Characterization of Tick-borne Disease Risk in Alabama using NASA Earth Observation Systems

NASA Applied Sciences’ DEVELOP National Program
Marshall Space Flight Center/University of Alabama at Birmingham

Presenter: Steve Padgett-Vasquez
Community Concerns

• Currently, many state officials and physicians do not recognize the presence of Lyme disease and STARI in Alabama.
• The general public is not aware of the basic measures to prevent Tick-borne Illnesses (TBI).
• Objectives: Increase awareness of TBI and identify likely tick infested areas.
Project Methodology

Partners
- Dr. Robert Carter (JSU)
- Birmingham Lyme
- Camp Coleman
- UAB’s Outdoor Pursuits
- Dr. Leslie McClure (UAB School of Public Health)

Study Area & Period
- Talladega National Forest, Fort McClellan, and Birmingham, Alabama
- 5 terms, Summer 2009-Fall 2010

Satellite Imagery Utilized
- Landsat TM
- ASTER (Terra)

Science Advisor
Jeffrey C. Luvall, Ph.D.
NASA Marshall Space Flight Center

Lab Location
Lab of Global Health Observation
Director: Sarah H. Parcak, Ph.D.
University of Alabama at Birmingham
Lyme Disease (LD)


- Common symptoms: Erythema migrans, fever, fatigue and headache.

- 1982-Willy Burgdorfer found spirochetes in midgut of ticks sent from Shelter Island, NY, a place with endemic LD.

- The etiologic agent was named *Borrelia burgdorferi*.

- If left untreated, may result in long term effects: arthritis, neurocognitive difficulties or fatigue.

- First documented case of LD in Alabama was reported in 1986.
Blacklegged tick distribution

Blacklegged Tick
(Ixodes scapularis)
Distribution of other tick species
Other tick-borne Illnesses (TBI)

Confirmed Vector
- Blacklegged Tick
- Lone Star Tick
- American Dog Tick
- Brown Dog Tick
- Gulf Coast Tick

TBI
- Anaplasmosis
- Babesiosis
- Erlichiosis
- Rickettsiosis
- Rocky Mountain Spotted Fever
- STARI
- Tularemia
Primary Prevention

• Reducing exposure to ticks is the best defense against TBI.

• Primary personal protection methods:
  – Wear protective clothing
  – Wear light colored clothing
  – Apply tick (insect) repellants
  – Perform tick checks
  – Avoid or reduce time spent in high risk areas
The CDC Lyme disease prevention webpage states: “Ask your local health department and park or extension service about tick infested areas to avoid.”

However, NO local health department and park or extension service in the state of Alabama provide information about tick infested areas.
Remote sensing is a technique used to analyze emitted and reflected energy from earth, in multiple parts of the electromagnetic spectrum, using aircraft and satellites.
Environmental Factors for Ticks Populations

- Temperature: -10 to 35°C.
- Relative humidity: no lower than 80%.
- Vegetation: forest cover and decaying vegetation help maintain relative humidity.
- Soil moisture helps tick avoid desiccation.
Normalized Difference Vegetation Index

- Creates a ratio between -1 and 1 using the visible and NIR bands
- Helps separate areas with vegetation and those without.
- Can track vegetation vigor.

\[
NDVI = \frac{(NIR - RED)}{(NIR + RED)}
\]
ASTER NDVI and SM
Tick Drag across 12 sites in the Talladega National Forest

Tick Count vs Soil Moisture (%)
Tick Life Cycle

Stages:
- Egg
- Larva
- Nymph
- Adult

(2 years)
Limitations

• Small sample size.

• CDC case data does not indicate time of year or location of contraction.

• Vegetation by itself may not be a good indicator of tick presence.

• Need to consider the ecology of the vector and hosts.
Tick Hosts

- Small mammals
  - For larval and nymphal stages

- White-tailed deer
  - For adult stage

- Over 30 types of animals and many species of birds may be hosts
Ecological factors

• What are the preferred environments of the hosts?

• How can we measure environmental factors through remote sensing?

• How can we explain tick distribution?
Fort McClellan
Methodology
Methodology

Overall ASTER image

Plot 1 (ASTER)
Methodology

Overall ASTER image

Plot 1 (ASTER)

Plot 1 (NDVI)
## NDVI Range

<table>
<thead>
<tr>
<th>NDVI Range</th>
<th>&lt; 0.00</th>
<th>0.00-0.09</th>
<th>0.10-0.19</th>
<th>0.20-0.29</th>
<th>0.30-0.39</th>
<th>0.40-0.49</th>
<th>0.50-0.59</th>
<th>&gt; 0.60</th>
</tr>
</thead>
</table>

### Results – % NDVI class: plot detail

The table above categorizes the NDVI range for each plot. Each plot shows different visualizations of NDVI values across various ranges.
## Results – Table 1

Overall tick density by plot and species

<table>
<thead>
<tr>
<th>Plot</th>
<th>ALSF</th>
<th>ALSM</th>
<th>LSN</th>
<th>DOG M</th>
<th>DOG F</th>
<th>DOG N</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>8</td>
<td>7</td>
<td>67</td>
<td>2</td>
<td>3</td>
<td>1</td>
<td>88</td>
</tr>
<tr>
<td>2</td>
<td>4</td>
<td>11</td>
<td>108</td>
<td>1</td>
<td>0</td>
<td>2</td>
<td>126</td>
</tr>
<tr>
<td>3</td>
<td>1</td>
<td>2</td>
<td>13</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>16</td>
</tr>
<tr>
<td>4</td>
<td>11</td>
<td>17</td>
<td>175</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>204</td>
</tr>
<tr>
<td>5</td>
<td>6</td>
<td>15</td>
<td>172</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>197</td>
</tr>
<tr>
<td>6</td>
<td>8</td>
<td>5</td>
<td>37</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>51</td>
</tr>
<tr>
<td>7</td>
<td>5</td>
<td>3</td>
<td>25</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>33</td>
</tr>
<tr>
<td>8</td>
<td>6</td>
<td>6</td>
<td>271</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>283</td>
</tr>
<tr>
<td>9</td>
<td>8</td>
<td>9</td>
<td>74</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>91</td>
</tr>
<tr>
<td>10</td>
<td>0</td>
<td>2</td>
<td>9</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>11</td>
</tr>
<tr>
<td>11</td>
<td>2</td>
<td>1</td>
<td>2</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>6</td>
</tr>
<tr>
<td>12</td>
<td>0</td>
<td>0</td>
<td>5</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>6</td>
</tr>
<tr>
<td>Total</td>
<td>59</td>
<td>78</td>
<td>958</td>
<td>7</td>
<td>6</td>
<td>4</td>
<td>1112</td>
</tr>
</tbody>
</table>

### Amblyomma americanum N=1095

### Dermacentor variabilis N=17

#### General Conclusions
1) **Difference by species** - *Amblyomma Americanum* made up 98.5% of all ticks counted
2) **Difference by stage of development** - Nymphal ticks represented 86.5% of the total ticks sampled
3) **Difference by plot** – Tick counts ranged by plot from 283 (25% of total) to 6 (<1% of total)
Results – % NDVI class analysis

NDVI class proportion by plot sorted by tick count
Results – Integrated image variables

Plot 9
- Mean plot digital number: 170.3
- % NDVI by class:
  - < 0.00: 15%
  - 0.00-0.09: 6%
  - 0.10-0.19: 5%
  - 0.20-0.29: 4%
  - 0.30-0.39: 4%
  - 0.40-0.49: 2%
  - 0.50-0.59: 4%
  - > 0.60: 60%
- Patch area (meters^2): 91382.3
- Distance to nearest edge from centroid (m): 1.6
- Edge length (m): 854.9
- Edge length/Patch area ratio: 0.00002

Plot 8
- Mean plot digital number: 155.4
- % NDVI by class:
  - < 0.00: 7%
  - 0.00-0.09: 2%
  - 0.10-0.19: 2%
  - 0.20-0.29: 3%
  - 0.30-0.39: 6%
  - 0.40-0.49: 2%
  - 0.50-0.59: 3%
  - > 0.60: 76%
- Patch area (meters^2): 63711.5
- Distance to nearest edge from centroid (m): 46.2
- Edge length (m): 1217.2
- Edge length/Patch area ratio: 0.01910
## Results – Image variables by tick count

<table>
<thead>
<tr>
<th>Plot</th>
<th>Edge length (m)</th>
<th>Patch area (m²)</th>
<th>Distance to nearest edge (m)</th>
<th>Edge length/Patch area ratio</th>
<th>Tick density</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>523.52</td>
<td>5747.2</td>
<td>17.19</td>
<td>9.11%</td>
<td>88</td>
</tr>
<tr>
<td>2</td>
<td>669.51</td>
<td>7460.5</td>
<td>15</td>
<td>8.97%</td>
<td>126</td>
</tr>
<tr>
<td>3</td>
<td>2217.65</td>
<td>107075.1</td>
<td>46.15</td>
<td>2.07%</td>
<td>16</td>
</tr>
<tr>
<td>4</td>
<td>1372.8</td>
<td>59244.7</td>
<td>8.97</td>
<td>2.32%</td>
<td>204</td>
</tr>
<tr>
<td>5</td>
<td>432.44</td>
<td>3863.8</td>
<td>15</td>
<td>11.19%</td>
<td>197</td>
</tr>
<tr>
<td>6</td>
<td>1241</td>
<td>43837.1</td>
<td>58.29</td>
<td>2.83%</td>
<td>51</td>
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<tr>
<td>7</td>
<td>1346.49</td>
<td>156,744</td>
<td>58.59</td>
<td>0.86%</td>
<td>33</td>
</tr>
<tr>
<td>8</td>
<td>1217.2</td>
<td>63711.5</td>
<td>46.24</td>
<td>1.91%</td>
<td>283</td>
</tr>
<tr>
<td>9</td>
<td>854.86</td>
<td>91382.3</td>
<td>1.61</td>
<td>0.94%</td>
<td>91</td>
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<tr>
<td>10</td>
<td>153.55</td>
<td>199610.57</td>
<td>55.65</td>
<td>0.08%</td>
<td>11</td>
</tr>
<tr>
<td>11</td>
<td>1185.9</td>
<td>188249.8</td>
<td>77.27</td>
<td>0.63%</td>
<td>6</td>
</tr>
<tr>
<td>12</td>
<td>655.55</td>
<td>198277.6</td>
<td>33.81</td>
<td>0.33%</td>
<td>6</td>
</tr>
</tbody>
</table>
Conclusions

• Tick density inversely associated with plots where > 90% of all area is over NDVI of 0.60.
• Satellite remote sensing can identify environmental factors associated with likely tick habitats.

• What is the next step?
  – Statistical analysis to be performed.
  – RT-PCR
  – Initial findings: forest fragmentation, the theory of island biogeography, and meta population dynamics to be explored.
  – Risk Perception survey created and awaiting IRB approval
Transition to Partner

**Partners:**
Alabama Department of Health
Birmingham Lyme
Camp Coleman

**Benefits to Partner**
- Identified high risk areas
  - Map of high risk areas
- Camp Coleman
  - 5 presentations on prevention and treatment
  - Reached approx 40-50 campers each session

**Project Transition Plan**
- Best practices document
  - Document can be used as a guide for continued outreach at Camp Coleman or as a basis for new effort by Birmingham Lyme and the Alabama Department of Health
Outreach

CAMP COLEMAN
Bus/Equestrian Center Entrance

FIRE/RESCUE RANCE

[Images of people outdoors and indoors, engaging in outreach activities.]
MSFC/UAB Team Members
Summer 2009-Fall 2010

• Joshua Harden, B.S.
• Joe Olson
• Connor Whitley
• Michael Behring, M.S.
• Taylor Poston, M.P.H.
• Damien Willis, M.S.
• Jonathan Adams, M.S.
• Rusty Nall, B.S.
• Stephen L. Firsing III, M.P.A., M.A.
• Emily G. Capilouto
• Robyn Hyden, B.A.
• Kathryn Jackson
• Kyle Levy, M.S.
• Marilyn McAllister, M.S.

Foreign Nationals
• Steve Padgett-Vasquez, M.S. (Honduras)
• Jin Huang, B.S. (China)
• Nathan Renneboog, B.S. (Belgium)
• Sarah Hemmings, M.S. (Canada)
• Meghan Tipre, B.D.S. (India)
• Zhang Yan, M.P.H. (China)
• Kathryn Roa, M.D. (Philippines)
• Shveta Setia, B.D.S. (India)
• Lili Xie, M.D. (China)

Advisors
• Dr. Jeffrey C. Luvall- NASA MSFC Advisor
• Dr. Sarah H. Parcak- LGHO Director
• Dr. Donna Burnett- Science Advisor
Fort McClellan
Fort McClellan
Island Biogeography
Island Biogeography
Results - 500 m diameter NDVI plots