**Title**:  Spatiotemporal Analysis of American three-toed woodpeckers (*Picoides dorsalis*) and bark beetle outbreaks in Colorado

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## Introduction

Spruce beetle (*Dendroctonous rufipennis* Kirby) outbreaks are a natural part of subalpine forest development in the Rocky Mountains (Veblen et al. 1991), though their impact on bird communities has not been formally described. Woodpeckers are the highest-ranked biological predator of the spruce beetle and significantly reduce the beetle brood (Koplin and Baldwin 1970, Schmid and Frye 1977), yet research is needed to better understand woodpecker associations with broad-scale disturbances such as spruce beetle outbreaks. The goal of this research project is to pinpoint American three-toed woodpecker (*Picoides dorsalis*, here in ATTW) habitat associations with spruce beetle outbreaks because this species is such an important spruce beetle predator (Hutchinson 1951, Koplin and Baldwin 1970, Schmid and Frye 1977).  Results from the research may have important management applications in subalpine forests where spruce beetle outbreaks are likely to become more common and forest management activities will intensify in the coming years (Agricultural Act, 2014).   Our results quantify the extent by which ATTWs occupy bark beetle infested forests.

## Research Question

At a regional scale, do American three-toed woodpeckers exhibit a strong association with bark beetle outbreaks.

**Data Sources**

The Bird Conservancy of the Rockies (formerly Rocky Mountain Bird Observatory) provided point count survey data for Colorado, Idaho, Montana, and Wyoming for 2010 to 2014. The file contained the UTM coordinates for each point count location, the elevation at that point, all bird species present, and the primary habitat. For the purpose of this project, we subsisted the data and only included data for Colorado in our analyses. The map of the original data (see slide 6) shows the original ATTW detection data and general bark beetle damage for the San Juan region from 2010 to 2014 damage. Mountain bark beetle is especially present in the foothills north of Denver. All detections of ATTWs were extracted from the raw data and converted into into ESRI shapefiles, with original attributes preserved. We used aerial detection survey (ADS) data shapefiles from the US Forest Service to map forest mortality across Colorado. A DEM of Colorado and a general basemap were downloaded from the National Geographic website for use in mapping study areas

**Methods**

*Data Processing*

The area of interest for our analysis is the San Juan Mountain range located in SW Colorado. First, we needed to manipulate the original survey point count data of ATTW because the data are for bird detections at individual points within a transect. Because birds have a home range of about 2 km squared during the breeding season to move around in, it is more meaningful ecologically to calculate abundance within an area rather than at a single point. We executed a 500 m buffer tool around each ATTW detection point and then ran a dissolve tool on the buffers. This would make any overlapping ATTW buffers into a single ATTW study area and any buffered ATTW points that don't overlap into their own study area. In addition to this, this would also create study areas of a reasonable size for each ATTW home range. Within the dissolve tool we calculated the sum of the ATTW counts and the average elevation for each ATTW study area.

In order to obtain polygons of bark beetle infestation, we used the publicly available ADS data supplied by the U.S. Forest Service. This was done by extracting all bark beetle damage codes (column DCA1) within the 11000 to 11999 range. These codes encompass any tree mortality that was identified by the survey mappers as bark beetle induced (subfamily *Scolytinae*).

To determine the proximity of woodpecker study areas to beetle-infested forests, we created a model in model builder (see slide 8) so that we could iterate the model for each year of woodpecker detection and the yearly beetle-infestation polygons. For the model we used two different datasets used to calculate the final distances of the ATTW study areas to the nearest bark beetle outbreaks by year for the San Juan Mountain range. From there we created two parameterizations, one calculating the beetle distance for a single imputed year ('Year') and the other calculating the final beetle distances in the years ahead ('Years Ahead'), going all the way up to three years when the model is run. We then created three placeholder values ('DMG year0, DMG year plus1', and 'DMG year plus2') so that we could calculate the distance to bark beetle infestation polygons that were detected 1 year later, two years later, and three years later respectively. This is because there is often a lag between the onset of infestation and when the needles on the tree turn brown, so we wanted to make sure that we accounted for that lag in detection of beetle infestation by aerial surveyors.

Once the variables of bark beetle damage areas by year were calculated, a 'Generate Near Table' tool was used to calculate the closest distance between the edge of an ATTW study area and the edge of the nearest beetle infestation polygon for year0, year plus1 and year plus2. The reason why we calculated the nearest distance from the ATTW study areas to the bark beetle outbreak polygons is because we want to know how far the ATTW sightings were to the nearest outbreaks. In some cases, the ATTW counts were within a beetle outbreak polygon (Distance="0") telling us that a study area where ATTWs were detected was within a bark beetle outbreak area. Once the final distances from ATTW study areas to the nearest bark beetle outbreaks were calculated, we joined the final output table to the original ATTW study area polygons and calculated three new fields called "Distance to Beetle Plus0, Distance to Beetle Plus1, and Distance to Beetle Plus2," that was attributed with the distances calculated by the near tool and were added to the final output table of the model.

Lastly, we wanted to calculate the primary habitat for each study area as a final variable to use in our statistical analyses. Because the primary habitat is recorded by Bird Conservancy surveyors at each point count location, we were able to use these data. We converted the original point counts to a raster of primary habitat codes and calculated the "majority" habitat for each study area using the *zonal statistics as table* tool. We joined this table to the study areas and calculated a new field called "PrimaryHab" with the outcomes from the zonal statistics for each study area. We were then able to export the final study area attribute table to excel, convert them to csv. files and then import them to the R statistical software environment for analyses

*Statistical Analyses*

In order to determine whether or not the independent variables we calculated were important in predicting woodpecker abundance within an area, we used a poisson regression. The poisson model is the appropriate regression model to use when the dependent variable is a count. The poisson model is a generalized linear model that takes the logarithm of the mean as a linear function of the observed covariates. It then determines which variables are the most important in predicting increased counts. We ran the poisson regression for 2014

**Results**

From the data, the spruce beetle outbreak was detected on 485,000 acres in 2014. The total area affected by the spruce beetle since 1996 has increased to almost 1.4 million acres statewide. The map (see slide 9) of the San Juan Mountains of SW Colorado shows where the spruce beetle outbreak has been expanding over the last couple years and the woodpecker counts for the sites located in that area for 2013 and 2014 . This area really highlights the relationship between the bark beetle outbreak and woodpecker abundance. The results showed that for all years from 2010 to 2014, an average of seventy-one percent of study areas with 4 or more ATTW detections were within bark beetle-infested polygons of the same year. In the years 2013 and 2014 point counts overlap some of the point count data from 2011 to 2012 so we used different sized points. The overlap of point counts for each consecutive year possibly suggesting that ATTWs revisited these sites (see slide 9). In 2011, there were no point counts greater than or equal to 4. This was apparent in 23 of 34 sites. Secondly, one hundred percent of study areas during 2010 to 2014 containing 11 or more ATTW detections were within beetle-infested polygons of the same year and comprised 7 sites. The results table shows the sum, mean, minimum, and maximum number of ATTW detections from 2010-2014, the number of sites with four or more ATTW detections and the percentage of sites with 4 or more ATTW detections (see slide 11). We found that the range of ATTW detections varied from 2010-2014 with the largest range of ATTW detections in 2014 and the median of ATTW detections stays relatively the same from 2010-2014 (see slide 12).

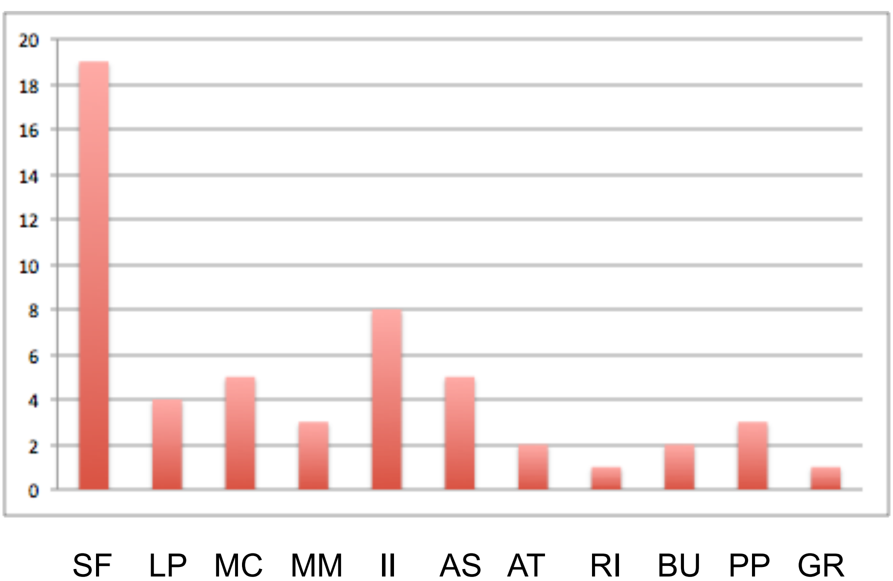
*Statistical Analysis*

We conducted a poisson regression for 2014 only because that was the year of the greatest sample size ($N$ = 55 study areas). Our results indicate that ATTW abundance is strongly associated with elevation, and primary habitat. All variables used in the model were highly significant predictors of increased ATTW counts ($p < 0.0001$). ATTW were most commonly found in Spruce-Fir forests over any other habitat type (See Figure A, below). These birds also seem to gravitate towards higher elevations. ATTW were also more likely to occur very close to, or within, a beetle infestation polygon. ADS data is not yet available for 2015 so we were only able to calculate the distance to beetle infestation polygons detected in 2014.

Table 1. Poisson Regression for association between distance to beetle infestation, elevation, and primary habitat.

| | Variables | Estimate | Std. Error | Z value | P value |
|---|---|---|---|---|---|
| | Intercept | -1.90E+00 | 8.10E-01 | -2.345 | 0.019044 * |
| | Dis_B_2014 | -4.42E-05 | 1.28E-05 | -3.462 | 0.000536 *** |
| | Mean Elevation | 1.17E-03 | 2.36E-04 | 4.961 | 7.02e-07 *** |
| 2014 | Primary Habitat | -9.15E-02 | 2.42E-02 | -3.784 | 0.000154 *** |
| | Null deviance: 188.73 on 54 degrees of freedom | | | | |
| | Residual deviance: 106.11 on 51 degrees of freedom | | | | |
| | AIC: 264.19 | | | | |
| | Significance codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1 | | | | |

Figure A.  Histogram of the number of ATTW study areas found in each habitat type.




Habitat codes are Spruce-Fir, Lodgepole Pine, Mixed Conifer, Montane Meadow, Insect Infested, Aspen, Alpine Tundra, Riparian Area, Burned Area, Ponderosa Pine, and Grassland respectively.

## Discussion

Our results indicate that there is a connection between spruce beetle outbreaks and increases in abundance of the ATTW. Results from the poisson regression (Table 1) show that distance to bark beetle polygons, elevation, and primary habitat are all significant predictors of ATTW abundance across the landscape. Conservation practices, in response to bark beetle outbreaks, should focus on preserving patches of bark beetle infested forests for ATTW habitat.

*Snags along the way*

We ran into a few snags with running the model. We first went down the road of a model outputting Euclidean distance, which ended up creating vague results in the relationship between ATTW counts and bark beetle outbreaks. Due to this, we made the decision to generate near tables that outputted the distance from woodpecker study sites buffers to the nearest beetle polygon. ADS data is limited in a sense that it is done manually by a person flying above the forests writing down what they see, making it prone to human induced error in delineating what is and what is not beetle-kill. We ran a poisson regression with ATTW count as the dependent variable using just presence data in our analysis and did not include absence data except as general overview maps. ATTW absence data (figure 7), in addition to presence data might be useful to better understand ATTW habitat and may be important for better delineation of their home ranges and foraging sites.

*Individual contributions*

We split up the research so that each of our expertise would benefit the analysis. Julia, our project leader has expertise and knowledge of ATTWs in her current research. Matt has expertise both as an ecologist and in working with RStudio in generating statistical tables and the box-cox diagrams. Ellen has a background as a Burned Area Emergency Rehabilitation (BAER) specialist.

*Future Directions*

Our working model to analyze ATTW population counts can be used to analyze other states that fall within the Rocky Mountain range. Fire may also be an important disturbance to consider for ATTW habitat. Three-toed woodpeckers are a fire dependent species that prefer mixed-severity habits (Kotliar et. al., 2008). Per our discussion, fires will strengthen our current work as they are of abiotic importance to the ATTW. The map of the 2013 Papoose Fires (slide 15) shows that most of the woodpeckers' sightings were outside the existing burn boundaries. Researchers have studied the woodpecker’s response to burn severity and prey availability. Three-toed woodpeckers established territories in moderately burned heterogeneous habitat, more so than in high severity or unburned areas (Kotliar et. al., 2008). Future projects may extend these bird abundance studies to the San Juan Mountains.

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