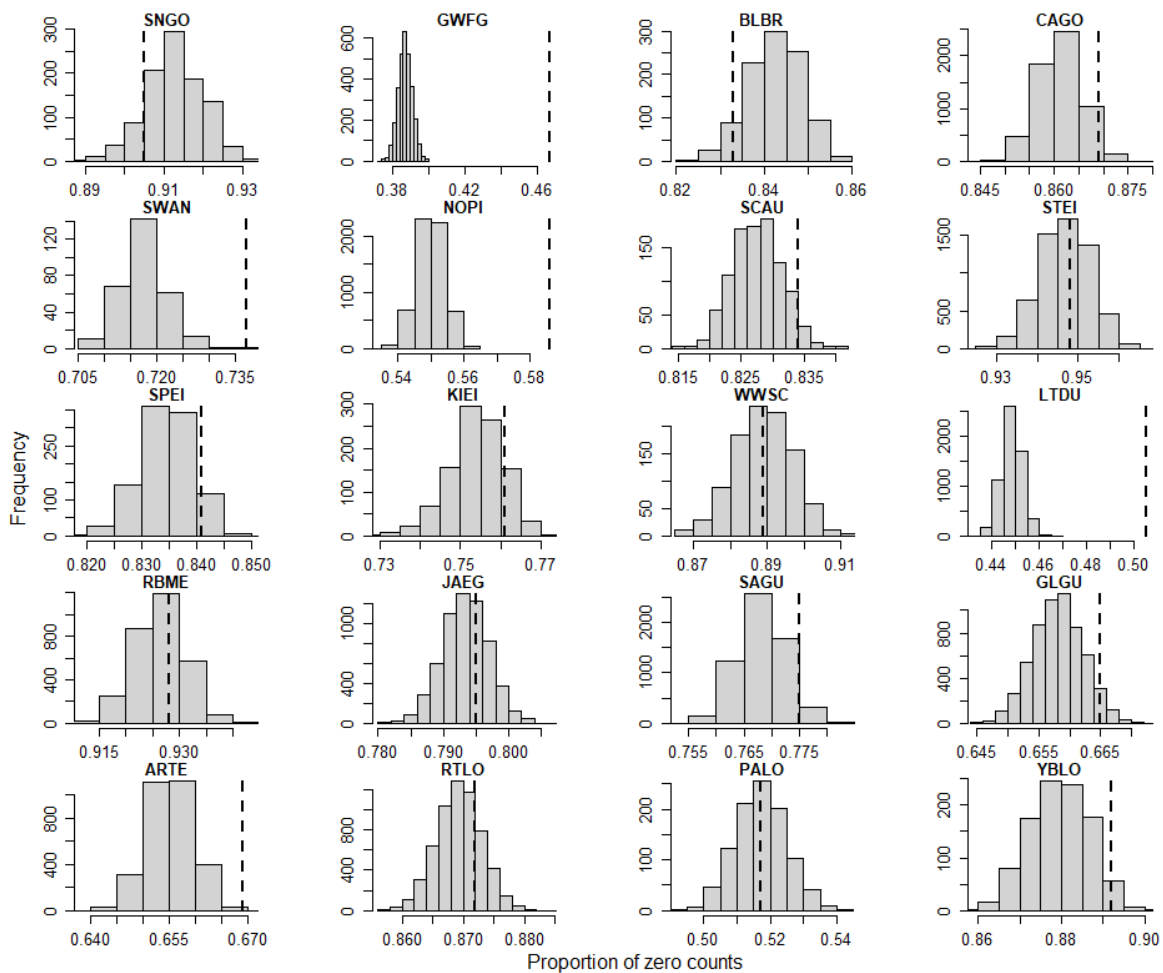


## **Appendix 1: Zero-inflation**

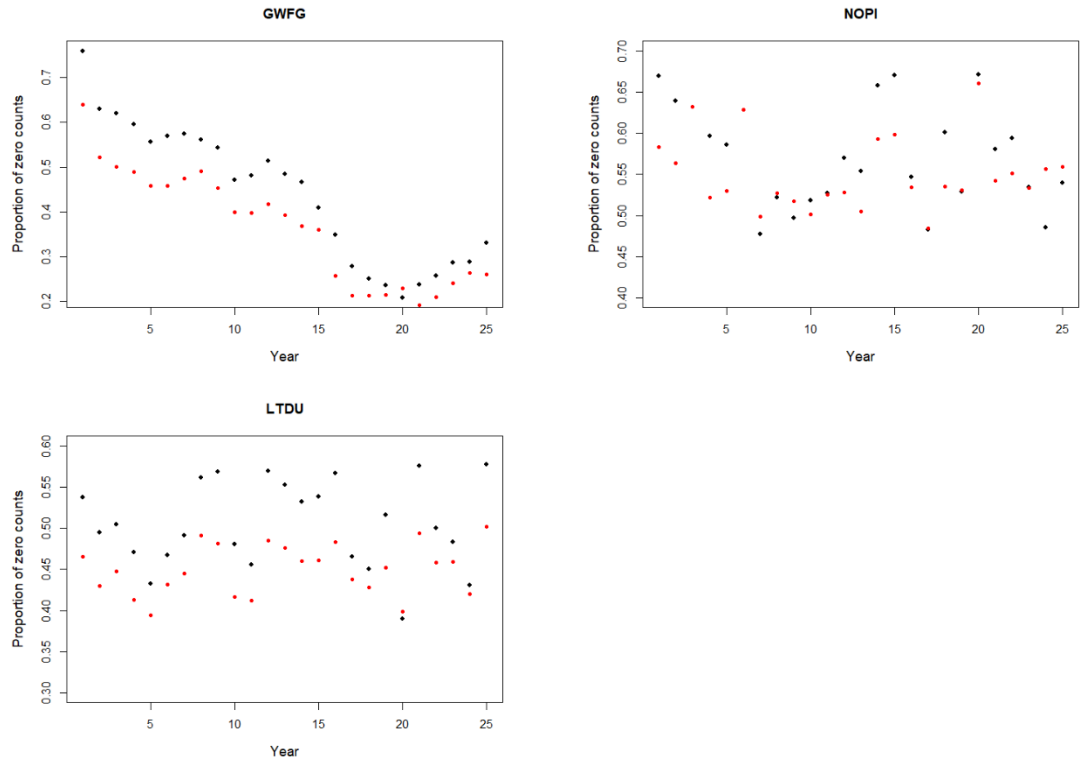
### **Spatio-temporal population change of arctic-breeding waterbirds**

We evaluated the ability of our model structure to accurately represent the number of zeros in the data by deriving 3,000 realizations of count data using Monte Carlo simulations of converged model parameter estimates and associated error and comparing the resulting proportion of zeros in the realized counts with the proportion of zeros observed in the real data (Figure 1). Results suggest negative binomial models were sufficient for most species, but underestimated the proportion of zeros for Greater White-fronted Goose, Northern Pintail, and Long-tailed Duck by 0.02 to 0.05. These species were the most abundant and broadly distributed in our study and thus, higher mean abundance may have prevented the level of overdispersion necessary in the negative binomial distribution to accurately reflect the number of zeros in the data. Further examination of the spatio-temporal trends in bias showed no pattern in bias through time; estimates were generally consistently lower for realized data (Figure 2). Patterns in space showed that locations of disagreement were generally peripheral to high density areas (Figure 3). The negative binomial Northern Pintail model could adequately predict the number of zeros in the early survey replicate, but not the later survey (Figure 4). As a result of this analysis we reran the three biased species using a zero-inflated negative binomial distribution (ZINB) (see main text).

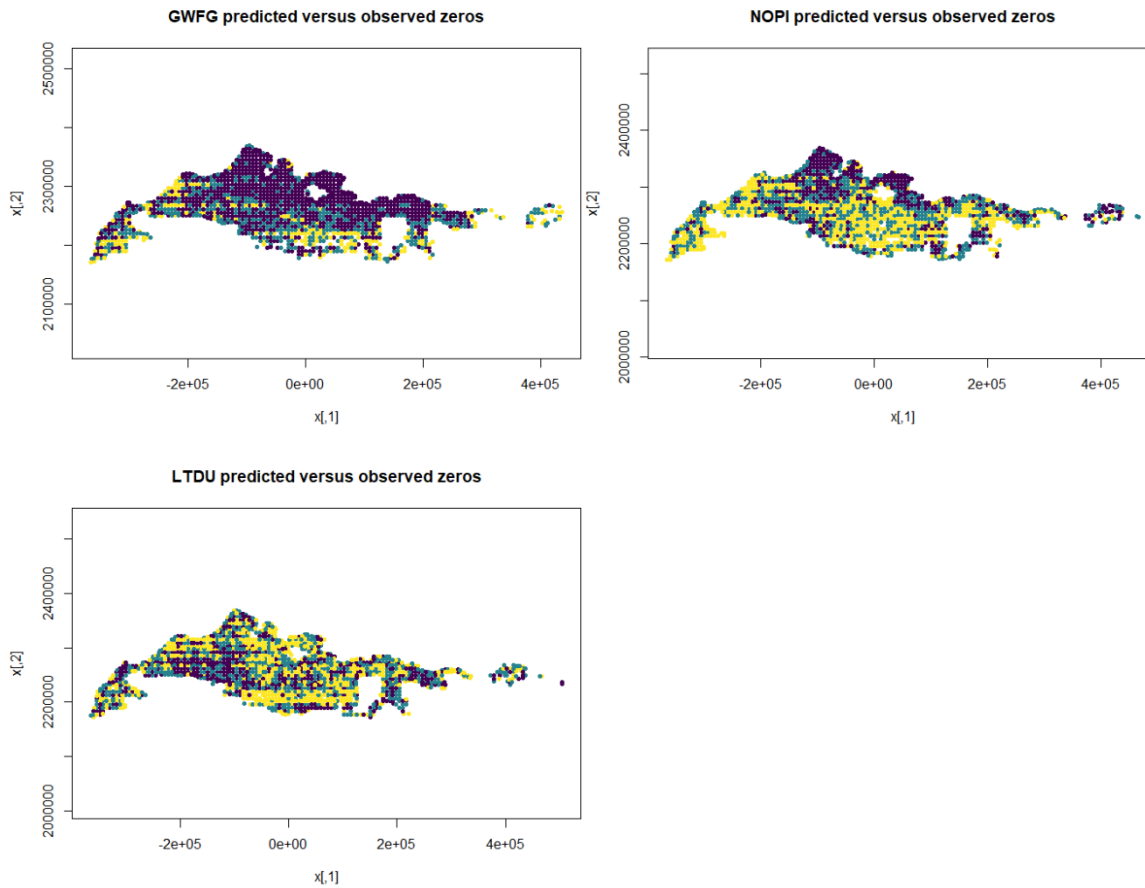
**Figure A1.1.** Proportion of zero counts from the data and 3,000 realizations of count data from four species of waterbirds counted on the Arctic Coastal Plain, Alaska 1992–2016. Species include: Lesser Snow Goose (SNGO), Greater White-fronted Goose (GWFG), Black Brant (BLBR), Cackling Goose (CAGO), Tundra Swan (TUSW), Northern Pintail (NOPI), Scaup (Lesser and Greater combined) (SCAU), Steller’s Eider (STEI), Spectacled Eider (SPEI), King Eider (KIEI), White-winged Scoter (WWSC), Long-tailed Duck (LTDU), Red-breasted Merganser (RBME), Jaeger (Pomarine, Parasitic, and Long-tailed combined) (JAEG), Sabine’s Gull (SAGU), Glaucous Gull (GLGU), Arctic Tern (ARTE), Red-throated Loon (RTLO), Pacific Loon (PALO), and Yellow-billed Loon (YBLO). We report the distribution of realized values and the actual proportion of zeros as a dashed line.



**Figure A1.2.** Annual mean proportion of zero counts from the data and 3,000 realizations of count data from three species of waterbirds counted on the Arctic Coastal Plain, Alaska 1992–2016 (year 1 = 1992) including Greater White-fronted Goose (GWFG), Northern Pintail (NOPI), and Long-tailed Duck (LTDU). Black points denote mean actual data and red points denote mean realizations.



**Figure A1.3.** Proportion of zero counts from the data and 3,000 realizations of count data from three species of waterbirds counted on the Arctic Coastal Plain, Alaska 1992–2016 including Greater White-fronted Goose (GWFG), Northern Pintail (NOPI), and Long-tailed Duck (LTDU). Purple denotes areas where realized data and actual data both predicted non-zero counts, teal-blue areas are areas of disagreement between realized and actual data (i.e., only one group predicted a zero count), and yellow denotes areas where both realized and actual data resulted in zero counts.



**Figure A1.4.** Proportion of zero counts from the data and 3,000 realizations of count data from three species of waterbirds counted on the Arctic Coastal Plain, Alaska 1992–2016 including Greater White-fronted Goose (GWFG), Northern Pintail (NOPI), and Long-tailed Duck (LTDU). We report the distribution of realized values and the actual proportion of zeros as a dashed line for each survey replicate (early, late).

