Ecoacoustics Theory & Soundscape Ecology in Alaska’s Wilderness

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AQC
Soundscape Workshop
February 2021
Sound in Earth’s History

- Earth sounds have existed for over 4 billion years
- Animal sounds have existed for 400 million years
- Machine noise has existed for over 300 years
- Sound is used by every animal on Earth in some form
- Sound is present in nearly all terrestrial, aquatic, and marine systems
Noise & The Extinction of Natural Sounds

• Noise is a human-created problem from our prolific use of machines

Road Traffic
Air Traffic
Sea Traffic
Biodiversity loss

Biodiversity loss, in percent, compared to an intact ecosystem

Source: National History Museum Data Portal. Data from 2016
## Biodiversity loss

<table>
<thead>
<tr>
<th>Group</th>
<th>Endangered</th>
</tr>
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<tbody>
<tr>
<td>Amphibians</td>
<td>1,393</td>
</tr>
<tr>
<td>Reptiles</td>
<td>578</td>
</tr>
<tr>
<td>Birds</td>
<td>683</td>
</tr>
<tr>
<td>Mammals</td>
<td>708</td>
</tr>
<tr>
<td>Fish</td>
<td>1,098</td>
</tr>
<tr>
<td>Invertebrates</td>
<td>2,150</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>6,032</strong></td>
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</tbody>
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Source: National History Museum Data Portal. Data from 2016
The Question: What is the Ecological Role of Sound?

Ecoacoustics (est. 2014)

Ecological processes in nature
Species communication
Human-Nature Relationships
Noise impacts
Human culture & psychology
Sound is Information

- Animals are knowledgeable & aware of their environment
- Sense organs enable animals to acquire information & interact
- Sound is information within a template of other ecological information, called the **Eco-Field**
Acoustic Eco-Field

• It is safe to say for sound-dependent species the Acoustic Eco-field is vital to their existence

• Sounds in Nature are used for:
  • Communication
  • Habitat selection
  • Prey location
  • Risk assessment

• Noise disturbance can significantly affect animal behavior
Components of Sound in Nature

- Biophony
- Geophony
- Anthrophony
Acoustic Space: The Area Sound Occupies

Acoustic Space

Acoustic Eco-Field

Physical Landscape
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</table>

Empty Acoustic Space
<table>
<thead>
<tr>
<th>Biophony</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bird</td>
</tr>
</tbody>
</table>

Single species calling
Acoustic Community of multiple animal sounds
Sonotope

A mix of biophony, geophony, & technophony

<table>
<thead>
<tr>
<th>Biophony</th>
<th>Geophony</th>
<th>Technophony</th>
</tr>
</thead>
<tbody>
<tr>
<td>Birds</td>
<td>Wind</td>
<td>Cars</td>
</tr>
<tr>
<td>Insects</td>
<td>Rain</td>
<td>Planes</td>
</tr>
<tr>
<td>Amphibians</td>
<td>River</td>
<td></td>
</tr>
<tr>
<td>Mammals</td>
<td></td>
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</tbody>
</table>
**Soundscape**
A landscape of sound patterns associated with physical organisms, geophysical events, & human activity

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<th>Technophony</th>
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<tr>
<td>Mammals</td>
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</table>
Theories of Sounds in Nature: Biophony

• Soniferous species use the acoustic space and acoustic eco-field in many ways
• **Acoustic Niche** – acoustic space must be available for animals to call and be heard
• **Soundscape Orientation** – sounds from others help animals locate resources
• **Acoustic Habitat** – animals require suitable acoustic conditions to be successful
Natural Sounds are Essential to Life
Acoustic Habitats & Noise

Time (seconds)

Frequency (kHz)

Biophony
(Acoustic Community)

Masking Effect
Technophony
(Car Noise)

Biophony
(Acoustic Community)

Geophony
(Rushing Water)

15 June 2020 @ 09:30 AM
Kenai National Wildlife Refuge, Alaska

- 2 million acres
- Alaska in miniature
Kenai National Wildlife Refuge: Wilderness

- 1.3 million acres of Wilderness
- Wilderness Act 1964
  - Required to preserve natural processes & opportunities for solitude
- ANILCA 1980
  - Established Wilderness
  - Allows snowmobiling in Wilderness for “traditional activities”
The Importance of Natural Quiet & Issue of Snowmobile Noise

• Winter is quiet – reduced biophony & quieter geophony

• Natural Quiet is important to wildlife & naturalness
  • Perfect conditions for rest & hibernation
  • Reduces stress
  • Resources identified with acoustic information are more rare

• Natural Quiet is important to human solitude
  • Unique acoustic experience
  • Sense of true solitude of internal and external quiet

• Snowmobile Noise degrades these Wilderness qualities
Acoustic Footprint of Snowmobile Noise & Natural Quiet Refugia

Sound Sampling

• Recorded sounds for 1 min every 30 min
• 27 sites in Wilderness areas
• 37 sites outside Wilderness areas
Acoustic Footprint of Snowmobile Noise & Natural Quiet Refugia

Sound Identification

• Listened to 60,000 recordings
  • Natural Quiet = Biophony + Subtle Geophony
  • Snowmobile Noise

• Calculated sound energy
  \( (\text{soundscape power}) \) @ 1-kHz intervals

• Summarized patterns of soundscape power over months and 24-h days
Acoustic Footprint of Snowmobile Noise & Natural Quiet Refugia

Acoustic-Environmental Relationships
- Took the average soundscape power at each site
- Overlaid with other environmental variables (16 variables)
- Used Machine Learning to find acoustic-environmental relationships
- Generated predictive models to map snowmobile noise & natural quiet
Snowmobile Noise

Natural Quiet

Soundscapes Power

Month

Snowmobile Noise

Natural Quiet

Soundscapes Power

Hour
<table>
<thead>
<tr>
<th>Rank</th>
<th>Snowmobile Noise</th>
<th>Natural Quiet</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Closer to Rivers</td>
<td>Further from Snowmobile Trails</td>
</tr>
<tr>
<td>2</td>
<td>Closer to Lakes</td>
<td>Further from Rivers</td>
</tr>
<tr>
<td>3</td>
<td>Closer to Wetlands</td>
<td>Further from Off-Trail Snowmobile Hot Spots</td>
</tr>
<tr>
<td>4</td>
<td>Closer to Off-Trail Snowmobile Hot Spots</td>
<td>Further from Oil/Gas Compressors</td>
</tr>
<tr>
<td>5</td>
<td>Closer to Snowmobile Trails</td>
<td>Further from Urban Areas</td>
</tr>
</tbody>
</table>
Acoustic Footprint of Snowmobile Noise & Natural Quiet Refugia

Acoustic Footprint of Snowmobile Noise

<table>
<thead>
<tr>
<th>Class</th>
<th>Total Area</th>
<th>Impact Area</th>
<th>% Impacted</th>
</tr>
</thead>
<tbody>
<tr>
<td>Non-Wilderness</td>
<td>667,749</td>
<td>291,673</td>
<td>44</td>
</tr>
<tr>
<td>Wilderness Open to Snowmobiling</td>
<td>625,648</td>
<td>243,604</td>
<td>39</td>
</tr>
<tr>
<td>Wilderness Closed to Snowmobiling</td>
<td>694,755</td>
<td>29,176</td>
<td>4</td>
</tr>
<tr>
<td>All Wilderness</td>
<td>1,320,403</td>
<td>272,779</td>
<td>21</td>
</tr>
<tr>
<td>All KENWR</td>
<td>1,988,152</td>
<td>564,452</td>
<td>28</td>
</tr>
</tbody>
</table>

Natural Quiet Refugia

<table>
<thead>
<tr>
<th>Class</th>
<th>Total Area</th>
<th>Quiet Area</th>
<th>% Quiet</th>
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</thead>
<tbody>
<tr>
<td>Non-Wilderness</td>
<td>667,749</td>
<td>118,297</td>
<td>18</td>
</tr>
<tr>
<td>Wilderness Open to Snowmobiling</td>
<td>625,648</td>
<td>223,346</td>
<td>36</td>
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<tr>
<td>Wilderness Closed to Snowmobiling</td>
<td>694,755</td>
<td>443,810</td>
<td>64</td>
</tr>
<tr>
<td>All Wilderness</td>
<td>1,320,403</td>
<td>667,156</td>
<td>51</td>
</tr>
<tr>
<td>All KENWR</td>
<td>1,988,152</td>
<td>785,453</td>
<td>40</td>
</tr>
</tbody>
</table>

Natural quiet predominantly occurred in
- Restricted areas to snowmobiling (mainly Kenai Mountains)
- Areas inaccessible to snowmobiling (forests)
The Alaska Conundrum: Accessing & Enjoying the Alaskan Wilderness

- Snowmobiling clearly degrades wilderness quality
- Snowmobilers are *not insidious* but also seek connection with nature
- Access to wilderness is difficult
- Machines have enabled access to many wilderness areas
- “The Alaska Conundrum” - Using machines to enjoy wilderness while diminishing its wilderness qualities
- There are now quieter alternatives to our machines of choice
Fragments of Extinction

• Sound has been an ecological driver of evolution for 4 billion years
• Noise is expansive & pervasive across the Earth
• Noise is an additional driver of extinction

TedxTalks:
- https://youtu.be/_uktZkTB58M

• Noise reduces human experiences in nature
• It takes sound awareness to appreciate it & prevent these

Thank You for Listening