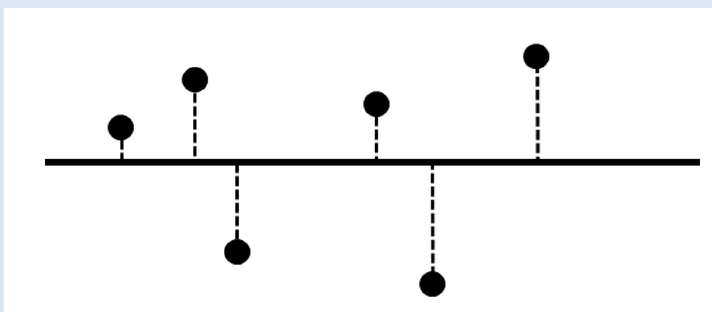
Estimating Abundance of Black-Legged Kittiwakes in Prince William Sound: Distance Sampling in a Bayesian Framework

Jessica Stocking, Nathan Hostetter, and Tomas Ivasauskas

What is Distance Sampling?

- Distance sampling is commonly used to estimate abundance of wildlife (Buckland et al. 2001)
- Data are collected by counting individuals and recording perpendicular distances from the transect
- It is assumed that not all individuals are observed (imperfect detection) and detection declines with distance
- Traditionally analyzed using a frequentist framework, however, Bayesian approaches may provide additional flexibility



Observation distances were estimated perpendicular to the linear transect

Motivation

Wildlife in the Prince William Sound suffered dramatically from the effects of the 1989 Exxon Valdez oil spill. Long-term impacts of the spill on seabird populations are of conservation concern. Black-legged Kittiwake (*Rissa tridactyla*) is of particular conservation interest because declining populations across North America.

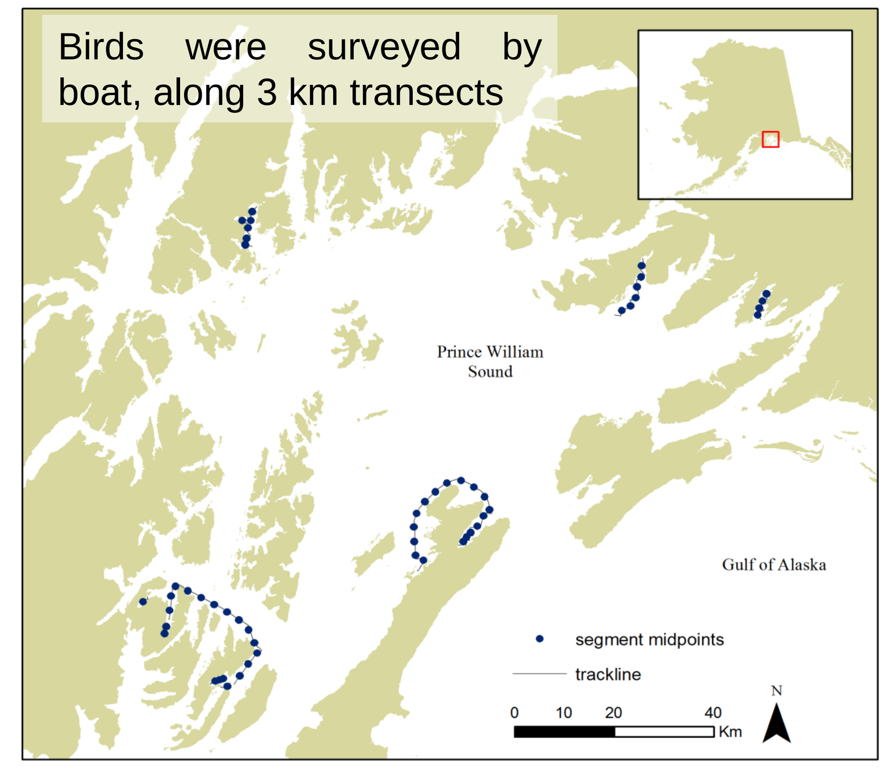
Objectives

- Use distance sampling to estimate kittiwake abundance
- Investigate how spatial covariates influence kittiwake abundance
- Model detection probability as a function of distance and sea state
- Model abundance using two different discrete positive distributions

Data

- Prince William Sound Science Center conducted surveys over the course of a week in November 2007
- Data include observations, distance from transect, and covariate information
- Transects were divided into 3 km segments (sites)
- 53 sites were surveyed
- Observations were assigned to 50 m bins; the maximum observation distance was 150 m
- **Abundance covariates:** Sea surface temperature, Depth, Slope
- **Detection covariate**: Sea state (i.e. wave height)

The Black-Legged Kittiwake (*Rissa tridactyla*) has a circumpolar distribution in the northern hemisphere.



Birds were surveyed by boat, along 3 km transects

Analysis

- Detection probability was estimated using a half-normal detection function: $p_k = \int_{b_k}^{b_{k+1}} \exp\left(-\frac{x^2}{2\sigma^2}\right) dx$, where σ is the scale parameter for the half-normal detection function, x is perpendicular distance, and b_k denotes distance bin k
- We allowed detection at each site (i) to vary by sea state (wave height): $\log(\sigma_i) = \alpha_0 + \alpha_1 SeaState_i$
- The total number of observations in site i (n_i) was linked to abundance (N_i) by assuming: $n_i \sim Binomial(p.t_i, N_i)$, where $p.t_i$ is total detection probability in site i ($p.t_i = \sum_k p_{k_i}$)
- We investigated two discrete positive distributions for abundance: $N_i \sim Negative\ Binomial(\lambda_i, r)$ **OR** $N_i \sim Poisson(\lambda_i)$
- We allowed abundance to vary as a function of spatial covariates: $\log(\lambda_i) = \beta_0 + \beta_1 SeaTemp_i + \beta_2 Depth_i + \beta_3 Slope_i$
- Total number of individuals in the observation area was: $N.total = \sum N_i$.
- Trace plots, $\hat{R}$ (all <1.1), and autocorrelation plots indicated adequate convergence
- Results reported as means and 95% credible intervals

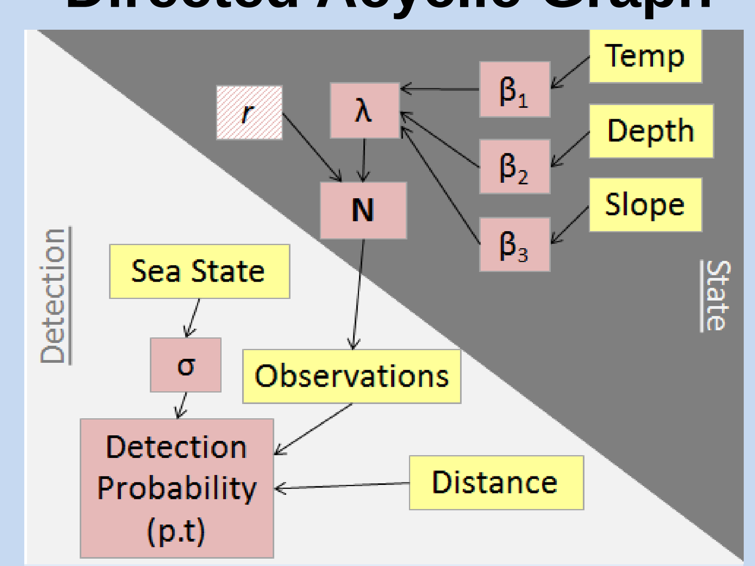
Implementation

- JAGS accessed through rjags
- 3 Markov chains
- 30,000 burn-in and 20,000 saved iterations per chain
- Priors:

$$\beta \sim Normal(0, 1000)$$
$$r \sim Uniform(0, 15)$$
$$\alpha_0 \sim Normal(0, 1000)$$
$$\alpha_1 \sim Uniform(-1, 0)^*$$

* Required informative prior

Directed Acyclic Graph



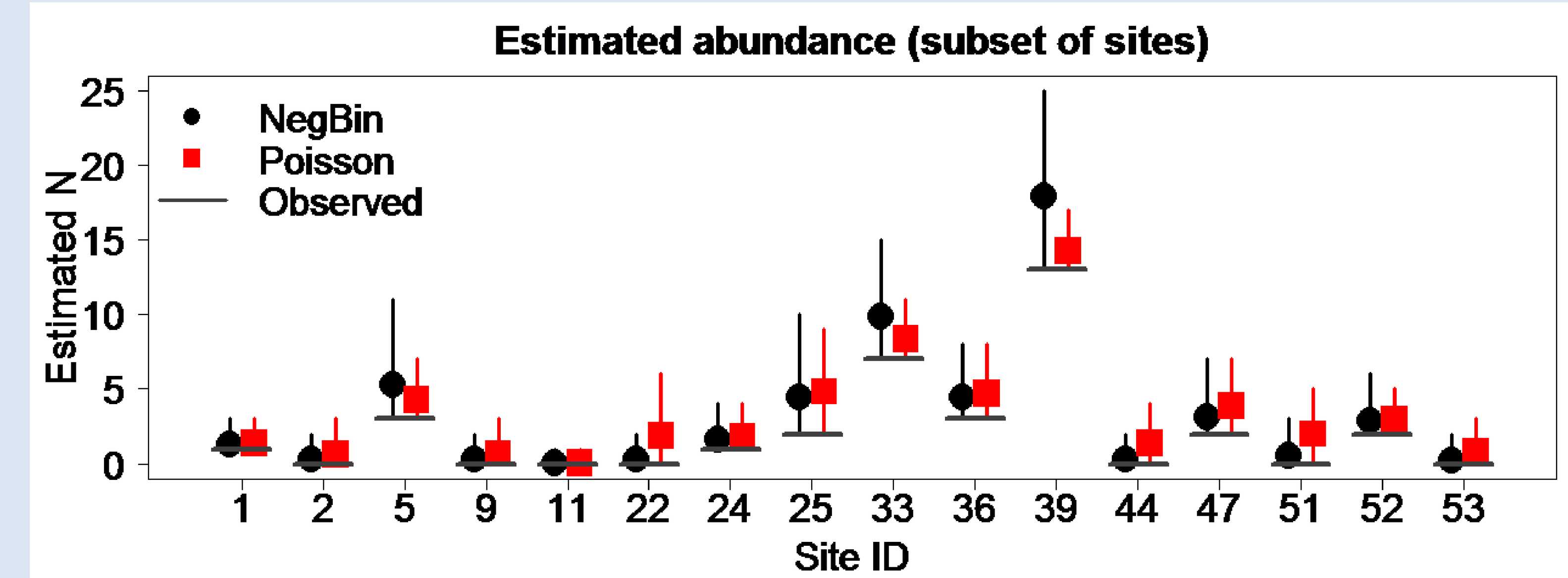
Yellow=Data Pink=Estimated Parameters

Model assumptions

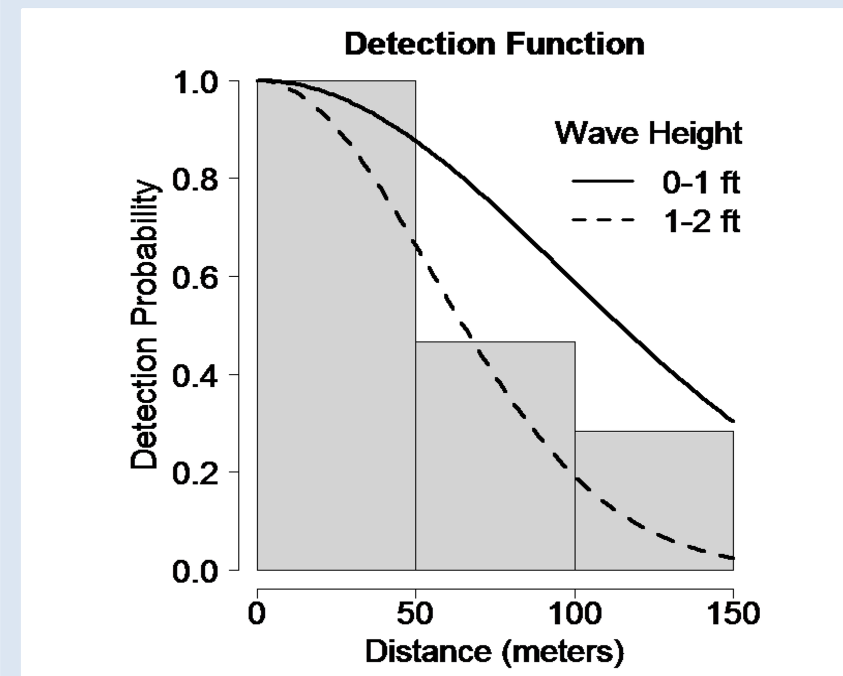
1. Individuals on the transect line (distance=0) are perfectly detected
2. Objects are detected at their initial locations
3. Distances are accurately measured
4. Detection decreases with distance
5. Individual observations are independent

Results

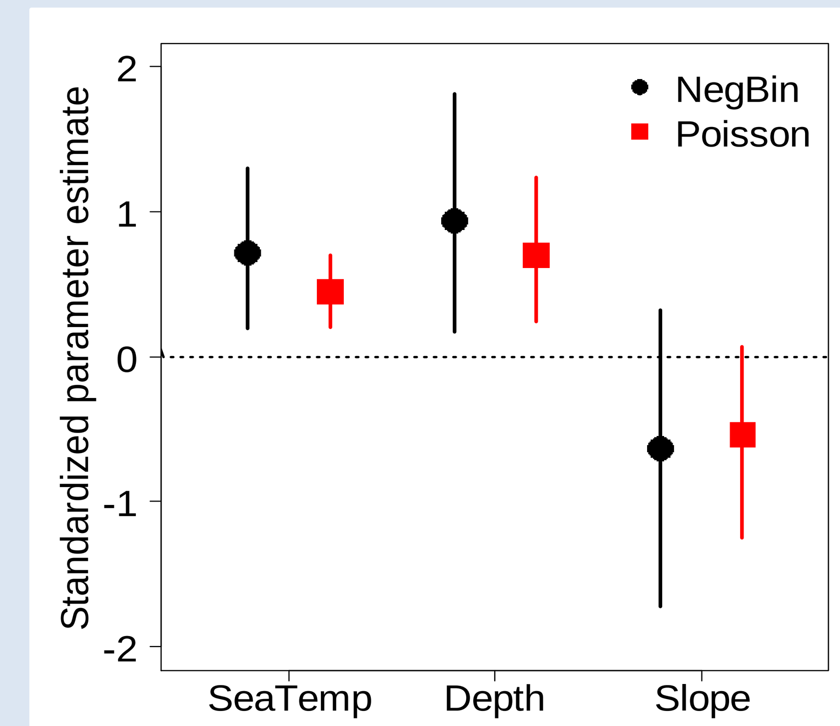
- Total observed: 105 kittiwakes
- Estimated total:174 kittiwakes (138-216)
- Detection probability influenced by distance and sea state
- Positive relationships between kittiwake abundance and sea temperature and depth
- Negative relationship between kittiwake abundance and slope, but credible intervals overlapped zero
- Site-specific estimates differed between Poisson and Negative Binomial distributions



Mean abundance (95% credible intervals) at a subset of representative site.



Frequency of observations by distance bin. Lines are detection functions at two sea states (wave height).



Parameter estimates for three covariates on abundance.

Future Directions

Validation/ Comparison → Prediction → Multi-season/species

References

Buckland, S. T., D. R. Anderson, K. P. Burnham, J. L. Laake, D. L. Borchers, and L. Thomas, 2001. Introduction to distance sampling – Estimating abundance of biological populations. Oxford University Press.

Royle, J. A., D. K. Dawson, and S. Bates, 2004. Modeling abundance effects in distance sampling. Ecology 85:1591–1597.