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EUROPEAN CENTRE FOR DISEASE PREVENTION AND CONTROL

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"European Network for Arthropod Vector Surveillance for Human Public Health"

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Driving forces for change in geographical distribution of *Ixodes ricinus* ticks in Europe

WP 2 – Period 3

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Aims

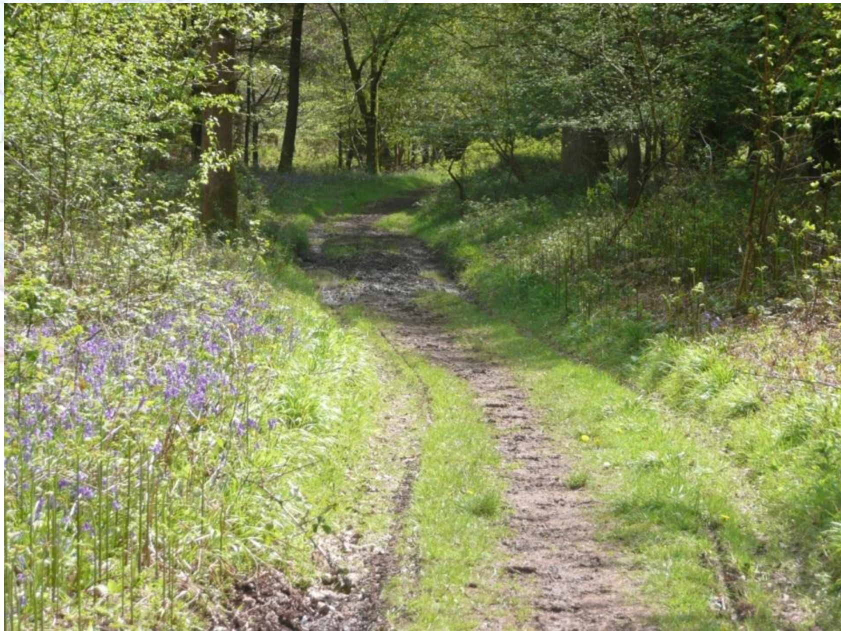
- Review drivers for change in distribution of *Ixodes ricinus* in Europe
  - Published literature
  - Expert opinion
    - Input from 19 institutions (academia, government, ECDC)
    - Experts from 14 EU member states
- Drivers include:
  - Climatic effects at altitude and latitude
  - Land use change; habitat connectivity; urban green space
  - Changes in agriculture
  - Changes in tick host distribution

Biology/ecology of *I. ricinus* of relevance to determining changes in their distribution

- Important disease vector of Lyme borreliosis, Tick-borne encephalitis, Rickettsiosis, Anaplasmosis + pathogens of veterinary concern
- Survival and distribution limited by:
  - Microclimate: host seeking vs. desiccation
  - Habitat: moist, predominantly woodland, or wood/forest-edge, ecotonal
  - Host availability: stage specific
  - Dispersal on hosts: minimal movement
  - Questing – ambush strategy – weather dependent

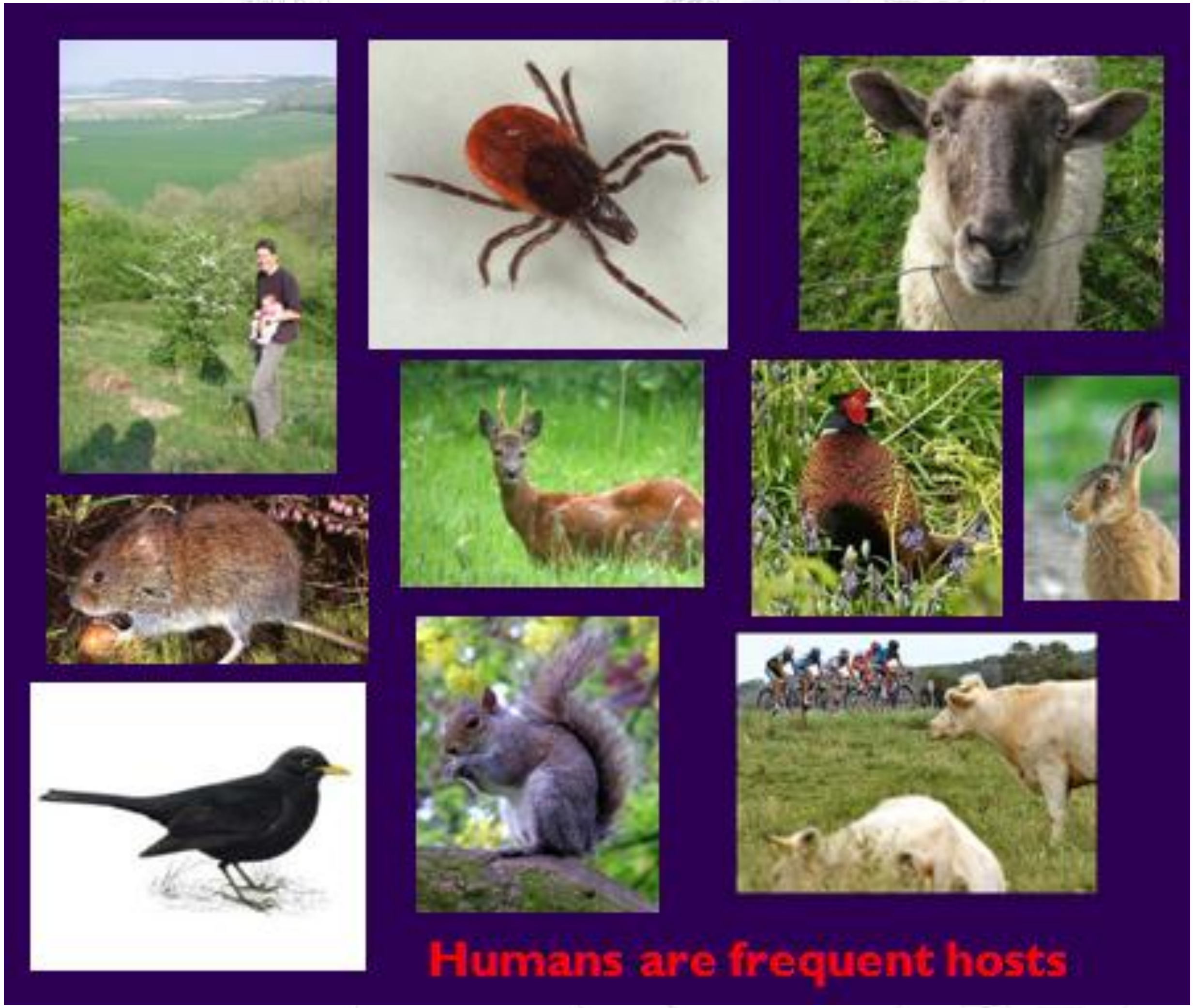
Biology/ecology of *I. ricinus*

- Microclimate
  - Affected by macroclimatic change
    - Temperature
    - Rainfall
    - Humidity
    - Snow cover
- Habitat
  - Mostly woodland species
  - Ecotonal habitat
  - Grassland, heathland
  - Urban parks



Biology/ecology of *I. ricinus*

- Host availability



Biology/ecology of *I. ricinus*

- Host availability
  - Peaks in rodent populations; indirect effect of weather and climatic changes
  - Increase in abundance and range of large tick hosts, e.g. deer
  - Re-introduction of species, e.g. wild boar
  - Promotion of wildlife corridors
- Dispersal on hosts
  - Increased numbers of blood hosts and greater dispersal to new habitats
  - Migration of animals
- Questing
  - Longer seasons afforded by climate – increasing sustainability for tick populations

Questions to answer

- Will 'climate change' affect tick distributions?
  - Is it all about temperature and rainfall?
  - Is there any evidence at high altitudes and high latitudes?
- Is there an indirect effect of CC on *I. ricinus*?
  - By impacting on vegetation periods
  - By impacting on host abundance and distribution
- How important is the spread of deer to increasing tick distributions or the release of game birds?

Questions to answer

- What effect does human intervention act as a driver for change?

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Questions to answer

- What effect does human intervention act as a driver for change?
  - Wildlife and species conservation
  - Re-wilding
  - Habitat connectivity
  - Urban green corridors
  - Woodland/forest management
  - Changes in agricultural subsides for wildlife
  - Changes in agricultural intensification
  - Hunting and game management
  - Increase in human exposure
  - Peri-urban expansion into the ‘green belt’

Ixodes ricinus at altitude

Ixodes ricinus at altitude

- Studies in Czech republic (Daniel et al 2006; Materna et al 2008)
  - Tick abundance decreases with increasing altitude
  - Rate of egg survival and hatching decreased with altitude
    - No eggs hatched >1150 masl
    - 33% eggs hatched >1070 masl
  - Variability in egg hatching rates greater at altitude
  - Moulting rates decrease with altitude
    - Larvae to nymph
    - Nymph to adult
  - Increasing altitude acting a surrogate for less favourable microclimate

Ixodes ricinus at altitude - aspect

Ixodes ricinus at altitude - aspect

- Studies in Switzerland (Jouda et al 2004; Burri et al 2007; Moran Cadenas et al 2007)
  - Aspect (i.e. orientation of mountainside) impacts tick survival even at the same altitude
  - Ticks found up to 1450 masl
    - Higher densities on south-facing vs. north-facing slopes
  - Explained by differences in saturation deficit at the same altitude due to microclimate
- Studies in Wales (Medlock et al 2008)
  - During daytime surveys in hot summers (2003), ticks were more common on east and west facing slopes. Perhaps avoiding high temperatures.
  - Abundance by aspect may change seasonally and daily

Ixodes ricinus at altitude with latitude

Ixodes ricinus thresholds at altitude with latitude

- Does the altitudinal limit change with latitude?

  UPPER ALTITUDINAL LIMIT

  – Austria (Holzmann et al 2009): 1560 masl
  – Switzerland (Jouda et al 2004): 1450 masl
  – Italy (Rizzoli et al 2002): ~1300 masl
  – Czech (Danielova et al 2006): 1080-1270 masl
  – Scotland (Gilbert 2010): 700 masl

  LOWER ALTITUDINAL LIMIT

  - Greece (Papa et al 2008; 2011): 600 masl
  - Spain (Estrada Pena pc): lower threshold in Pyrenees differs between Atlantic and Mediterranean coasts.
    - West – east gradient. 0-2000 masl (west); >1000 masl (east)

Ixodes ricinus at altitude – evidence of change

- Any evidence that these altitudinal limits have changed?
  - Bosnia & Herzegovina (Omeragic 2010)
    - 1950s: <800 masl
    - 1960s: 900 masl
    - 2010s: 1190 masl
  - Czech (Daniel 2003; Materna et al 2005; Danielova et al 2006; 2008)
    - 1950s and 1990s: 700 masl
    - 2001: 1100-1250 masl (two mountain ranges)
  - Slovakia (Derdakova pc)
    - Increase from 800 masl – 1200 masl

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Is climate a driver at altitude?

- Czech republic (Daniel et al 2004; Danielova et al 2008; 2010)
  - At tick field study sites in two mountain ranges
    - At 1000 masl between 1961 and 2005
      - Annual mean temp increased by 1.4 deg C
      - Spring/summer temp increased by 3.5 deg C
- High temperatures at altitude may:
  - Increase the length of development: evidence of extended seasons in Hungary (Srete et al 2005; Szell et al 2006)
  - Increase abundance of ticks
  - However, enhanced snow cover promotes overwintering (ground >0deg C) - Sweden
  - Impact on humidity at lower altitudes - Greece

Is habitat change a driver at altitude

- Ticks cannot climb mountains alone
- Longer vegetation periods at higher altitudes favours browsing for animal hosts
  - Deer move to higher altitudes in spring, promoting tick dispersal (Materna et al 2008)
  - Shorter snow periods promote new ground for deer at higher altitude
  - Re-population of alps by deer
  - Ticks now feeding on mammals which previously lived in unsuitable habitats – chamois (Rizzoli pc)

Land use change as a driver at altitude

- Land use change at altitude
  - Move from solely timber to more complex ecosystems, changes in amount of coppice, and high forest (e.g. Italy – Rizzoli pc)

Land use change as a driver at altitude

- Land use change at altitude
  - Slovakia & Czech republic – land formerly cultivated at altitude has been left uncultivated
    - Increase in vegetation, and rodents
    - New populations of ticks
  - Czech republic
    - Increase in harvesting deer at altitude, deer being managed for hunting

Ixodes ricinus at latitude

- Northern extent:
  - Not latitudinally limited in
    - UK
    - Denmark
    - Poland
    - Baltic states
- Concern for Norway, Sweden, Finland

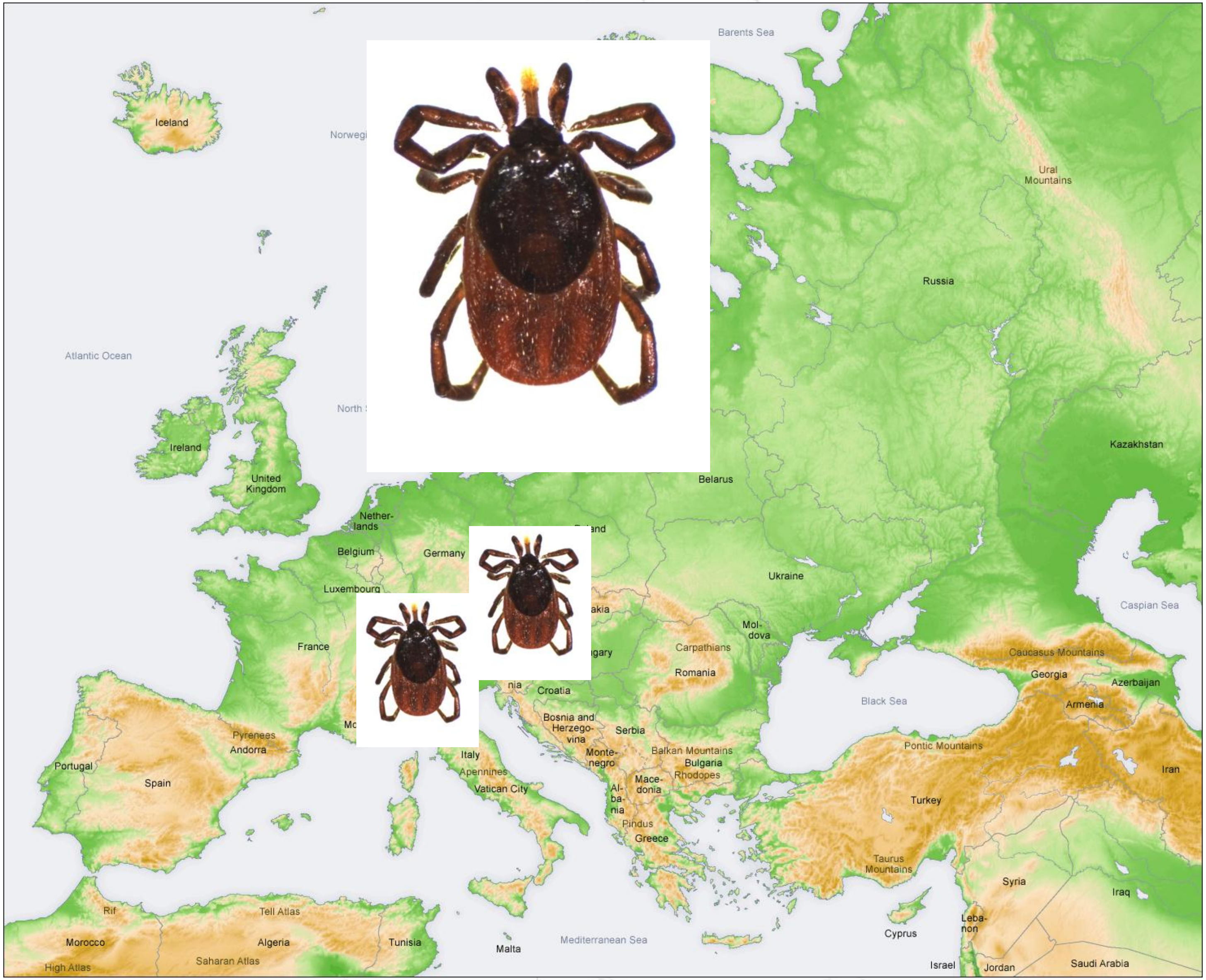
Ixodes ricinus at latitude

- Sweden (Jaenson et al 1994; Talleklint & Jaenson 1998; Lindgren et al 2000; Jaenson et al 2009; Jaenson & Lindgren 2011; Jaenson et al 2012; Jaenson pc)
  - Shift in distribution apparent during 1980s and 1990s through field survey
  - Linked climatically to reduction in number of days <-12 deg C during winter, and generally mild winters, extended spring and autumn seasons
  - No coincident change in land use
  - Expansion of deer accepted (Jaenson et al 2012)
  - Ticks found in previously tick-free areas at higher latitudes in Sweden

Ixodes ricinus at latitude

- Warmer climate exerts an effect on:
  - Vegetation period (VP) becomes longer
    - IR found where VP exceeds 180 days (rarely < 160d)
  - Reduced length of snow cover
    - IR consistently present where SC < 125 days (absent > 175d)
  - Prolonged VP:
    - Favours increased abundance and higher densities of deer (specifically roe deer)
  - Milder winters:
    - Promote survival of deer
  - Coincident decline in deer predators (fox scabies)
  - Increase in ticks
- Norway (Jore et al 2011): 400km northward expansion of *I. ricinus*

I don't live in the alps or Fennoscandia!



Impact of patchiness, connectivity and urban green corridors

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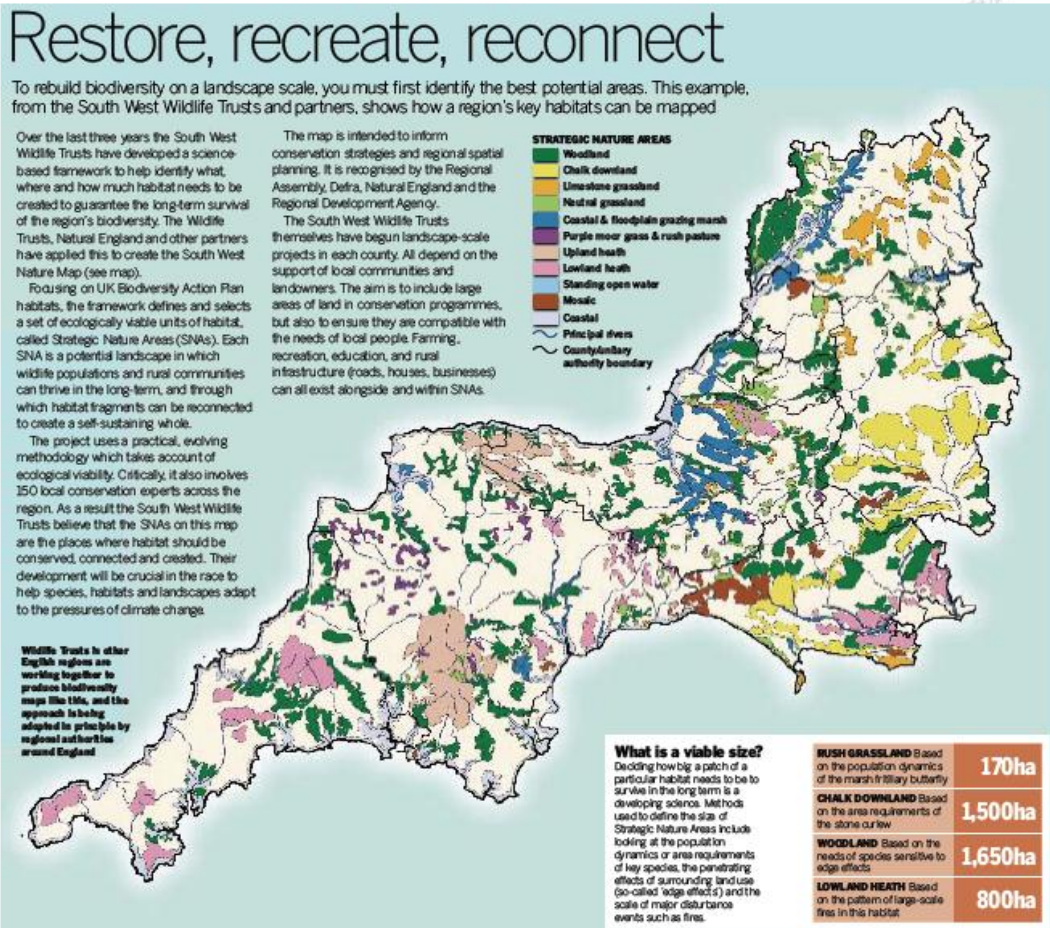


Restore, recreate, reconnect

To rebuild biodiversity on a landscape scale, you must first identify the best potential areas. This example, from the South West Wildlife Trusts and partners, shows how a region's key habitats can be mapped

Over the last three years the South West Wildlife Trusts have developed a science-based framework to help identify what, where and how much habitat needs to be created to guarantee the long-term survival of the region's biodiversity. The Wildlife Trusts, Natural England and other partners have applied this to create the South West Nature Map (see map).

Focusing on UK Biodiversity Action Plan habitats, the framework defines and selects a set of ecologically viable units of habitat, called Strategic Nature Areas (SNAs). Each SNA is a potential landscape in which wildlife populations and rural communities can thrive in the long-term, and through which habitat fragments can be reconnected to create a self-sustaining whole.

The project uses a practical, evolving methodology which takes account of ecological viability. Critically, it also involves 150 local conservation experts across the region. As a result the South West Wildlife Trusts believe that the SNAs on this map are the places where habitat should be conserved, connected and created. Their development will be crucial in the race to help species, habitats and landscapes adapt to the pressures of climate change.

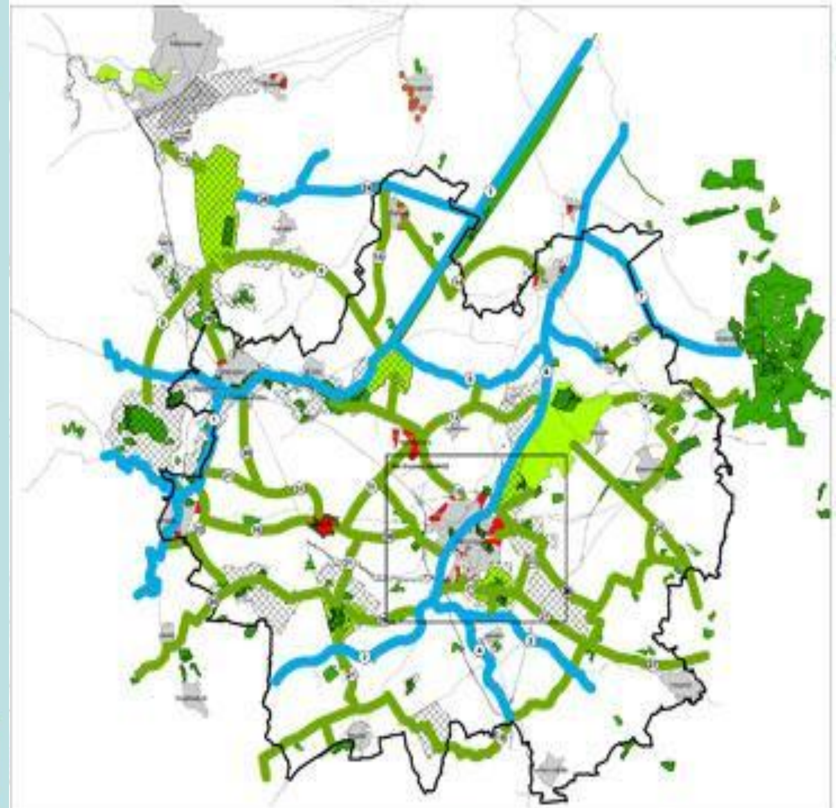
The map is intended to inform conservation strategies and regional spatial planning. It is recognised by the Regional Assembly, Defra, Natural England and the Regional Development Agency.

The South West Wildlife Trusts themselves have begun landscape-scale projects in each county. All depend on the support of local communities and landowners. The aim is to include large areas of land in conservation programmes, but also to ensure they are compatible with the needs of local people. Farming, recreation, education, and rural infrastructure (roads, houses, businesses) can all exist alongside and within SNAs.

Wildlife Trusts in other English regions are working together to produce biodiversity maps like this, and the approach is being adopted in principle by regional authorities around England

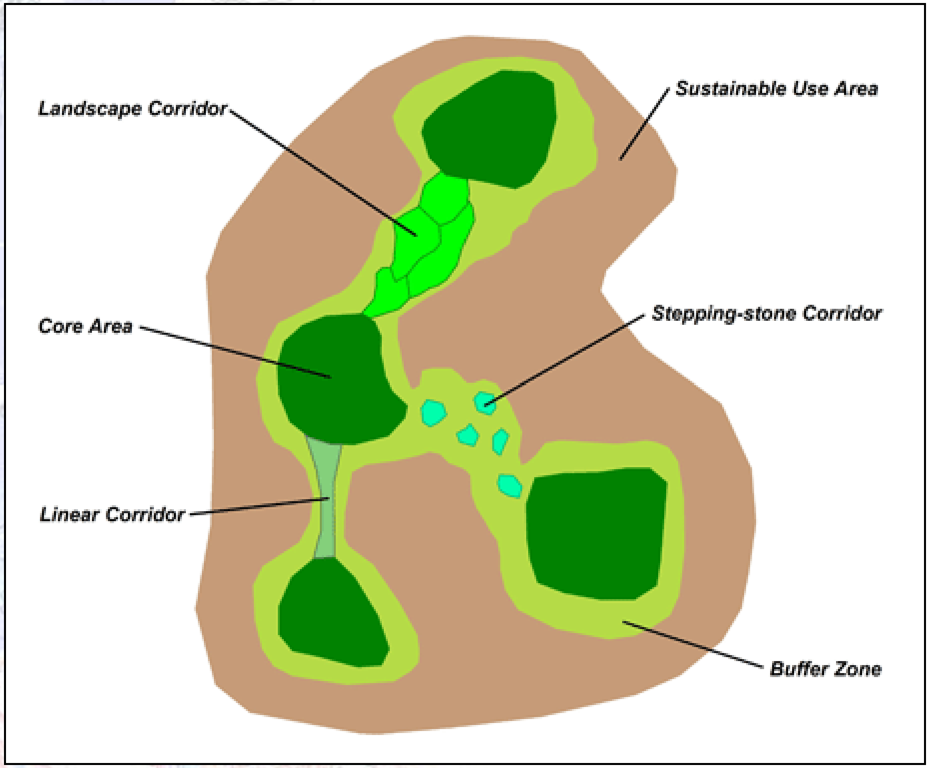
What is a viable size?
Deciding how big a patch of a particular habitat needs to be to survive in the long term is a developing science. Methods used to define the size of Strategic Nature Areas include looking at the population dynamics or area requirements of key species, the penetrating effects of surrounding land use (so-called 'edge effects') and the scale of major disturbance events such as fires.

RUSH GRASSLAND Based on the population dynamics of the marsh fritillary butterfly	170ha
CHALK DOWNLAND Based on the area requirements of the stone curlew	1,500ha
WOODLAND Based on the needs of species sensitive to edge effects	1,650ha
LOWLAND HEATH Based on the pattern of large-scale fires in this habitat	800ha



Impact of patchiness, connectivity and urban green corridors

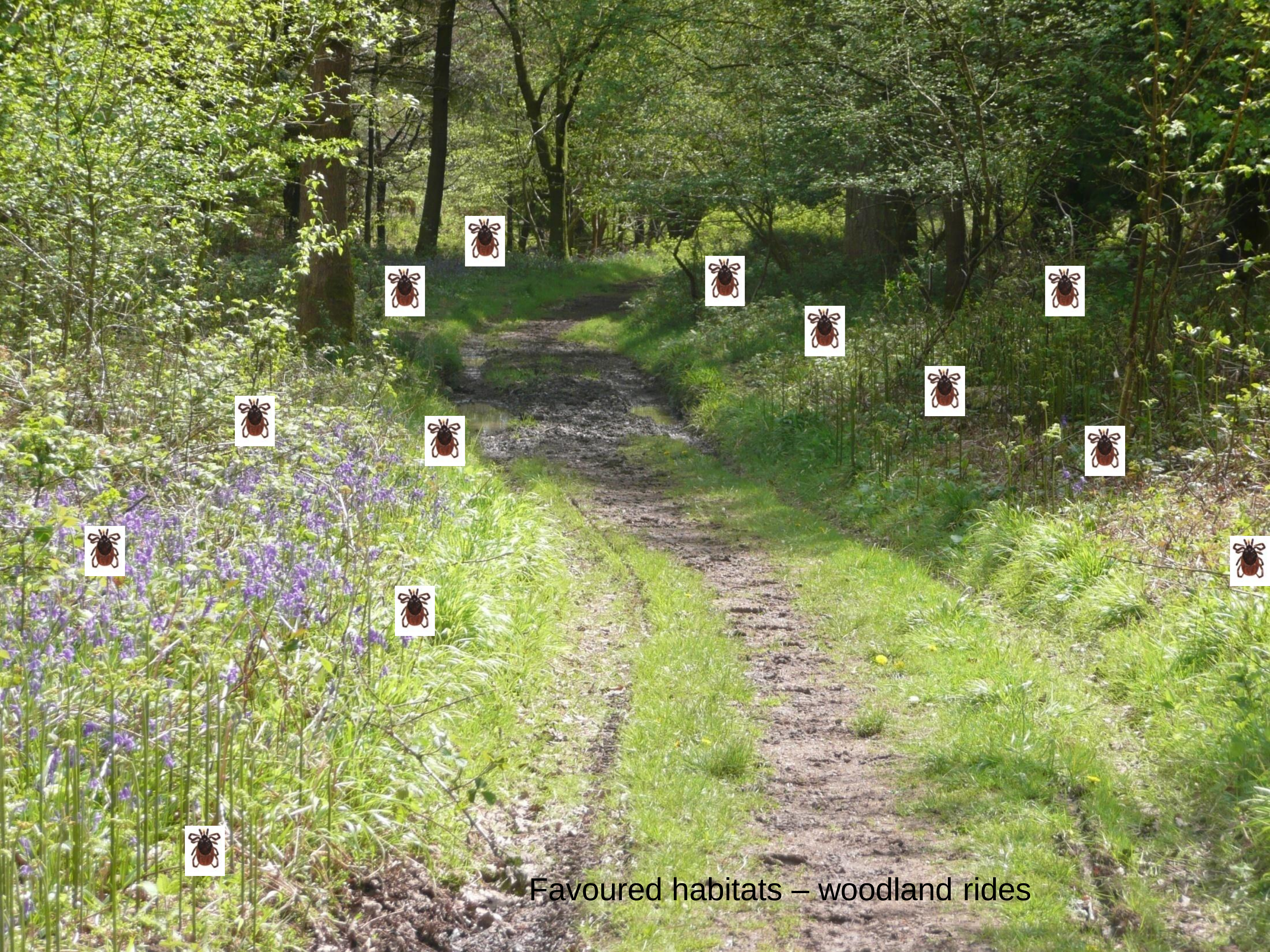
- Afforestation and habitat connectivity across Europe
– Spain (Estrada-Pena pc; Oteo pc)
    - Habitat configuration, degree of connectivity between patches
    - More *I. ricinus* where connectivity is higher
    - Distance between patches (i.e. habitat fragmentation) are inversely related to the probability of successful invasion and establishment of IR in new areas (Estrada-Pena 2003



Life in the ecotone

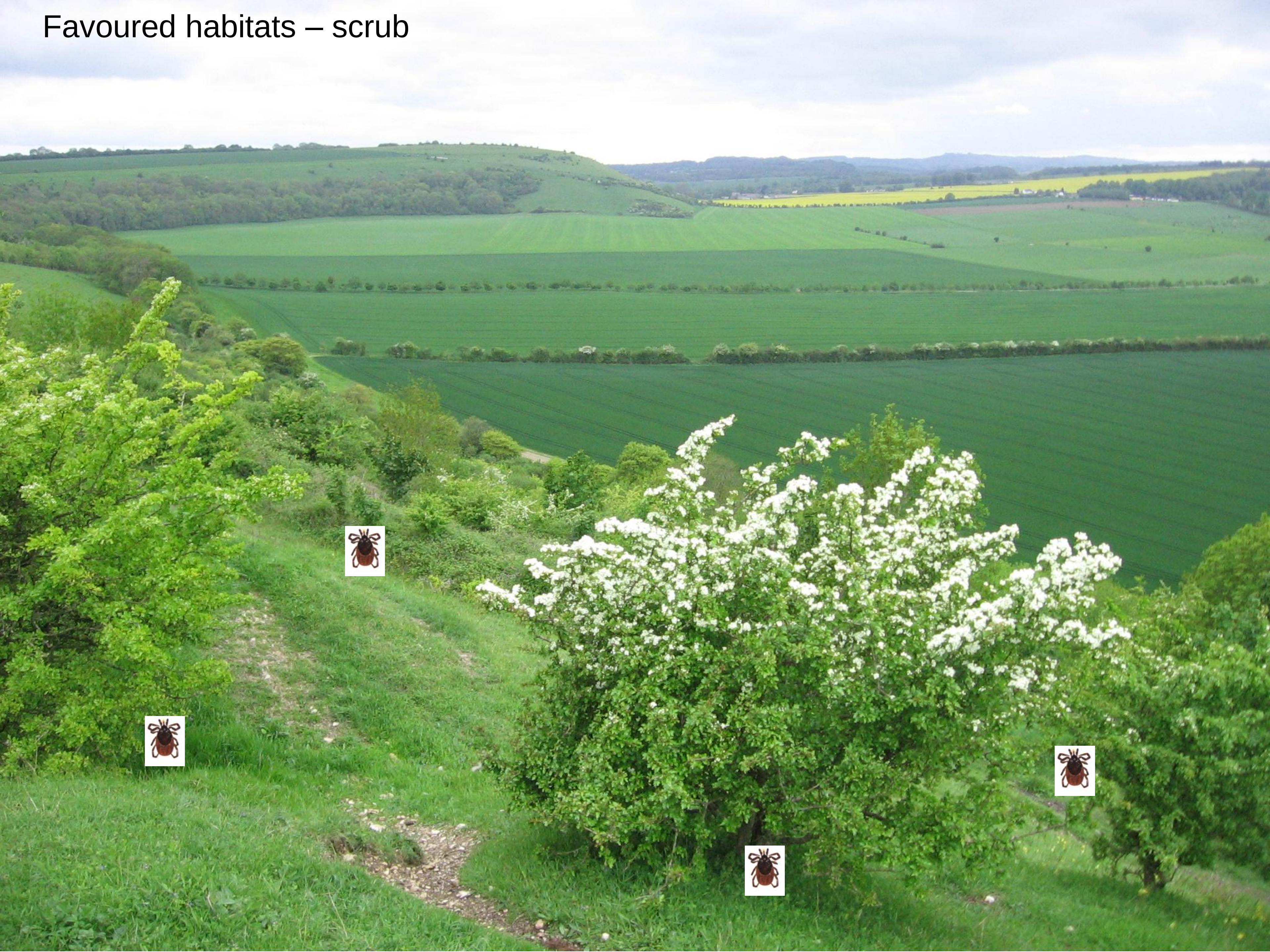
- UK (Medlock et al 2008; 2012)
  - Field margins provide new habitats for ticks
  - New ecotonal habitat for ticks and animals
  - New links for small mammal dispersal

Favoured habitats – the ecotone



Favoured habitats – woodland rides

Favoured habitats – scrub



Translating research into new interventions

Health Protection Agency

Woodland management to control ticks

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

1. Nymphs are most active in spring (April-June)
2. Hot spots of tick activity more common on S- W-facing rides
3. Overhanging vegetation & dense litter support more ticks
4. Increased bracken & bramble cover concentrate tick feeding
5. Keep to low swards
6. Walk along centre of tracks; avoid animal tracks
7. Ticks are less active on hot or very wet days
8. Always wear light trousers and brush off tics; reduces likelihood of bites

King's College London

Advice to the public in woodlands

Expansion of main tick hosts

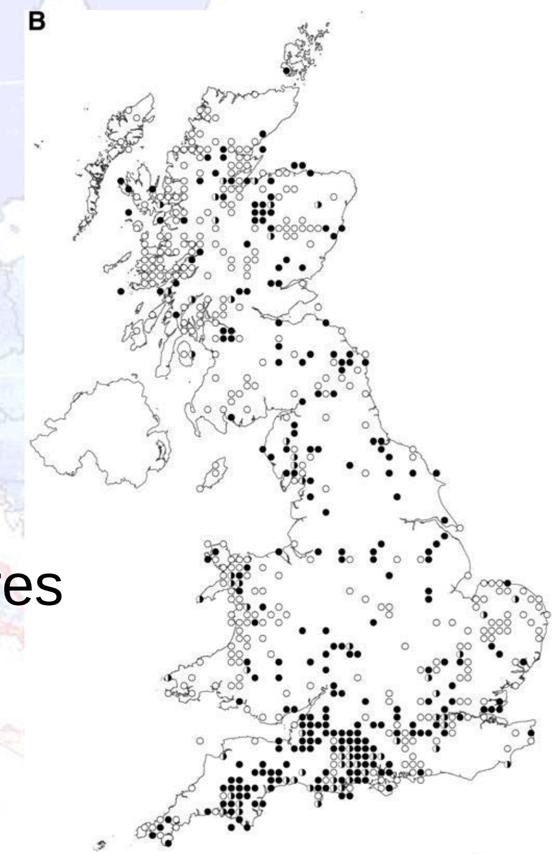
- Denmark (Jensen & Jesperson 2005)
  - Roe deer populations considered main driver for *I. ricinus* expansion in Denmark
  - Why?
    - Behavioural adaptation to human disturbance
      - Spread into towns and cities
    - 10-25% increase in afforestation in country
    - Changes in agricultural practice
    - More people feeding deer
    - Decline in predators (scabies in fox)
- Germany (Schwarz et al 2009)
  - Stable deer population; increase in wild boar
- Swedish islands – no boar/deer, populations maintained by hares (Jaenson pc)

Anthropogenic factors

- Baltic states (Randolph pc)
  - National herds of sheep and cattle have declined
  - Area under cultivation of field crops diminished
  - Natural regeneration of herbaceous and woody vegetation
  - Invasion by rodents, deer and ticks
  - Massive broadcast use of pesticides has stopped allowing better tick survival
  - Changes in forest ownership
  - Overlap of tick and human activities
  - Increase in ticks and TBD in Latvia (Vanwambeke et al 2010)

Need for ground-based surveillance

- So many of these theories are anecdotal
- Only ground-based surveys can provide real evidence of change



- Submission of ticks through surveillance schemes
- Analysis of historical data
- Monitoring incidence of human and animal TBDs
- Hunting records
- Public/ field worker questionnaires

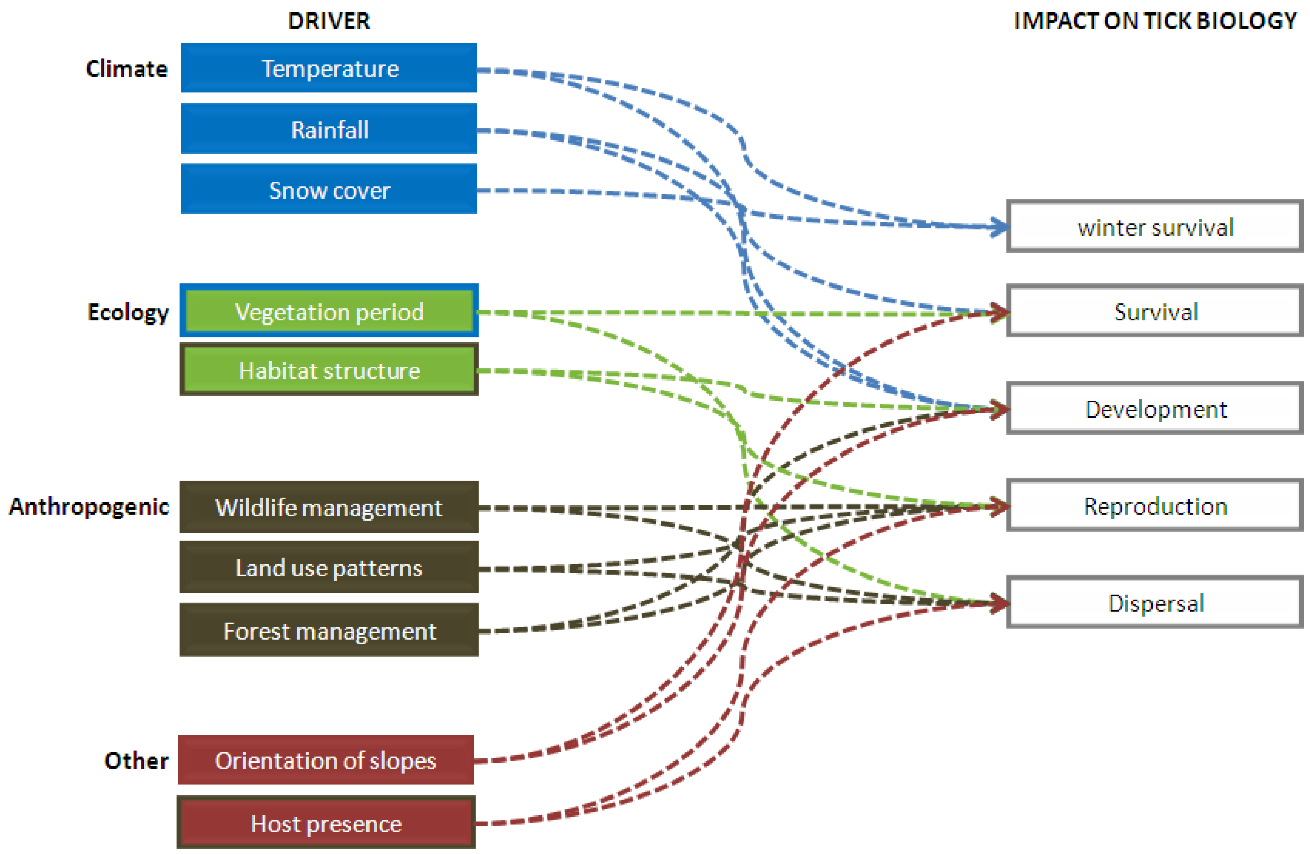
Good examples across Europe inc. Norway, Portugal, Sweden, UK

Table 1. Overview of the key drivers and their mode of action for change in geographical distribution of *Ixodes ricinus* ticks in Europe

KEY DRIVER	Driver	Mode of action of driver	Impact on ticks biology	Impact on spread or abundance at		
				altitude	latitude	endemic zones
Climate	Temperature	Increased temperature during winter months	increased winter survival	X	X	
		Overall increased temperature (winter and summer)	extended development period	X	X	
	Rainfall	Increased humidity	extended development period, increased survival			
	Snow cover	isolation, preventing ground temperature falling below 0	increased winter survival	X	X	
	Extended vegetation period (increased temperature and reduced snow cover)	Altitudinal and latitudinal expansion of deciduous woodland creating suitable conditions for Ixodes ricinus	improved microclimate with increased tick survival, and development	X	X	
		Dispersal of roe deer at higher altitude and latitude	Enhanced dispersal and reproduction	X	X	
Anthropogenic	Wildlife management	Increased habitat for *Ixodes ricinus*	Enhanced dispersal	X	X	
		Increased habitat for hosts	Enhanced dispersal	X	X	
		Increased host abundance	Enhanced reproduction			X
	Changes in land use patterns	Increased habitat for *Ixodes ricinus*	Enhanced dispersal			X
		increased habitat for hosts	Enhanced dispersal			X
		Increased host abundance	Enhanced reproduction			X
	Forest management	reforestation, creation of suitable habitats		X	X	X
Ecological / geographical factors	Habitat structure and connectivity	Increase in suitable environment	Enhanced reproduction and development			X
		Improved hosts dispersal	Enhanced dispersal			X
	Orientation of mountain slopes	Impact on microclimate	Impact on survival, development	X		
	Host dispersal	Behaviour adaptation of roe deer to human presence	Enhanced tick reproduction and dispersal			X

Conceptual framework of drivers for change in geographical distribution of *I. ricinus*

Figure 1. Conceptual framework of drivers for change in geographical distribution of *Ixodes ricinus*. The drivers can be divided into those directly related to: climatic change (blue), ecological changes (green), anthropogenic change (brown), and others (red). The colour of the outline indicates the indirect effect of one driver upon the other (see text and table 1 for details on the mode of actions of the drivers).



Conclusions

- Many factors responsible for driving changes in distribution of *I. ricinus* at altitude, latitude and within endemic range
- All strongly interlinked – many biological disciplines, acting directly and indirectly
- Often not well understood or quantified
- Better understanding and mapping of *I. ricinus* is essential to asses risk of TBD
- Enhanced tick surveillance with harmonised approaches for comparison of data
- ….enabling Europe to follow trends…

……improve PH messages and advice to policy and public