Science, Service, Stewardship

Designing a large scale aerial survey of polar bears and ice-associated seals in the Chukchi Sea

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Rationale

- Retreating summer sea ice and increasing human activity in Arctic marine environments have raised concerns about population trends of polar bears and ice-associated seals

Bearded seal
Erignathus barbatus

Ringed seal
Phoca hispida

Polar bear
Ursus maritimus

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Rationale

- In coordination with Russian scientists, we conducted aerial, instrument-based surveys of these species in the Chukchi Sea in the spring of 2016
- Before conducting surveys we performed simulation analyses to determine anticipated precision and examine the performance of alternative levels of effort and flight track allocation strategies
- These are important analyses, because surveys are very expensive and we want to know whether they will generate reliable estimates of abundance

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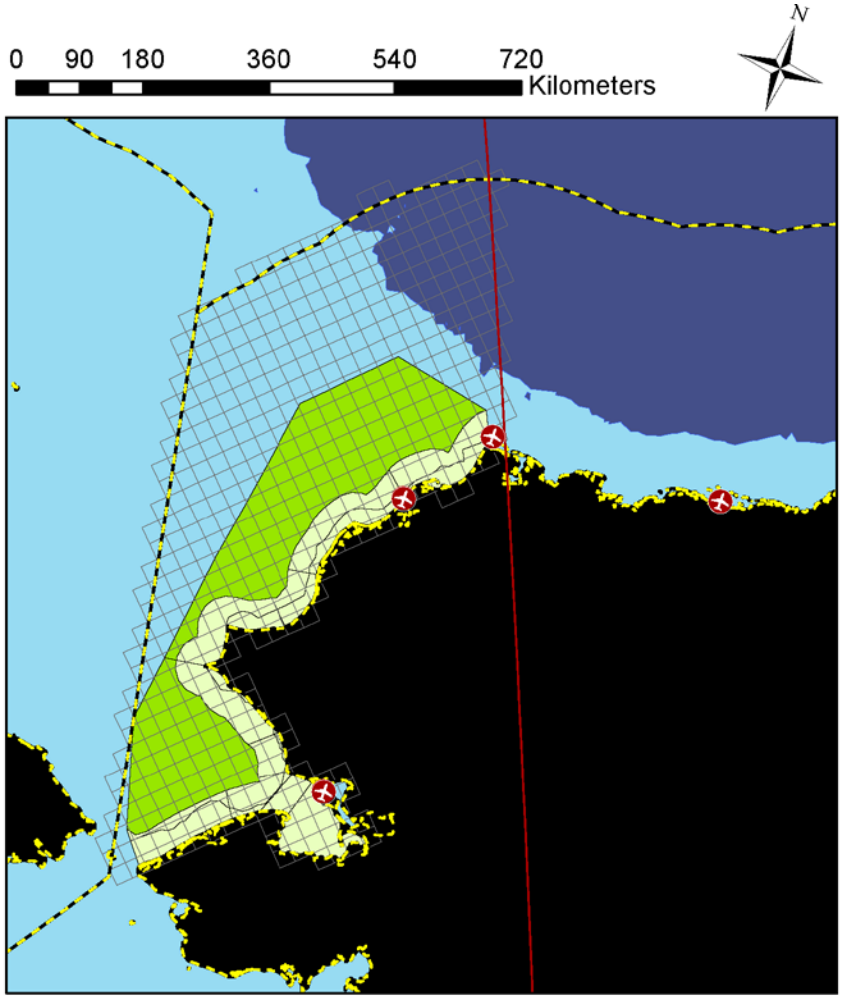
Study area



- U.S. portion of Chukchi Sea
- 25km x 25km grid cells
- Bounded to south by Bering Strait
- Bounded to west and north by U.S. EEZ
- Bounded to east by 156°

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Simulation setup

1) Generate abundance
2) Simulate Surveys
3) Estimate abundance
4) Calculated bias and anticipated precision

iterate

Select survey design that maximizes cumulative precision

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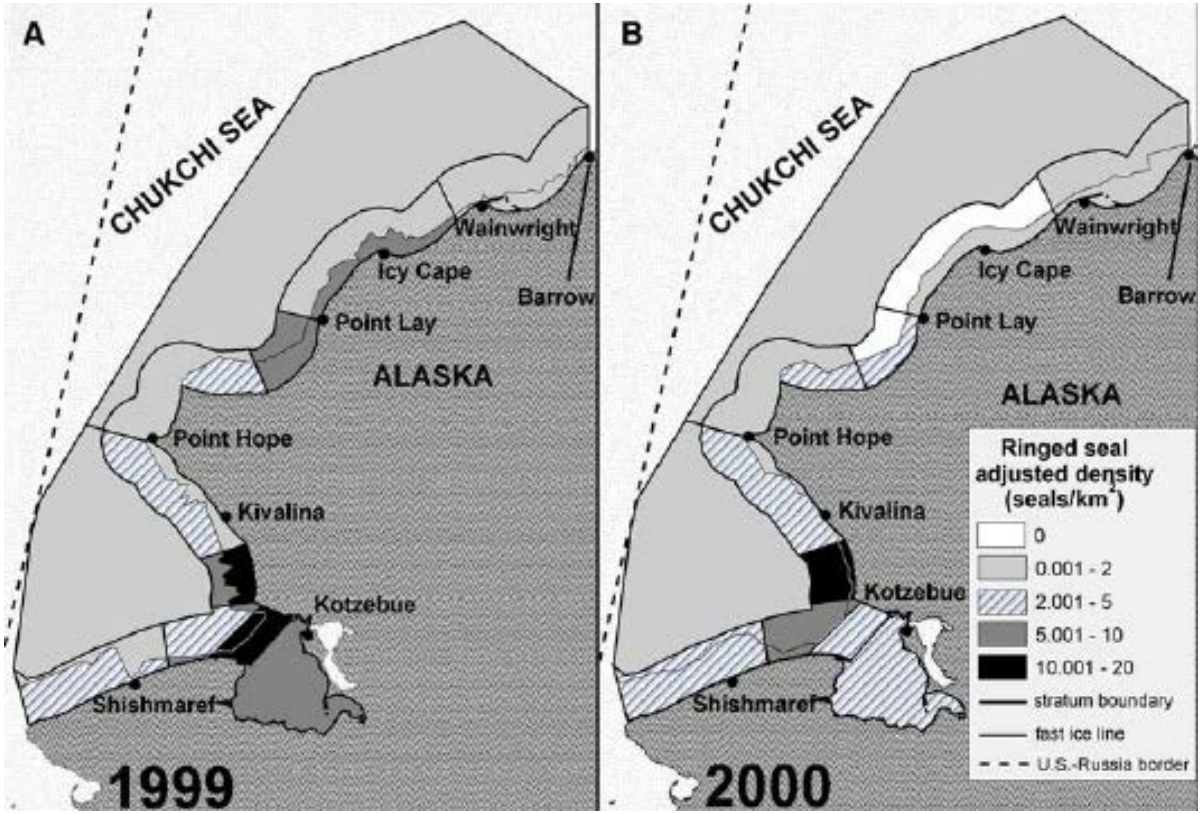
Simulating abundance

- Base expected seal abundance on published density estimates (Bengtson et al. 2005)



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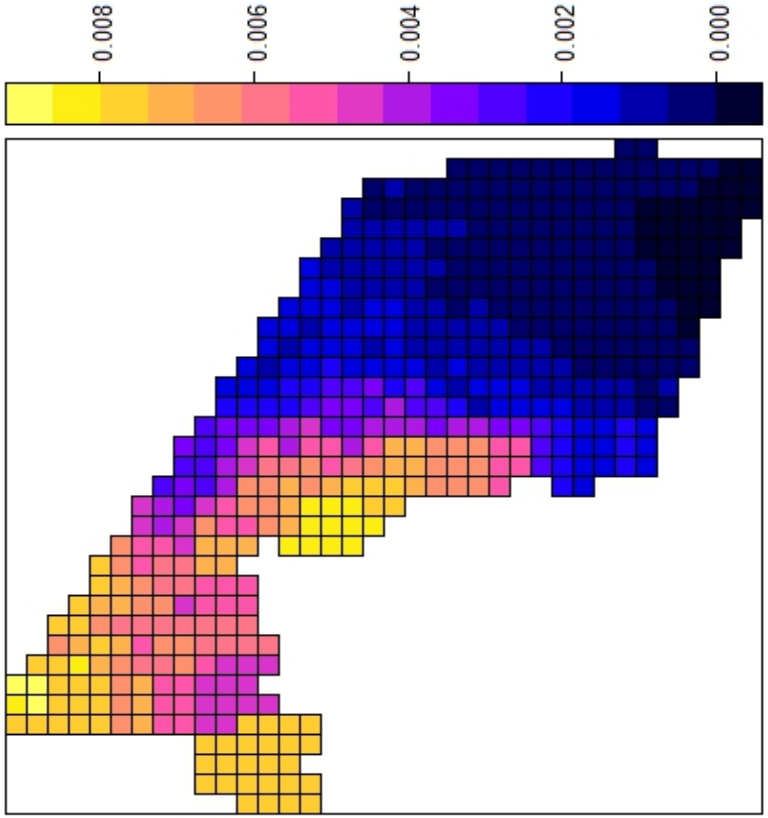
Simulating abundance

- Base polar bear distribution on resource selection functions fitted to satellite records from neck-collared females



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Simulating abundance

- Expected polar bear abundance: 1,000
- Expected ringed seal abundance: 434,000
- Expected bearded seal abundance 19,300

Simulated abundance using expected abundance as a mean, but also included spatially autocorrelated random effects, η_s, and additional Gaussian noise

$$N_s \sim \text{Poisson}\,(\lambda_s)$$
$$\log(\lambda_s) = \log(\mu_s) + \eta_s + \epsilon_s$$

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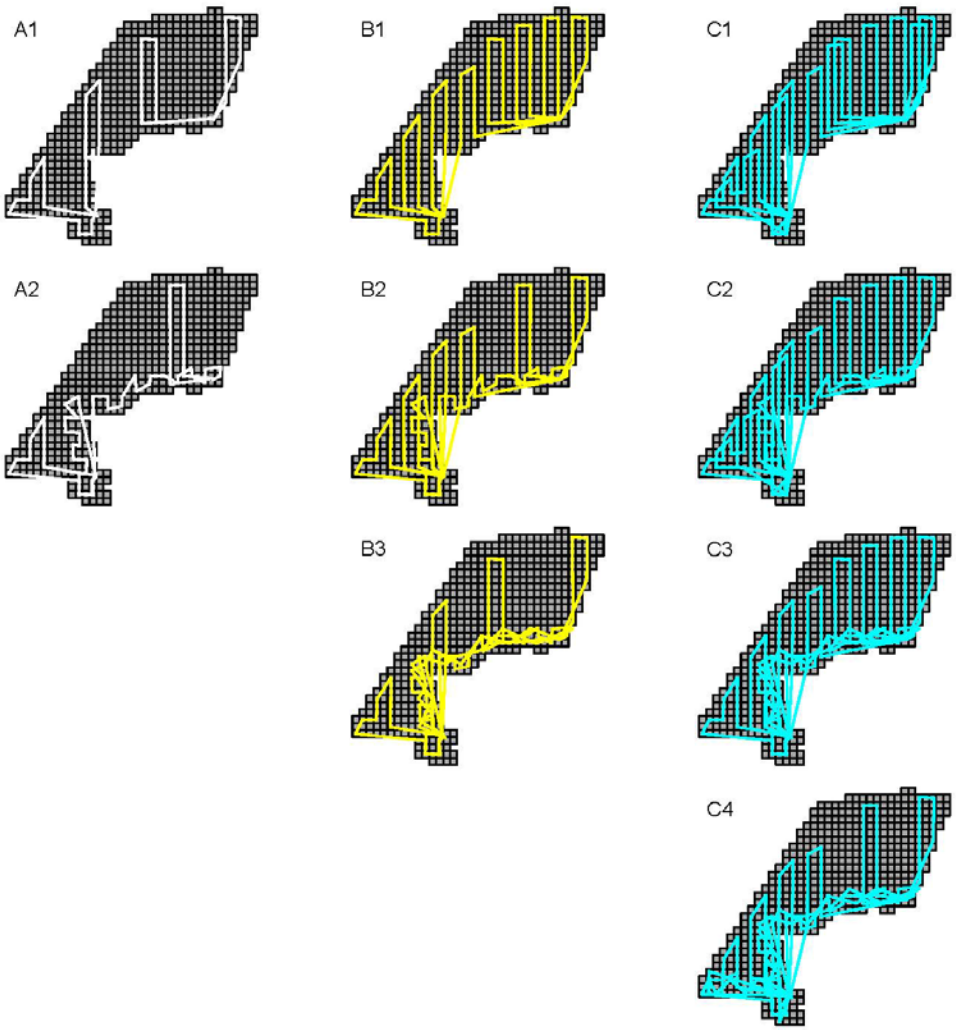
Simulating surveys



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Simulating surveys

- Counts in each surveyed cell generated according to Poisson distribution, depending on how much area (A_s) is surveyed in each cell
- Incomplete detection simulated
    1. availability
        - Polar bears – 100%
        - Bearded seals – 48%
        - Ringed seals – 65%
    2. imperfect detection of infrared scanners (94%)

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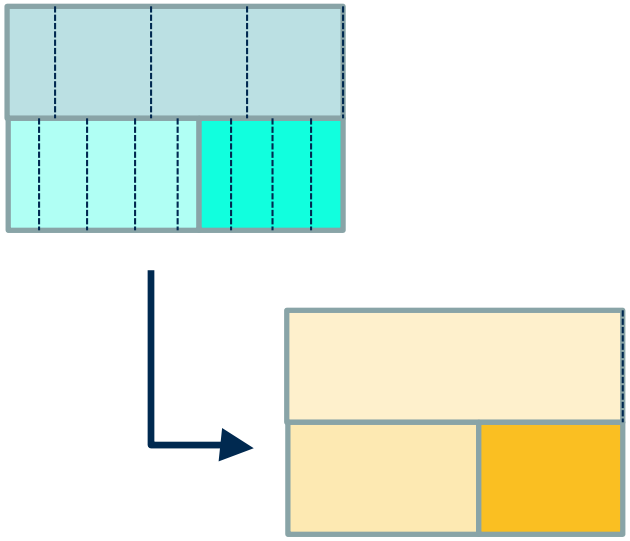
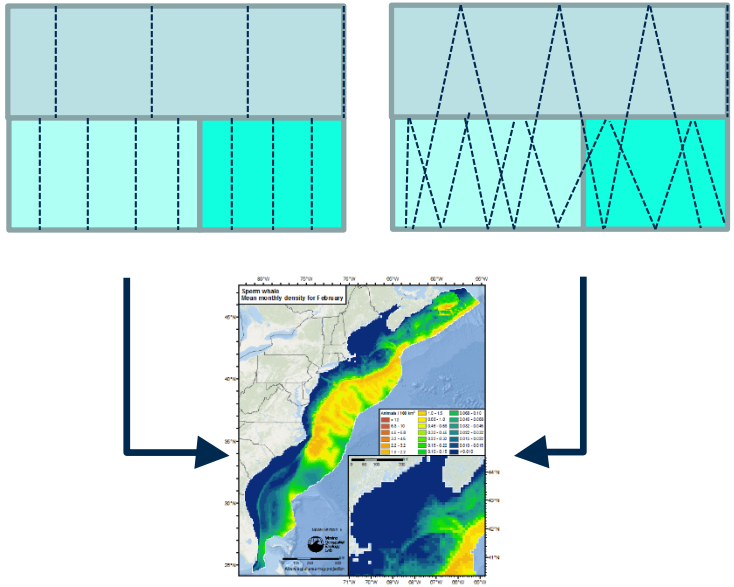
Estimating abundance

Refresher: Design- vs. model-based inference

A. Design-based



B. Model-based



Duke University (sperm whales)

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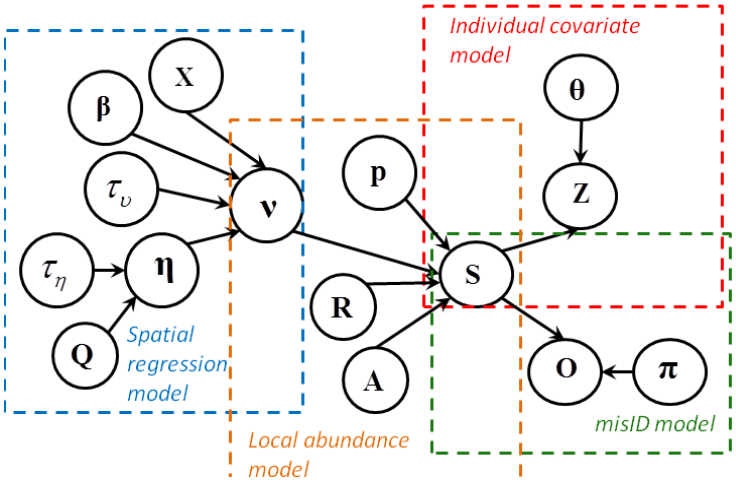
Estimating abundance

- For each simulation, we estimated abundance of all 3 species with a hierarchical, Bayesian spatial regression model
- Use covariate relationships to explain variation in counts and to predict abundance in unsampled locations (e.g., distance from land, northing, easting, strata, spatially autocorrelated random effects)



Conn et al. 2015, Methods in Ecology and Evolution

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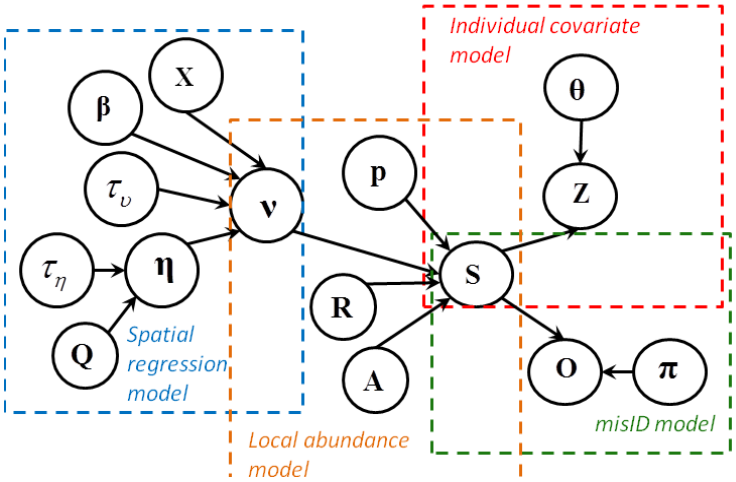
Estimating abundance

- Fit multiple models with different levels of complexity to each dataset. 9 models for seals, 4 models for polar bears
- We do not use the same variables to estimate abundance as we do to generate the data (that's cheating!)
- Importantly, model accounts for uncertainty in detection estimates



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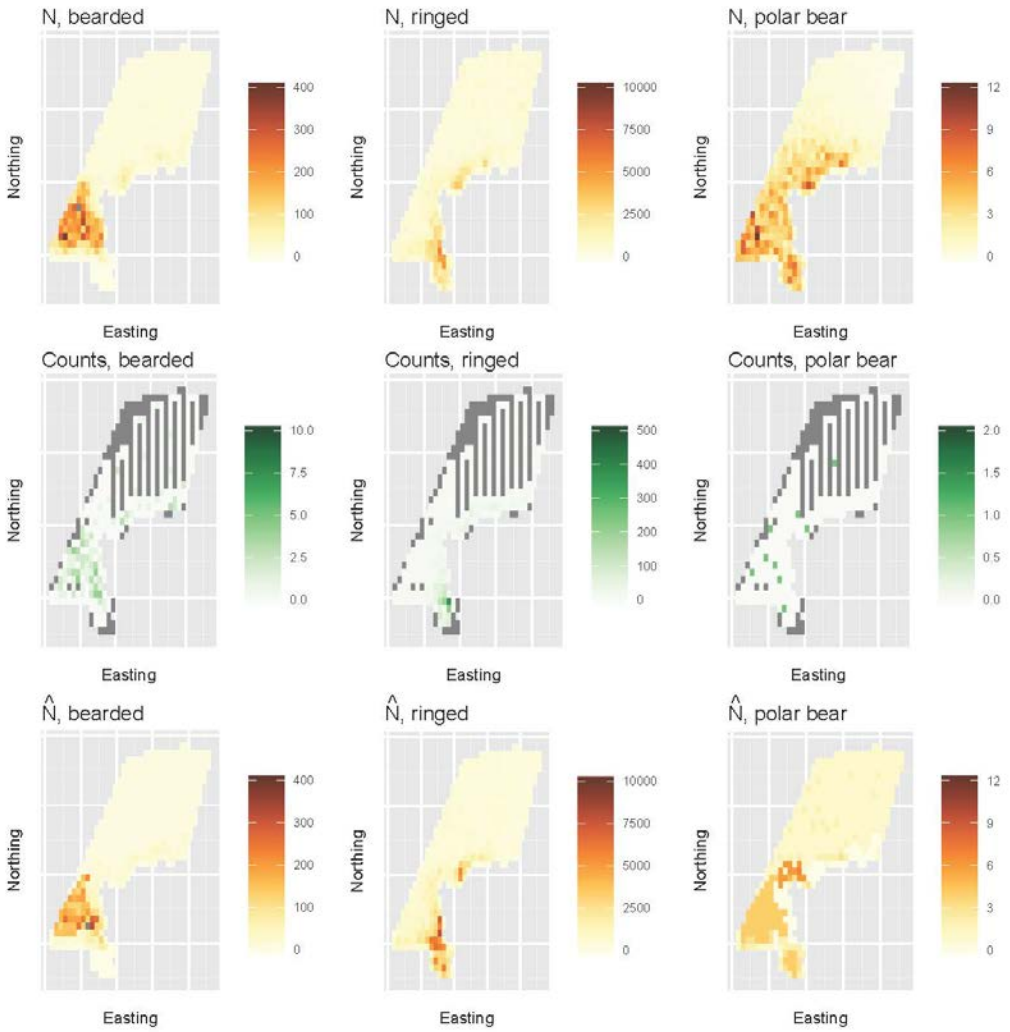
Example of one simulation



Repeat 100 times!

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Simulation results: bias

Species	4 flights (3920km)	8 flights (7840km)	12 flights (11760km)
Bearded seals	-8% to 54%	-7% to 8%	-9% to 7%
Ringed seals	-2% to 21%	-3% to 6%	-4% to 10%
Polar Bears	NA	-11% to 38%	-9% to 11%

- Lower bias for flight designs with more even spatial coverage
- Lower bias with more complicated estimation models

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Simulation results: precision (CV)

Species	4 flights (3920km)	8 flights (7840km)	12 flights (11760km)
Bearded seals	0.19 – 0.39	0.15 – 0.18	0.13 – 0.15
Ringed seals	0.10 – 0.14	0.09 – 0.11	0.09 – 0.10
Polar Bears	NA	0.35 – 0.97	0.28 – 0.35

- Could likely obtain sufficient precision for seals with 8 flights
- 12 or more flights would be better for polar bears, but still somewhat imprecise

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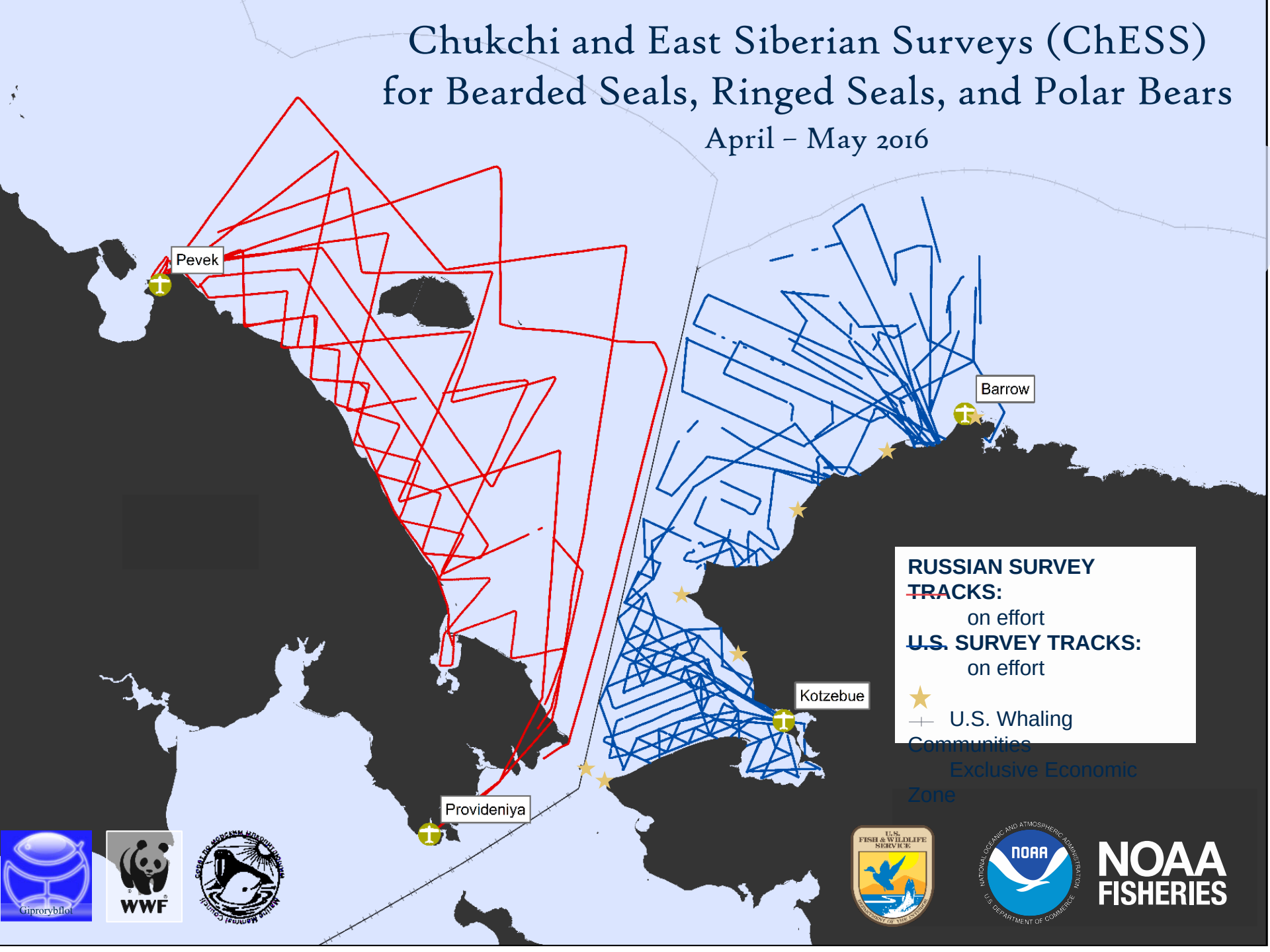
Conclusions

- This study provided confirmation that we could obtain good precision for ice-associated seals with 8 or more flights and a spatial regression estimation procedure
- Increased number (12 or more) flights needed for polar bears
- Integral to getting additional funding (e.g. U.S. Fish & Wildlife Service & WWF for Polar Bears)
- More generally, this or a related analysis is an important step to conduct before implementing expensive population surveys

Chukchi and East Siberian Surveys (ChESS) for Bearded Seals, Ringed Seals, and Polar Bears

April – May 2016



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Acknowledgments

Further information:

Conn, P. B., E.E. Moreland, E. Regehr, E.L. Richmond, M.F. Cameron, and P. L. Boveng. 2016. Using simulation to evaluate wildlife survey designs: polar bears and seals in the Chukchi Sea. Royal Society Open Science 3:150561.