Lizards, ticks, and *Borrelia*: Why a herpetologist is studying Lyme disease

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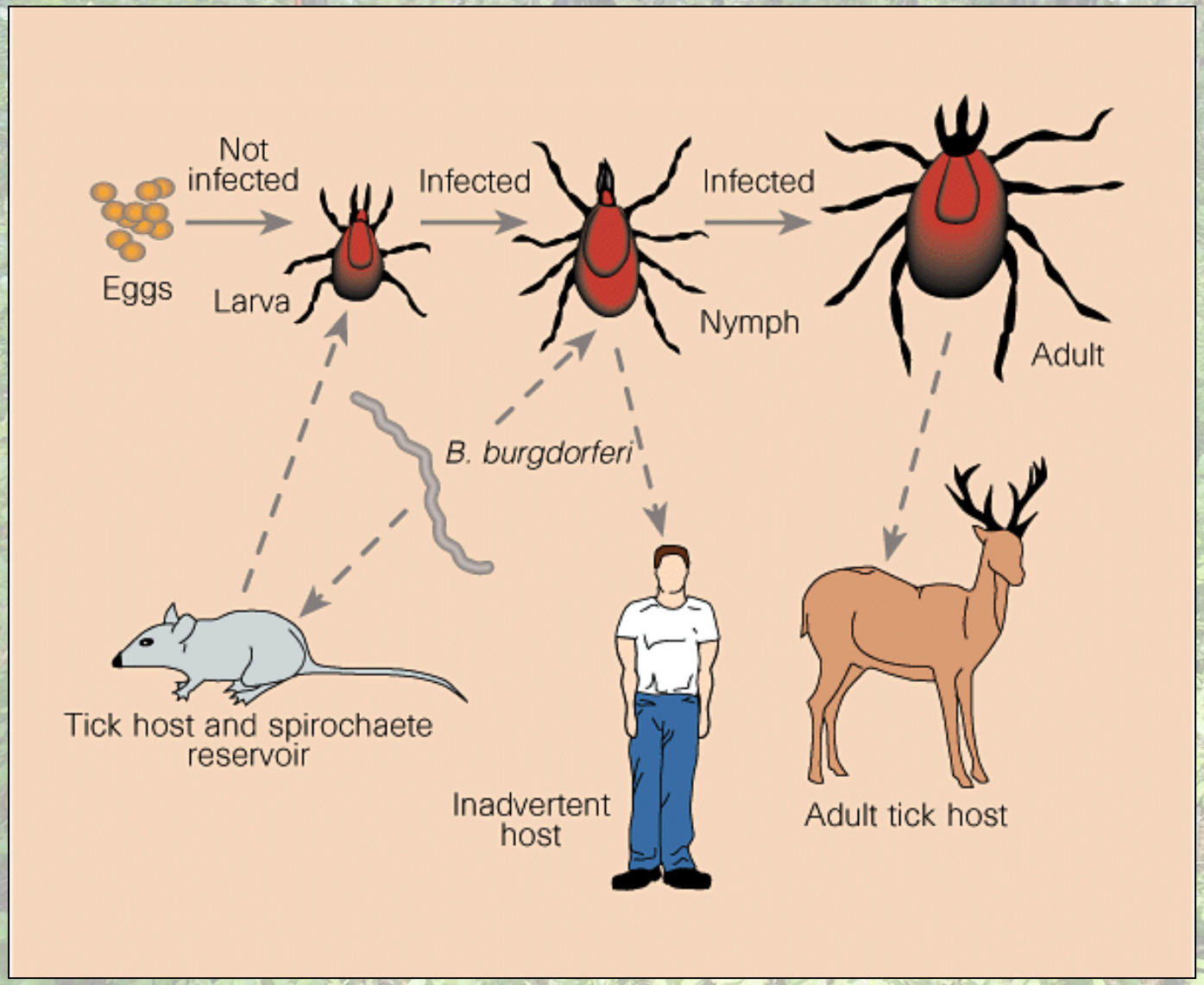
Introduction

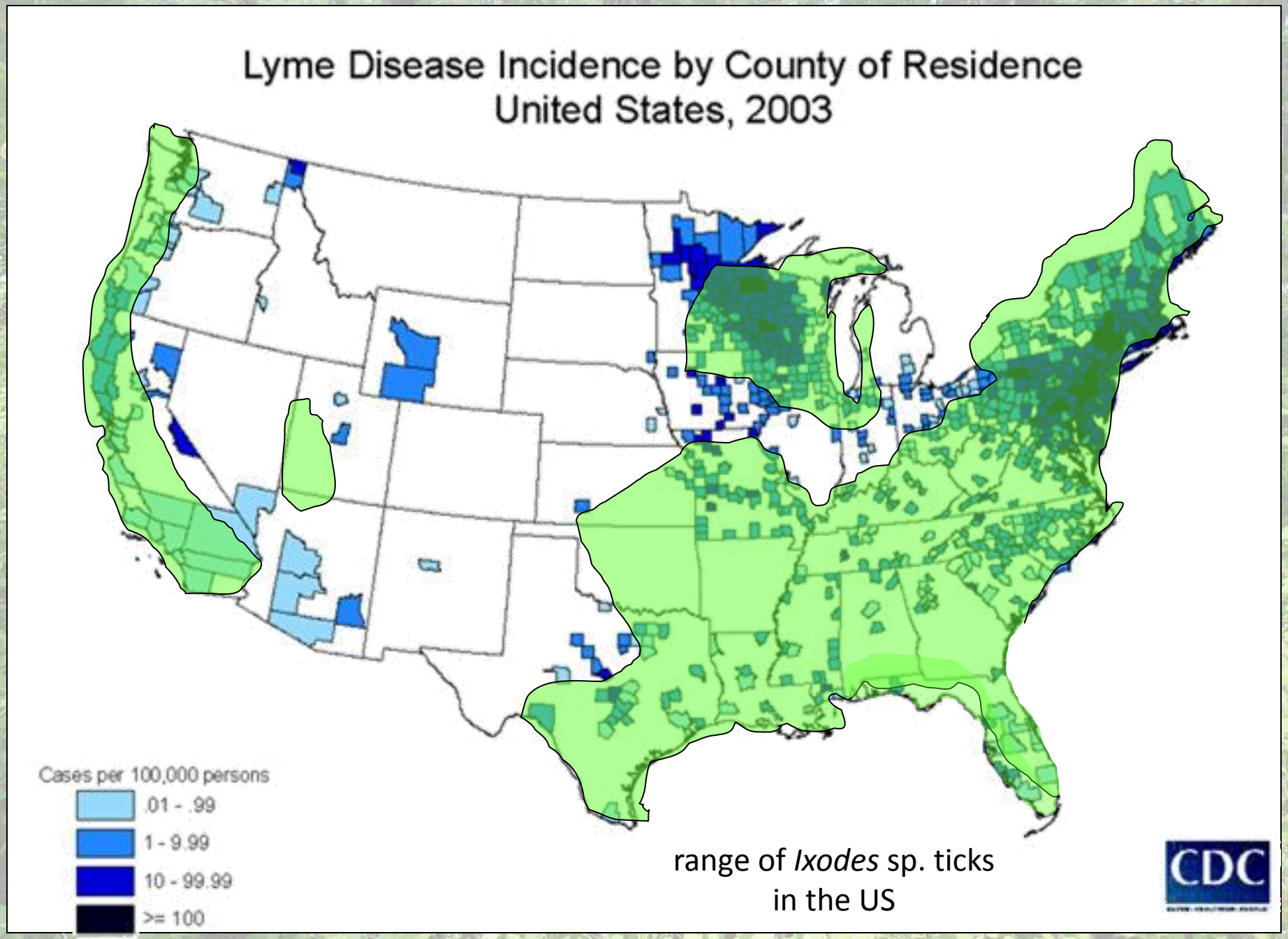
- **Lyme disease: most common vector-vector-borne disease in U.S.**
- **Pathogen: bacteria *Borrelia burgdorferi***
- **Vector: blacklegged tick (*Ixodes scapularis*)**

http://wildlifehealth.tennessee.edu/lyme_gradient/index.htm, Photo: http://lymegradient.blogspot.com/2012/08/more-photos-from-tick-gardens.html

Lyme Disease Cycle



http://www.thefastertimes.com/globalpandemics/2010/01/20/film-review-%E2%80%98under-our-skin%E2%80%99-lyme-disease-documentary/



range of *Ixodes* sp. ticks in the US

4 Hypotheses

- **Biodiversity or "Dilution" effect hypothesis (Ostfeld and Keesing 2000a & b)**
- **"Phenology hypothesis" (Ogden et al. 2008)**
- **"Genetic hypothesis" (Rich et al. 1995, Norris et al. 1996, Qiu et al. 2002)**
- **"Abundance hypothesis" (Piesman, 2002; Duik-Wasser et al., 2006)**

Biodiversity/ Dilution effect

- **High species diversity (species richness plus evenness) + reservoir incompetent hosts + reservoir competent hosts= vector infection prevalence**

Biodiversity/ Dilution effect

TABLE I. Mammal and bird data used in the dilution potential model, taken from LoGiudice et al. (2003).

Host species		Model parameter		
		Mean larval burden, B_i	Population density, N_i	Reservoir competence, C_i
Eastern chipmunk	*Tamias striatus*	36	10	55
Raccoon	*Procyon lotor*	127	0.2	1.3
Short-tailed shrew	*Blarina brevicauda*	62.9	25	41.8
Songbirds	*	1.7	31.6	11.7
Shrews	*Sorex* spp.	55.5	25	51.2
Squirrels	†	142	8.1	14.7
Striped skunk	*Mephitis mephitis*	66.8	0.05	9.7
Virginia opossum	*Didelphis virginiana*	254	1	2.6
White-footed mouse	*Peromyscus leucopus*	27.8	20	92.1
White-tailed deer	*Odocoileus virginianus*	239	0.25	4.6

* American robin (*Turdus migratorius*), wood thrush (*Hylocichla mustelina*), veery (*Catharus fuscescens*), and ovenbird (*Seiurus aurocapillus*).
† Gray squirrel (*Sciurus carolinensis*) and red squirrel (*Tamiasciurus hudsonicus*).

C_i :mean proportion of larval ticks infected by a host.

(Giery and Ostfeld, 2007)

Biodiversity/ Dilution effect

What about lizards?

TABLE I. Results of attempts to experimentally infect naïve western fence lizards by exposing them to feeding by *Borrelia bissettii*-infected *Ixodes pacificus* nymphs.

	Nymphs put on lizards			Infection status of lizards postnymphal tick exposure or of xenodiagnostic ticks as determined by PCR		
Lizard no.	Total no.	Infection prevalence (%)	No. fed fully (%)*	Lizard blood	No. replete xenodiagnostic larvae (pos./no. tested)	No. xenodiagnostic larvae after molting to nymphs (pos./no. tested)
1	16	50	14 (88)	Negative	0/20	0/10
2	31	10–50	9 (29)	Negative	0/20	0/10
3	15	40	4 (27)	Negative	0/15	0/3
4	15	50	7 (47)	Negative	0/19	0/10
5	15	50	10 (67)	Negative	0/21	0/10
6	15	50	5 (33)	Negative	0/18	0/30

* Eighteen of these replete nymphs (range, 2–7 per lizard) were assayed for *B. bissettii* with negative results.

Borreliacidal activity observed in the blood of the Western Fence Lizard (*Sceloporus occidentalis*) (Kuo et al., 2000)

(Lane et al., 2006)

Biodiversity/ Dilution effect

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http://srelherp.uga.edu/lizards/index.htm, http://backyardzoologist.wordpress.com/tag/western-fence-lizards/
http://www.californiaherps.com/noncal/misc/misclizards/pages/e.fasciatus.html

Biodiversity/ Dilution effect

TABLE V. Realized reservoir competence of wild-caught *Eumeces fasciatus* and *Sceloporus undulatus* for *Borrelia burgdorferi* infection shown by xenodiagnosis using *Ixodes scapularis* larvae.

Species	No. lizards	Mean larvae/lizard	Range larvae/host	No. positive/n tested (%)
E. fasciatus	20	8.2	(1–18)	0/164 (0)
S. undulatus	10	5.1	(1–11)	1/51 (1.96)

(MD and NY: Giery and Ostfeld, 2007)

More research on lizard competency on the east coast is needed

TABLE 4

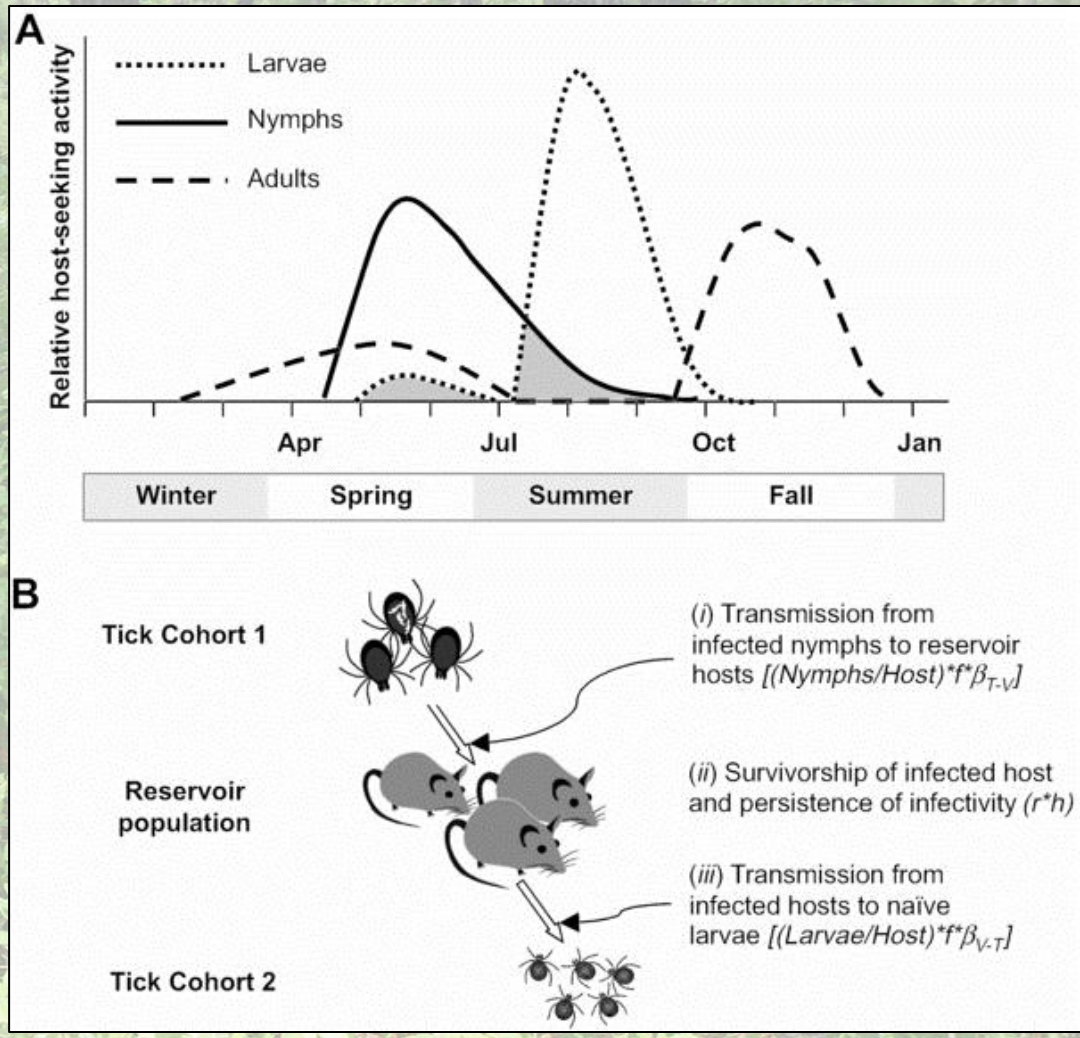
Proportion of *Ixodes scapularis* nymphs infected with *Borrelia burgdorferi* during larval feeding on tick-exposed southeastern five-lined skinks (*Eumeces inexpectatus*) and green anoles (*Anolis carolinensis*)

Lizard species	Animal no.	No. of ticks examined	No. of ticks infected	Percent infected
Five-lined skink	1	6	0	0
	2	21	5	23.8
	3	182	61	33.5
	4	45	3	6.7
	5	80	12	15.0
	6	90	19	21.1
	Total	424	100	23.6
Green anoles	1	7	0	0
	2	20	0	0
	3	14	0	0
	4	4	1	25.0
	5	1	0	0
	6	1	0	0
	Total	47	1	2.1

(LA: Levin et al., 1996)

Phenology hypothesis

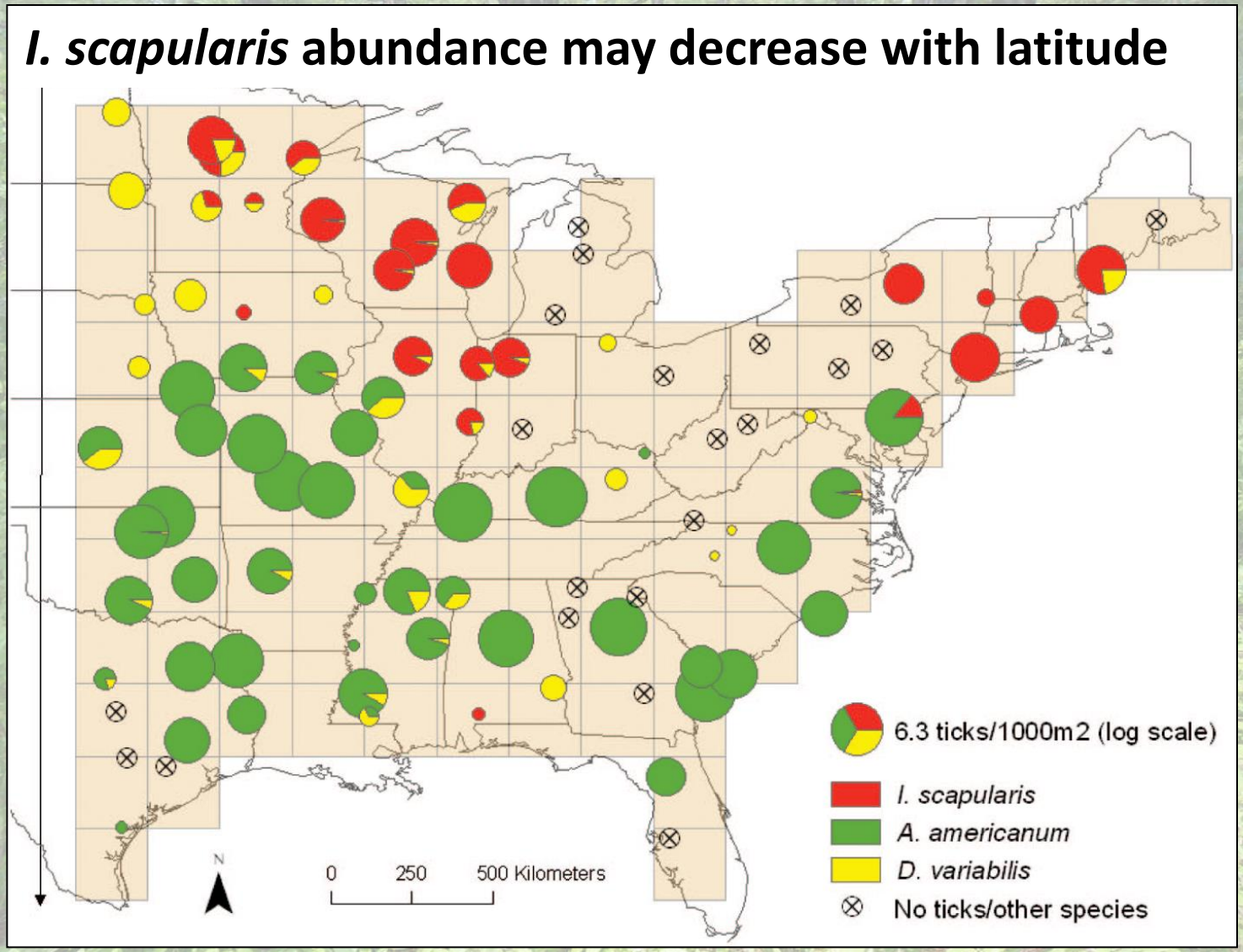
- **Infected hosts must acquire *B. burgdoferi* infections from previously infected nymphs to pass the spirochete to larvae**
- **For larvae to become infected, nymph activity must precede larval activity**



(Tsao, 2009)

Abundance Hypothesis

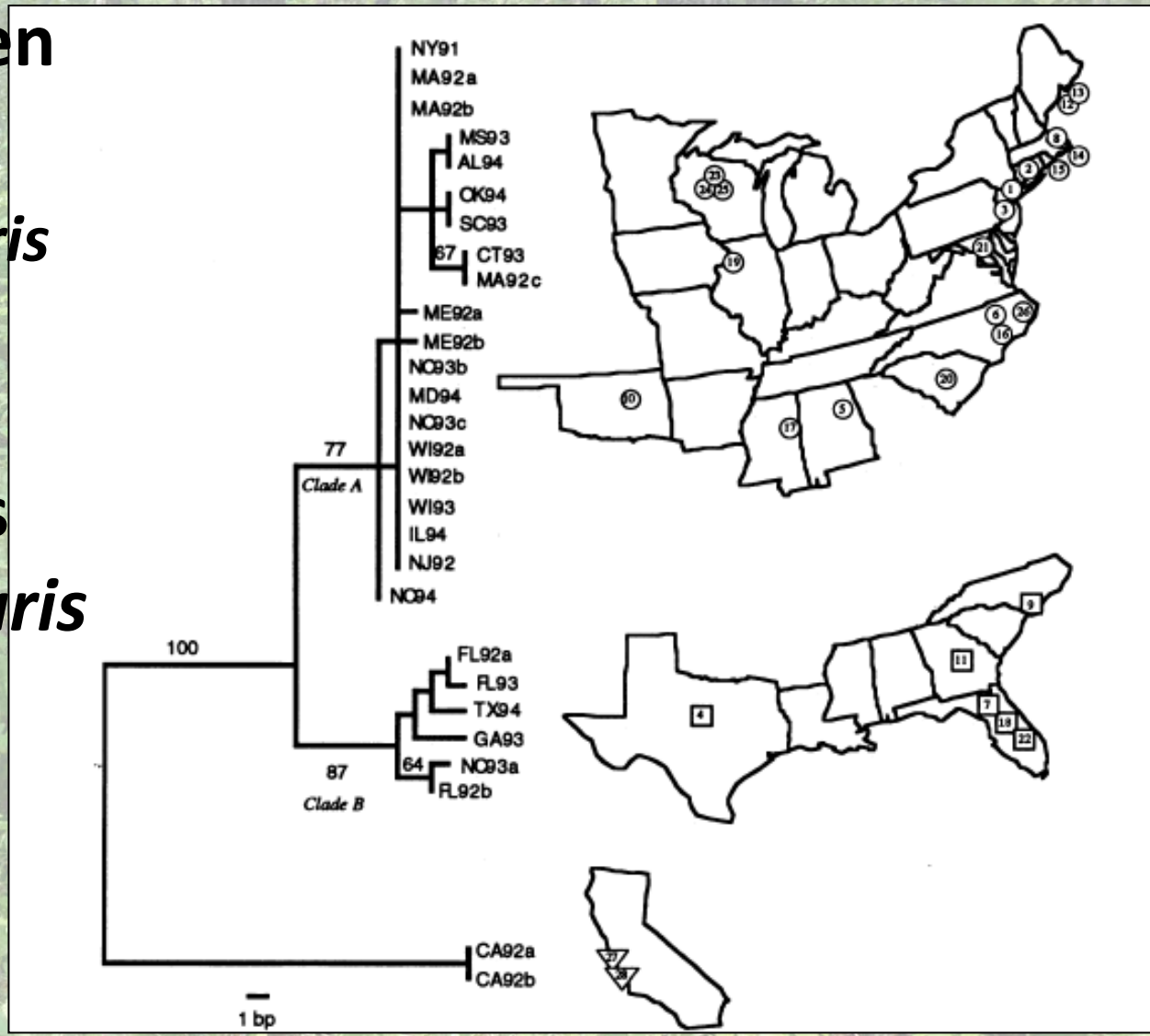
***I. scapularis* abundance may decrease with latitude**



Density per 1,000 m^2 (log scale) of the most abundant species of ticks (nymphs and adults pooled) collected in each of the 95 study sites (Diuk-Wasser et al., 2006)

Genetic Hypothesis

- Two genetic clades have been identified
  - split *I. scapularis* into north and south
- Do these clades affect *I. scapularis* questing behaviors?



The Team

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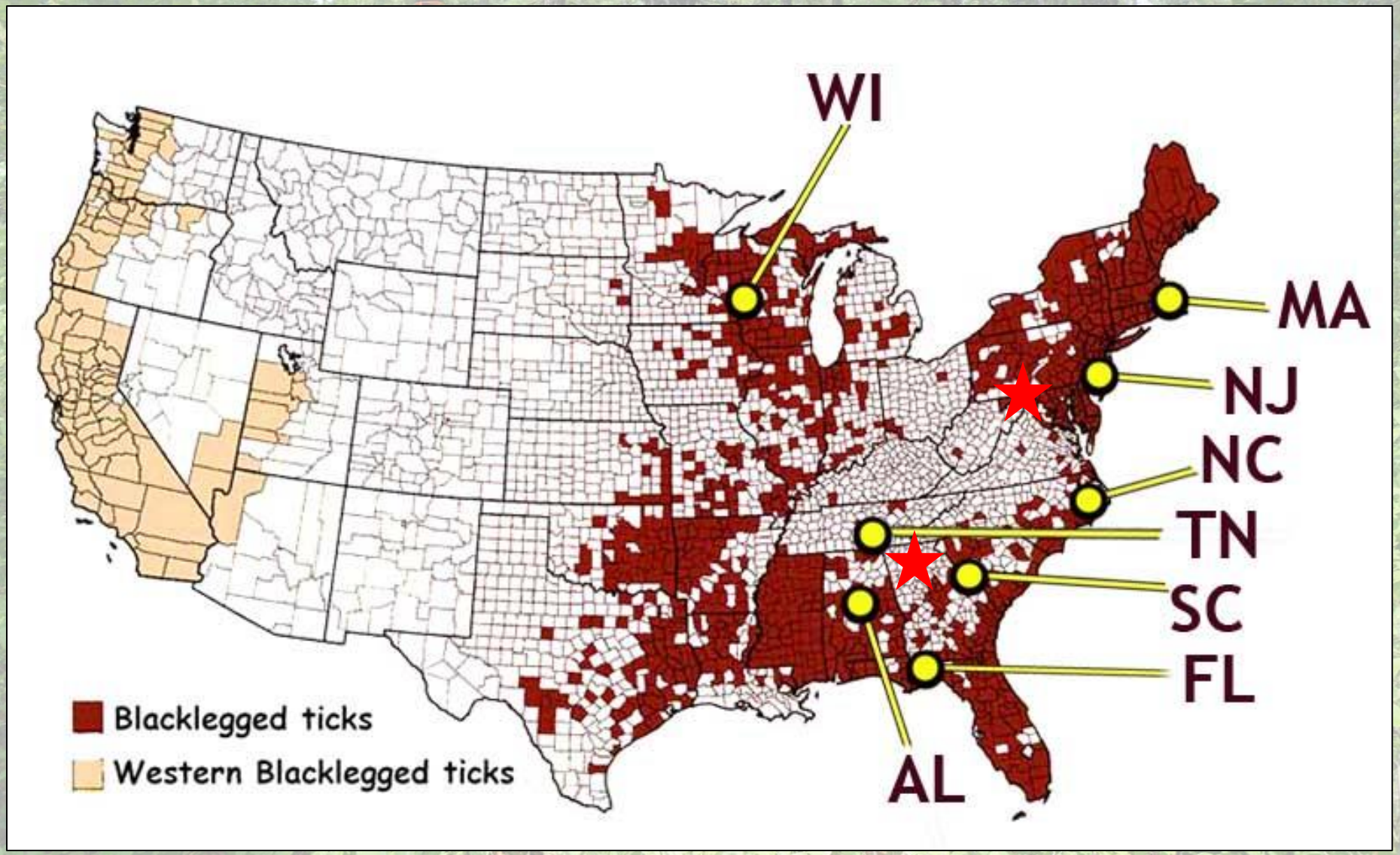
Methods



http://wildlifehealth.tennessee.edu/lyme_gradient/index.htm

Methods


SRS Array A- Dry Bay


SRS Array B- Four-Mile

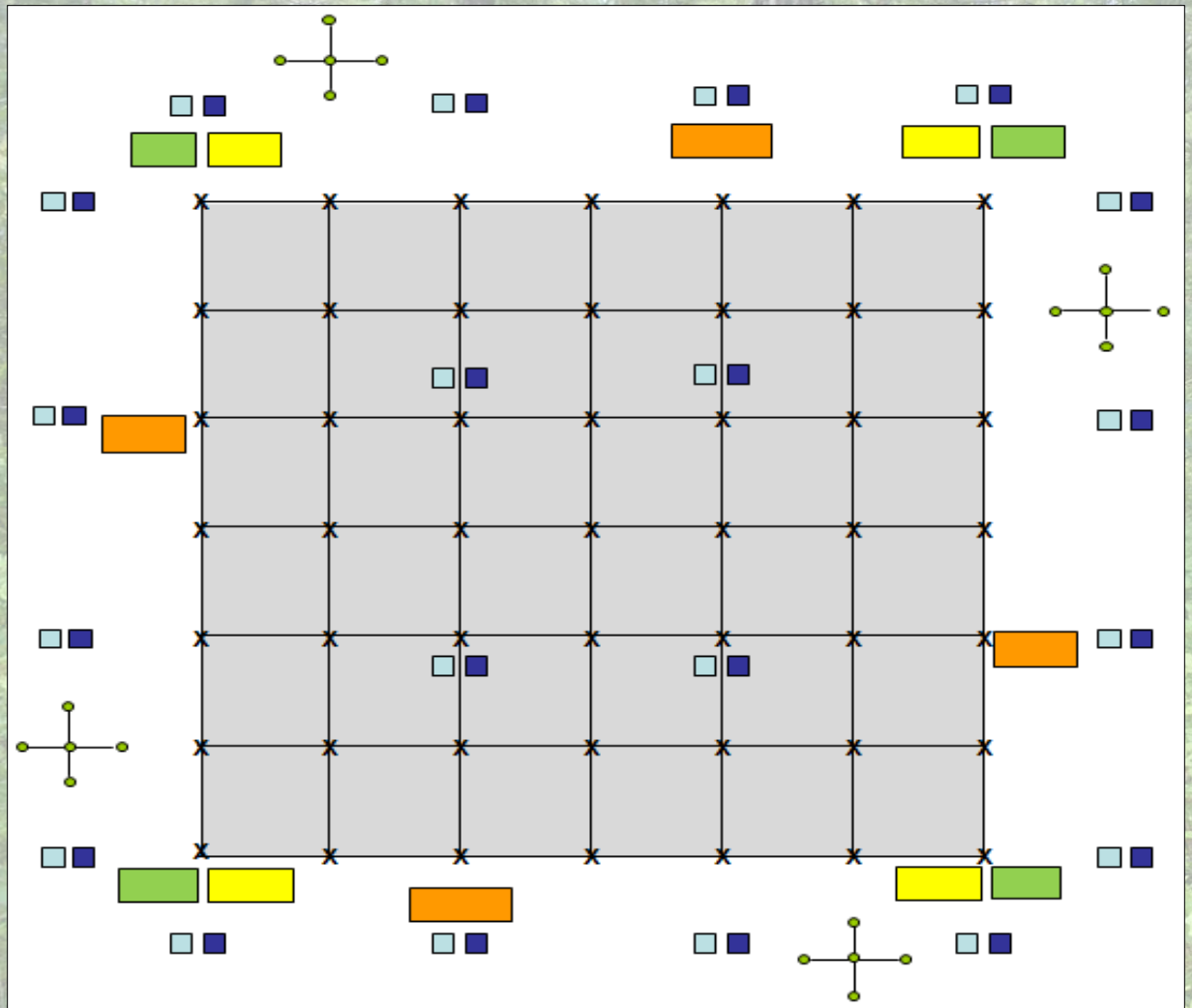
Savannah River Site (SRS) Array Locations


SRS Array C- Long Tin

Methods

Rutgers University's Pinelands Field Station(PFS)

Methods



- 49 Sherman traps
- 4 Tomahawk traps
- 4 Camera traps
- 4 Scent lure stations
- 4 Pitfall/drift fence arrays (20 buckets)
- 20 Metal coverboards
- 20 Wooden coverboards
- 20 Burlap bands

Methods

Methods

Collecting Data and Marking Individuals

Peromyscus gossypinus

Plestiodon laticeps

Scincella lateralis

Methods

Collecting Data and Marking Individuals


Peromyscus gossypinus


Sceloporus undulatus

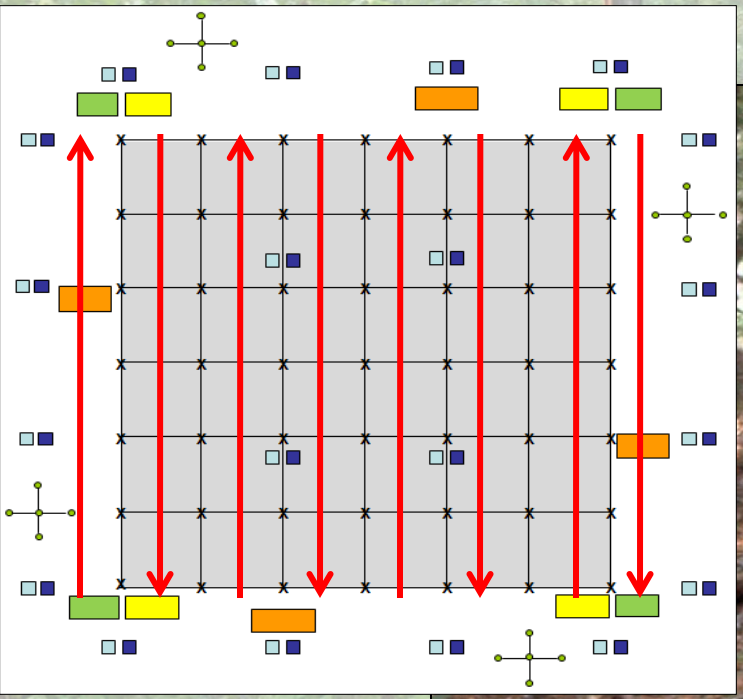

Plestiodon fasciatus

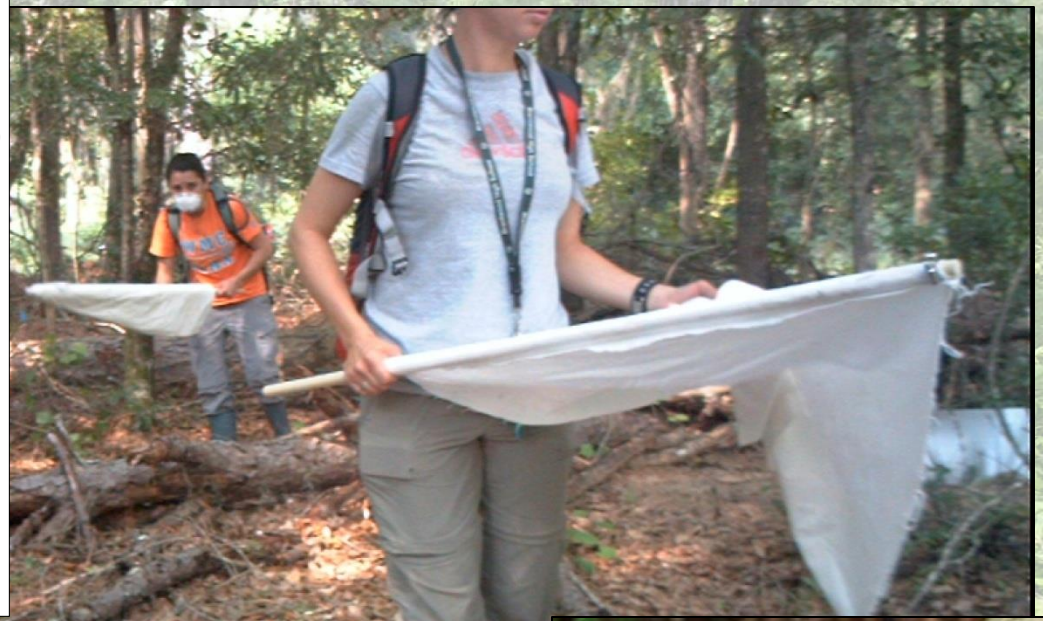

Anolis carolinensis


Anolis carolinensis

Methods

Flag/ Drag

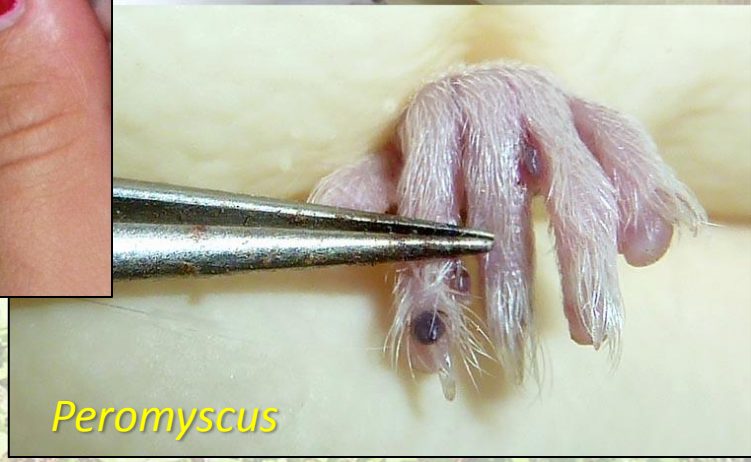




720m total

http://lymegradient.blogspot.com/search?updated-max=2012-04-03T21:59:00-07:00&max-results=10&start=20&by-date=false

Results



http://wildlifehealth.tennessee.edu/lyme_gradient/training1.htm

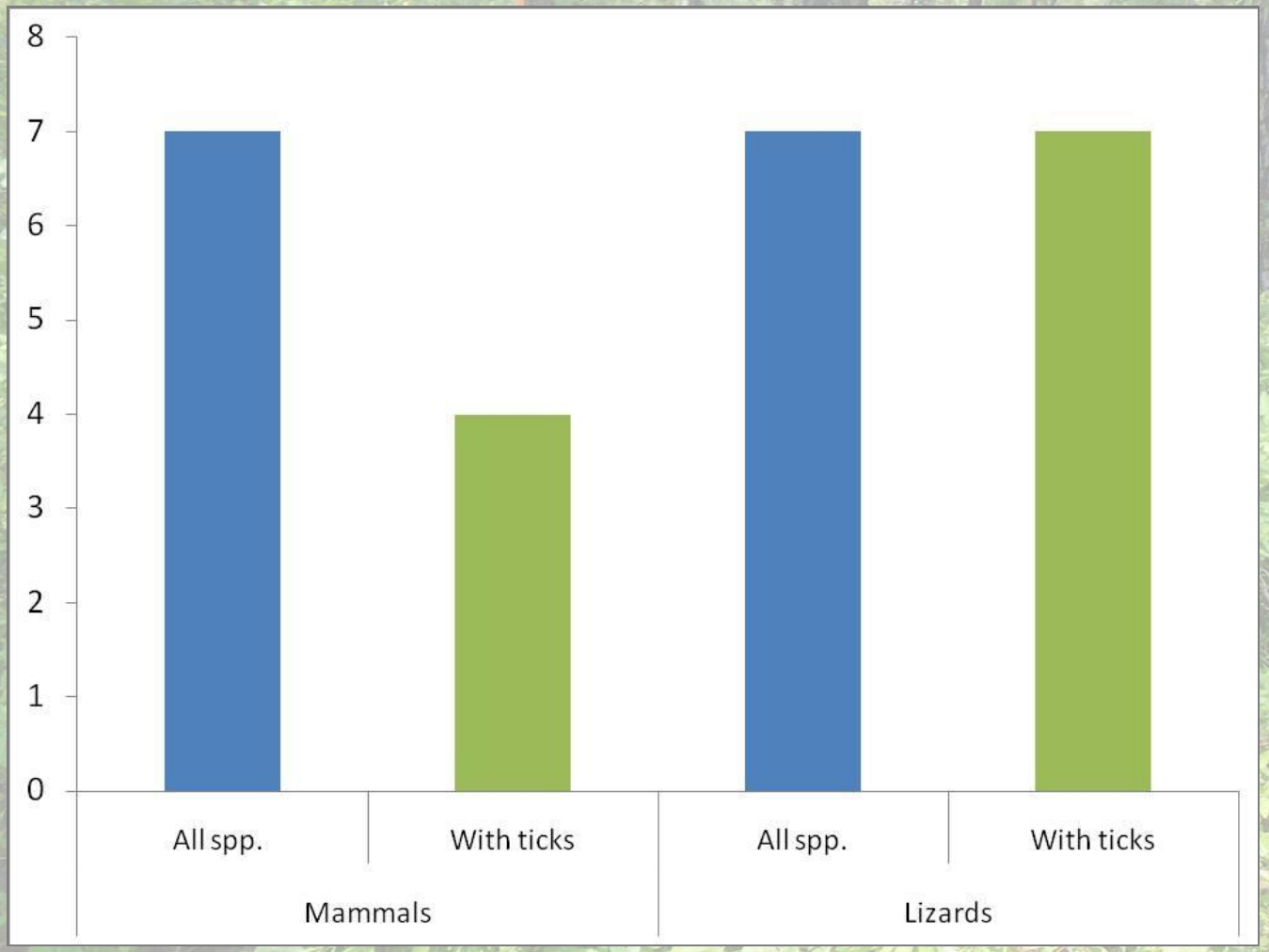
Results

Capture effort and capture rates (hours per capture) for each sampling method for all trapping periods (2010-2012)

	PFS			SRS		
Method	Total trap hours/ checks	Small mammal	Lizard	Total Trap hours/ checks	Small mammal	Lizard
Sherman traps	18,828[a]	1/105	-	116,868	1/618	-
Pitfall traps	21,240[a]	1/923	1/5,310	91,872	1/1,997	1/718
Coverboards	720[b]	-	1/720	8,686	-	1/20
Burlap	360[b]	-	1/90	2,099	-	1/22

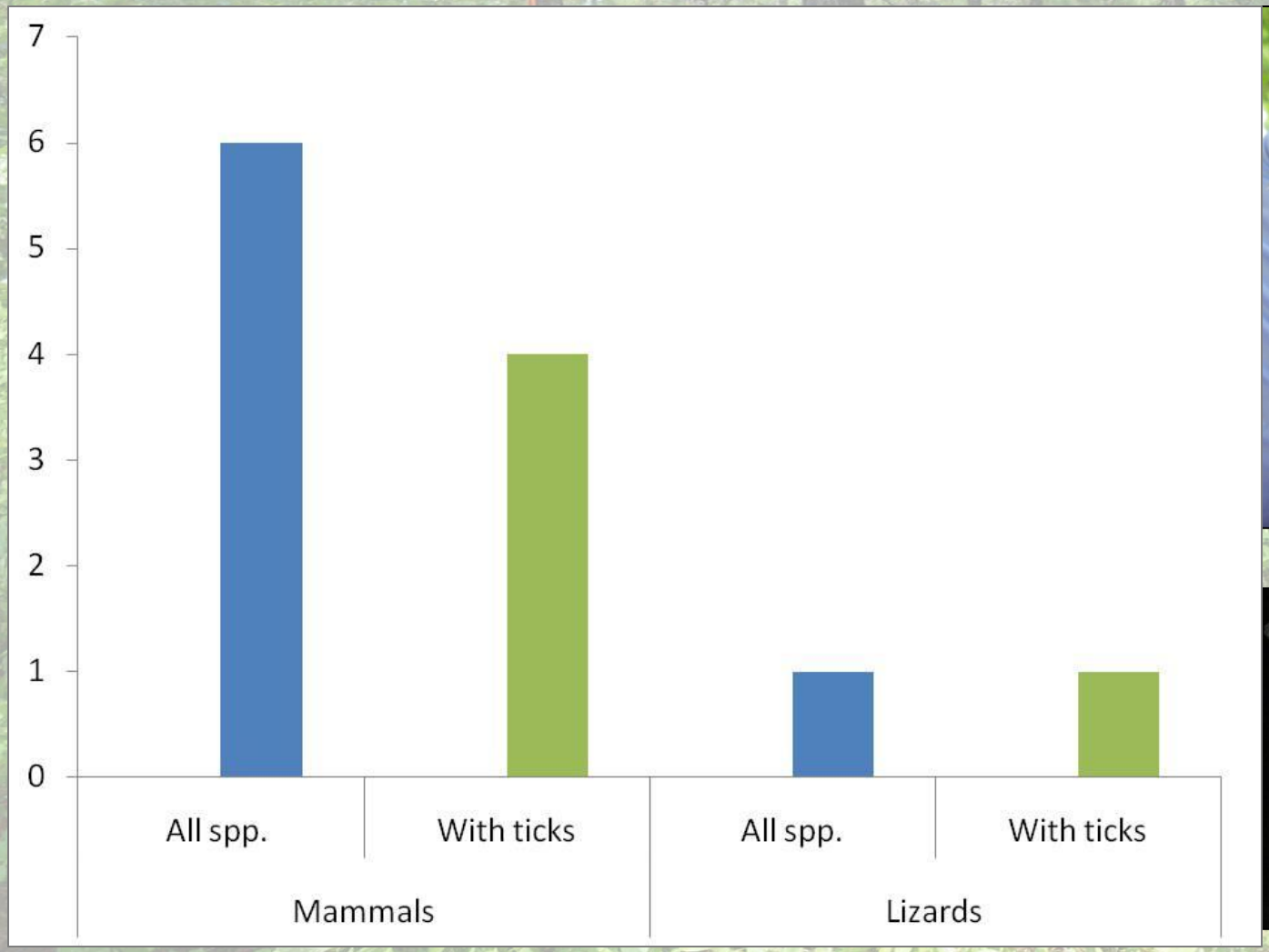
[a] trap hours; [b] checks

Results



Species richness at SRS with number of species that hosted ticks.

Results



Species richness at PFS with number of species that hosted ticks.

Results

Species	No. infested/ No. captured	% infested	Mean LL (±SE)	Mean NN (±SE)
SRS				
P. laticeps	49/81	60.49	6.75 (3.15)	1.56 (0.19)
Sorex species	7/15	46.67	4.86 (0.75)	0
Plestiodon fasciatus	8/18	44.44	3.33 (0.47)	1.4 (0.12)
P. inexpectatus	4/16	25.00	1	1
Aspidoscelis sexlineata	2/18	11.11	1	1
Scincella lateralis	7/108	6.48	1.43 (0.12)	0
Peromyscus gossypinus	12/184	6.52	1.75 (0.23)	1
Sceloporus undulatus	2/58	3.45	1	3
Anolis carolinensis	1/143	0.70	1	0
PFS				
Microtus pinetorum	5/6	83.33	2.75 (0.34)	3
Sorex species	3/5	60.00	2.73 (1.05)	0
Peromyscus leucopus	66/129	51.16	5.54 (1.56)	1.25 (0.14)
Sceloporus undulatus	1/15	6.67	3	0

Results

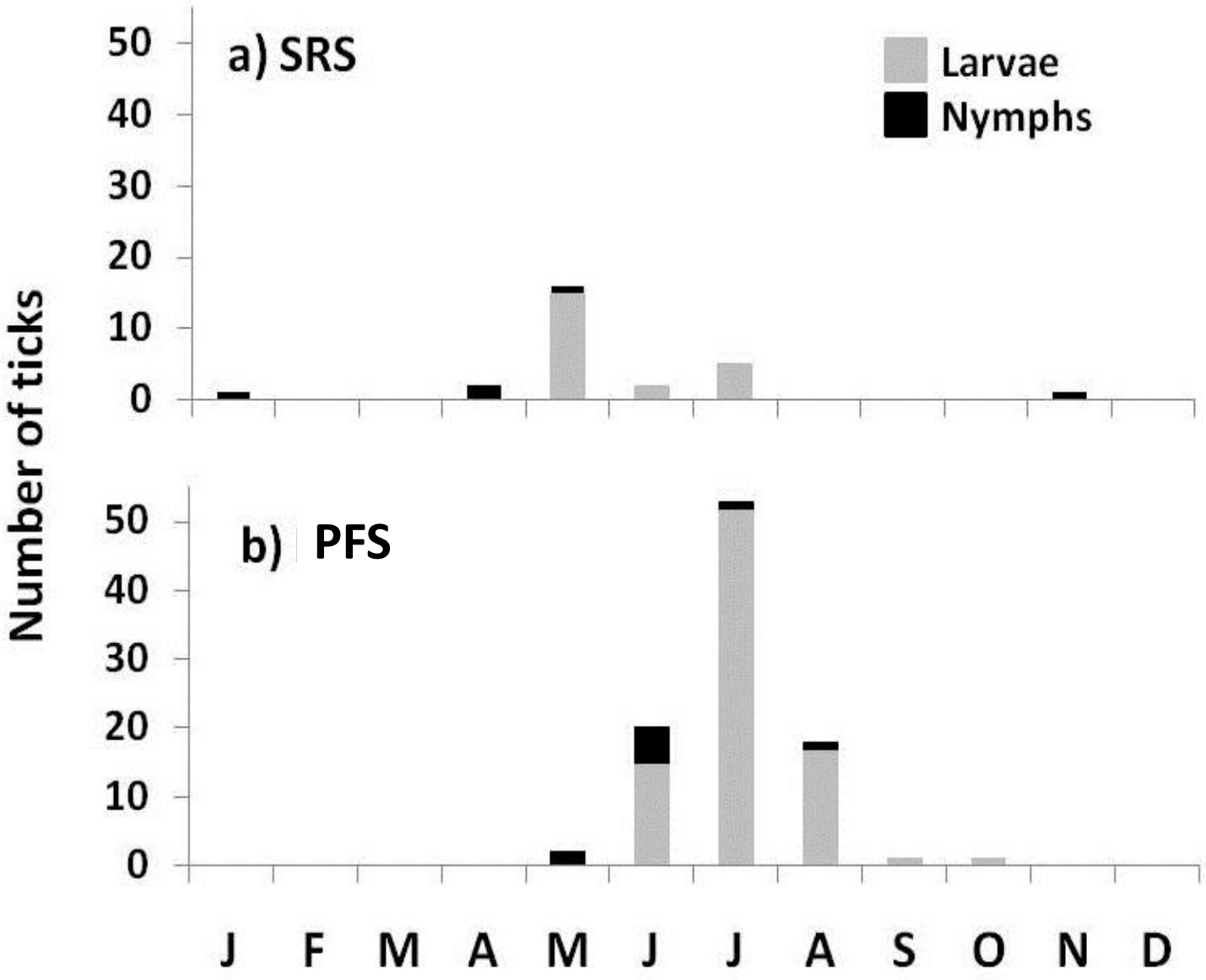
Both Sites

- **Northern mammals had higher tick burdens**
- **Southern lizards had higher tick burdens**

SRS		PFS	
Total ticks from hosts	% from lizards	Total ticks from hosts	% from lizards
261	80.5	496	0.6

Flag/ Drag

Results

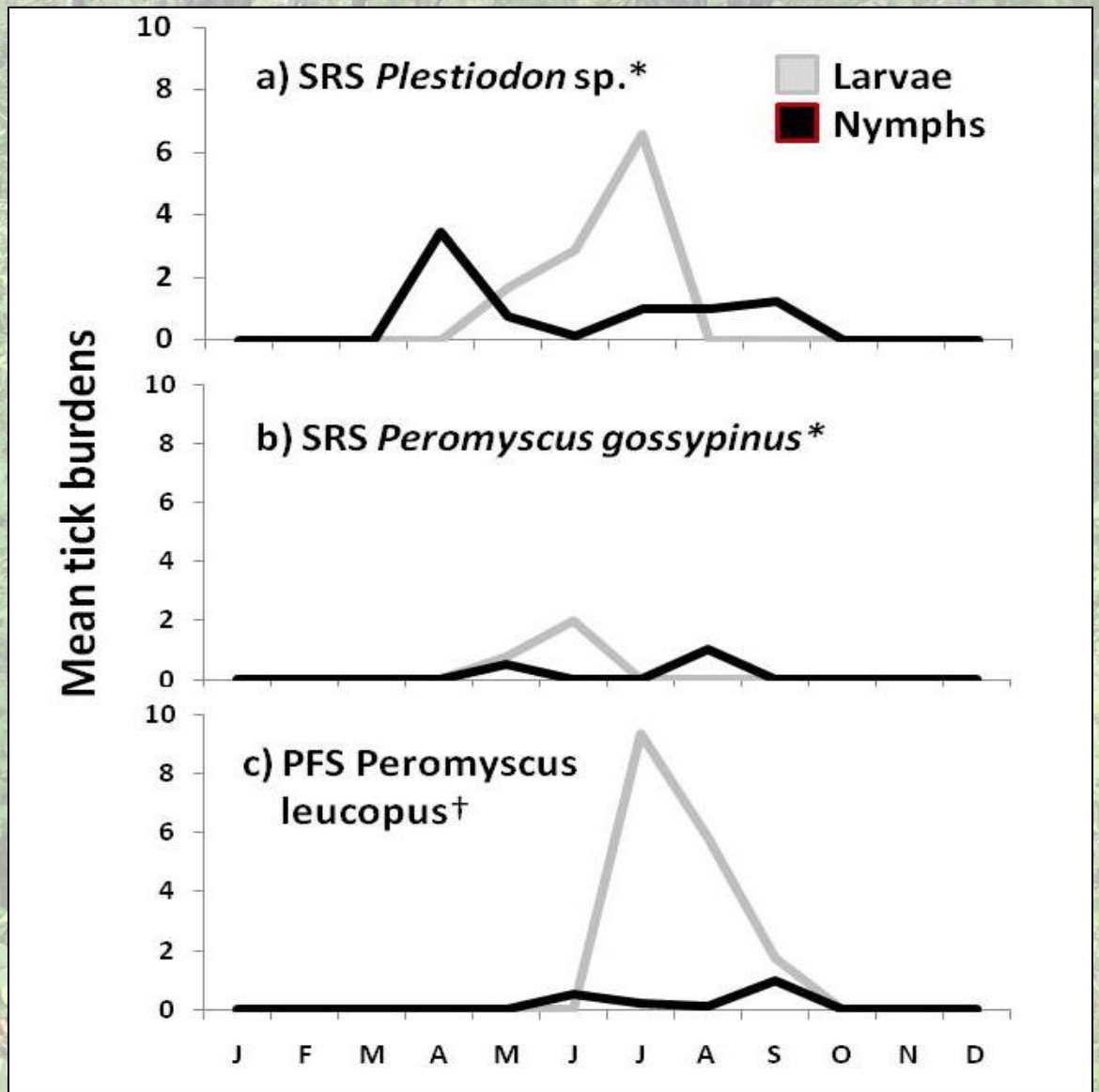


Results

I. scapularis on Hosts

******Plestiodon* **and** ***P. gossypinus*** **mean tick burdens from 2010-2012 combined at SRS.**

† ***P. leucopus*** **mean tick burdens from PFS in 2011.**



Discussion

Dilution Effect Hypothesis

- **Results at SRS:**
  - **Confirmed importance of lizards (*Plestiodon)***

  - ***Peromyscus* were infested by *I. scapularis* significantly less frequently than were *Plestiodon* at SRS**

Discussion

Dilution Effect Hypothesis

- **In NJ:**
  - ***P. leucopus* and *Sorex* were the predominant hosts for juvenile *I. scapularis***
  - **Significantly higher mean burdens on infested individuals of *P. leucopus* at PFS than *P. gossypinus* at SRS**

Discussion

Phenology Hypothesis

- **Emergence juvenile *I. scapularis* at SRS earlier in than at PFS**
- **Nymphs at both SRS and PFS emerged before larvae**
- **Does not support Phenology Hypothesis.**

Discussion

Abundance Hypothesis

- **Fewer immature *I. scapularis* flag/drag at SRS than at PFS**

- **Difficulties of collecting juvenile *I. scapularis* in the southeastern U.S. have been seen before**

Discussion

Abundance Hypothesis

- Abundance of immature *I. scapularis* on *Plestiodon* at SRS
- Is there really lower abundance of *I. scapularis* in the south?
- Future research needed

P. laticeps

Discussion

Genetic Hypothesis

- **Perhaps behavioral differences between *I. scapularis* juveniles at SRS and PFS based on flag/drag success**

- **clades may quest differently because associated with different host communities**

What's Happening now

- Series of secondary studies

Laboratory study of reservoir competence of *Sceloporus undulatus* for *Borrelia burgdorferi*.

Infestation Date	host	% hosts with engorged larvae*	Number of engorged larvae	% infected	# infected/# tested
3 August	mouse†	100		79.9 %	167/209
30 July	lizard‡	100	153	0	0/99
7 Sept	lizard	90	42	0	0/34
3 Oct	lizard	70	35	0	0/17
2 Nov	lizard	80	37	0	0/9

*** Percent of host animals from which at least one engorged larva was recovered.**

† Five *Peromyscus leucopus* from uninfected lab colony.

‡ Ten *Sceloporus undulatus*, wild-caught from southern/central New Jersey.

What's Happening now

- Completion of all btwn site data analysis
- Modeling
- Paper writing

Acknowledgements

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Wonderful hosts at field sites
Many wonderful field and lab students!