Brunswick Point Peep Models

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Roberts Bank, Delta, BC, is situated in the great Pacific Flyway and serves as an important stopover for peeps migrating north in the spring. It therefore hosts a large seasonal population of peeps: namely, Western sandpiper (WESA) and Dunlin (DUNL), that rely on the seasonal nutritional bounty provided by the Fraser River delta.

This document describes the suite of models used to estimate yearly changes in spatial distribution and abundance of peeps in the Roberts Bank estuary.

There are two datasets used in this modelling pipeline:

1. `dat`, which contains bird counts + environmental covariates
2. `sr`, which contains species ratio data (WESA:DUNL)

For an interactive interface with the `dat` dataset used in this document, see [https://popovs.shinyapps.io/peepr/].

```
summary(dat)
```

```
##   survey_date          start_time          station
##  Min.   :1997-04-21   Length:2060        Length:2060
##  1st Qu.:2004-04-19   Class :character   Class :character
##  Median :2009-04-17   Mode  :character   Mode  :character
##  Mean   :2009-04-02
##  3rd Qu.:2014-04-18
##  Max.   :2022-05-11
##
##            station_n             station_s    mumblies_yn       mud_yn
##  Coal Port      :600   Bend           :  72   Mode :logical   Mode :logical
##  Pilings        :498   Coal Port      :  56   FALSE:1864      FALSE:1862
##  Brunswick Point:338   View corner    :  49   TRUE :196       TRUE :198
##  34th St pullout:219   34th St pullout:  17
##  View corner    :192   Pilings        :  15
##  Bend           :130   (Other)        :   1
##  (Other)        : 83   NA's           :1850
##   marsh_yn       tide_edge_yn    flying_yn        final_count
##  Mode :logical   Mode :logical   Mode :logical   Min.   :     0
##  FALSE:1983      FALSE:1980      FALSE:2044      1st Qu.:   300
##  TRUE :77        TRUE :80        TRUE :16        Median :  3550
##                                                  Mean   : 11961
##                                                  3rd Qu.: 13500
##                                                  Max.   :222500
##                                                  NA's   :7
```

```
##      p_wesa          elev_min         elev_max      elev_median
##  Min.   :  0.00   Min.   :-0.040   Min.   :3.960   Min.   :2.240
##  1st Qu.: 48.43   1st Qu.: 0.840   1st Qu.:4.300   1st Qu.:3.065
##  Median : 80.12   Median : 1.220   Median :4.420   Median :3.255
##  Mean   : 67.61   Mean   : 1.237   Mean   :4.415   Mean   :3.238
##  3rd Qu.: 90.91   3rd Qu.: 1.647   3rd Qu.:4.550   3rd Qu.:3.405
##  Max.   :100.00   Max.   : 3.610   Max.   :4.850   Max.   :3.800
##  NA's   :725      NA's   :66       NA's   :66      NA's   :66
##    elev_mean       elev_range         flow       total_precip
##  Min.   :2.660   Min.   :0.450   Min.   : 736   Min.   : 0.000
##  1st Qu.:2.970   1st Qu.:2.700   1st Qu.:2420   1st Qu.: 0.000
##  Median :3.038   Median :3.200   Median :3100   Median : 0.000
##  Mean   :3.043   Mean   :3.177   Mean   :3252   Mean   : 2.174
##  3rd Qu.:3.118   3rd Qu.:3.600   3rd Qu.:4090   3rd Qu.: 2.000
##  Max.   :3.788   Max.   :4.640   Max.   :7830   Max.   :28.200
##  NA's   :66      NA's   :66      NA's   :5      NA's   :4
##    mean_temp           u                 v              windspd
##  Min.   : 3.80   Min.   :-19.8067   Min.   :-42.347   Min.   : 5.292
##  1st Qu.: 9.20   1st Qu.: -4.1311   1st Qu.: -9.631   1st Qu.:10.583
##  Median :10.50   Median : -1.2155   Median :  0.000   Median :12.875
##  Mean   :10.69   Mean   : -0.9227   Mean   : -1.434   Mean   :14.220
##  3rd Qu.:11.90   3rd Qu.:  2.2231   3rd Qu.:  8.391   3rd Qu.:16.573
##  Max.   :20.70   Max.   : 15.0489   Max.   : 20.454   Max.   :43.750
##                  NA's   :66         NA's   :66        NA's   :66
##     wind_deg        station_n_no    station_s_no    station_diff
##  Min.   :-177.55   Min.   :1.000   Min.   :3.000   Min.   :0.000
##  1st Qu.: -76.73   1st Qu.:4.000   1st Qu.:5.000   1st Qu.:1.000
##  Median :  34.98   Median :5.000   Median :6.000   Median :1.000
##  Mean   :  17.63   Mean   :5.567   Mean   :6.062   Mean   :1.005
##  3rd Qu.: 122.49   3rd Qu.:8.000   3rd Qu.:8.000   3rd Qu.:1.000
##  Max.   : 179.93   Max.   :8.000   Max.   :8.000   Max.   :2.000
##  NA's   :66                        NA's   :1850    NA's   :1850
##    julian_day           dos.V1
##  Min.   : 98.0   Min.   :-2.5490775
##  1st Qu.:112.0   1st Qu.:-0.7951215
##  Median :118.0   Median :-0.0434260
##  Mean   :118.2   Mean   :-0.0142948
##  3rd Qu.:125.0   3rd Qu.: 0.8335520
##  Max.   :138.0   Max.   : 2.4622255
##
```

```
summary(sr)
```

```
##   survey_date              wesa             dunl            total
##  Min.   :1997-04-21   Min.   :   0.0   Min.   :   0.0   Min.   :   0.0
##  1st Qu.:2005-04-20   1st Qu.: 123.8   1st Qu.:  41.0   1st Qu.: 283.0
##  Median :2009-04-24   Median : 353.5   Median :  92.0   Median : 523.0
##  Mean   :2009-10-04   Mean   : 467.1   Mean   : 175.6   Mean   : 642.8
##  3rd Qu.:2015-04-18   3rd Qu.: 717.0   3rd Qu.: 200.5   3rd Qu.: 941.2
##  Max.   :2022-05-11   Max.   :2605.0   Max.   :5000.0   Max.   :5047.0
##
##      p_wesa           p_dunl            year       julian_day
##  Min.   :  0.00   Min.   :  0.00   2006   : 23   Min.   :101.0
##  1st Qu.: 53.04   1st Qu.:  8.83   2019   : 23   1st Qu.:112.0
```

```
##  Median : 81.32   Median : 18.68   2005   : 18   Median :117.0
##  Mean   : 68.94   Mean   : 31.06   2007   : 18   Mean   :117.7
##  3rd Qu.: 91.17   3rd Qu.: 46.96   2008   : 18   3rd Qu.:123.0
##  Max.   :100.00   Max.   :100.00   2012   : 18   Max.   :137.0
##  NA's   :2        NA's   :2        (Other):202
##         dos.V1
##  Min.   :-2.2763470
##  1st Qu.:-0.7798519
##  Median :-0.0996268
##  Mean   :-0.0111976
##  3rd Qu.: 0.7166433
##  Max.   : 2.6212735
##
```

Species composition model

The daily ratio of Western sandpiper (WESA) to Dunlin (DUNL) across the entire study period is first modelled using a dataset of known species ratios (species ratios are not measured during every survey).

The ratios are modelled using a binomial generalized linear mixed model (binomial GLMM). The resulting predicted ratios are then used to estimate the number of WESA vs. DUNL per day.

Five models are built and compared

```
## Data: sr
## Models:
## lme5: y ~ 1 + (1 | year)
## lme4: y ~ dos + (1 | year)
## lme2: y ~ dos + I(dos^2) + (1 | year)
## lme3: y ~ dos + (dos | year)
## lme1: y ~ dos + I(dos^2) + (dos + I(dos^2) | year)
##      npar   AIC   BIC logLik deviance   Chisq Df Pr(>Chisq)
## lme5    2 64756 64764 -32376    64752
## lme4    3 25804 25815 -12899    25798 38954.1  1     <2e-16 ***
## lme2    4 16295 16310  -8144    16287  9510.6  1     <2e-16 ***
## lme3    5 22521 22540 -11255    22511     0.0  1          1
## lme1    9 11083 11117  -5532    11065 11446.2  4     <2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

The best-fit model is `lme1`. Add in the residuals from `lme1` to the dataset in order to estimate overdispersion. If the standard deviation of residuals is < 1, the model is an appropriate candidate for predicting daily species ratios.

```
sr$resids <- residuals(lme1)

lme4::glmer(y ~ dos + I(dos^2) + (dos + I(dos^2)|year) + (1|resids),
            family = binomial,
            data = sr)
```

```
## Generalized linear mixed model fit by maximum likelihood (Laplace
##   Approximation) [glmerMod]
```

```
##  Family: binomial  ( logit )
## Formula: y ~ dos + I(dos^2) + (dos + I(dos^2) | year) + (1 | resids)
##    Data: sr
##       AIC       BIC    logLik  deviance  df.resid
##  3409.879  3447.562 -1694.939  3389.879       310
## Random effects:
##  Groups Name        Std.Dev. Corr
##  resids (Intercept) 0.94716
##  year   (Intercept) 0.65139
##         dos         0.06454  -1.00
##         I(dos^2)    0.41479  -0.65  0.68
## Number of obs: 320, groups:  resids, 319; year, 24
## Fixed Effects:
## (Intercept)          dos     I(dos^2)
##      1.8826       1.3770      -0.8085
```

```
sr_glmm <- lme1
```