

# Complex Ecology of Lyme Disease in the South



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# Incidence\* rates for Lyme disease cases reported to CDC

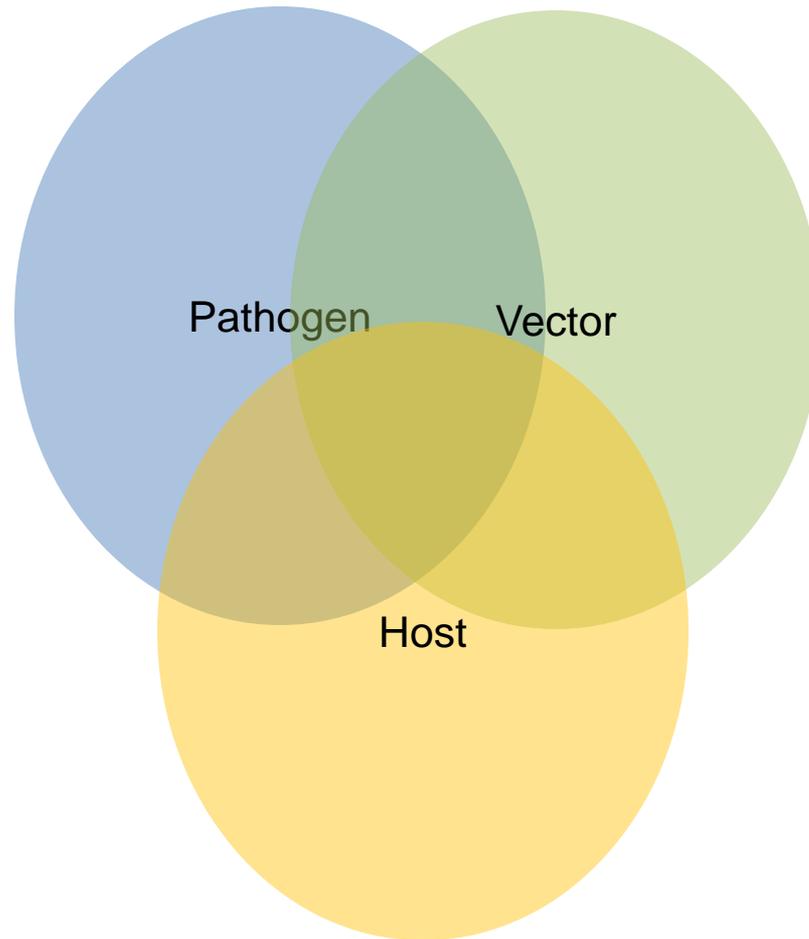
State	2005	2006	2007	2008	2009
Maryland	22.1	22.2	45.8	31.0	25.7
Virginia	3.6	4.7	12.4	11.4	8.9
North Carolina	0.6	0.4	0.6	0.2	0.2
South Carolina	0.4	0.5	0.7	0.3	0.5
Georgia	0.1	0.1	0.1	0.4	0.4
Florida	0.3	0.2	0.2	0.4	0.4

\*incidence=confirmed cases per 100,000 persons, calculated using July 1st population estimates for each year

Source: [http://www.cdc.gov/ncidod/dvbid/lyme/ld\\_IncidenceRatesbyState20052009.htm](http://www.cdc.gov/ncidod/dvbid/lyme/ld_IncidenceRatesbyState20052009.htm)

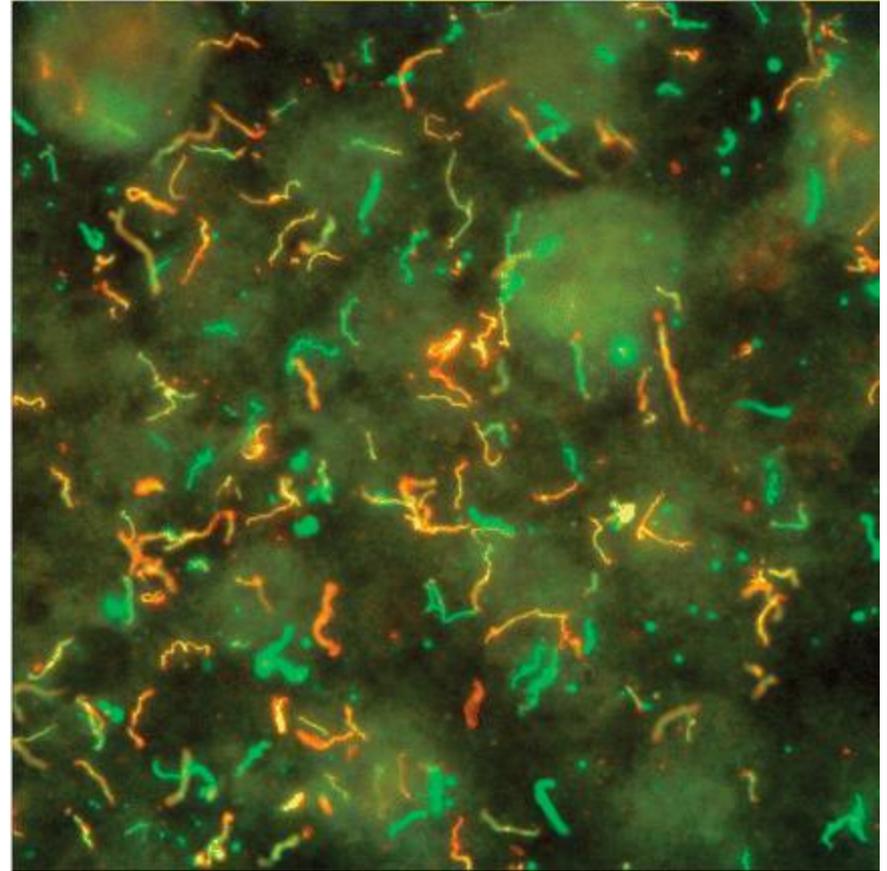
## Is Lyme disease expanding southward?

# Lyme Disease is a zoonotic disease.



# *Borrelia burgdorferi* s. l.

Pathogen



Cover photo: Infect. Immun. 2008. 76(5)

## Southern members of the *Borrelia burgdorferi* s. l. complex of genospecies

- *B. burgdorferi* s.s., *B. bissettii*, *B. andersoni*

### Newly described genospecies

- *B. carolinensis* (Rudenko et al. 2009a. J. Clin. Micro. 47:134-141.): isolated from *Peromyscus gossypinus* and *Neotoma floridana*.
- *B. americana* (Rudenko et al. 2009b. J. Clin Micro. 47:3875-3880): isolated from *Ixodes minor* nymph.
- *B. kurtenbachii* sp. nov. (Margos et al. 2010. Ticks Tick-Borne Dis. 1:151-158.): potentially occurs in the south but not yet documented.

# Diverse *Borrelia* genospecies occur in the southern US.

- Do these new *Borrelia burgdorferi* s.l. genotypes represent phenotypes that cause human disease?
- How are these *Borrelia* genospecies maintained in nature? Do the tick vectors and rodent reservoir hosts vary?
- What is the geographic distribution of these genospecies in the southern US.

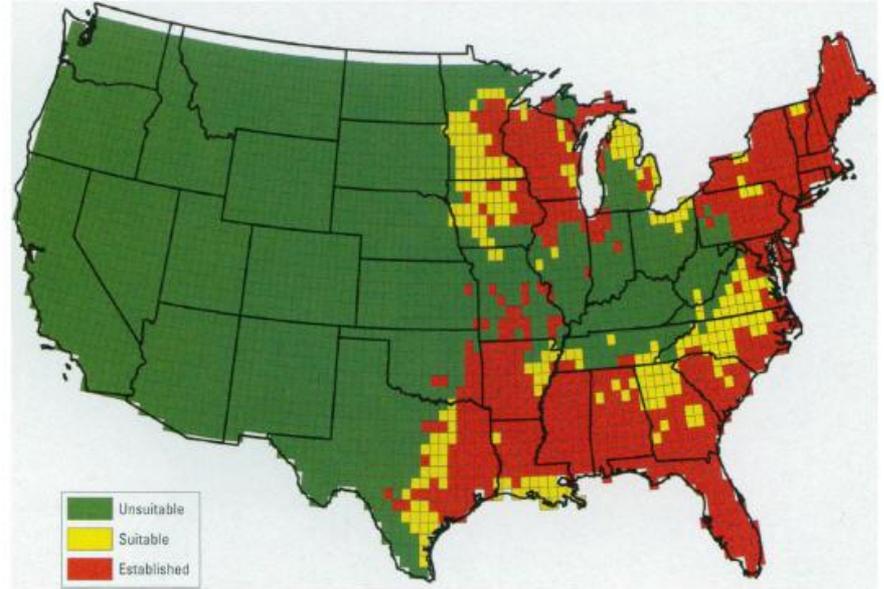
Vector

*Ixodes* spp. in the  
*I. ricinus* complex



# Prototypical Lyme borreliosis vector: *Ixodes scapularis* (black-legged tick)

- A member of the *I. ricinus* complex.
- Distributed geographically in the upper midwestern, northeastern and throughout the southern US.

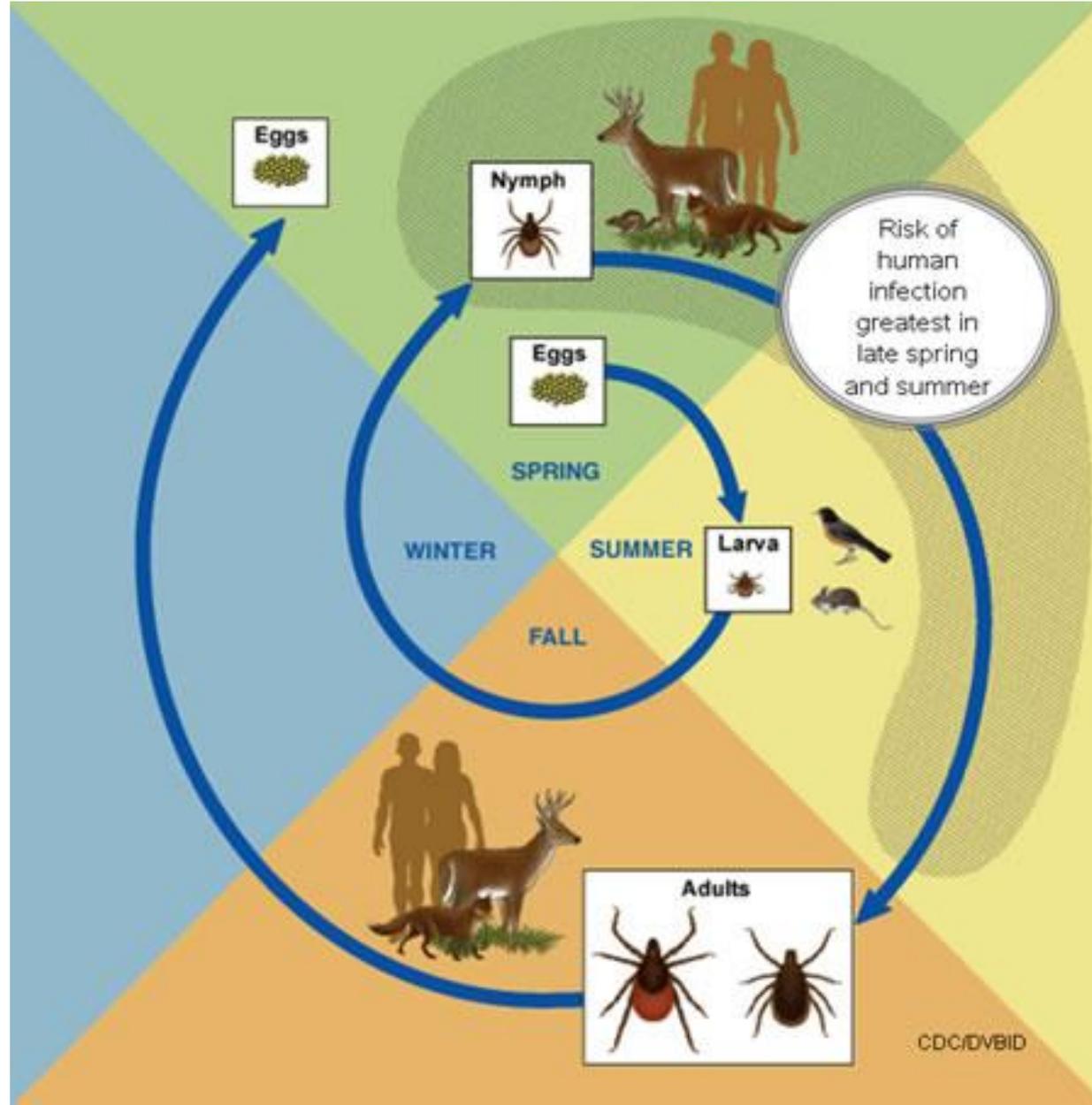


**Figure 5.** New distribution map for *I. scapularis* in the United States. To determine whether a given cell can support *I. scapularis* populations, a probability cutoff point for habitat suitability from the autologistic model was assessed by sensitivity analysis. A threshold of 21% probability of establishment was selected, giving a sensitivity of 97% and a specificity of 86%. This cutoff was used to reclassify the reported distribution map (Dennis et al. 1998). The autologistic model defined 81% of the reported locations ( $n = 427$ ) as established and 14% of the absent areas ( $n = 2,327$ ) as suitable. All other reported and absent areas were considered unsuitable. All areas previously defined as established maintained the same classification.

Source: Brownstein et al. 2003. Environ. Hlth. Perspec. 111:1152-1157.

# Life cycle of *I. scapularis* in the NE

- In LD endemic areas, *I. scapularis* has a 2-year life cycle in which the seasonal activity of nymphs precedes that of larvae.
- Spring-summer occurrence of LD is correlated with nymph activity.
- In the northeast and upper midwest US, *I. scapularis* is an enzootic vector as well as a bridge vector for *B. burgdorferi* to people.



# *Borrelia burgdorferi* s. l. transmission

- Enzootic: wildlife  $\rightleftharpoons$  tick
  - *Ixodes scapularis*
  - *Ixodes affinis*
  - *Ixodes minor*
- Endemic: wildlife  $\rightleftharpoons$  tick  $\longrightarrow$  human
  - *Ixodes scapularis*
  - ?

# *Ixodes scapularis* occurs throughout the southern US, but...

- Do southern and northern *I. scapularis* have the same life cycle?
  - Adults are active in late fall-winter in the south and north
  - Nymphs are difficult to collect in the south
- Do southern *I. scapularis* bite people?
  - Rarely compared to northern *I. scapularis* or other ticks in the south (Falco and Fish 1988, 1989; Felz et al. 1996; Merten and Durden 2000)
- What tick species commonly bite people?

Numbers and life stages of tick species collected by flagging vegetation on the home grounds of 32 residences in Chatham County, NC from April 9 to July 24, 2005.

Tick species	Number collected (% of total)			
	Females	Males	Nymphs	All stages
<i>Amblyomma americanum</i>	578 (8.9)	506 (7.8)	5,390 (82.9)	6,474 (99.6)
<i>Dermacentor variabilis</i>	17 (0.3)	10 (0.2)	0	27 (0.4)
<i>Ixodes scapularis</i>	0	0	1 (< 0.1)	1 (< 0.1)

From Apperson et al. 2008. VBZD 8:597-606.

Highest attack rates would be expected from lone star ticks, which residents often refer to as “deer ticks”.

Numbers and life stages of tick species collected by flagging vegetation at 26 sites in Chatham County, NC in 2006.

Tick species	Number collected (% of total)			
	Females	Males	Nymphs	All stages
<i>Amblyomma americanum</i>	260 (7.0)	342 (9.3)	3,093 (83.7)	3,695 (98.6)
<i>Dermacentor variabilis</i>	15 (0.4)	21 (0.6)	0	36 (1.0)
<i>Ixodes scapularis</i>	4 (0.1)	0	15 (0.4)	19 (0.5)

Smith et al. 2010. VBZD 10:939-952.

# Enzootic transmission of the Lyme disease spirochete does occur in the southern US.

- Enzootic transmission of *B. burgdorferi s.l.* has been well documented in Georgia, South Carolina, and North Carolina (Oliver et al. 2003. PNAS 100:11642-11645; Clark, et al. JME 39:198-206; Ouellette et al. 1997. JWD 33:28-39.).
- Hundreds of isolates of *Borrelia burgdorferi s. l.* have been cultured from ticks and wildlife in the southern US, but not one isolate has been obtained from a human.

The ecology *Ixodes* spp. and *Borrelia burgdorferi* s. l. in the south appears to be changing.

Harrison, B. A., et al. 2010. Recent discovery of widespread *Ixodes affinis* (Acari: Ixodidae) distribution in North Carolina with implications for Lyme disease studies. J. Vector Ecol. 35:174-179.

- ***Ixodes affinis* has been collected by flagging vegetation in 32 of 40 counties in the Coastal Plain of North Carolina.**
- **Not found (yet) in the Piedmont.**
- **Similar distribution in SC and GA.**

*Ixodes affinis* is an enzootic vector of *Borrelia burgdorferi* s. l.

Maggi, R.G., et al. 2010. *Borrelia* species in *Ixodes affinis* and *Ixodes scapularis* ticks collected from the coastal plain of North Carolina. Ticks Tick-borne Dis. 1:168-171.

*Borrelia burgdorferi* s. s. and *B. bissettii* detected by PCR in *Ixodes affinis* and *Ixodes scapularis* ticks collected from the coastal plain of North Carolina 2008 and 2009.

- **52/155 (35.6%) were infected with *B. burgdorferi* s.s.**
- **43/155 (29.0%) were infected with *B. bissetti***
- **0/298 (0%) *Ixodes scapularis* adults contained *Borrelia* spp. DNA.**

*Peromyscus leucopus*  
White-footed mouse



Host



*Odocoileus virginianus*  
White-tailed deer

# The dilution effect...

Is the lack of *Borrelia burgdorferi* infection in *Ixodes scapularis* adults a result of larvae and nymphs feeding on vertebrates that are not reservoir-competent?

**Table 3. Ticks infesting rodents that were live-trapped on Marine Corps Base, Camp Lejeune from July, 1990 to January 30, 1992. A total of 6,113 trap-nights were expended at 26 trapping sites.**

Species	No. tick-infested/ no. examined	% tick infested	No. recaptured	<i>Ixodes scapularis</i>		<i>Amblyomma americanum</i>		<i>Dermacentor variabilis</i>	
				l	n	l	n	l	n
White-footed mouse ( <i>Peromyscus leucopus</i> )	10/58	17.2	20	1	0	0	0	17	3
Cotton mouse ( <i>P. gossypinus</i> )	10/49	20.4	8	4	0	0	1	7	3
Golden mouse ( <i>Ochrotomys nuttallii</i> )	2/8	25.0	1	0	0	0	0	8	4
House mouse ( <i>Mus musculus</i> )	1/3	33.3	0	0	0	0	0	3	0
Cotton Rat ( <i>Sigmodon hispidus</i> )	0/11	0.0	0	0	0	0	0	0	0
<b>Totals</b>	<b>23/129</b>	<b>17.8</b>	<b>29</b>	<b>5</b>	<b>0</b>	<b>0</b>	<b>1</b>	<b>35</b>	<b>10</b>

Apperson, Levine, et al. 1993. Exp Appl Acarol 17:719-731.

**Table 2.** Tick species infesting lizards captured on Marine Corps Base, Camp from April 1 to September 30, 1991. A total of 2,195 trap-days were expended with drift fences at 10 sites.

Species	No. tick infested/no. examined	% tick infested	No. captured in drift fences	No. recaptured	<i>Ixodes scapularis</i>	
					larvae	nympths
<i>Eumeces inexpectatus</i> (southeastern five-lined skink)	23/33	69.7	33	7	69	27
<i>E. laticeps</i> (broad-headed skink)	7/8	87.5	7	0	45	11
<i>Scincella lateralis</i> (ground skink)	19/51	37.3	40	1	27	9
<i>Ophisaurus ventralis</i> (eastern glass lizard)	5/6	83.3	4	0	47	0
<i>Cnemidophorus sexlineatus</i> (six-lined race runner)	0/14	0.0	14	1	0	0
<i>Sceloporus undulatus</i> (northern fence lizard)	0/11	0.0	7	0	0	0
<i>Anolis carolinensis</i> (green anole)	0/24	0.0	13	1	0	0
<b>Totals</b>	<b>54/147</b>	<b>36.7</b>	<b>118</b>	<b>10</b>	<b>188</b>	<b>47</b>

# Are lizards reservoir competent?

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
Green anole	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

# Long term investigation of *B. burgdorferi* transmission on the Outer Banks of NC



Characterize spirochete transmission:

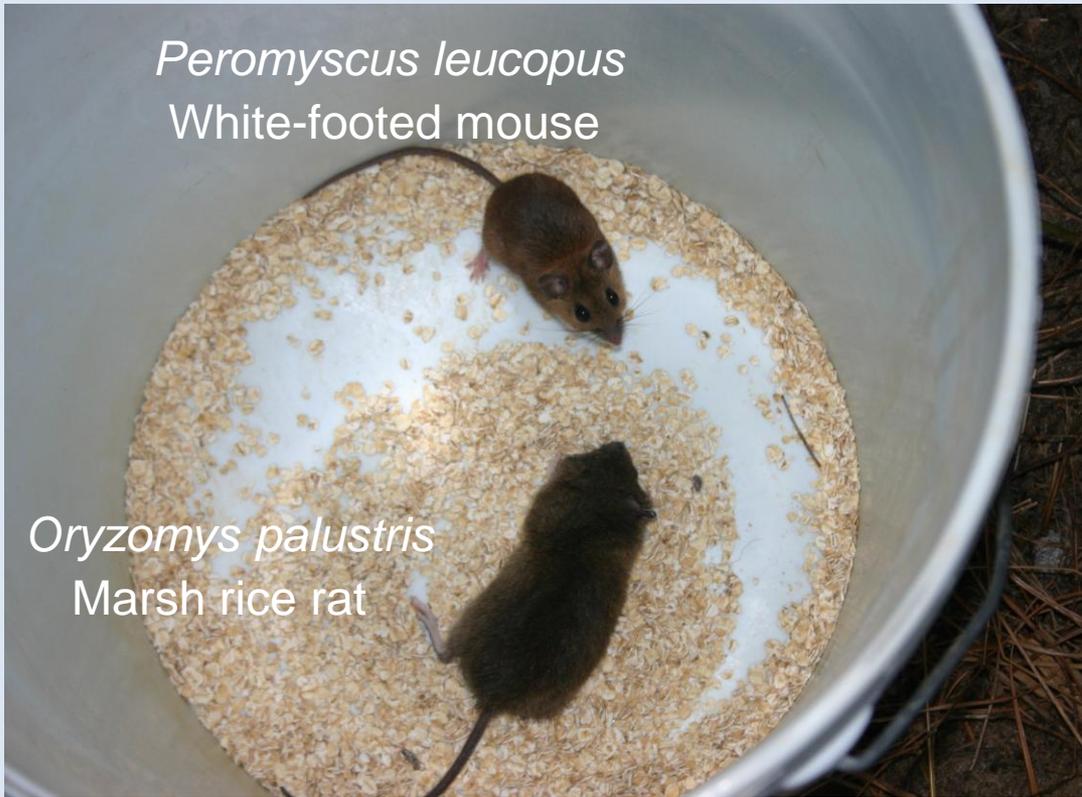
- Infection rates in rodents
- Infection rates in ticks





*Peromyscus leucopus*  
White-footed mouse

*Oryzomys palustris*  
Marsh rice rat



Important rodent hosts  
for *Ixodes scapularis* on  
Pine Island

*Marsh rabbit*  
(*Sylvilagus palustris*)



# Hosts of *Ixodes scapularis* on the Outer Banks of NC

- The rice rat (*Oryzomys palustris*), white footed mouse (*Peromyscus leucopus*), eastern cottontail (*Sylvilagus floridanus*) and marsh rabbit (*Sylvilagus palustris*) are the principal rodent hosts immature *I. scapularis*.
- Rodent abundance and tick burdens on rodents (< 1.0 per animal) appear to be low relative to the northeastern US.
- *Borrelia burgdorferi* infection rates in rice rats and white footed mice from several localities on the Outer Banks have varied from 12 – 50% over a 15 year period. A small percentage (<5%) of rabbits were culture positive.

# Ticks on the Outer Banks

- All stages of the lone star tick (*Amblyomma americanum*), adult American dog tick (*Dermacentor variabilis*), and adult black-legged tick (*Ixodes scapularis*) have been collected by flagging vegetation.
- *Borrelia burgdorferi* has only been detected or cultured from *I. scapularis*. Infected ticks have been collected at multiple localities over a 15 year period on the Outer Banks.

More questions than answers...

# FIELD-BASED ECO-EPIDEMIOLOGY STUDIES PROVIDE A FOUNDATION FOR DISEASE PREVENTION

- Physician-based cohort studies of patients presumptively diagnosed with a tick-borne illness in counties reporting a high incidence.
- Clinical specimens for pathogen identification by culture and molecular methods.
- Environmental surveys and ecological studies of the interaction of ticks and wildlife at the sites where patients were infected.

Thanks to the organizers of this  
symposium.