Wireless Sensor Networks for Biological Habitat Monitoring
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Motivation

Humans are Destructive/Evil!
- Leave trash
- Trample plant life
- Change behavioral patterns
- Reduced breeding success
  - Fifteen minutes of exposure in seabird colonies can reduce yearly breeding by 20%

...and sensors are not*
- Can be deployed anytime, anywhere
  - Off-peak seasons
  - In hospitable/troublesome environments
- Long-term placement
- Economical
  - No need to station scientists
- Loads of data, from many more sites (vs. by-hand)
  - Easier to build reliable, complex models for later analysis
  - Realtime redistribution – e.g. greatduckisland.net

*relatively speaking
Case Study
Great Duck Island

Questions to Answer
- Learn favorable climates for seabirds
- Monitor usage patterns of burrows
- Compare micro-climates based on environment and usage

Data to Collect
- Popularity from ‘presence/absence data’
  - Hourly measurements
  - Infrared / thermal changes
- “Environmental differentials”
  - Measurements every few hours

Nitty Gritty
Technology
**Network Requirements**

- Nine months of stable operation
- Self-Maintenance
  - Handle power/network outages
  - Data redundancy
- Log / Replay sensor logs
  - Borealis?

**Network Topology**

**Sensors**

- Light, temperature, infrared, humidity, barometric pressure
- Combinations can detect specific conditions
- Custom weather board for Mica Motes

**Sensors**

- Power is a big issue
  - Limited solar power available
  - Lots of sensors and network activity necessary; *alone*, the processor can run 1.4 hours per day
  - Outages mean caching and wasted transmissions -- both expensive operations!
- Health monitoring, compression, and reprogramming the mote help
  - Also high cost -- amortized over future savings
### Power Consumption

<table>
<thead>
<tr>
<th>Operation</th>
<th>nAh</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transmitting a packet</td>
<td>20.000</td>
</tr>
<tr>
<td>Receiving a packet</td>
<td>8.000</td>
</tr>
<tr>
<td>Radio listening for 1 millisecond</td>
<td>1.250</td>
</tr>
<tr>
<td>Operating sensor for 1 sample (analog)</td>
<td>1.080</td>
</tr>
<tr>
<td>Operating sensor for 1 sample (digital)</td>
<td>0.347</td>
</tr>
<tr>
<td>Reading a sample from the ADC</td>
<td>0.011</td>
</tr>
<tr>
<td>Flash Read Data</td>
<td>1.111</td>
</tr>
<tr>
<td>Flash Write/Erase Data</td>
<td>83.333</td>
</tr>
</tbody>
</table>

### Great Duck Island, Maine
- Thirty-two sensors hand-deployed
- Remotely monitored/maintained at Stanford
- A few weeks of data reveal petrels occupy burrows based on a ±3°C temperature differential and daylight conditions
  - Network good for at least five months more

### Future Needs
- Localization (GPS), time synchronization, and self-configuration
  - E.g. for air delivery
- More sensors
  - Chemical, sonic, geological, etc.
- Scalability
  - Biological deployments over larger sites
- Better ‘energy harvesting’
  - Power is too problematic for long-term viability of a more complex network
- Development of a ‘habitat monitoring kit’
Contributions

- A proof-of-concept network
  - Long-term
  - Previously out-of-reach data
  - Self-healing
  - Relayed live to a public website -- get people excited for future projects!
- New environmental sensor hardware
- Solid benchmark for new networks
  - E.g. hardware, power, and calibration