**Validation of Aerial and Ground Counts of Middle Fork Salmon River Chinook Salmon Redds – Data Analysis and Results**

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**Introduction**

Spawning salmon dig with their tails to clear fine particles from the streambed, deposit their eggs, and then cover the eggs with coarse gravel. This creates a mound and a depression in the substrate that is called a redd. In small streams, redds typically are visible from the ground or low-flying aircraft. Fishery managers conduct redd counts to assess abundance and spatial distribution of spawning salmon. Surveys are done annually in all available spawning habitats, or in smaller areas that have been surveyed historically and encompass core spawning areas. When compared among many years for the same areas, redd counts are thought to provide an index for describing trends in population size.

Despite widespread use, the reliability of redd counts is unknown. An important assumption in using index counts to estimate abundance is that the relationship between the index and true abundance (i.e., detection probability, *p*) is known (Engemen 2001). However, *p* rarely is known. Raw counts from redd surveys typically are assumed to equal the true number of redds within the survey area (*p* = 1), or to equal a constant proportion of redds over time or space (*p* is constant). This assumption has not been verified for salmon (but see studies of bull trout redd counts by Dunham et al. 2001and Muhlfeld et al. 2007). It is important to examine this assumption, because variation in *p* can cause error in inferences made from redd counts (Boulinier et al. 1998, Anderson 2001, 2003).

Sightability models that account for variation in *p* could improve estimates of redd abundance. If variation in *p* is associated with measurable differences in habitat, observers, or other factors, sightability models can be used to estimate total population size from redd counts. Variables that may affect *p* for salmon redds include variables associated with observers (e.g., training; experience; eyesight; interest; fatigue level), variables associated with the environment (e.g., substrate size and color; water depth, color, and turbidity; periphyton growth; sun angle and shading; presence of bed features that mimic redds), and variables associated with the redds themselves (e.g., redd age; size; morphology; color; contrast with surrounding substrate; abundance; overlap with other redds; spatial arrangement of redds within a reach).

Traditional sightability models are binary logistic regression models: given an animal is present, it is either seen or unseen and the likelihood of being seen is modeled as a function of covariates (Steinhorst and Samuel 1989, Fieberg 2012, Fieberg 2015). In these models, *p* ranges from 0 to 1 and the fitted model is used to adjust counts in future surveys. A notable source of error in redd counts, however, occurs when observers mistakenly count prior-year redds or redd-like streambed features as current-year redds. These errors of “commission” can lead to detection probabilities > 1 and overestimation of the true number of redds in a reach.

We described error in counts of spring/summer Chinook salmon redds in the Middle Fork of the Salmon River, Idaho. Specific goals were to:

1. Describe accuracy (bias and precision) of redd counts.
2. Describe factors that affect error in redd counts.
3. Determine whether sightability models can be applied to adjust raw counts.
4. Recommend protocols for redd counts that increase their utility.

**Field Surveys and Data QA/QC**

Study sites were selected non-randomly, and included historical trend sites and sites with a range of covariate conditions. Despite lack of random sampling, the sample was fairly large (Table 1) and encompassed the range spawning habitats that occur across the Middle Fork Salmon River watershed. To identify spawning habitat in the MFSR basin, we created a map describing the cumulative distribution of salmon redds identified during aerial surveys from 1995-2005. We classified gaps between redds that exceeded 400 m as unsuitable and areas within 400 m of as suitable habitat for spawning. For redds at the ends of suitable habitat and for individual redds, a buffer of three meters on either side of the redd was created and labelled as spawning habitat. We overlaid a map of redds sampled in this study from 2001-2005 onto the spawning habitat map and the redds counted within each stratum were compared (Table 1).

**Table 1. Aerial counts for all spawning habitat in the basin**.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | **Number of reaches surveyed** | **Aerial redd count within survey sites, 2001-2005** | **Aerial redd count in MFSR basin, 1995-2005** | **% redds within survey sites** |
| 2001 | 8 | 555 | 1789 | 31% |
| 2002 | 16 | 789 | 1730 | 46% |
| 2003 | 11 | 764 | 2271 | 34% |
| 2004 | 14 | 289 | 832 | 35% |
| 2005 | 9 | 121 | 458 | 26% |
| **Total** | **15** | **2522** | **7080** | **36%** |

We surveyed 30 sites, which ranged in length from 0.3 km to 8.1 km. However, 13 sites were subsequently omitted from the analysis because of incomplete data. These sites were Marsh 2, Capehorn (Marsh 4), Knapp (Marsh 5), Elk 1, Sulphur 1, Sulphur 3, Mainstem MFSR 1, Big 4, Big 6, Big 7 Big 8, Big 9, and Loon 4. In addition, we omitted individual years from some sites due to data quality problems (e.g., 2001 data for certain surveyors). Reasoning for keeping or removing data is recorded in the *Redd Validation Project Records Report*. After we removed these sites and surveys from the dataset, the final dataset for analysis included redds from 17 sites ranging in length from 1.6 to 8.1 km (83.8 km total). Sites were sampled for one year (two sites), two years (two sites), three years (one site), four years (ten sites) or five years (two sites). A total of 59 census surveys were completed.

At all sites, an individual surveyor obtained a redd census by counting redds approximately every four days from before spawning started through completion of spawning. Fish tend to stay on redds for five to seven days, so this frequency meant that census surveyors tended to see fish actively constructing and completing redds. Census surveyors noted streambed features that were not true redds but that might be confused for redds (e.g., redds from prior year Chinook or from other species such as steelhead, and non-redd features on the streambed that could be mistaken for redds). Cumulative census counts were considered to equal the “true” number of redds.

Other redd count data in the study included aerial survey data (n = 59) for one experienced surveyor (R. Thurow, USFS) and ground survey data (n = 191) for 1-12 surveyors with varying experience. We measured covariates, which included factors associated with surveyors, the environment, or redds themselves. Some covariates were measured at the scale of individual redds and other were measured at the reach scale. We analyzed the data statistically at the reach scale, in some cases combining redd-scale data to estimate reach-scale average values for covariates (Table 2).

We measured some variables in the field but did not ultimately include them in the analysis because 1) there were large numbers of records with missing (e.g., turbulence, conductivity) or improperly collected (e.g., riparian height) values, or 2) the variable was thought to correlate strongly with another variable that was selected for analysis (e.g., canopy cover taken with a densiometer was included in candidate models, but riparian vegetation height was not included).

**Table 2. Methods used to measure or estimate covariates.**

| **Variable** | **Description** | **Units** | **Methods for Data Collection** |
| --- | --- | --- | --- |
| AveWidth | Stream width | m | Average of width measured with a measuring tape at transects every 200 m. |
| AveDepth | Stream depth | cm | Average of depth measured with a stadia at transects every 200 m. |
| Slope | Reach gradient | unitless | Calculated as elevation gain / stream length. |
| AveCanopy | Overhead canopy cover | % | Average value for four densiometer measurements taken at transects every 200 m. |
| PeakQ | Current year peak flow | cfs | Peak flow from Nov 1 to Aug 1 preceding the survey at the Middle Fork gauge. |
| OthrDens | Density of “others” | #/km | Count of non-redd features / reach length in km recorded during census surveys. These include prior year redds and non-redd features that could be confused for a redd. |
| LYabund | Last year’s aerial count | # | For the reach. |
| AveSunny | Sun versus shade | % | Percent of true redds that were in the sun during the survey. Location of sun versus shade was estimated for individual redds using a GIS shade model that used aspect, topography, riparian vegetation height, and sun position at time of the redd survey. |
| AveBadCond | Poor survey conditions | unitless | Poor flight conditions during helicopter surveys as noted by R. Thurow. |
| Experience3 | Observer experience level | unitless | Experience for each surveyor rated by R. Thurow. Nominal scale where 0 = minimal training and experience; 1 = thorough training and recent experience; 2 = thorough training and past experience. |
| AveContrast | Contrast with substrate | unitless | Average contrast between redd color and substrate color rated on ordinal scale; 1=none to 5=max). |
| ANNDist | Avg nearest neighbor distance | m | Average distance (m) to closest redd. |
| redd\_dens | Density of redds (current year) | #/km | Census count / reach length in km. |
| AveOverlap | Overlap with other redds | % | Average percent of each redd’s area that overlaps with another redd. |
| AveAge | Age | days | For true redds, count of days between first date of “complete” redd in census and date of independent survey; average age for all redds in reach reported. |
| EscapeEst | MFSR Escapement | # redds | IDFG Escapement Estimate for Middle Fork Salmon River. |

**Data Analysis**

**General approach**

Redd counts generally are done at scales similar to our study sites (~1-10 km stream reaches) and this scale is an appropriate scale at which to conceptualize sightability models. Factors that affect redd sightability could be measured at both redd- and reach-scales; however, factors at the reach scale are easier to measure, especially for landscape variables that do not change among years or that can be modeled or estimated, for example using GIS. Measuring factors that affect sightability at the redd-scale probably would not be done routinely due to the fieldwork required. Redd-scale analysis, however, could be important for gaining insight into why errors are made in redd counts and for improving training and protocols for redd counts. The current analysis evaluates *only* reach-scale variables.

We used the large dataset described above to conduct four distinct studies (Table 3):

1. Sightability model for aerial counts;
2. Sightability model for ground counts;
3. Validation study for aerial counts; and
4. Validation study for ground counts.

Sightability model studies used covariates that could be measured annually for use in sightability models. Different sightability models could feasibly be developed and applied for different conditions (e.g., for different gradient channels, different escapements, etc.). The simplest scenario would be that a single sightability model would be recommended under all conditions.

Validation studies incorporated a larger set of covariates, some of which could not be measured on an annual basis for application in sightability models. We anticipated that the validation dataset might provide additional insight into sources of error in redd counts and recommended best practices for redd counts.

**Data Formatting and Statistical Analysis**

The final dataset for analysis is stored in an Access database, *ReddAnalysisyymmdd.mdb*, where *yymmdd* indicates the version date. Because of the database format, all analyses and survey-level statistics were done by survey – year – reach – surveyor. We used SAS to manipulate data into the format required for analysis in R (filename is: *all-preprocessing-yymmdd.sas*). A summary of all data preparation files is described in *code-summary-yymmdd.xls*.

Classification variables included year, reach and, for ground counts, surveyor (Table 3). There are strong arguments for considering year a fixed effect but we specified year as a random effect because we want to make inferences about other years and because we think the dominant effect of year will be captured with redd density and ‘other’ density. We used exploratory statistics and professional judgment to choose a final set of covariates for inclusion in model sets, which we expected would maximize predictive potential and minimize correlations among predictor variables (Table 3).

Table 3. Variables included in redd count sightability model and validation studies.

|  |  |  |  |  |  | **Ground Surveys** | | **Aerial Surveys** | |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Category** | **Variable** | **Variable Description** | **Units** | **Scale** | **Effect Type** | **Validation Study** | **Sightability Study** | **Validation Study** | **Sightability Study** |
|  | Surveyor | Surveyor |  |  | Random | 1 | 1 |  |  |
|  | Year | Year |  |  | Random | 1 | 1 | 1 | 1 |
|  | Reach | Reach |  |  | Random | 1 | 1 | 1 | 1 |
| Environment | AveWidth | Stream width | m | continuous | Fixed | 1 | 1 | 1 | 1 |
| Environment | AveDepth | Stream depth | cm | continuous | Fixed | 1 | 1 | 1 | 1 |
| Environment | AveDepth\* AveDepth | Average depth squared. Expect threshold effect - at certain depth, omissions increase dramatically | cm2 | continuous | Fixed | 1 | 1 | 1 | 1 |
| Environment | Slope | Reach gradient | unitless | continuous | Fixed | 1 | 1 | 1 | 1 |
| Environment | AveCanopy | Overhead canopy cover | % | continuous | Fixed | 1 | 1 | 1 | 1 |
| Environment | PeakQ | Current year peak flow at MF gauge | cfs | continuous | Fixed | 1 | 1 | 1 | 1 |
| Environment | OthrDens | Density of “others” (redd-like features) | #/km | continuous | Fixed | 1 |  | 1 |  |
| Environment | LYabund | Last year’s aerial count | # redds | continuous | Fixed | 1 | 1 | 1 | 1 |
| Environment | AveSunny | Percent of redds in the sun | % | continuous | Fixed |  |  | 1 |  |
| Environment | AveBadCond | Poor survey conditions. If there is an effect here consider removing records from dataset where AveBadCond=yes | unitless | Binary (0=no, 1=yes) | Fixed |  |  | 1 | 1 |
| Environment/ Redd | log(ANNDist) | Log transformed average nearest neighbor distance. Use log because range is very large | m | continuous | Fixed | 1 |  | 1 |  |
| Redd | AveContrast | Contrast with substrate | unitless | Ordinal (1=none to 5=max) | Fixed | 1 |  | 1 |  |
| Redd | redd\_dens | Density of redds (current year) | #/km | continuous | Fixed | 1 |  | 1 |  |
| Redd | AveOverlap | Overlap with other redds | % | continuous | Fixed | 1 |  | 1 |  |
| Redd | AveAge | Age | days | continuous | Fixed | 1 |  | 1 |  |
| Redd | EscapeEst | IDFG Escapement Estimate for MFSR. Confounded w Year. EscapeEst used as a surrogate for redd\_density when density and clustering of true redds unknown. | # redds | continuous | Fixed |  | 1 |  | 1 |
| Interaction | LYabund\*PeakQ | Last year's redds (aerial count) visible | unitless | continuous | Fixed | 1 | 1 | 1 | 1 |
| Surveyor | ExperienceCat | Experience level |  | Nominal (0,1,2) | Fixed | 1 | 1 |  |  |
|  |  |  | **Total # variables in candidate models** | | | 17 | 12 | 18 | 12 |

**Model Descriptions**

Errors in redd counts can be caused by errors of omission (not detecting a true redd) and errors of commission (falsely identifying a non-redd as a redd). These two distinct processes come from different distributions and might have differences in significant predictor variables, thus they were modeled individually. Within each study we evaluated three response variables representing errors of omission, errors of commission, and fraction of true redds observed (Table 4, Item II).

*Errors of omission (i.e., non-detection).* True redds counted or omitted (redd\_correct/TrueReachCt) comes from a binomial distribution (i.e., sum of successes of Bernoulli trials). The binomial distribution is characterized by n (# trials) and p (probability of correct identification in a trial) **(Model sets A1, G2).**

*Errors of commission.* The count of commissions in a site (CommitReachCt/km) comes from a Poisson distribution (i.e., frequency of commission, can’t have individual redds committed or not). The Poisson distribution is characterized solely by the parameter , which is both the mean and the variance. The Poisson distribution includes nonnegative integers; as increases the distribution moves to the right and spreads out. One assumption is that the number of commissions in one area of a site can reasonably be modeled as statistically independent of the number of commissions in another area of the site **(Model sets A2, G3).**

*Fraction of true redds observed.* We analyzed the dataset using a traditional sightability study approach, where the response variable is the fraction of true redds counted at the reach scale (frxn\_true log transformed; range 0 to ~3.00). Unlike the “two process” approach, this approach conceptualizes the analysis as one process and assumes that all responses are coming from the same distribution. With this approach the effects of omissions versus commissions cannot be explained, but it is straightforward to use a single fitted model as a sightability model. **(Model sets A3, G4)**.

We evaluated bias and precision of redd counts in four separate studies: 1) Sightability Air, 2) Sightability Ground, 3) Validation Air, and 4) Validation Ground. Within each study we modeled the three responses described above to describe errors of omission and commission and the fraction of true redds observed. To help select candidate models, we examined bivariate relationships between independent variables and considered the expected functional form between independent and dependent variables (Appendix A). We tested models using raw data and data standardized using Z-scores.[[1]](#footnote-1) Thus we constructed 24 model sets (4 studies x 3 responses x 2 data types). We used the R package LME4 to perform mixed-model analysis at the reach scale, and we used AIC for model selection. Candidate model sets for each analysis are detailed in Appendix B.

Table 4. Analytical Approach for describing error in ground and aerial counts (2001-2005) of Chinook salmon redds in MFSR basin. Covariates are described in Tables 2-3. As of 2/5/2016, we are NOT attempting to complete Item III, but Items I-II, and IV-V are being addressed in current analysis.

|  | **Objective** | **General Approach** | **Statistical Analysis** | **Response Variable** | **Outcome** |
| --- | --- | --- | --- | --- | --- |
| I | Describe accuracy (bias and precision) of redd counts in MFSR basin | Descriptive statistics | Report accuracy within and among years, reaches, observers (perhaps report by factors that turn out important in II). |  | Description of error in redd counts. |
| II | Describe factors associated with error in redd counts | Rank candidate models using AIC. | Reach scale for true redds counted or omitted. (A1, G2) | redd\_correct / TrueReachCt  (=omissions) | --Factors associated with error in redd counts ID’d.  --For “Sightability” dataset, demonstrate how this model could be used as a sightability model to adjust raw redd counts.  --For “Validation” dataset, note additional factors that are important and discuss how training or additional fieldwork could be done to minimize effects of important factors. |
| Reach scale for commission frequency. (A2, G3) | CommitReachCt / km | --Predict commissions at reach scale  --Combine results from G2 and G3 analyses for reach scale predictions |
| Reach scale for fraction of true redds counted at reach scale. (A3, G4) | frxn\_true | Predict observer count relative to true count. Compare results of G4 to results of G2 + G3 |
| III | Determine whether sightability models can be applied to improve redd counts | A. Cross validation1 where dataset is split (probably by survey years).  B. If bias is present, build final sightability model(s) using full dataset | 1. Build model(s) with training dataset(s)  2. Validate model(s) with test dataset(s).  3. Describe utility of sightability model(s): how does the “best” model perform? If performance is adequate, then proceed to #4.  4. Build final sightability model using full dataset. (Note that unless #3 dictates otherwise, this likely will be the same as for II. |  | --Present sightability models with best parameter estimates.  --Evaluate performance of sightability model(s) and demonstrate validity of approach:  -If performance is good then application of sightability model will be recommended in IV.  -If performance is poor then discuss why we think this |
| IV | Recommendations to improve redd counts | Discuss salient points of study design, analysis and results. |  |  | --Describe limitations of sightability models.  --Describe how managers could use models. |
| V | Recommendations for further validation work. | Discuss salient points of study design, analysis and results. |  |  | --Discuss results of Analysis II as related to recommendations for training and redd count protocols  --Further validation work needed in MFSR system.  --Recommendations for validation work in other systems? |

**Results**

**Interpretation**

**Interpreting AIC results – brief review**

Under the model selection approach, several models, each representing one hypothesis, are simultaneously evaluated in terms of support from observed data. Models can be ranked and assigned weights, providing a quantitative measure of relative support for each hypothesis. The absolute AIC score is not meaningful but the differences in scores between models can be used as a rough guideline (Burnham and Anderson 2002, pp 70, 446). Models within 1-2 of the best model have substantial support. Some authors have used a cut-off of 2 and others of 3. Using 3 is more inclusive of alternative models and a more conservative criterion that a model can stand alone.

When differences (ΔAICc) between multiple models are within 3 units of the best model then that means all those models are plausible. Where models have similar levels of support, model averaging can be used to make robust parameter estimates and predictions, i.e., to estimate the effect of the variables included within all plausible models. Model averaging weights the variables in the model by the AIC weight and adjusts the estimate accordingly.

The best model is not necessarily a good model – it is just the best out of the ones that you elected to include. However, if you populate the model set with models that cannot predict the response variable then the “null model” (intercept-only model) will be the “best” model. If the null model is the best of the set, it means that the variables in the alternative hypotheses (alternative models) are not good predictors of the response variable. Additionally, you can use confidence intervals or standard errors for model estimates in the best models to see how confident you can be that the variables included can explain the variation in the response variable.

**Results:**

**S.A1z. Sightability-Air-Omissions-Zscores**

Best model, omissions, is M5 alone:

Negatively related to PeakQ

Positively related to LYAbund

Positively related to the interaction of PeakQ\*LYAbund

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | M.ID | M.AIC | num.obs | num.par | Correction | M.AICC | min.AICC | delta | AICC\_wts |
| 4 | M5 | 469.1038 | 57 | 5 | 1.176471 | 470.2803 | 470.2803 | 0 | 94.79397 |
| 1 | M1 | 470.4578 | 57 | 11 | 5.866667 | 476.3245 | 470.2803 | 6.044186 | 4.616388 |
| 8 | M20 | 479.9874 | 57 | 3 | 0.45283 | 480.4402 | 470.2803 | 10.1599 | 0.589638 |
| 7 | M19 | 506.4159 | 57 | 3 | 0.45283 | 506.8688 | 470.2803 | 36.58845 | 1.08E-06 |
| 5 | M6 | 506.7644 | 57 | 3 | 0.45283 | 507.2172 | 470.2803 | 36.9369 | 9.04E-07 |
| 6 | M18 | 509.9228 | 57 | 3 | 0.45283 | 510.3756 | 470.2803 | 40.0953 | 1.86E-07 |
| 3 | M3 | 509.2901 | 57 | 5 | 1.176471 | 510.4665 | 470.2803 | 40.18623 | 1.78E-07 |
| 2 | M2 | 509.2901 | 57 | 5 | 1.176471 | 510.4665 | 470.2803 | 40.18623 | 1.78E-07 |

Model 5

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | Estimate | Std. Error | z value | Pr(>|z|) |
| (Intercept) | 0.440885 | 0.180807 | 2.438426 | 0.014751 |
| z.sc(PeakQ) | -0.10099 | 0.045807 | -2.20467 | 0.027477 |
| z.sc(LYabund) | 0.147261 | 0.109796 | 1.341231 | 0.179846 |
| z.sc(PeakQ):z.sc(LYabund) | 0.493426 | 0.12043 | 4.097187 | 4.18E-05 |

Model 1 (Global)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | Estimate | Std. Error | z value | Pr(>|z|) |
| (Intercept) | 0.497231 | 0.146283 | 3.399092 | 0.000676 |
| z.sc(AveWidth) | 0.343922 | 0.195942 | 1.755224 | 0.079221 |
| z.sc(AveDepth) | -0.09332 | 0.203813 | -0.45786 | 0.64705 |
| z.sc(Slope) | -0.16582 | 0.188068 | -0.88168 | 0.377952 |
| z.sc(AveCanopy) | -0.23982 | 0.143334 | -1.67317 | 0.094293 |
| z.sc(PeakQ) | -0.14142 | 0.063821 | -2.21593 | 0.026696 |
| z.sc(LYabund) | 0.16615 | 0.110206 | 1.507633 | 0.131649 |
| AveBadCond | -0.10065 | 0.161615 | -0.62278 | 0.533429 |
| z.sc(EscapeEst) | -0.04925 | 0.061604 | -0.79951 | 0.423997 |
| z.sc(PeakQ):z.sc(LYabund) | 0.478018 | 0.125604 | 3.805766 | 0.000141 |

**S.A2z. Sightability-Air-Omissions-Zscores**

Best model, commissions, is M5 alone: (note this is similar to S.A1z)

Negatively related to PeakQ

Positively related to LYAbund

Positively related to the interaction of PeakQ\*LYAbund

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | M.ID | M.AIC | num.obs | num.par | Correction | M.AICC | min.AICC | delta | AICC\_wts |
| 4 | M5 | 394.3919 | 57 | 5 | 1.176471 | 395.5684 | 395.5684 | 0 | 99.66399 |
| 1 | M1 | 401.7284 | 57 | 11 | 5.866667 | 407.5951 | 395.5684 | 12.02671 | 0.243765 |
| 8 | M20 | 409.0859 | 57 | 3 | 0.45283 | 409.5387 | 395.5684 | 13.97031 | 0.092241 |
| 7 | M19 | 517.3901 | 57 | 3 | 0.45283 | 517.843 | 395.5684 | 122.2746 | 2.80E-25 |
| 5 | M6 | 518.5548 | 57 | 3 | 0.45283 | 519.0077 | 395.5684 | 123.4393 | 1.56E-25 |
| 6 | M18 | 518.5925 | 57 | 3 | 0.45283 | 519.0453 | 395.5684 | 123.4769 | 1.53E-25 |
| 3 | M3 | 520.2884 | 57 | 5 | 1.176471 | 521.4649 | 395.5684 | 125.8965 | 4.58E-26 |
| 2 | M2 | 520.2884 | 57 | 5 | 1.176471 | 521.4649 | 395.5684 | 125.8965 | 4.58E-26 |

M5

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | Estimate | Std. Error | z value | Pr(>|z|) |
| (Intercept) | -3.58845 | 0.446436 | -8.038 | 9.13E-16 |
| z.sc(PeakQ) | -0.25569 | 0.052078 | -4.9097 | 9.12E-07 |
| z.sc(LYabund) | 1.010964 | 0.140544 | 7.193214 | 6.33E-13 |
| z.sc(PeakQ):z.sc(LYabund) | 1.351371 | 0.149301 | 9.051349 | 1.41E-19 |

M1

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | Estimate | Std. Error | z value | Pr(>|z|) |
| (Intercept) | -3.62618 | 0.427651 | -8.47928 | 2.27E-17 |
| z.sc(AveWidth) | 0.646312 | 0.60107 | 1.075269 | 0.282254 |
| z.sc(AveDepth) | -0.1896 | 0.619597 | -0.30601 | 0.759601 |
| z.sc(Slope) | 0.227997 | 0.560185 | 0.407003 | 0.684006 |
| z.sc(AveCanopy) | -0.28282 | 0.494596 | -0.57181 | 0.567448 |
| z.sc(PeakQ) | -0.20946 | 0.062477 | -3.35265 | 0.0008 |
| z.sc(LYabund) | 1.018764 | 0.142838 | 7.132292 | 9.87E-13 |
| AveBadCond | 0.119891 | 0.189544 | 0.632525 | 0.527044 |
| z.sc(EscapeEst) | 0.091166 | 0.062719 | 1.453558 | 0.146069 |
| z.sc(PeakQ):z.sc(LYabund) | 1.411435 | 0.157157 | 8.981054 | 2.68E-19 |

**S.A3z. Sightability-Air-Frxn\_True-Zscores**

Best model, commissions, is M19 alone:

Positively related to AveSunny (=percent of redds in the sun)

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | M.ID | M.AIC | num.obs | num.par | Correction | M.AICC | min.AICC | delta | AICC\_wts |
| 7 | M19 | 62.55833 | 57 | 3 | 0.45283 | 63.01116 | 63.01116 | 0 | 95.89253 |
| 5 | M6 | 70.4754 | 57 | 3 | 0.45283 | 70.92823 | 63.01116 | 7.91707 | 1.83069 |
| 4 | M5 | 71.59866 | 57 | 5 | 1.176471 | 72.77513 | 63.01116 | 9.763974 | 0.727051 |
| 8 | M20 | 72.36881 | 57 | 3 | 0.45283 | 72.82164 | 63.01116 | 9.810483 | 0.710339 |
| 6 | M18 | 73.49594 | 57 | 3 | 0.45283 | 73.94877 | 63.01116 | 10.93761 | 0.404308 |
| 3 | M3 | 74.11851 | 57 | 5 | 1.176471 | 75.29498 | 63.01116 | 12.28382 | 0.206247 |
| 2 | M2 | 74.11851 | 57 | 5 | 1.176471 | 75.29498 | 63.01116 | 12.28382 | 0.206247 |
| 1 | M1 | 73.85174 | 57 | 11 | 5.866667 | 79.71841 | 63.01116 | 16.70725 | 0.022587 |

M19

|  |  |  |  |
| --- | --- | --- | --- |
|  | Estimate | Std. Error | t value |
| (Intercept) | 0.894386 | 0.051721 | 17.29235 |
| z.sc(AveSunny) | 0.187549 | 0.052181 | 3.594178 |

M1

|  |  |  |  |
| --- | --- | --- | --- |
|  | Estimate | Std. Error | t value |
| (Intercept) | 0.888117 | 0.058638 | 15.1458 |
| z.sc(AveWidth) | -0.00612 | 0.072607 | -0.08435 |
| z.sc(AveDepth) | 0.069414 | 0.076626 | 0.905881 |
| z.sc(Slope) | 0.008685 | 0.070654 | 0.122927 |
| z.sc(AveCanopy) | -0.11633 | 0.067242 | -1.72999 |
| z.sc(PeakQ) | -0.20831 | 0.064158 | -3.24685 |
| z.sc(LYabund) | 0.137849 | 0.095072 | 1.449937 |
| AveBadCond | -0.0428 | 0.142082 | -0.30122 |
| z.sc(EscapeEst) | -0.11449 | 0.07056 | -1.62254 |
| z.sc(PeakQ):z.sc(LYabund) | 0.086916 | 0.115708 | 0.751168 |

**S.G2z. Sightability-Ground-Omissions-Zscores**

Best model, omissions, is M1 alone, the global model

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | M.ID | M.AIC | num.obs | num.par | Correction | M.AICC | min.AICC | delta | AICC\_wts |
| 1 | M1 | 1308.181 | 191 | 13 | 2.056497 | 1310.238 | 1310.238 | 0 | 99.9932 |
| 4 | M5 | 1329.003 | 191 | 6 | 0.456522 | 1329.459 | 1310.238 | 19.22149 | 0.0067 |
| 8 | M20 | 1337.803 | 191 | 4 | 0.215054 | 1338.018 | 1310.238 | 27.78076 | 9.28E-05 |
| 7 | M17 | 1343.781 | 191 | 8 | 0.791209 | 1344.572 | 1310.238 | 34.33482 | 3.50E-06 |
| 6 | M13 | 1350.891 | 191 | 5 | 0.324324 | 1351.215 | 1310.238 | 40.97776 | 1.26E-07 |
| 3 | M3 | 1362.262 | 191 | 6 | 0.456522 | 1362.719 | 1310.238 | 52.48098 | 4.02E-10 |
| 2 | M2 | 1362.262 | 191 | 6 | 0.456522 | 1362.719 | 1310.238 | 52.48098 | 4.02E-10 |
| 5 | M6 | 1366.594 | 191 | 4 | 0.215054 | 1366.809 | 1310.238 | 56.57123 | 5.20E-11 |

M1

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | Estimate | Std. Error | z value | Pr(>|z|) |
| (Intercept) | 0.882696 | 0.163619 | 5.39484 | 6.86E-08 |
| z.sc(AveWidth) | 0.059952 | 0.082171 | 0.729605 | 0.465631 |
| z.sc(AveDepth) | -0.02361 | 0.091544 | -0.25794 | 0.796452 |
| z.sc(Slope) | -0.27888 | 0.08572 | -3.25336 | 0.00114 |
| z.sc(AveCanopy) | -0.03502 | 0.06881 | -0.50888 | 0.610836 |
| z.sc(PeakQ) | 0.144429 | 0.047737 | 3.02551 | 0.002482 |
| z.sc(LYabund) | 0.275064 | 0.070561 | 3.89825 | 9.69E-05 |
| ExperienceCatB | -1.22065 | 0.25354 | -4.81444 | 1.48E-06 |
| ExperienceCatC | -0.27985 | 0.309378 | -0.90455 | 0.365702 |
| z.sc(EscapeEst) | 0.072191 | 0.045937 | 1.571547 | 0.116056 |
| z.sc(PeakQ):z.sc(LYabund) | 0.444969 | 0.090703 | 4.905792 | 9.31E-07 |

**S.G3z. Sightability-Ground-Commissions-Zscores**

Best model, commissions, is M1 alone, the global model

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | M.ID | M.AIC | num.obs | num.par | Correction | M.AICC | min.AICC | delta | AICC\_wts |
| 1 | M1 | 1571.369 | 191 | 13 | 2.056497 | 1573.426 | 1573.426 | 0 | 85.39206 |
| 8 | M20 | 1576.743 | 191 | 4 | 0.215054 | 1576.958 | 1573.426 | 3.532563 | 14.59927 |
| 4 | M5 | 1591.359 | 191 | 6 | 0.456522 | 1591.816 | 1573.426 | 18.38996 | 0.008671 |
| 6 | M13 | 1728.008 | 191 | 5 | 0.324324 | 1728.332 | 1573.426 | 154.9061 | 1.97E-32 |
| 5 | M6 | 1729.118 | 191 | 4 | 0.215054 | 1729.333 | 1573.426 | 155.907 | 1.19E-32 |
| 3 | M3 | 1732.21 | 191 | 6 | 0.456522 | 1732.667 | 1573.426 | 159.2412 | 2.25E-33 |
| 2 | M2 | 1732.21 | 191 | 6 | 0.456522 | 1732.667 | 1573.426 | 159.2412 | 2.25E-33 |
| 7 | M17 | 1732.341 | 191 | 8 | 0.791209 | 1733.132 | 1573.426 | 159.7063 | 1.79E-33 |

M1

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | Estimate | Std. Error | z value | Pr(>|z|) |
| (Intercept) | -3.16949 | 0.393863 | -8.04719 | 8.47E-16 |
| z.sc(AveWidth) | 0.166848 | 0.372574 | 0.447826 | 0.654279 |
| z.sc(AveDepth) | 0.160736 | 0.39532 | 0.406598 | 0.684303 |
| z.sc(Slope) | 0.003532 | 0.341825 | 0.010331 | 0.991757 |
| z.sc(AveCanopy) | 0.190663 | 0.2668 | 0.714629 | 0.474838 |
| z.sc(PeakQ) | 0.269495 | 0.041468 | 6.498855 | 8.09E-11 |
| z.sc(LYabund) | 0.601292 | 0.063242 | 9.507782 | 1.95E-21 |
| ExperienceCatB | -0.16816 | 0.214491 | -0.78399 | 0.433044 |
| ExperienceCatC | 0.274407 | 0.259237 | 1.058521 | 0.289818 |
| z.sc(EscapeEst) | 0.209132 | 0.038468 | 5.436565 | 5.43E-08 |
| z.sc(PeakQ):z.sc(LYabund) | 0.665863 | 0.081713 | 8.148804 | 3.68E-16 |

**S.G4z. Sightability-Ground-Frxn\_True-Zscores**

Best models, frxn\_true, are M5, M1 (global), M13, and M20 (intercept only)

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | M.ID | M.AIC | num.obs | num.par | Correction | M.AICC | min.AICC | delta | AICC\_wts |
| 4 | M5 | 252.8164 | 191 | 6 | 0.456522 | 253.2729 | 253.2729 | 0 | 49.60791 |
| 1 | M1 | 253.6479 | 191 | 13 | 2.056497 | 255.7044 | 253.2729 | 2.431546 | 14.70779 |
| 6 | M13 | 255.5914 | 191 | 5 | 0.324324 | 255.9157 | 253.2729 | 2.642845 | 13.23319 |
| 8 | M20 | 256.1406 | 191 | 4 | 0.215054 | 256.3556 | 253.2729 | 3.08273 | 10.62049 |
| 7 | M17 | 257.4943 | 191 | 8 | 0.791209 | 258.2855 | 253.2729 | 5.012629 | 4.046432 |
| 5 | M6 | 258.7021 | 191 | 4 | 0.215054 | 258.9171 | 253.2729 | 5.644271 | 2.950618 |
| 3 | M3 | 258.8598 | 191 | 6 | 0.456522 | 259.3163 | 253.2729 | 6.043422 | 2.416787 |
| 2 | M2 | 258.8598 | 191 | 6 | 0.456522 | 259.3163 | 253.2729 | 6.043422 | 2.416787 |

M5

|  |  |  |  |
| --- | --- | --- | --- |
|  | Estimate | Std. Error | t value |
| (Intercept) | 0.942466 | 0.071662 | 13.15155 |
| z.sc(PeakQ) | -0.06666 | 0.033803 | -1.97202 |
| z.sc(LYabund) | 0.069246 | 0.055044 | 1.258003 |
| z.sc(PeakQ):z.sc(LYabund) | -0.01505 | 0.068415 | -0.22005 |

M1

|  |  |  |  |
| --- | --- | --- | --- |
|  | Estimate | Std. Error | t value |
| (Intercept) | 0.982901 | 0.071892 | 13.67198 |
| z.sc(AveWidth) | -0.12206 | 0.062979 | -1.93817 |
| z.sc(AveDepth) | 0.097802 | 0.06855 | 1.426727 |
| z.sc(Slope) | -0.02239 | 0.05917 | -0.37839 |
| z.sc(AveCanopy) | -0.03322 | 0.054802 | -0.60613 |
| z.sc(PeakQ) | -0.09846 | 0.043853 | -2.2453 |
| z.sc(LYabund) | 0.060843 | 0.054375 | 1.118944 |
| ExperienceCatB | -0.34091 | 0.116285 | -2.93167 |
| ExperienceCatC | -0.01713 | 0.106124 | -0.16146 |
| z.sc(EscapeEst) | -0.03751 | 0.045525 | -0.824 |
| z.sc(PeakQ):z.sc(LYabund) | -0.04934 | 0.072124 | -0.68411 |

M13

|  |  |  |  |
| --- | --- | --- | --- |
|  | Estimate | Std. Error | t value |
| (Intercept) | 0.991541 | 0.073575 | 13.47661 |
| ExperienceCatB | -0.27343 | 0.115458 | -2.36822 |
| ExperienceCatC | -0.01869 | 0.092659 | -0.20169 |

M20

|  |  |  |  |
| --- | --- | --- | --- |
|  | Estimate | Std. Error | t value |
| (Intercept) | 0.93012 | 0.083767 | 11.1036 |

**V.A1z. Sightability-Air-Omissions-Zscores**

Best models, omissions, is M1 (global) alone

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | M.ID | M.AIC | num.obs | num.par | Correction | M.AICC | min.AICC | delta | AICC\_wts |
| 1 | M1 | 424.5166 | 57 | 17 | 15.69231 | 440.209 | 440.209 | 0 | 99.99815 |
| 12 | M12 | 460.8867 | 57 | 5 | 1.176471 | 462.0632 | 440.209 | 21.85426 | 0.001796 |
| 5 | M5 | 469.1038 | 57 | 5 | 1.176471 | 470.2803 | 440.209 | 30.07136 | 2.95E-05 |
| 10 | M10 | 470.4823 | 57 | 3 | 0.45283 | 470.9352 | 440.209 | 30.72621 | 2.13E-05 |
| 7 | M7 | 474.4595 | 57 | 5 | 1.176471 | 475.636 | 440.209 | 35.42706 | 2.03E-06 |
| 15 | M20 | 479.9874 | 57 | 3 | 0.45283 | 480.4402 | 440.209 | 40.23126 | 1.84E-07 |
| 4 | M4 | 497.7206 | 57 | 3 | 0.45283 | 498.1734 | 440.209 | 57.96447 | 2.59E-11 |
| 9 | M9 | 501.1205 | 57 | 3 | 0.45283 | 501.5733 | 440.209 | 61.36432 | 4.73E-12 |
| 8 | M8 | 504.9076 | 57 | 3 | 0.45283 | 505.3604 | 440.209 | 65.15146 | 7.12E-13 |
| 11 | M11 | 505.2094 | 57 | 3 | 0.45283 | 505.6623 | 440.209 | 65.4533 | 6.12E-13 |
| 14 | M19 | 506.4159 | 57 | 3 | 0.45283 | 506.8688 | 440.209 | 66.65981 | 3.35E-13 |
| 6 | M6 | 506.7644 | 57 | 3 | 0.45283 | 507.2172 | 440.209 | 67.00826 | 2.81E-13 |
| 13 | M18 | 509.9228 | 57 | 3 | 0.45283 | 510.3756 | 440.209 | 70.16666 | 5.80E-14 |
| 3 | M3 | 509.2901 | 57 | 5 | 1.176471 | 510.4665 | 440.209 | 70.25759 | 5.54E-14 |
| 2 | M2 | 509.2901 | 57 | 5 | 1.176471 | 510.4665 | 440.209 | 70.25759 | 5.54E-14 |

M1

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | Estimate | Std. Error | z value | Pr(>|z|) |
| (Intercept) | 0.510026 | 0.164025 | 3.109444 | 0.001874 |
| z.sc(AveWidth) | 0.066132 | 0.232045 | 0.284995 | 0.775648 |
| z.sc(AveDepth) | -0.25228 | 0.236411 | -1.06714 | 0.28591 |
| z.sc(Slope) | -0.28529 | 0.214382 | -1.33077 | 0.183266 |
| z.sc(AveCanopy) | -0.12853 | 0.172525 | -0.74502 | 0.456259 |
| z.sc(PeakQ) | -0.25143 | 0.065145 | -3.85962 | 0.000114 |
| z.sc(OthrDens) | -0.12369 | 0.097065 | -1.2743 | 0.202556 |
| z.sc(LYabund) | 0.456724 | 0.133081 | 3.431931 | 0.000599 |
| z.sc(AveSunny) | 0.020072 | 0.094058 | 0.213403 | 0.831012 |
| z.sc(AveContrast) | -0.01753 | 0.080078 | -0.21888 | 0.826747 |
| z.sc(redd\_dens) | 0.075942 | 0.142031 | 0.53469 | 0.592864 |
| z.sc(AveOverlap) | -0.19319 | 0.076325 | -2.53118 | 0.011368 |
| z.sc(AveAge) | -0.61865 | 0.137769 | -4.4905 | 7.11E-06 |
| AveBadCond | 0.093693 | 0.189934 | 0.493294 | 0.621805 |
| z.sc(log(ANNDist)) | 0.203943 | 0.171416 | 1.189759 | 0.234141 |
| z.sc(PeakQ):z.sc(LYabund) | 0.814935 | 0.153638 | 5.304265 | 1.13E-07 |

**V.A2z. Sightability-Air-Commissions-Zscores**

Best models, commissions, are M5

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | M.ID | M.AIC | num.obs | num.par | Correction | M.AICC | min.AICC | delta | AICC\_wts |
| 5 | M5 | 394.3919 | 57 | 5 | 1.176471 | 395.5684 | 395.5684 | 0 | 99.86365 |
| 15 | M20 | 409.0859 | 57 | 3 | 0.45283 | 409.5387 | 395.5684 | 13.97031 | 0.092426 |
| 1 | M1 | 395.3342 | 57 | 17 | 15.69231 | 411.0265 | 395.5684 | 15.45809 | 0.043926 |
| 7 | M7 | 457.8124 | 57 | 5 | 1.176471 | 458.9889 | 395.5684 | 63.42053 | 1.69E-12 |
| 8 | M8 | 479.6998 | 57 | 3 | 0.45283 | 480.1526 | 395.5684 | 84.58422 | 4.29E-17 |
| 9 | M9 | 499.0792 | 57 | 3 | 0.45283 | 499.532 | 395.5684 | 103.9637 | 2.65E-21 |
| 4 | M4 | 503.3064 | 57 | 3 | 0.45283 | 503.7592 | 395.5684 | 108.1909 | 3.21E-22 |
| 10 | M10 | 510.9068 | 57 | 3 | 0.45283 | 511.3596 | 395.5684 | 115.7912 | 7.17E-24 |
| 12 | M12 | 513.6096 | 57 | 5 | 1.176471 | 514.7861 | 395.5684 | 119.2177 | 1.29E-24 |
| 14 | M19 | 517.3901 | 57 | 3 | 0.45283 | 517.843 | 395.5684 | 122.2746 | 2.80E-25 |
| 11 | M11 | 518.3991 | 57 | 3 | 0.45283 | 518.8519 | 395.5684 | 123.2835 | 1.69E-25 |
| 6 | M6 | 518.5548 | 57 | 3 | 0.45283 | 519.0077 | 395.5684 | 123.4393 | 1.57E-25 |
| 13 | M18 | 518.5925 | 57 | 3 | 0.45283 | 519.0453 | 395.5684 | 123.4769 | 1.54E-25 |
| 3 | M3 | 520.2884 | 57 | 5 | 1.176471 | 521.4649 | 395.5684 | 125.8965 | 4.58E-26 |
| 2 | M2 | 520.2884 | 57 | 5 | 1.176471 | 521.4649 | 395.5684 | 125.8965 | 4.58E-26 |

M5

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | Estimate | Std. Error | z value | Pr(>|z|) |
| (Intercept) | -3.58845 | 0.446436 | -8.038 | 9.13E-16 |
| z.sc(PeakQ) | -0.25569 | 0.052078 | -4.9097 | 9.12E-07 |
| z.sc(LYabund) | 1.010964 | 0.140544 | 7.193214 | 6.33E-13 |
| z.sc(PeakQ):z.sc(LYabund) | 1.351371 | 0.149301 | 9.051349 | 1.41E-19 |

**V.A3z. Sightability-Air-frxn\_true-Zscores**

Best models, frxn\_true, are M19 and M9

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | M.ID | M.AIC | num.obs | num.par | Correction | M.AICC | min.AICC | delta | AICC\_wts |
| 14 | M19 | 62.55833 | 57 | 3 | 0.45283 | 63.01116 | 63.01116 | 0 | 66.4818 |
| 9 | M9 | 65.36008 | 57 | 3 | 0.45283 | 65.81291 | 63.01116 | 2.801755 | 16.37983 |
| 12 | M12 | 66.83138 | 57 | 5 | 1.176471 | 68.00785 | 63.01116 | 4.996694 | 5.466187 |
| 8 | M8 | 68.19712 | 57 | 3 | 0.45283 | 68.64995 | 63.01116 | 5.638788 | 3.965113 |
| 7 | M7 | 68.48348 | 57 | 5 | 1.176471 | 69.65995 | 63.01116 | 6.648796 | 2.392958 |
| 10 | M10 | 70.31606 | 57 | 3 | 0.45283 | 70.76889 | 63.01116 | 7.75773 | 1.374463 |
| 6 | M6 | 70.4754 | 57 | 3 | 0.45283 | 70.92823 | 63.01116 | 7.91707 | 1.269208 |
| 11 | M11 | 71.72069 | 57 | 3 | 0.45283 | 72.17352 | 63.01116 | 9.16236 | 0.68096 |
| 5 | M5 | 71.59866 | 57 | 5 | 1.176471 | 72.77513 | 63.01116 | 9.763974 | 0.504061 |
| 15 | M20 | 72.36881 | 57 | 3 | 0.45283 | 72.82164 | 63.01116 | 9.810483 | 0.492474 |
| 13 | M18 | 73.49594 | 57 | 3 | 0.45283 | 73.94877 | 63.01116 | 10.93761 | 0.280305 |
| 4 | M4 | 73.6107 | 57 | 3 | 0.45283 | 74.06353 | 63.01116 | 11.05237 | 0.264674 |
| 1 | M1 | 59.35318 | 57 | 17 | 15.69231 | 75.04549 | 63.01116 | 12.03433 | 0.161987 |
| 3 | M3 | 74.11851 | 57 | 5 | 1.176471 | 75.29498 | 63.01116 | 12.28382 | 0.14299 |
| 2 | M2 | 74.11851 | 57 | 5 | 1.176471 | 75.29498 | 63.01116 | 12.28382 | 0.14299 |

M19

|  |  |  |  |
| --- | --- | --- | --- |
|  | Estimate | Std. Error | t value |
| (Intercept) | 0.894386 | 0.051721 | 17.29235 |
| z.sc(AveSunny) | 0.187549 | 0.052181 | 3.594178 |

M9

|  |  |  |  |
| --- | --- | --- | --- |
|  | Estimate | Std. Error | t value |
| (Intercept) | 0.897119 | 0.066527 | 13.4851 |
| z.sc(log(ANNDist)) | 0.163779 | 0.053179 | 3.079775 |

**V.G2z. Sightability-Ground-Omissions-Zscores**

Best model, omissions, is M1 (global)

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | M.ID | M.AIC | num.obs | num.par | Correction | M.AICC | min.AICC | delta | AICC\_wts |
| 1 | M1 | 1232.816 | 191 | 18 | 3.976744 | 1236.793 | 1236.793 | 0 | 100 |
| 15 | M15 | 1316.167 | 191 | 8 | 0.791209 | 1316.959 | 1236.793 | 80.16552 | 3.91E-16 |
| 5 | M5 | 1329.003 | 191 | 6 | 0.456522 | 1329.459 | 1236.793 | 92.66607 | 7.55E-19 |
| 18 | M20 | 1337.803 | 191 | 4 | 0.215054 | 1338.018 | 1236.793 | 101.2254 | 1.05E-20 |
| 12 | M12 | 1337.758 | 191 | 6 | 0.456522 | 1338.215 | 1236.793 | 101.4219 | 9.47E-21 |
| 17 | M17 | 1343.781 | 191 | 8 | 0.791209 | 1344.572 | 1236.793 | 107.7794 | 3.94E-22 |
| 16 | M16 | 1345.635 | 191 | 6 | 0.456522 | 1346.091 | 1236.793 | 109.2981 | 1.85E-22 |
| 14 | M14 | 1346.589 | 191 | 6 | 0.456522 | 1347.045 | 1236.793 | 110.2522 | 1.15E-22 |
| 10 | M10 | 1347.731 | 191 | 4 | 0.215054 | 1347.946 | 1236.793 | 111.1532 | 7.30E-23 |
| 7 | M7 | 1349.814 | 191 | 6 | 0.456522 | 1350.271 | 1236.793 | 113.4777 | 2.28E-23 |
| 13 | M13 | 1350.891 | 191 | 5 | 0.324324 | 1351.215 | 1236.793 | 114.4224 | 1.42E-23 |
| 3 | M3 | 1362.262 | 191 | 6 | 0.456522 | 1362.719 | 1236.793 | 125.9256 | 4.52E-26 |
| 2 | M2 | 1362.262 | 191 | 6 | 0.456522 | 1362.719 | 1236.793 | 125.9256 | 4.52E-26 |
| 4 | M4 | 1363.787 | 191 | 4 | 0.215054 | 1364.002 | 1236.793 | 127.2085 | 2.38E-26 |
| 8 | M8 | 1365.528 | 191 | 4 | 0.215054 | 1365.743 | 1236.793 | 128.9497 | 9.98E-27 |
| 9 | M9 | 1365.792 | 191 | 4 | 0.215054 | 1366.007 | 1236.793 | 129.2135 | 8.74E-27 |
| 6 | M6 | 1366.594 | 191 | 4 | 0.215054 | 1366.809 | 1236.793 | 130.0158 | 5.85E-27 |
| 11 | M11 | 1371.174 | 191 | 4 | 0.215054 | 1371.389 | 1236.793 | 134.5959 | 5.93E-28 |

M1

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | Estimate | Std. Error | z value | Pr(>|z|) |
| (Intercept) | 1.087531 | 0.170251 | 6.387794 | 1.68E-10 |
| z.sc(AveWidth) | -0.04936 | 0.099653 | -0.4953 | 0.620388 |
| z.sc(AveDepth) | -0.01386 | 0.10714 | -0.12937 | 0.897067 |
| z.sc(Slope) | -0.33205 | 0.098849 | -3.35919 | 0.000782 |
| z.sc(AveCanopy) | 0.005189 | 0.079852 | 0.064984 | 0.948187 |
| z.sc(PeakQ) | 0.211296 | 0.044087 | 4.792716 | 1.65E-06 |
| z.sc(OthrDens) | -0.06074 | 0.058688 | -1.03505 | 0.300644 |
| z.sc(LYabund) | 0.58265 | 0.084244 | 6.916209 | 4.64E-12 |
| ExperienceCatB | -1.40315 | 0.248785 | -5.64002 | 1.70E-08 |
| ExperienceCatC | -0.264 | 0.303529 | -0.86977 | 0.384429 |
| z.sc(AveContrast) | 0.056427 | 0.04395 | 1.283884 | 0.199183 |
| z.sc(redd\_dens) | -0.21527 | 0.070893 | -3.03652 | 0.002393 |
| z.sc(AveOverlap) | -0.03999 | 0.04624 | -0.8648 | 0.387149 |
| z.sc(AveAge) | -0.17766 | 0.055164 | -3.22051 | 0.00128 |
| z.sc(log(ANNDist)) | 0.122838 | 0.08851 | 1.387848 | 0.165183 |
| z.sc(PeakQ):z.sc(LYabund) | 0.682143 | 0.098409 | 6.931728 | 4.16E-12 |

**V.G3z. Sightability-Ground-Commissions-Zscores**

Best models, commissions, is M1 (global)

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | M.ID | M.AIC | num.obs | num.par | Correction | M.AICC | min.AICC | delta | AICC\_wts |
| 1 | M1 | 1510.426 | 191 | 18 | 3.976744 | 1514.403 | 1514.403 | 0 | 100 |
| 8 | M8 | 1563.525 | 191 | 4 | 0.215054 | 1563.74 | 1514.403 | 49.33756 | 1.93E-09 |
| 14 | M14 | 1564.932 | 191 | 6 | 0.456522 | 1565.389 | 1514.403 | 50.98612 | 8.48E-10 |
| 7 | M7 | 1566.672 | 191 | 6 | 0.456522 | 1567.128 | 1514.403 | 52.7257 | 3.55E-10 |
| 18 | M20 | 1576.743 | 191 | 4 | 0.215054 | 1576.958 | 1514.403 | 62.55552 | 2.61E-12 |
| 5 | M5 | 1591.359 | 191 | 6 | 0.456522 | 1591.816 | 1514.403 | 77.41292 | 1.55E-15 |
| 9 | M9 | 1609.495 | 191 | 4 | 0.215054 | 1609.71 | 1514.403 | 95.30755 | 2.01E-19 |
| 12 | M12 | 1648.914 | 191 | 6 | 0.456522 | 1649.371 | 1514.403 | 134.9681 | 4.92E-28 |
| 15 | M15 | 1649.847 | 191 | 8 | 0.791209 | 1650.638 | 1514.403 | 136.2351 | 2.61E-28 |
| 10 | M10 | 1665.666 | 191 | 4 | 0.215054 | 1665.881 | 1514.403 | 151.478 | 1.28E-31 |
| 11 | M11 | 1720.56 | 191 | 4 | 0.215054 | 1720.775 | 1514.403 | 206.3722 | 1.54E-43 |
| 13 | M13 | 1728.008 | 191 | 5 | 0.324324 | 1728.332 | 1514.403 | 213.9291 | 3.51E-45 |
| 6 | M6 | 1729.118 | 191 | 4 | 0.215054 | 1729.333 | 1514.403 | 214.9299 | 2.13E-45 |
| 4 | M4 | 1729.495 | 191 | 4 | 0.215054 | 1729.71 | 1514.403 | 215.3075 | 1.76E-45 |
| 16 | M16 | 1729.539 | 191 | 6 | 0.456522 | 1729.995 | 1514.403 | 215.5927 | 1.53E-45 |
| 3 | M3 | 1732.21 | 191 | 6 | 0.456522 | 1732.667 | 1514.403 | 218.2642 | 4.02E-46 |
| 2 | M2 | 1732.21 | 191 | 6 | 0.456522 | 1732.667 | 1514.403 | 218.2642 | 4.02E-46 |
| 17 | M17 | 1732.341 | 191 | 8 | 0.791209 | 1733.132 | 1514.403 | 218.7292 | 3.19E-46 |

M1

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | Estimate | Std. Error | z value | Pr(>|z|) |
| (Intercept) | -3.23675 | 0.370178 | -8.74378 | 2.25E-18 |
| z.sc(AveWidth) | 0.121781 | 0.34062 | 0.357528 | 0.720697 |
| z.sc(AveDepth) | 0.225987 | 0.361154 | 0.625735 | 0.531489 |
| z.sc(Slope) | 0.0508 | 0.312242 | 0.162693 | 0.87076 |
| z.sc(AveCanopy) | 0.238221 | 0.243993 | 0.976343 | 0.328894 |
| z.sc(PeakQ) | -0.06293 | 0.041234 | -1.52626 | 0.126946 |
| z.sc(OthrDens) | 0.181327 | 0.049942 | 3.630725 | 0.000283 |
| z.sc(LYabund) | 0.442993 | 0.072884 | 6.078095 | 1.22E-09 |
| ExperienceCatB | -0.31444 | 0.246719 | -1.2745 | 0.202485 |
| ExperienceCatC | 0.179903 | 0.307395 | 0.585251 | 0.558379 |
| z.sc(AveContrast) | 0.007939 | 0.039201 | 0.202512 | 0.839516 |
| z.sc(redd\_dens) | 0.411676 | 0.065273 | 6.307008 | 2.84E-10 |
| z.sc(AveOverlap) | 0.013474 | 0.040195 | 0.335205 | 0.73747 |
| z.sc(AveAge) | -0.09147 | 0.04524 | -2.02179 | 0.043198 |
| z.sc(log(ANNDist)) | 0.027869 | 0.064174 | 0.434276 | 0.664088 |
| z.sc(PeakQ):z.sc(LYabund) | 0.429586 | 0.094272 | 4.556889 | 5.19E-06 |

**V.G4z. Sightability-Ground-frxn\_true-Zscores**

Best models, frxn\_true, is M1 (global)

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | M.ID | M.AIC | num.obs | num.par | Correction | M.AICC | min.AICC | delta | AICC\_wts |
| 1 | M1 | 221.8722 | 191 | 18 | 3.976744 | 225.8489 | 225.8489 | 0 | 98.80327 |
| 9 | M9 | 234.7399 | 191 | 4 | 0.215054 | 234.9549 | 225.8489 | 9.105997 | 1.040948 |
| 7 | M7 | 238.4705 | 191 | 6 | 0.456522 | 238.927 | 225.8489 | 13.07804 | 0.14286 |
| 14 | M14 | 243.741 | 191 | 6 | 0.456522 | 244.1975 | 225.8489 | 18.34854 | 0.010243 |
| 8 | M8 | 247.4545 | 191 | 4 | 0.215054 | 247.6696 | 225.8489 | 21.82065 | 0.001805 |
| 10 | M10 | 250.8971 | 191 | 4 | 0.215054 | 251.1121 | 225.8489 | 25.2632 | 0.000323 |
| 15 | M15 | 250.7645 | 191 | 8 | 0.791209 | 251.5557 | 225.8489 | 25.70676 | 0.000259 |
| 5 | M5 | 252.8164 | 191 | 6 | 0.456522 | 253.2729 | 225.8489 | 27.42393 | 0.00011 |
| 12 | M12 | 254.7286 | 191 | 6 | 0.456522 | 255.1851 | 225.8489 | 29.33618 | 4.21E-05 |
| 16 | M16 | 254.8436 | 191 | 6 | 0.456522 | 255.3001 | 225.8489 | 29.45116 | 3.98E-05 |
| 13 | M13 | 255.5914 | 191 | 5 | 0.324324 | 255.9157 | 225.8489 | 30.06678 | 2.92E-05 |
| 18 | M20 | 256.1406 | 191 | 4 | 0.215054 | 256.3556 | 225.8489 | 30.50666 | 2.35E-05 |
| 4 | M4 | 257.1643 | 191 | 4 | 0.215054 | 257.3794 | 225.8489 | 31.53043 | 1.41E-05 |
| 17 | M17 | 257.4943 | 191 | 8 | 0.791209 | 258.2855 | 225.8489 | 32.43656 | 8.94E-06 |
| 6 | M6 | 258.7021 | 191 | 4 | 0.215054 | 258.9171 | 225.8489 | 33.0682 | 6.52E-06 |
| 11 | M11 | 259.0543 | 191 | 4 | 0.215054 | 259.2694 | 225.8489 | 33.42044 | 5.47E-06 |
| 3 | M3 | 258.8598 | 191 | 6 | 0.456522 | 259.3163 | 225.8489 | 33.46736 | 5.34E-06 |
| 2 | M2 | 258.8598 | 191 | 6 | 0.456522 | 259.3163 | 225.8489 | 33.46736 | 5.34E-06 |

M1

|  |  |  |  |
| --- | --- | --- | --- |
|  | Estimate | Std. Error | t value |
| (Intercept) | 1.054544 | 0.06753 | 15.61598 |
| z.sc(AveWidth) | -0.12377 | 0.056495 | -2.19089 |
| z.sc(AveDepth) | 0.078186 | 0.059073 | 1.323545 |
| z.sc(Slope) | -0.03358 | 0.052739 | -0.63673 |
| z.sc(AveCanopy) | -0.00485 | 0.049069 | -0.09886 |
| z.sc(PeakQ) | -0.00439 | 0.042008 | -0.10452 |
| z.sc(OthrDens) | -0.00596 | 0.041118 | -0.14503 |
| z.sc(LYabund) | 0.30202 | 0.062681 | 4.818342 |
| ExperienceCatB | -0.41093 | 0.110549 | -3.7172 |
| ExperienceCatC | -0.05014 | 0.108118 | -0.46378 |
| z.sc(AveContrast) | 0.014237 | 0.035601 | 0.39991 |
| z.sc(redd\_dens) | 0.0282 | 0.060686 | 0.464694 |
| z.sc(AveOverlap) | 0.000731 | 0.038926 | 0.01879 |
| z.sc(AveAge) | -0.10171 | 0.044384 | -2.29166 |
| z.sc(log(ANNDist)) | 0.268606 | 0.05563 | 4.828451 |
| z.sc(PeakQ):z.sc(LYabund) | 0.221878 | 0.080468 | 2.757336 |

**References**

Anderson, D. R. 2001. The need to get the basics right in wildlife field studies. Wildlife Society

Bulletin 29(4): 1294-1297.

Anderson, D. R. (2003). Response to Engeman: index values rarely constitute reliable information. Wildlife Society Bulletin 31(1): 288-291.

Boulinier, T., J. D. Nichols, et al. (1998). Estimating species richness: the importance of heterogeneity in species detectability. Ecology 79(3): 1018-1028.

Dunham et al. 2001 (Bull trout redd detection paper)

Engemen 2001

Fieberg 2012 R sightability package paper, uses Steinhorst and Samuel 1989 but doesn’t account for commissions

Fieberg 2015. R sightability package manual

Muhlfeld et al. 2007 (Bull trout redd detection paper)

Steinhorst and Samuel 1989

**Status/Notes: Last update 2/8/2016**

**Overview of Analyses we are Conducting**

Ground/Air x Sightability/Validation x 3 Response Variables x Original units/Zscores

2 x 2 x 3 x 2 = 24 analyses

**To Do:**

Generate results for all 24 analyses –DONE except R2

Fill in interpretation reports

**Analysis and Output**

Steps for analysis in DPs notes

Code Output – for older output I want to save, save into a folder name with the output date/version, b/c a new R run will overwrite files in output folders

Notes on Model Sets: Add notes on handwritten sheets from work w DP

**Interpretation** – template created, fill in the sections for each analysis

Currently working on putting results into output template Results for 12 \* 2 analyses. Get everything in a template and provide interpretation for each piece.

**Need code to generate R2 values** for each model output. Not something we need immediately to proceed, but I think it’s something we will want to “ground” the model selection results

Need to generate figures and tables for results

**Need to check LME4, glmer updates** and modify code if needed.

This may be too much data and analysis for just 2 papers, but I’ll get results into figures and manuscript form first and we can decide then.

**Issues / Notes:**

Look at effect of transformed covariates with Z-scores. Cannot take log of z-scores that are negative or zero. Also, squared transformation for one variable.

Model averaging – we don’t currently have code written to do this so if initial output suggests we want to do this, need to talk with Darcy.

Frxn\_true response variable is hard to interpret because the “optimal” is at 1.0 and both higher and lower values are bad = represent error. So how do we interpret coefficients in results?

Variables (continuous) rescaled to z-scores: coefficients are directly comparable within a model but to ground in reality need to back-calculate to original units (ie to say a 1 unit change in predictor causes “x” amount of change in response variable.

Check out recent Sightability model R code: no commissions

<http://cran.r-project.org/web/packages/SightabilityModel/>

**Appendix A**

**Functional Forms**

|  |  |
| --- | --- |
| Functional forms | Hypothesized relationships between independent and dependent variables from Russ Thurow and Claire McGrath |
|  |  |
| Correlations | look into correlation of variables. For ANNDist, AveOverlap, and redd\_dens, we are guessing ANNDist is going to be the best predictor, but also think redd-dens could be important on its own. Would be nice to include both variables. AveOverlap is easiest to measure during redd surveys, so maybe use this variable for "sightability" analysis and others for "validation" (whole dataset) analysis |
|  |  |
| S? | S' refers to whether the variable would be available in a traditional sightability modeling approach (routine field surveys), rather than just in our intensive validation study approach. We plan to do 2 separate analyses - one 'Validation' and one 'Sightability' |





**Appendix B**

**Latest file: ModelInputs\_wNotes\_160208.xls**

Definition of Model sets – first 12 pages are for non-scaled data and second 12 pages are for scaled data.

These spreadsheets are used to create bare csv files (no notes) for input to R code.

S.A1

S.A2

S.A3

S.G2

S.G3

S.G4

V.A1

V.A2

V.A3

V.G2

V.G3

V.G4

**S.A1**



**S.A2**



**S.A3**



**S.G2.**



**S.G3**



**S.G4**



**V.A1**



**V.A2**



**V.A3**



**V.G2**



**V.G3**



**V.G4** 

***Next 12 model sets are for analysis of scaled data (Z-scores)***

**S.A1z**



**S.A2z**



**S.A3z**



**S.G2z**



**S.G3z**



**S.G4z**



**V.A1z**



**V.A2z**



**V.A3z**



**V.G2z**



**V.G3z**



**V.G4z**



1. Standardizing data brings different indicators, which have different units, into the same scale with an average of zero and a standard deviation of one. A z-score indicates how many standard deviations from the mean an individual measurement is. The average of zero avoids introducing aggregation distortions steming from differences in indicators’ means. The scaling factor is the standard deviation of the indicator across [↑](#footnote-ref-1)