Abundance and Ecological Distribution of Antarctic Pack Ice Seals in the Pacific Sector of the Southern Ocean

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Abstract
Crabeater, Weddell, leopard, and Ross seals compose a large portion of the world’s population of seals. However, these seals’ abundance, distribution, and the magnitude of their ecological role in the Southern Ocean remain poorly understood. As part of the Antarctic Pack Ice Seals (APIS) Program, an international collaboration to improve this understanding, we conducted line transect surveys between 150°E and 100°W longitudes in December, 1999 - March, 2003. The helicopter and ship survey transects comprised 25,561 km in pack ice and 2,680 km in shore-fast ice. We used satellite-linked dive recorders to estimate the proportion of seals hauled out and available to be counted. Crabeater seals were the most abundant (1,730,000), with highest densities on the shelf/isleps (1.12 seals/km²) and along the ice edge (0.89 seals/km²), and lowest densities in the interior pack ice (0.22 seals/km²). Weddell seals were less abundant (330,000) with densities that were higher on fast ice than over the shelf/isleps and over deep water (0.46, 0.14, and <0.04 seals/km², respectively). Ross seals (22,600) were estimated only from 160°-130°W because they rarely hauled-out after mid-February when other regions were surveyed. Their density was highest in interior pack ice (0.04 seals/km²). Leopard seals were the least abundant (12,400) with highest densities along the ice edge (0.03 seals/km²). These abundance estimates should be more accurate and precise than previous estimates due to use of line, rather than strip transects; coverage of a large area in a single year; and more direct estimation of the proportion of seals hauled out. The clear differences in distribution and abundance of these species were consistent with differences in their life history adaptations and ecological interactions with their biological and physical environments.

APIs Objectives
- Document the distribution and abundance of the four species of Antarctic pack-ice seals,
- Document biotic and abiotic variables that may govern the distribution of these seals, and
- Investigate the interactions among seals, penguins, fish, krill, and pack ice.

Determining the size of the survey region by accounting for the rapidly shrinking seasonal pack ice zone

SOLUTION: Time Polygons
"Time Polygons" represent the sea ice field present on the day of the nearest survey effort

Table 1. Habitat covariates and categories
<table>
<thead>
<tr>
<th>Covariate</th>
<th>Categories</th>
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<tbody>
<tr>
<td>Distance to Ice Edge</td>
<td>6-100 km, 101-200 km, &lt;200 km</td>
</tr>
<tr>
<td>Ice Concentration</td>
<td>6-50%, 51-99%, &gt;99%</td>
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<tr>
<td>Distance to Shelf</td>
<td>Within 100 km of shelf in shallow water &gt;100 km of shelf in deep water</td>
</tr>
<tr>
<td>Depth</td>
<td>&lt;300 m, &gt;300 m</td>
</tr>
</tbody>
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Density/Abundance Modeling
- Exploratory analysis (GAMs) indicated that most of the variation could be explained by a few habitat covariates and categories: (Table 1).
- GLMs were fit to the various combinations of habitat features.
- AIC was used to select the most parsimonious model.
- To reduce effects of autocorrelation on model selection, the 5983 blocks (5 km segments of effort) were stratified within each of the 131 flights and ship surveys to produce 554 samples with uniform habitat features within the sample.
- Total abundance for the survey region was estimated using final model predictions across the entire survey grid (all Time Polygons).
- Precision was estimated using a two-stage jackknife variance: haul-out variance (seals) and survey variance (replicate "flights")

Crabeater Seal Abundance
- Type = Distance to Shelf
- Survey Section = 1.73 million, 1.22 - 2.07

Weddell Seal Abundance
- Type = Ice Concentration + Depth
- Survey Section = 0.33 million, 0.14 - 0.76

Ross Seal Abundance
- Type = Ice Concentration + Depth
- Survey Section = 22.6 thousand, 11.7 - 43.7

Leopard Seal Abundance
- Type = Distance to Edge + Survey Section
- Survey Section = 12.4 thousand, 2.9 - 33.1

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