Applying Sustainable Development Goals to the Conservation of Winter Environments and Cold-adapted Species in a Warming World

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Winter: More than meets the eye

Pauli et al. 2013; Zuckerberg and Pauli 2018
Snow == Habitat

Extent
Duration
Variability
Subnivium

Physiology
Abundance
Interactions
Distribution
Snow in a warming world

~4 million km$^2$

Brown and Robinson 2011; Ning and Bradley 2015
Addressing UN Sustainable Development Goals

SDG 15 – ‘Life on Land’

Proportion of important sites for terrestrial biodiversity that are covered by protected areas (15.1.2)

Mapping winter biodiversity

Assessing protect areas coverage for important winter biodiversity
Project Objectives

Develop ecologically-relevant metrics to capture snow cover dynamics at regional and global scales using existing remotely sensed data

Integrate snow cover dynamics with large-scale, citizen science data to improve distribution modelling for winter vertebrate communities

Map winter biodiversity “hotspots” across multiple extents to assess and improve the conservation of winter biodiversity
Winter Habitat Indices

**Snow** – optical multispectral sensors

<table>
<thead>
<tr>
<th>Satellite/Sensor</th>
<th>Spatial Resolution</th>
<th>Imaging Frequency</th>
<th>Data Record</th>
</tr>
</thead>
<tbody>
<tr>
<td>MODIS*</td>
<td>500m</td>
<td>Daily</td>
<td>2000-On</td>
</tr>
<tr>
<td>Landsat (all sensors)</td>
<td>30m</td>
<td>16 days</td>
<td>1985-On</td>
</tr>
<tr>
<td>Landsat 8</td>
<td>30m</td>
<td>16 days</td>
<td>2013-On</td>
</tr>
<tr>
<td>Sentinel 2</td>
<td>10-30m</td>
<td>5 days</td>
<td>2017-On</td>
</tr>
<tr>
<td>Harmonized L8-S2</td>
<td>30m</td>
<td>2-3 days</td>
<td>2017-On</td>
</tr>
</tbody>
</table>

*Data from both MODIS sensors (Aqua & Terra) begin in 2002

**Frozen ground** – microwave sensors

<table>
<thead>
<tr>
<th>Data Product</th>
<th>Spatial Resolution</th>
<th>Imaging Frequency</th>
<th>Data Record</th>
</tr>
</thead>
<tbody>
<tr>
<td>MEaSUREs Freeze/Thaw</td>
<td>6-25km**</td>
<td>Daily</td>
<td>1979-2018*</td>
</tr>
</tbody>
</table>

**6 km data only available for the Northern Hemi from 2002-2018**
Winter Length

Snow season length = # days between first & last snow
Snow Cover Variability

Example Time-Series:

<table>
<thead>
<tr>
<th>no snow</th>
<th>no snow</th>
<th>snow</th>
<th>snow</th>
<th>snow</th>
<th>no snow</th>
<th>no snow</th>
<th>snow</th>
<th>snow</th>
<th>no snow</th>
</tr>
</thead>
<tbody>
<tr>
<td>State</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Abs(Change)</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>1</td>
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</tbody>
</table>

= 10 total obs

= 4 change events

SCV = 40%

# of Change Events

Total # of Observations
Subnivium Conditions

Freq. of frozen ground without snow = \# of frozen ground w/o snow days ÷ total \# frozen days

% of Frozen Season
1 - 10
11 - 20
21 - 30
31 - 40
41 - 50
51 - 60
61 - 70
71 - 80
81 - 90
91 - 100
## Winter Vertebrate Data Sources

<table>
<thead>
<tr>
<th>Data Source</th>
<th>Occurrence/Abundance</th>
<th>Spatial Extent/Resolution</th>
<th>Temporal Extent/Resolution</th>
<th>Taxa Included</th>
</tr>
</thead>
<tbody>
<tr>
<td>eBird</td>
<td>✓</td>
<td>✓ Global/3 km neighborhoods</td>
<td>2003-2020/Weekly</td>
<td></td>
</tr>
<tr>
<td>Furbearer Harvest Database</td>
<td>✓</td>
<td>✓ U.S. Wide/Varying Spatial Units</td>
<td>1900-2020/Annual</td>
<td></td>
</tr>
<tr>
<td>IUCN Range Maps</td>
<td>✓</td>
<td>✓ Global/~110 km</td>
<td>NA</td>
<td></td>
</tr>
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</table>
2004 – 2020
26M Checklists
6.5M Locations

Range
Occurrence
Abundance
Habitat
Snow cover as a biogeographic constraint

<table>
<thead>
<tr>
<th></th>
<th>Occurrence</th>
<th>Abundance</th>
</tr>
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<tbody>
<tr>
<td><strong>East</strong></td>
<td>75</td>
<td>75</td>
</tr>
<tr>
<td><strong>West</strong></td>
<td>75</td>
<td>75</td>
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The bar chart shows the percentage of species occurrence and abundance in the East and West regions.
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<td>![Bird Icon]</td>
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<td>![Range Map Constructor Icon]</td>
</tr>
</tbody>
</table>
Winter climate is a strong determinant of extratropical diversity gradients
Conserving Winter Habitat
Future Steps

Mammals are next

Protected area analysis

Winter biodiversity conservation
silvis.forest.wisc.edu/maps-data/