Abundance and species diversity hotspots of tracked marine predators across the North American Arctic


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Near-apex and apex predators

- Integrate resources across several spatial and temporal scales
  - Highly mobile
  - Sentinels to ecosystems
  - Strong top-down trophic control

Boyce et al. 2015 – Ecology Letters 18: 1001-1011
Arctic ecosystem stressors

- Climate change
- Shipping
- Mining
- Fisheries potential
- Oil and gas exploration and exploitation

Important to identify areas that sustain higher levels of abundance and biodiversity for conservation and management measures


[Images and graphs related to Arctic stressors and climate change]
Protected areas

3.7% - implemented
1.8% - designated
2.0% - proposed

Global goal of 10% by 2020

MPAtlas, 2018
Revolutionized study of animal movement ecology

Provide insight into:
- Fish-fishing fleet interactions
- Environmental drivers of habitat use
- Species diversity hotspots
- Identify critical conservation areas

Generally been species-specific in Arctic
<table>
<thead>
<tr>
<th>Species</th>
<th>N individuals</th>
<th>N days</th>
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</thead>
<tbody>
<tr>
<td><strong>Cetaceans and pinnipeds</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Beluga</td>
<td>115</td>
<td>8286</td>
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<tr>
<td>Bowhead</td>
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<td>7267</td>
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<tr>
<td>Narwhal</td>
<td>76</td>
<td>7212</td>
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<tr>
<td>Ringed seal</td>
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<td>16528</td>
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<td>Harbour seal</td>
<td>19</td>
<td>4084</td>
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<td>Walrus</td>
<td>38</td>
<td>1490</td>
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<tr>
<td><strong>Polar bears</strong></td>
<td><strong>312</strong></td>
<td><strong>65203</strong></td>
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<tr>
<td><strong>Seabirds</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Common eider</td>
<td>134</td>
<td>16772</td>
</tr>
<tr>
<td>King eider</td>
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<td>7173</td>
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<tr>
<td>Ivory gull</td>
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<td>4739</td>
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<td>Sabine’s gull</td>
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<td>Ross’s gull</td>
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<td>Herring gull</td>
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<td>Long-tailed duck</td>
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<td>Dovekie</td>
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<td>16455</td>
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<td>Parasitic jaeger</td>
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<td>757</td>
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<tr>
<td>Thick-billed murre</td>
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<td>15094</td>
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<tr>
<td><strong>Fishes</strong></td>
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<td></td>
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<tr>
<td>Greenland shark</td>
<td>45</td>
<td>164</td>
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<td>Greenland halibut</td>
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<td>14</td>
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<tr>
<td>Arctic skate</td>
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</table>
Approach and objectives

Compiled data from **1283 individuals across 21 species** - 1989-2016

- Cetaceans and pinnipeds - ARGOS
- Polar bears – ARGOS and GPS
- Seabirds – ARGOS and GLS
- Fishes – Pop-off

**Data processing**

- ARGOS and GLS
  - state-space model at 1d time-step
- GPS
  - 1 location per day
- **186,786 daily location estimates**

- Summer-autumn (June to December)
- Winter-spring (January to May)

**Objectives:**

1) Map species diversity hotspots across the Arctic by season
2) Assess overlap of species diversity hotspots relative to protected areas and exclusive economic zones by season
Hotspot analysis

- 50km x 50km grid cells
- Unique number of species per grid cell that season
- Getis-Ord Gi* statistic
  - Tests for significantly higher ("hotspots") and lower ("coldspots") spatial clustering among grid cells

Queiroz et al. 2016 – PNAS
Objective 1 - species diversity hotspots

West – Along coastline and continental shelf (summer)
  • Nutrient-rich Pacific water flowing eastward; Winter - Cape Bathurst Polynya

East – Lancaster Sound and along Baffin Island coastline (summer)
  • Fjords have high organic carbon content; Winter - Mobile pack ice offshore

South – Waters around Southampton Island and Hudson Strait (summer)
  • Higher primary productivity; Winter - Mobile pack ice
Objective 2 – hotspots relative to PAs and EEZs
Objective 2 – hotspots relative to PAs and EEZs

Level of conservation protection is very low across the North American Arctic
Total protected area overlap of 77,498 km$^2$ (5%) and 83,202 km$^2$ (7%)
  - Summer: 15% in East, <1% in West and South
  - Winter: 14% in East and <1% in West and South

Provide starting point to policy-makers to address deficiency in conservation protection
**Objective 2 – hotspots relative to PAs and EEZs**

Most hotspots within national jurisdictions – likely easier to implement protection?

Highlights need for multi-national collaboration and data-sharing

<table>
<thead>
<tr>
<th></th>
<th>Spatial overlap (km²)</th>
<th>Percentage overlap (% area)</th>
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</thead>
<tbody>
<tr>
<td><strong>EEZ</strong></td>
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<tr>
<td>Summer-autumn</td>
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<td>Canada</td>
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<td>U.S.A.</td>
<td>332,251</td>
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<tr>
<td>Greenland</td>
<td>90,582</td>
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<td>Russia</td>
<td>107,809</td>
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<tr>
<td>Winter-spring</td>
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<tr>
<td>Canada</td>
<td>798,429</td>
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<tr>
<td>U.S.A.</td>
<td>173,204</td>
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<tr>
<td>Greenland</td>
<td>163,811</td>
<td>13.73</td>
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<tr>
<td>Russia</td>
<td>57,713</td>
<td>4.84</td>
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</table>
Conservation implications

**Climate change**
- Associated with declines in body condition
- Species redistribution and ‘re-wiring’ of the food web

**Fisheries exploitation**
- Increase risk of bycatch mortality
  - Greenland shark and seabird

**Shipping**
- Increase risk of ship strikes, ice-breaking, Noise pollution

**Oil and gas exploration and exploitation**
- Seismic surveys
  - ecosystem disruption
- Increase zooplankton mortality
- Clyde River and Supreme Court of Canada
Future directions

• Large-scale retrospective analysis implemented by several other programs
  • Antarctica – RAATD
  • Pacific Ocean – GTOPP
  • Atlantic Ocean – SEATRACK
  • **No such programs for Arctic Ocean**

• Continue retrospective analysis of Arctic telemetry data
  • Incorporate:
    • more species data
    • environmental data
    • data types (i.e. acoustic telemetry, at-sea observations, TEK)

• Share telemetry resources amongst Arctic nations

• Implementation of appropriate multinational regulations and adaptive conservation strategies to protect the Arctic
Acknowledgements

Hunter’s and Trapper’s Associations across the Arctic and their hunters