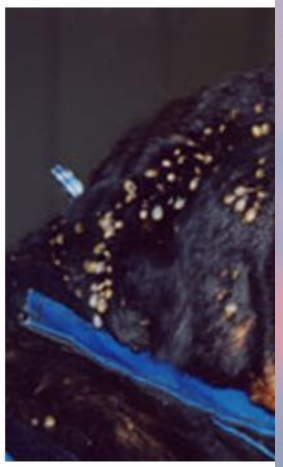
Humans are frequent hosts

Hedgehog tick, *Ixodes hexagonus*

Unusual & Imported ticks

Importation of non-native ticks & EU policy

Rhipic
sangu



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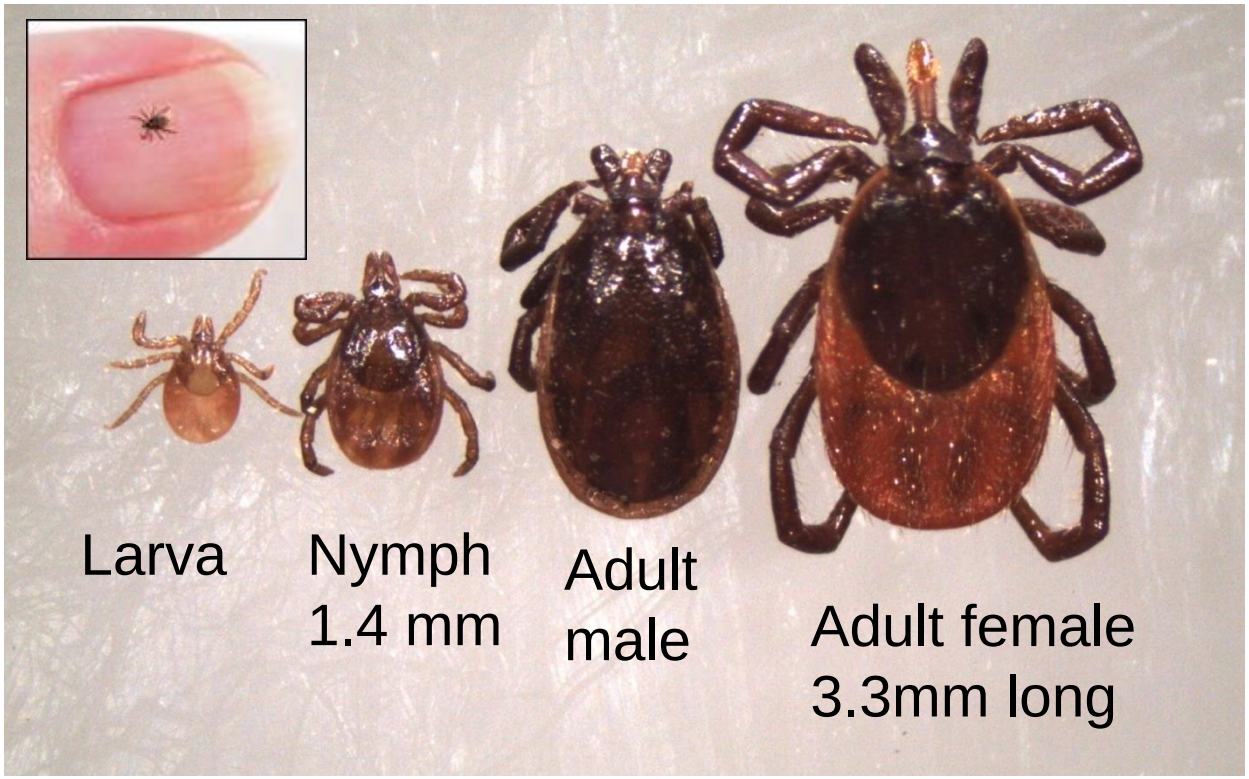
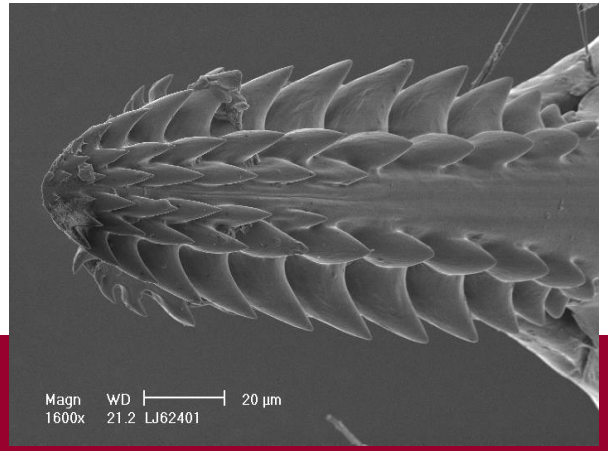
Ixodes ricinus (Deer/sheep tick)



Larva – 3 pairs of legs

Male – scutum covers entire body

Nymph and Female are similar – female much larger with genital aperture and porose area



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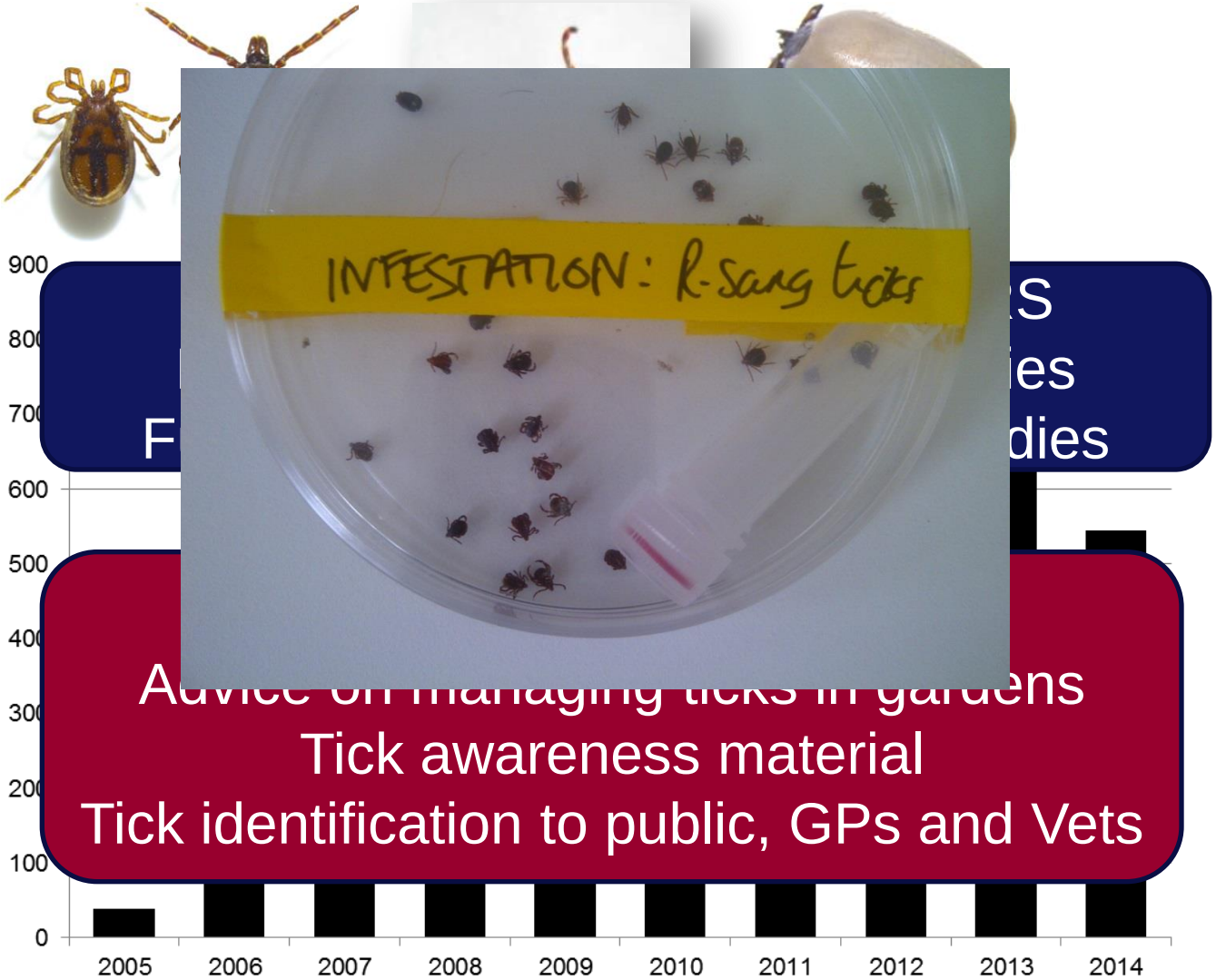
Nationwide tick surveillance



Tick awareness material

Tick identification to public, GPs and Vets

tick@phe.gov.uk

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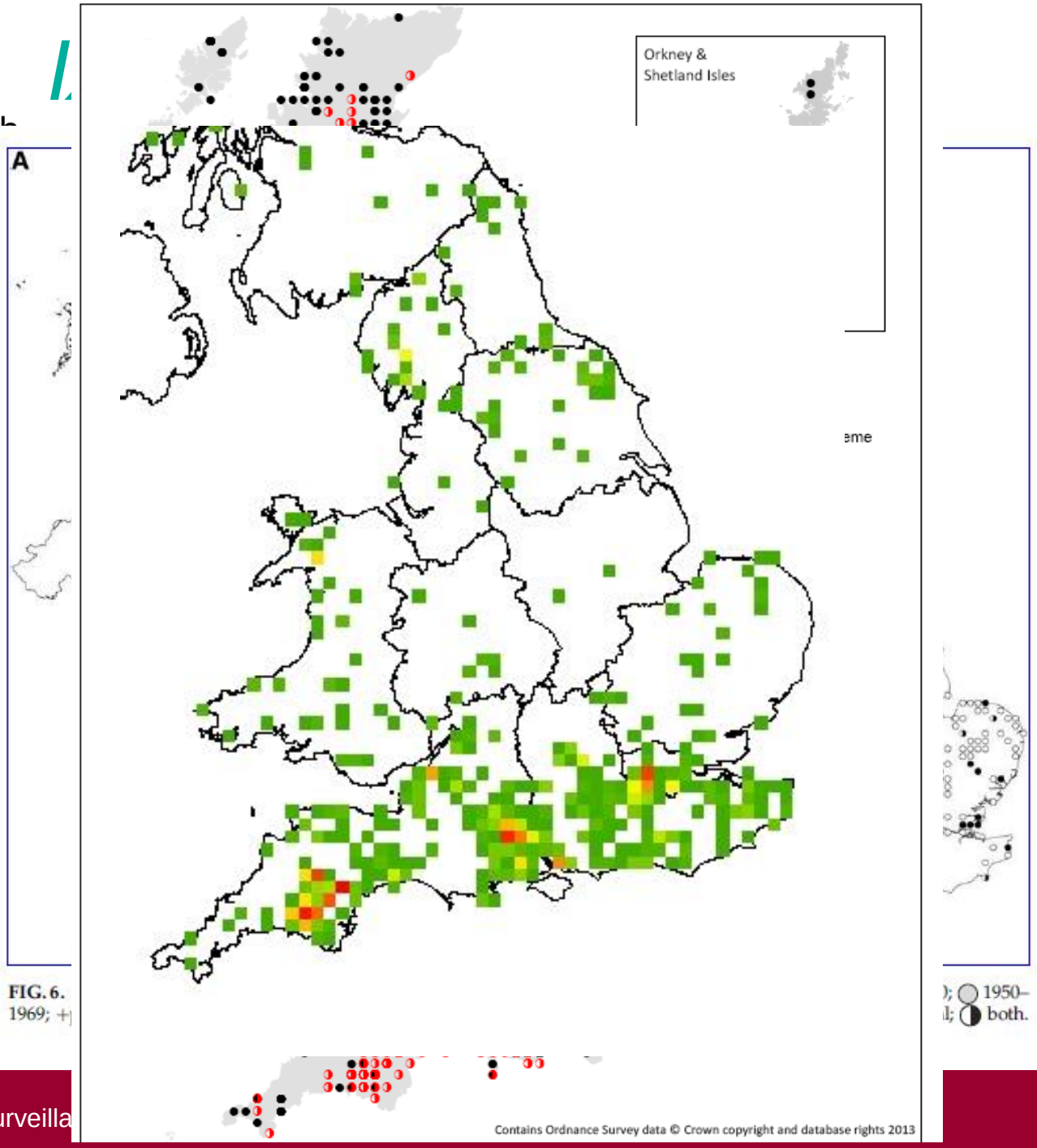

FIG. 6.

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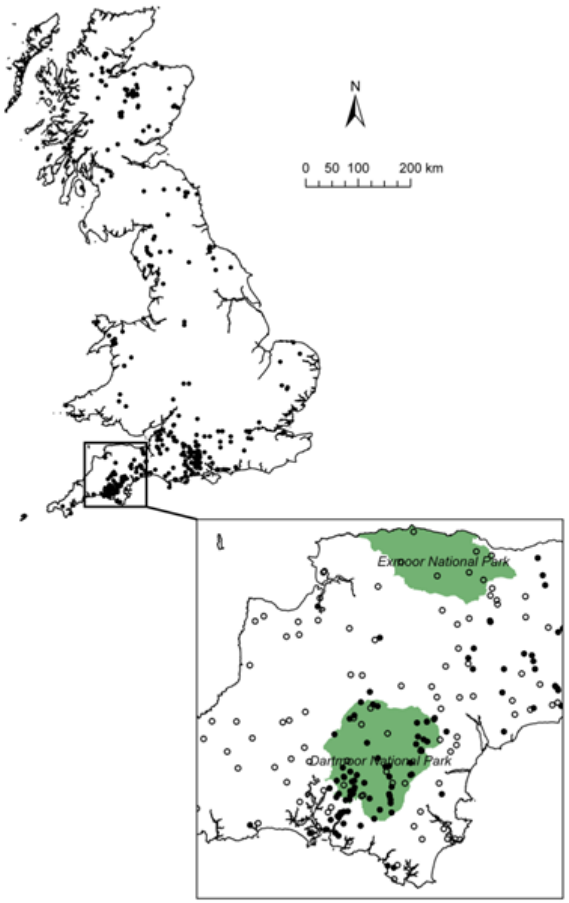
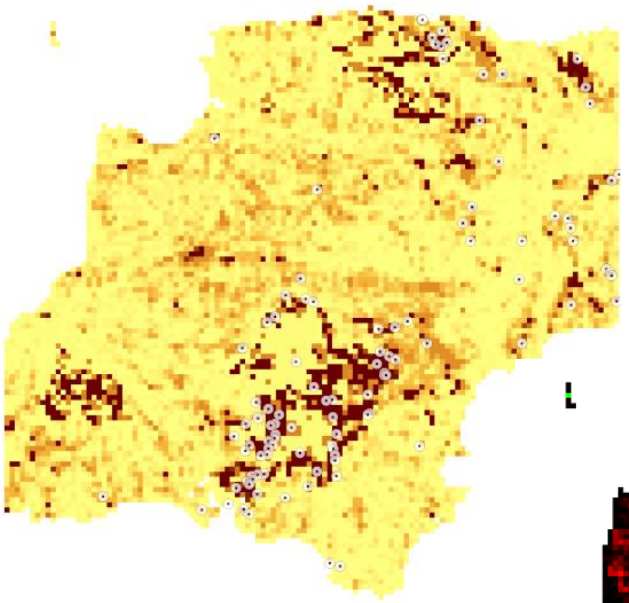
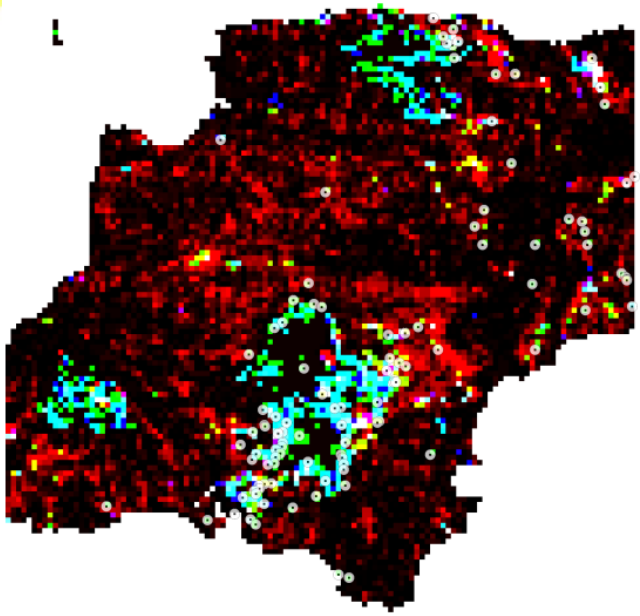
Using surveillance data for predictive mapping







Mapping *Ixodes ricinus* at a landscape scale, e.g. national park / AONB

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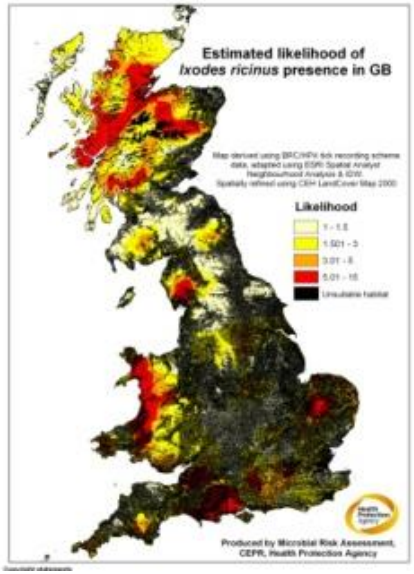
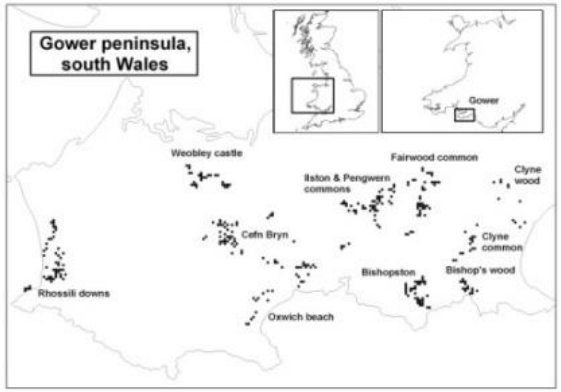


Mapping ticks in an AONB/National Park

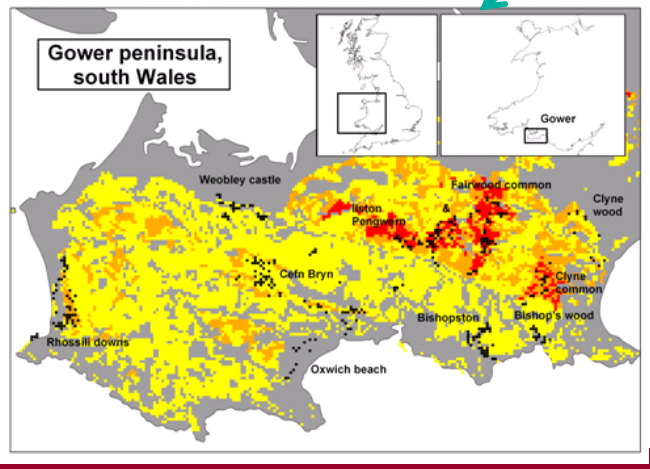


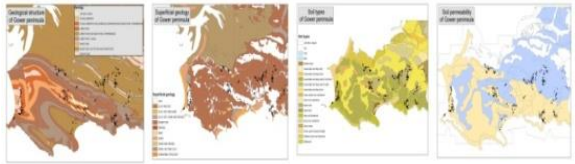
Surveying publicly accessible sites

Eco/environ variables

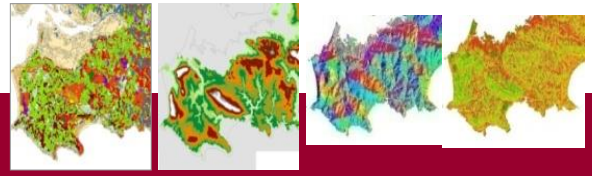
Predictor variables (landscape)
- **W, SW, SE and E aspects**
- **Calcareous & neutral grassland; heathland**
- **Impermeable soils**
- **Impermeable bedrock & superficial geologies**
- **Presence of cattle & sheep grazing**
- **Reduced slope**
- **High soil moisture**
- **Lower midday temperatures**

Refining risk





Identifying risk factors



Medlock *et al.* 2008

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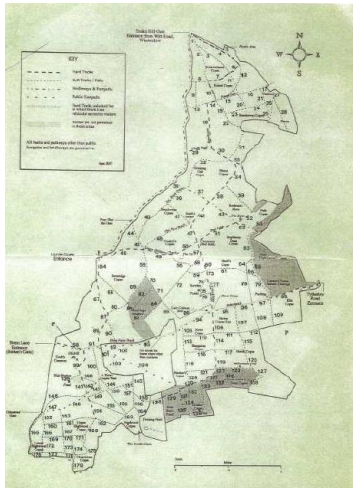
Mapping *Ixodes ricinus* at a habitat scale - implications for woodland management



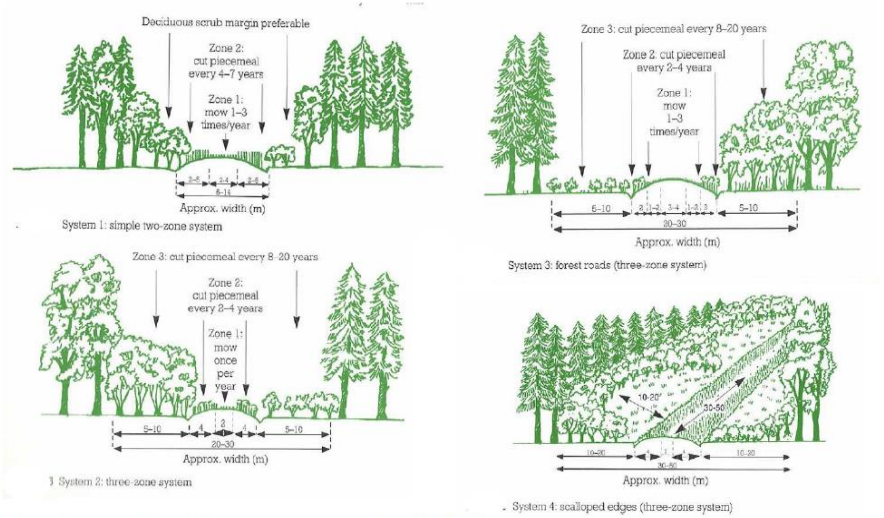
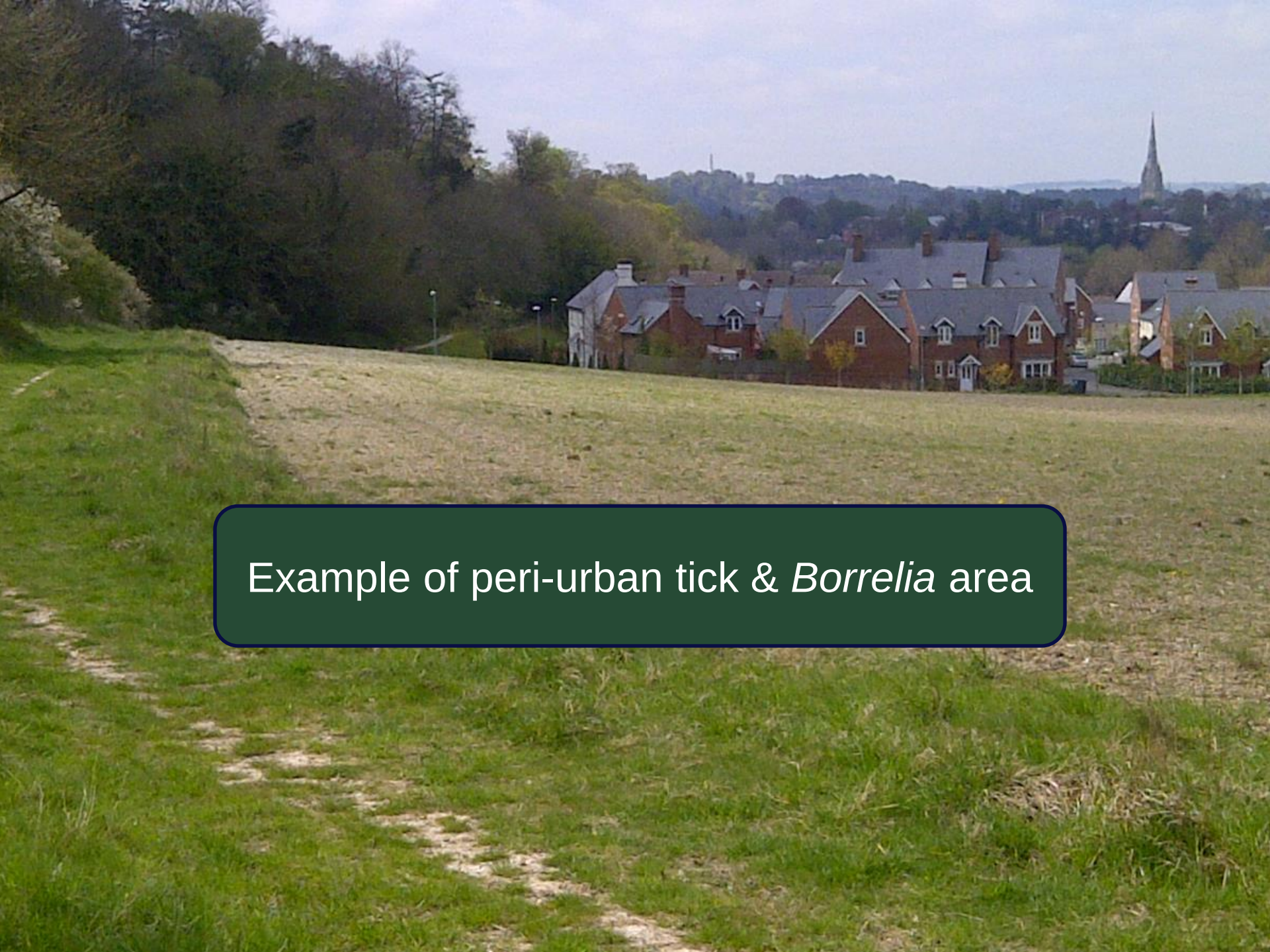


Figure 2: Schematic depiction of ride management strategies (after Warren & Fuller, 1993)

1. Management that promotes sunny south-facing rides promote nymph activity
2. Additional ride management is recommended in these locations
3. Regular mowing (and raking) of 1m path-side strip in spring should:
   a. Keep nymph activity down
   b. Reduce public exposure
   c. Benefit rare herb growth and bare-soil invertebrates
4. Mat/mulch management – raking/stacking of leaf litter
   a. Limits survival of ticks
   b. Promotes biodiversity – reptiles, herbs, invertebrates
5. Scalloped edges in bramble areas
6. Spot treatment with bracken herbicide in hot-spots

University of BRISTOL

Medlock *et al.* 2012

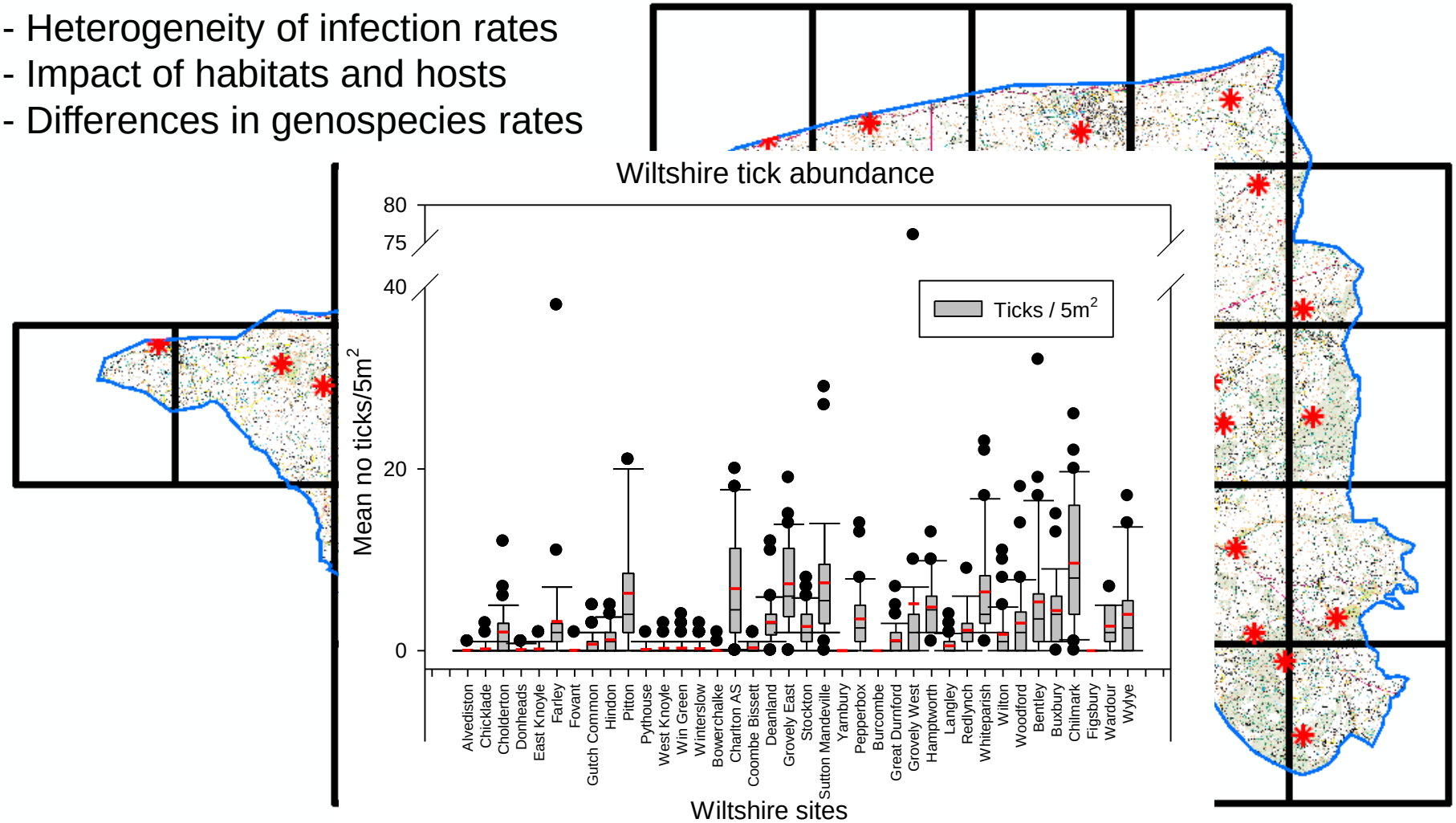


Example of peri-urban tick & *Borrelia* area

Linked [illegible] ffice data

Mapping *Borrelia* infection rates in ticks across a landscape – South Wiltshire

- Heterogeneity of infection rates
- Impact of habitats and hosts
- Differences in genospecies rates



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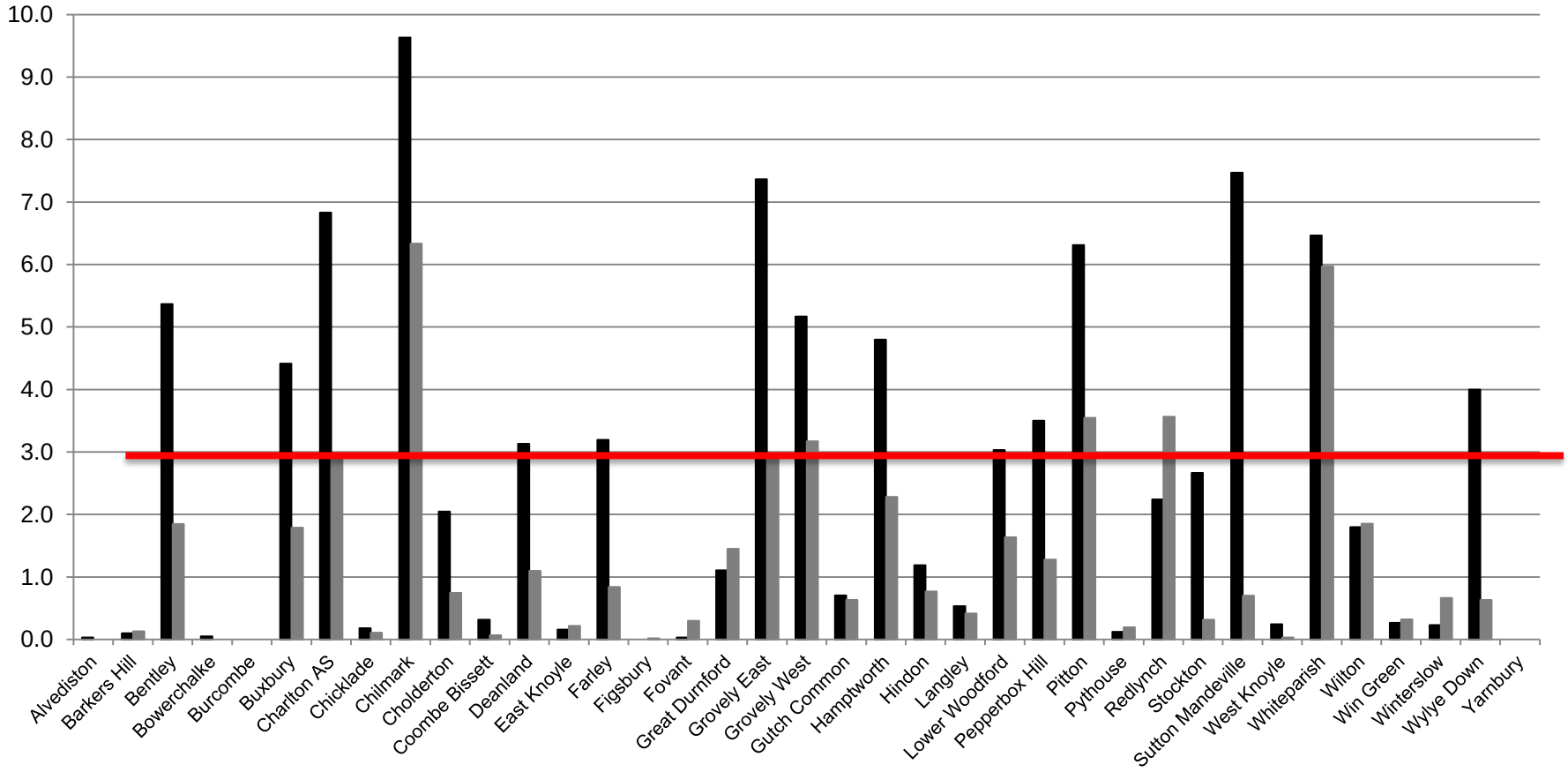
Ticks abundance (per sq metre) by location across a landscape

(black spring 2013, grey spring 2014)



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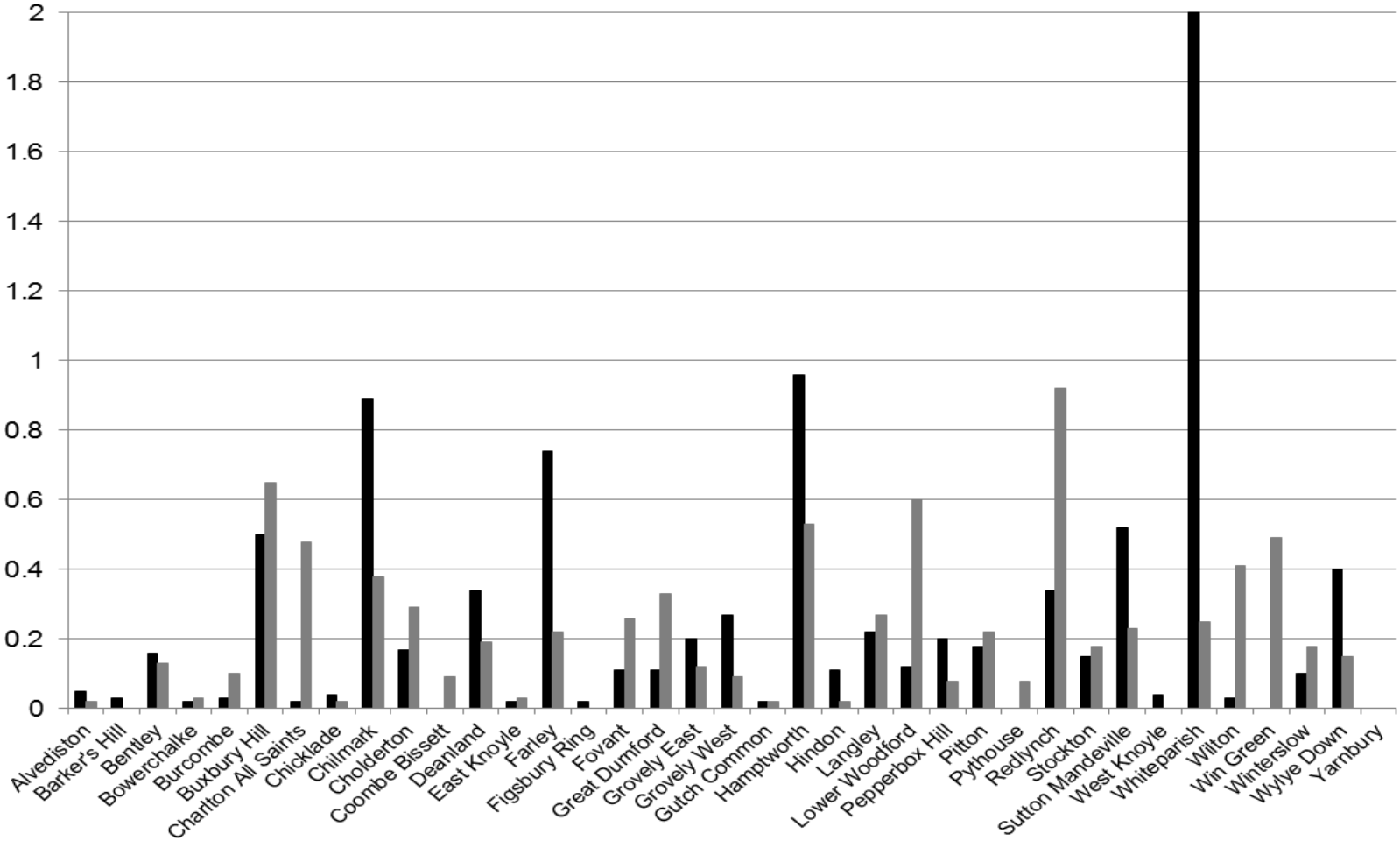
Tick abundance (per sq metre) by location across a landscape

(black autumn 2013, grey autumn 2014)



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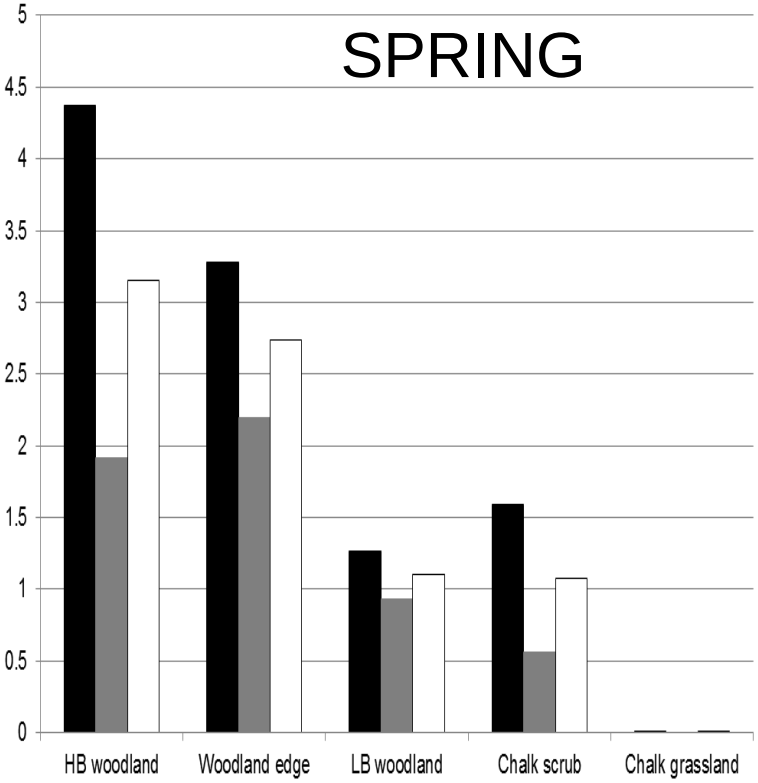
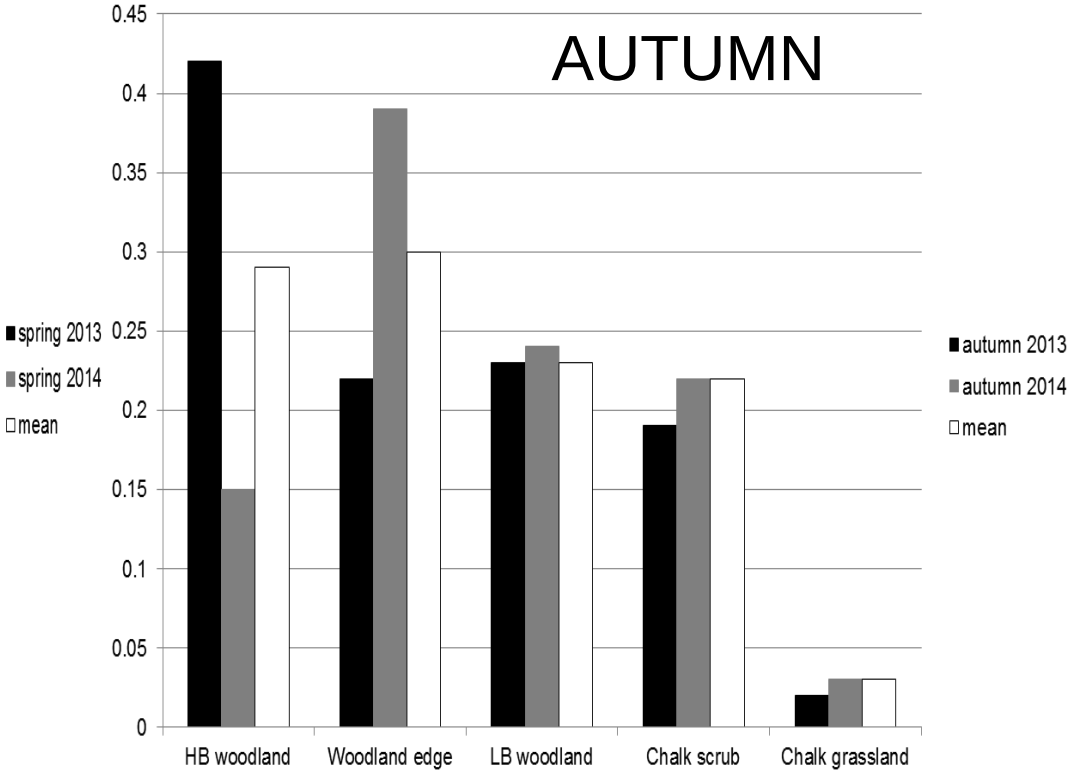
Tick abundance by habitat - south Wiltshire landscape study





Ticks being tested for *Borrelia*

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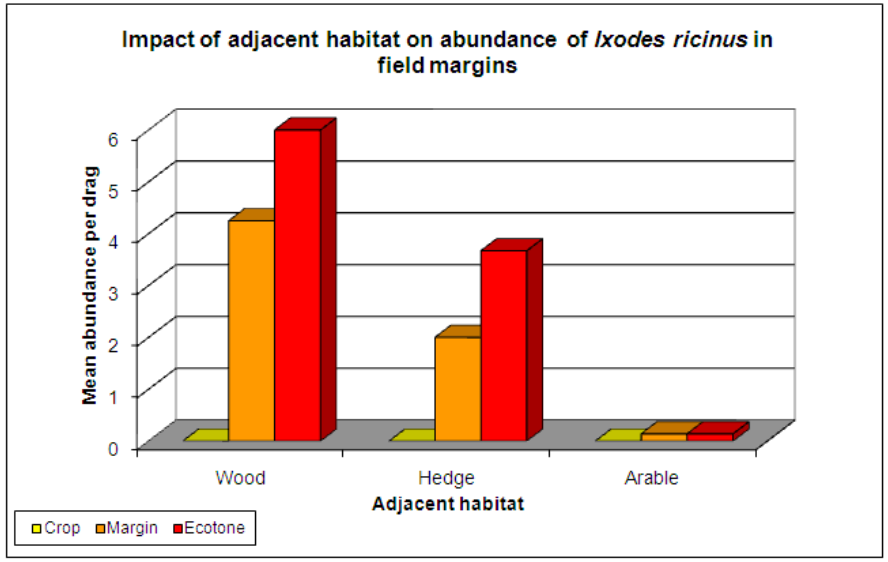
Impact of habitat corridors on *Ixodes ricinus* - the role of field margins as habitats for ticks



[dstl]

Prevalence rates of *Borrelia* in ticks

Location	Habitat	Nymphs tested	Prevalence
Coed y Brenin, Gwynedd	Mixed woodland	40	0
Dalby, Yorkshire	Mixed woodland	237	8.02
Glisland, Northunmbria	Conifer/grassland	55	0
Gisburn Forest, Lancashire	Conifer/grassland	253	0.79
Graig-fechan, Clwyd	Moorland	212	0.94
Hampsfell woos, Cumbria	Decid woodland	245	7.75
Harwood, Northumberland	Conifer/grassland	167	0
Kielder Forest, Northumberland	Conifer/grassland	185	0.54
Loch Doon, Ayrshire	Conifer/grassland	8	-
Madie Forest, Dumfries	Decid woodland	232	8.19
Mell Fell, Cumbria	Decid woodland	28	3.57
Naddle Forest, Cumbria	moorland	249	0
4 woodlands, Wiltshire	Woodland	215	1.4
Exmoor, Somerset	Woodland	120	9.9
4 woodlands, New Forest, Hants	Woodland	120	0.8
Richmond Park, London	Parkland	83	0
Swinley, Surrey	Pine woodland	94	2.12
Salisbury, Wiltshire	Urban fringe	111	6.3
3 sites, Dartmoor, Devon	Woodland/moorland	107	8.41
Cirencester, Glos	Woodland/ edge	252	5.62
South Downs, Suffolk	Woodland/ edge	252	1.93
Thetford, Norfolk	Woodland/ edge	253	2.08
Wytham, Oxon	Woodland/edge	9	0

Bettridge et al. 2013; Hansford et al. 2014; Layzell et al.

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Genospecies prevalence

Bettridge et al. 2013

71 ticks sequenced

- 58% *B. valaisiana*
- 33% *B. garinii*
- 3% *B. afzelii*

Hansford et al. 2014

24 ticks sequenced

- 50% *B. garinii*
- 29% *B. afzelii*
- 20% *B. valaisiana*

Layzell et al. (unpublished)

Glos

~5.5% Bbsl

~3.2% *B. garinii*

~2.3% *B. valaisiana*

South Downs

~2% all *B. garinii or B. valaisiana*

Norfolk

~2.2% Bbsl

~1.5% *B. afzelii*

Huge variation in genospecies dominance geographically
-> Implications for clinical presentation

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Ongoing work – National Parks / AONBs

North of England	
Kielder Forest (Northumberland)	2014, 2015
Grizedale forest, Lake District	2014, 2015
Forest of Bowland (Lancashire)	2014, 2015
Dalby Forest, North Yorkshire Moors	2014
Central & Eastern England	
Cotswolds (Gloucestershire)	2014
Thetford Forest (Norfolk)	2015
South Downs (Sussex)	2014, 2015
Richmond Park (London)	2014, 2015
Cannock Chase AONB	2015
Southern and South-west England	
Swinley Forest (Surrey heaths)	2014, 2015
New Forest (Hampshire)	2014, 2015
Wiltshire (CCWWD AONB)	2014, 2015
Quantocks (Somerset)	2014, 2015
Dartmoor (Devon)	2014, 2015
Exmoor (Somerset/|Devon)	2014, 2015
Forest of Dean (Gloucestershire)	2014
Mendip Hills AONB	2015
Wales	
Snowdonia (Gwynedd)	2015
Brecon Beacons (Powys)	2015
Pembrokeshire coast	2014 2015
Gower (Glamorgan)	2014, 2015
Wye valley (Monmouthshire)	2014, 2015

GIG CYMRU NHS WALES | Iechyd Cyhoeddus Cymru Public Health Wales

Ticks being tested for *Borrelia*

Lyme borreliosis Transmission cycle

Large mammals:
- Deer species
- Sheep


Not generally involved in transmission cycles; localised transmission through co-feeding in sheep reported; both important tick hosts

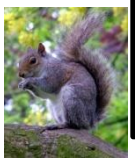
Blood host

Feed

ADULT FEMALE

Trans-stadial

Source of infection,
More conspicuous
Low no. lower risk

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- *M. agrestis*

HUMAN

probability
ection

ivity of
stages
- Seasonal behaviour of humans, hence exposure

Could understanding the ecology of *Borrelia burgdorferi* be employed in understanding:

1. **Rates of exposure**
2. **Determinants for high risk areas**
3. **Targeted management/grazing regimes to minimise ticks and *Borrelia***

- Host seasonal dynamics
- Seasonal changes in tick infestation rates
- Seasonal changes in tick infection rates
- Differences in Borrelia genospecies cycles

Trans-ovarial transmission very low: <2%

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Role of small mammals at *I. ricinus* hosts

- Wood mouse (*Apodemus sylvaticus*) most important rodent host of larvae in UK (Dorset)
  - Peak infestation in August
  - Support 120/larvae/hectare/day
  - **Higher than Bank vole** (Dorset: 30/larvae/ha/day)
  - Similar reports across Europe

- Bank vole (*Myodes glareolus*) **develops resistance to tick bites**
  - Reduced rates of engorgement
  - Reduced moulting rates
  - **Wood mice support higher tick fecundity**

- Yellow-necked mouse (*Ap. flavicollis*) – No UK studies, but similar data in Europe to WM
- Black striped mouse (*Ap. agrarius*) **most important rodent host in continental Europe: UK absent**
  - Larval infestation rates 2-3 x other small mammals
  - Nymphal infestation rates 5x
  - Infection rates 58% higher
  - In Germany contributes 5 times more spirochetal infection
  - **Absence in UK is therefore important**

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Small mammals and *Borrelia afzelii*

- Small mammals are important amplifying hosts of *B. burgdorferi*, particularly *B. afzelii*
- Infected by infective nymphs or transovarially infected larvae
- Life long infection (7-40 months)
- **Bank voles develop lower immunity to spirochaetes -> develop higher infection rates: possibly more important in transmission cycles, however engorged ticks develop less well**
- **Strong association between small mammal rodents with *B. afzelii***
- Studies in Slovakia on infection rates
  - Engorged nymphs from small mammals: 47% infected
  - Questing nymphs: 7% infected

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Role of other small/medium sized mammals

- Shrews (*Sorex araneus, S. minutus*)
  - Efficient tick predators
  - European studies: **80% infestation rates**; mean 40-60 larvae/shrew; 18% infect
- Dormice
  - Hazel dormouse (*Muscardinus avellanarius*) – arboreal, winter hibernation
  - Fat dormouse (*Glis glis*) – Germany: L infest 2-3x, N infest 20x
    - 9 yrs, synanthropic, 70% infected, 95% derived N
- Grey squirrel (*Sciurus carolinensis*)
  - Norfolk studies: mean L 8-19 compared to mouse L 1-4: upto 100 larvae
  - More important in spring/early summer – more arboreal in autumn
- Red squirrel (*Sciurus vulgaris*)
  - Switzerland study: 370L (64%), 380N (69%), 1 F on 1 animal cf. QL 3%, Qn 34%
  - **70% infection rates** (Bbss, Ba) – **Important for Scotland?**
- Siberian chipmunk (in France)
  - potential new host and reservoir

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Role of other animals

- Hedgehog (*Erinaceous europaeus)*
  - **Highly infested** with ticks: Ireland study - >400L, 60N on 1 adult
  - Also infested with ***I. hexagonus***:
    - In Switzerland – means 50L, 11N, 2.5 F *I. ricinus*
    - Co-infested in woodlands, mono-infested (IH) in urban areas: IH 24%
    - **Silent cycle of transmission**
- Lizards
  - Important **dilution hosts** in North America
  - Intensity of LD transmission negatively associated with Sand lizard dist in Ger.
- Migratory birds (Swedish study)
    - 23000 migrant birds surveyed, 2% infest, mean 2ticks/bird, 98% IR
    - 30% of ticks in spring infected
    - **>6.8m ticks enter Sweden each spring, 4.7m leave in autumn; 1.3m infected**
    - Redwing – migratory restlessness reactivating latent infections

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Role of woodland birds

- Ground feeding passerines are very important in Bb transmission
- Most important species (83% infested) are (Czech studies):
  - Robin (*Erithacus rubecula*)
  - Blackbird (*Turdus merula*)
  - Song thrush (*Turdus philomelos*)

- **Robin fed 51% of all larvae** feeding on birds
- **Blackbird fed 54% of all nymphs** (highest infestations 50 L and 20N/bird)
- Infection rates: 6-16% in larvae; 12-22% in nymphs
- ***Turdus* sp. and *E. rubecula* very important amplifiers for *B. garinii and B. valaisiana***

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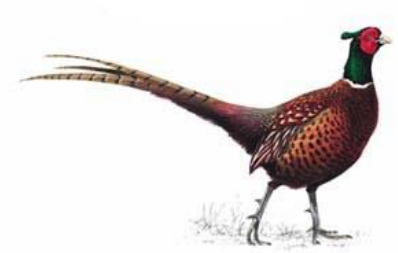
Role of pheasant

- ~20 million pheasant (*Phasianus colchicus*) released in UK each year
- Densities in Dorset/Wiltshire studies: 500-1200 birds/km^2



- **Feed large numbers of nymphs**:
  - 43n/bird in April; 23n/bird in June
  - <u>Most important host nymphal host</u>
- Male birds 4x infestation rates – testosterone and immunosuppression
- Infection rates in ticks from pheasant (Dorset):
  - 22% infected, cf. 0% questing population
  - **Mostly *B. garinii* (neuroborreliosis) and *B. valaisiana*** – important amplifiers – no evidence of *B, afzelii :* possibly eliminated
- Feed large numbers of questing nymphs -> exposure; infected adult ticks
- **Reduction in *B. afzelii* – zooprophylactic role**

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Role of deer

- **Very important host** for all stages
- Irish studies on Fallow deer:

	L/50m	N/30s	A/30s	Inf qN	Inf qA
Deer	22-118	33-34	5-6.6	1.7%	3.1%
No deer	1.5-5.5	1.6-12.5	0.1-1.2	12.4%	17.9%

- **Dilution hosts for *Bb***
  - Swedish studies
    - Compared moulted ticks from deer (0%) to questing N (7-11%)
    - 20% n infection rates: need 300,000 nymphs for infection
    - Typical infestation <100 nymphs
    - 100 ticks/kg vole v 3.7 ticks/kg deer -> immunity, low infection rates
- Role of deer: increase tick numbers; dilute infection rates -> sustain tick pop

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Role of livestock

- Sheep
  - Upland sheep – feed 80% of all larvae, >95% all N and A
  - **No systemic infection in sheep**
  - Studies in Scotland confirm **co-feeding transmission**
    - N:A 9cms; transmission during max. peaks of infestation
- Cattle
  - **Zooprophylactic role** on transmission
  - French studies: infection rates in questing ticks inside/outside cattle enclosures
    - 4x lower infection rates in Nymphs inside enclosures
    - 6x lower in Adults
  - **Could we use cattle to dilute infection rates, and mop up ticks?**

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Pathogen detection in vectors

rivm National Institute for Public Health and the Environment

Ticks:

- First detections of potentially pathogenic TB rickettsiae (Tijsse-Klasen et al 2011, 2013):
  - *Rickettsia helvetica* in *Ixodes ricinus*
  - *Rickettsia raoultii* in *Dermacentor reticulatus*
  - *Rickettsia massiliae* in *Haemaphysalis punctata*
- First detection of *Borrelia miyamotoi* – cause of Tick-borne relapsing fever (Hansford et al. in prep)
  - 3/951 ticks – low prevalence, however potential novel disease assoc with UK

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First detection of spotted fever group rickettsiae in *Ixodes ricinus* and *Dermacentor reticulatus* ticks in the UK

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***Borrelia miyamotoi* in host-seeking *Ixodes ricinus* ticks in England**

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Spotted fever group rickettsiae in *Dermacentor reticulatus* and *Haemaphysalis punctata* ticks in the UK

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Thanks for listening.

Any questions?