Kathryn M. Irvine, Thomas J. Rodhouse, Wilson J. Wright, Anthony R. Olsen. Occupancy Modeling Species-Environment Relationships with Non-ignorable Survey Designs. ***Ecological Applications***

Data S1

R-code to recreate empirical example results using pseudo-likelihood and likelihood estimation for single- season occupancy models.

Disclaimer: This software has been approved for release by the U.S. Geological Survey (USGS). Although the software has been subjected to rigorous review, the USGS reserves the right to update the software as needed pursuant to further analysis and review. No warranty, expressed or implied, is made by the USGS or the U.S. Government as to the functionality of the software and related material nor shall the fact of release constitute any such warranty. Furthermore, the software is released on condition that neither the USGS nor the U.S. Government shall be held liable for any damages resulting from its authorized or unauthorized use.

Author(s)

Kathryn M. Irvine
U.S. Geological Survey,
Northern Rocky Mountain Science Center,
Bozeman, MT 59715, USA
[4]E-mail: kirvine@usgs.gov

Thomas J. Rodhouse
U.S. National Park Service,
Upper Columbia Basin Network,
Bend, OR 97701, USA

Wilson J. Wright

U.S. Geological Survey,

Northern Rocky Mountain Science Center,

Bozeman, MT 59715, USA

Anthony R. Olsen

U.S. Environmental Protection Agency,

Western Ecology Division,

Corvallis, OR 97333, USA

File List (files found within DataS1.zip)

This Appendix includes the R code used for recreating the results in Figure 2.

`or_covs.csv`

`lano_dets.csv`

`mylu_dets.csv`

`myvo_dets.csv`

`pmle_functions.R`

`OR_model_fits.R`

Description

1. `or_covs.csv`-

   contains the empirical example Oregon dataset with columns for CONUS_10KM (= sample unit ID), Elevation_mean, and Forest_Percent_Gap for all sample units in Oregon ($N = 2660$). Elevation_mean was based on US Geological Survey 10-m digital elevation model and summarized to the 10-km x 10-km sample unit (https://lta.cr.usgs.gov/NED). Forest_Percent_Gap was created from GAP land cover 30-m resolution land cover map

(https://gapanalysis.usgs.gov/gaplandcover/). Forest cover was based on aggregated 'forest and woodland systems' and summarized to each 10-km x 10-km sample unit.

2. `lano_dets.csv`-

   Sample Unit ID is the same as CONUS_10KM in or_covs.csv. Each row is the observed detection/non-detection history for silver-haired bat (LANO; *Lasionycteris noctivagans*) at each of 91 sample units in 2016.

3. `mylu_dets.csv`-

   Sample Unit ID is the same as CONUS_10KM in or_covs.csv. Each row is the observed detection/non-detection history for little brown myotis (MYLU; *Myotis lucifugus*) at each of 91 sample units in 2016.

4. `myvo_dets.csv`-

   Sample Unit ID is the same as CONUS_10KM in or_covs.csv. Each row is the observed detection/non-detection history for long-legged myotis (MYVO; *Myotis volans*) at each of 91 sample units in 2016. The column SurveyType is the strata membership for the 91 surveyed sample units in 2016: "Prob" for the NABat Oregon sample units, "nonprob" for the legacy sites, or "FWS" for the NABat FWS R1 sample units.

5. `pmle_functions.R`-

   This file is the required code for implementing the models called in the file "OR_model_fits.R." It contains two functions:

   - *logL.fun*: log-likelihood of a proposed occupancy model with sample weights
   - *occ_pmle*: fits the single-season occupancy model with required inputs for occupancy model; detection model; detection history matrix, NAs okay; dataframe of site-level covariates; named list of visit-level covariates; vector of weights for PMLE fits.

     Example call to function to estimate occupancy model using P-MLE with forest and elevation occupancy covariates and constant detection for MYVO.

```
occ_pmle(~forest+elev.m,
                        ~1,
                        myvo_dh,
                        myvo_cov2,
                        list(blank=myvo_dh),
                        weights = myvo_wts)
```

Returns the following output (example for MYVO P-MLE results):

```
$params
[1] "alpha[0]" "beta[0]"  "beta[1]"  "beta[2]"


$estimates
[1] -0.72918766  2.73029511  2.24911931  0.01662806


$std.errors
[1] 0.1527564 1.3974652 1.1977440 0.4570784


$hessian
           [,1]      [,2]      [,3]       [,4]
[1,] 50.5219064  5.790555 -5.092232  0.1891535
[2,]  5.7905550  5.897079 -6.411697  0.2035330
[3,] -5.0922315 -6.411697  7.845033 -1.1351340
[4,]  0.1891535  0.203533 -1.135134  5.7853115


$converge
[1] 0


$AIC
```

```
[1] 372.8027
```

6. `OR_model_fits.R`:

   This file fits the single-season occupancy model using P-ML and ML for all three species and returns Figure 2 in the main text.