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 longitude in December, 1999 - March, 2000. The helicopter and ship survey transects comprised 25,561 km in pack ice and 2,080 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/slope (1.12 seals/km^2) and along the ice edge (0.89 seals/km^2), and lowest densities in the interior pack ice (0.22 seals/km^2). Weddell seals were less abundant (330,000) with densities that were higher on fast ice than over the shelf/slope and over deep water (0.46, 0.14, and <0.04 seals/km^2, respectively). Ross seals (22,600) were estimated only from 180°- 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/km^2). Leopard seals were the least abundant (12,400) with highest densities along the ice edge (0.03 seals/km^2). 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.
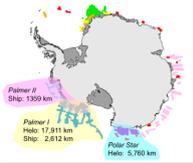
Abundance Estimator

$$\hat{N} = \frac{A}{a} \sum_{j=1}^{n} \frac{s_j}{\hat{p}_j \hat{h}_j}$$

A: size of survey region   a: size of sampled region
n: number of seal groups observed
s_j: number of seals in jth group
$\hat{p}_j$: estimated probability of detecting the jth group
$\hat{h}_j$: estimated probability the jth group was hauled out
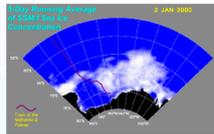
APIS Program survey sectors
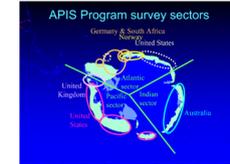
APIS International Survey Plan
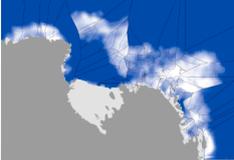
Line Transect Surveys

This study (total 27,642 km survey effort)

Determining the size of the survey region by accounting for the rapidly shrinking seasonal pack ice zone
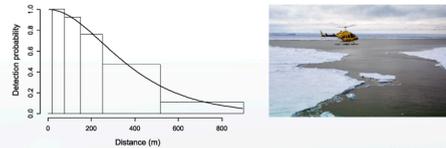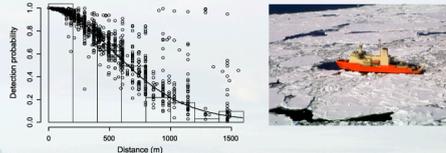
SOLUTION: Time Polygons

"Time Polygons" represent the sea ice field present on the day of the nearest survey effort
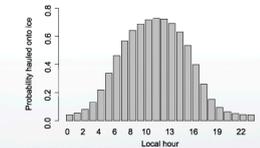
Detection Probability Helicopter Surveys

Detection Probability Ship Surveys

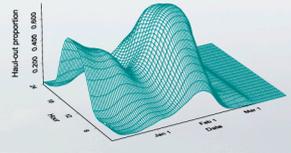### Crabeater Haul-out Probability

Ross Haul-out Probability

Density/Abundance Modeling

Table 1. Habitat covariates and categories

Distance to Ice Edge	0-100 km
	101-200 km
	<200 km
Ice Concentration	0-50%
	51-90%
	>90%
Distance to Shelf	Within 100 km of shelf in shallow water
	>100 km of shelf in deep water
Depth	=3000 m
	>3000 m

- Exploratory analysis (GAMs) indicated that most of the variation could be explained by a few habitat covariates and categories: (Table 1).

- To reduce effects of autocorrelation on model selection, the 5583 blocks (5 km segments of effort) were stratified within each of the 131 flights and ship surveys to produce 354 samples with uniform habitat features within the sample.

- GLMs were fit to the various combinations of habitat features.

- AIC was used to select the most parsimonious model.

- 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
~Ice Type + Distance to Shelf * Distance to Ice Edge + Survey Section
1.73 million; 1.22 - 2.67

85 seals/km^2
0 seals/km^2

Weddell Seal Abundance
~Ice Type + Ice Concentration + Depth * Distance to Ice Edge + Survey Section
0.33 million; 0.14 - 0.76

100 seals/km^2
0 seals/km^2

Ross Seal Abundance
~Ice Type + Ice Concentration + Depth
22.6 thousand; 11.7 - 43.7

0.65 seals/km^2
0 seals/km^2

Leopard Seal Abundance
~Ice Type + Distance to Edge + Survey Section
12.4 thousand; 2.9 - 53.1

0.65 seals/km^2
0 seals/km^2