Squirrels and their territory acquisition

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Background Information

Background

- Dataset based on a long-term study of wild North American red squirrels (27 years) in Yukon, Canada, focused on survival, reproduction, and population dynamics.

- Why study territory acquisition?

  Studying territory acquisition is crucial for understanding ecological balance, species interactions, resource use, and ecosystem stability.

Hypothesis and predictions

Hypothesis

Male and female juvenile North American red squirrels (*Tamiasciurus hudsonicus*) differ in their likelihood of acquiring a territory and sex is the biggest factor that affects whether they can acquire a territory.

Prediction

1. One sex (male or female) might have a higher likelihood of acquiring a territory.

2. Sex is the biggest factor that affects whether they can acquire a territory.

Method

For Prediction 1: One sex (male or female) might have a higher likelihood of acquiring a territory.

1. Data manipulation
   a. Converted the "owner" column into a binary variable "acquired_terr" (1 = acquired territory, 0 = not).
   b. Handled missing or invalid data

```
# Data manipulation
## Add a column indicate in 1 if "acquired territory" and 0 if "not yet acquired territory"
```{r}
juveniles_data <- juveniles %>% mutate(acquired_terr = case_when(owner == "acquired territory" ~ 1,
TRUE ~ 0) )
head(juveniles_data)
```

Handle missing or invalid data
```{r}
juveniles_data <- juveniles_data %>%
  drop_na(sex, Std.growth, Std.BD, z.cones, z.density, z.temp, Std.lynx, Std.mustelid,
          Std.hare.fall, acquired_terr, Std.Cleth)
```
```

2. Exploratory data analysis

a. Used logistic regression to see the odds of acquiring territory between males and females

b. This will include the significance difference in the likelihood of acquiring a territory between sexes

````
```{r}
# Logistic regression for Prediction 1
model_sex <- glm(acquired_terr ~ sex,
                 family = "binomial",
                 data = juveniles_data)
summary(model_sex)
```
````

3. Visualize the likelihood of territory acquisition by sex

   a. Used bar plot

```
juveniles_data %>%
  group_by(sex) %>%
  ggplot(aes(x = acquired_terr, fill = sex)) +
  geom_bar() +
    labs(title = "Acquisition of Territory by Sex",
         x = "Sex",
         y = "Number of squirrels")

juveniles_data %>%
  group_by(sex) %>%
  summarise(mean_likelihood = mean(acquired_terr)) %>%
  ggplot(aes(x = sex, y = mean_likelihood, fill = sex)) +
  geom_bar(stat = "identity") +
    labs(title = "Likelihood of Acquiring Territory by Sex",
         x = "Sex",
         y = "Mean Likelihood")
```
```
```

For Prediction 2:

Sex is the biggest factor that affects whether they can acquire a territory.

1. Performed logistic regression with <u>multiple predictors</u>
    - sex, std. birthdate, std. growth, std. lynx, std. hare, std. mustelid, std. Cleth, z. density, z. cones, z. Temperature
    - Not considering combined effects

```
```{r}
# Logistic regression for Prediction 2 with multiple predictors
model_full <- glm(acquired_terr ~ sex + Std.BD + Std.growth + Std.lynx +
                    Std.hare.fall + Std.mustelid + Std.Cleth + z.density +
                    z.cones + z.temp,
                  family = "binomial",
                  data = juveniles_data)
summary(model_full)
```
```

2. Evaluated the significance of each predictor using p-values to determine whether sex is the most influential factor.

```
Coefficients:
               Estimate Std. Error z value Pr(>|z|)    
(Intercept)     1.11407    0.09948  11.199  < 2e-16 ***
sexM           -0.52074    0.12713  -4.096 4.20e-05 ***
Std.BD         -0.76442    0.06596 -11.589  < 2e-16 ***
Std.growth      0.08042    0.08064   0.997   0.3186    
Std.lynx       -0.28595    0.14800  -1.932   0.0534 .  
Std.hare.fall   0.54824    0.14053   3.901 9.57e-05 ***
Std.mustelid   -0.02275    0.06788  -0.335   0.7375    
Std.Cleth       0.02200    0.07636   0.288   0.7732    
z.density       0.16341    0.11389   1.435   0.1513    
z.cones        -0.31415    0.07127  -4.408 1.05e-05 ***
z.temp         -0.02375    0.07895  -0.301   0.7635    
---
```

3. Conducted logistic regression with individual predictors and models including interactions between predators and prey.

```{r}
# Model for Std.BD
model_StdBD <- glm(acquired_terr ~ Std.BD, family = "binomial", data = juveniles_data)

# Model for Std.growth
model_Stdgrowth <- glm(acquired_terr ~ Std.growth, family = "binomial", data = juveniles_data)

# Model for Std.lynx
model_lynx <- glm(acquired_terr ~ Std.lynx, family = "binomial", data = juveniles_data)

# Model for Std.hare.fall
model_harefall <- glm(acquired_terr ~ Std.hare.fall, family = "binomial", data = juveniles_data)

# Model for Std.mustelid
model_mustelid <- glm(acquired_terr ~ Std.mustelid, family = "binomial", data = juveniles_data)
```

4. Compared these models with the "full" model using Aikake Information Criterion (AIC) to identify the most significant factor that influences territory acquisition in squirrels.

```
aic_values <- data.frame(
  Model = c("Full model", "sex", "Std.BD", "Std.growth", "Std.lynx", "Std.hare.fall",
"Std.mustelid", "Std.Cleth", "z.density", "z.cones", "z.temp", "combine_effect"),
  AIC = c(
    AIC(model_full),
    AIC(model_sex),
    AIC(model_StdBD),
    AIC(model_Stdgrowth),
    AIC(model_lynx),
    AIC(model_harefall),
    AIC(model_mustelid),
    AIC(model_Cleth),
    AIC(model_density),
    AIC(model_cones),
    AIC(model_temp),
    AIC(model_combine_effects)
  )
)
```

5. Visualized the effects of predictors on territory acquisition.

````
```{r}
juveniles_data |>
  ggplot(aes(x = Std.BD, y = acquired_terr)) +
  geom_point() +
  geom_smooth(method = "glm",
              method.args = list(family = "binomial")
              )
```
````

````
```{r}
juveniles_data |>
  ggplot(aes(x = Std.lynx, y = acquired_terr)) +
  geom_point() +
  geom_smooth(method = "glm",
              method.args = list(family = "binomial")
              )
```
````

Results

For Prediction 1:

- Males have lower odds of acquiring a territory (sexM coefficient = -0.39, p = 0.000446).

```
glm(formula = acquired_terr ~ sex, family = "binomial", data = juveniles_data)

Coefficients:
            Estimate Std. Error z value Pr(>|z|)    
(Intercept)  0.70475    0.07625   9.243  < 2e-16 ***
sexM        -0.39008    0.11110  -3.511 0.000446 ***
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

(Dispersion parameter for binomial family taken to be 1)

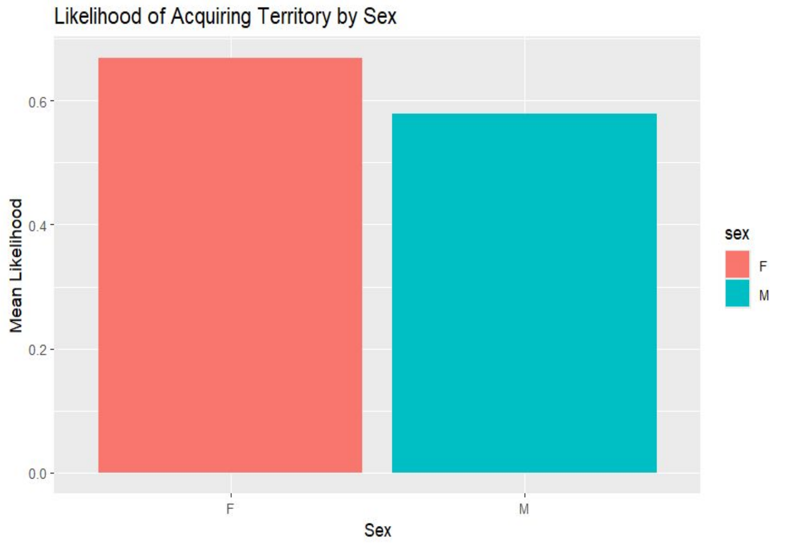
    Null deviance: 1853.9  on 1404  degrees of freedom
Residual deviance: 1841.6  on 1403  degrees of freedom
AIC: 1845.6

Number of Fisher Scoring iterations: 4
```

For Prediction 1:

- Males have lower odds of acquiring a territory (sexM coefficient = -0.39, p = 0.000446).
- Females have a higher likelihood in the graph.

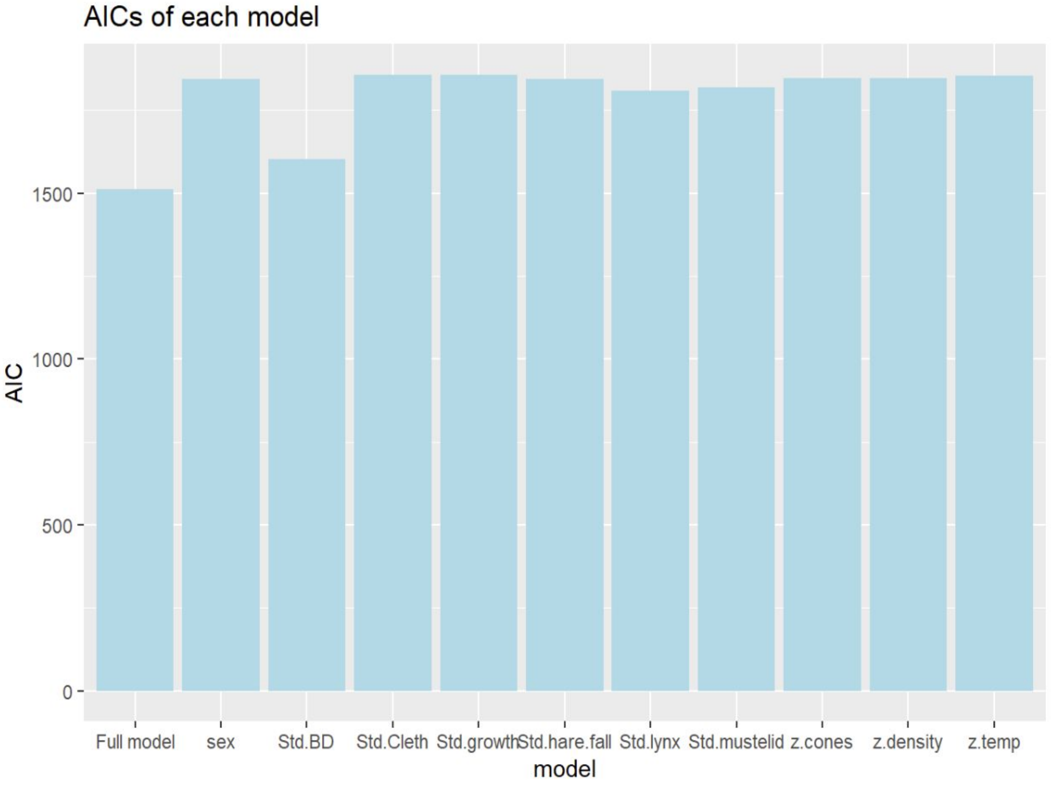
Conclusion: The null hypothesis that there is no difference in the likelihood of territory acquisition between males and females is rejected.



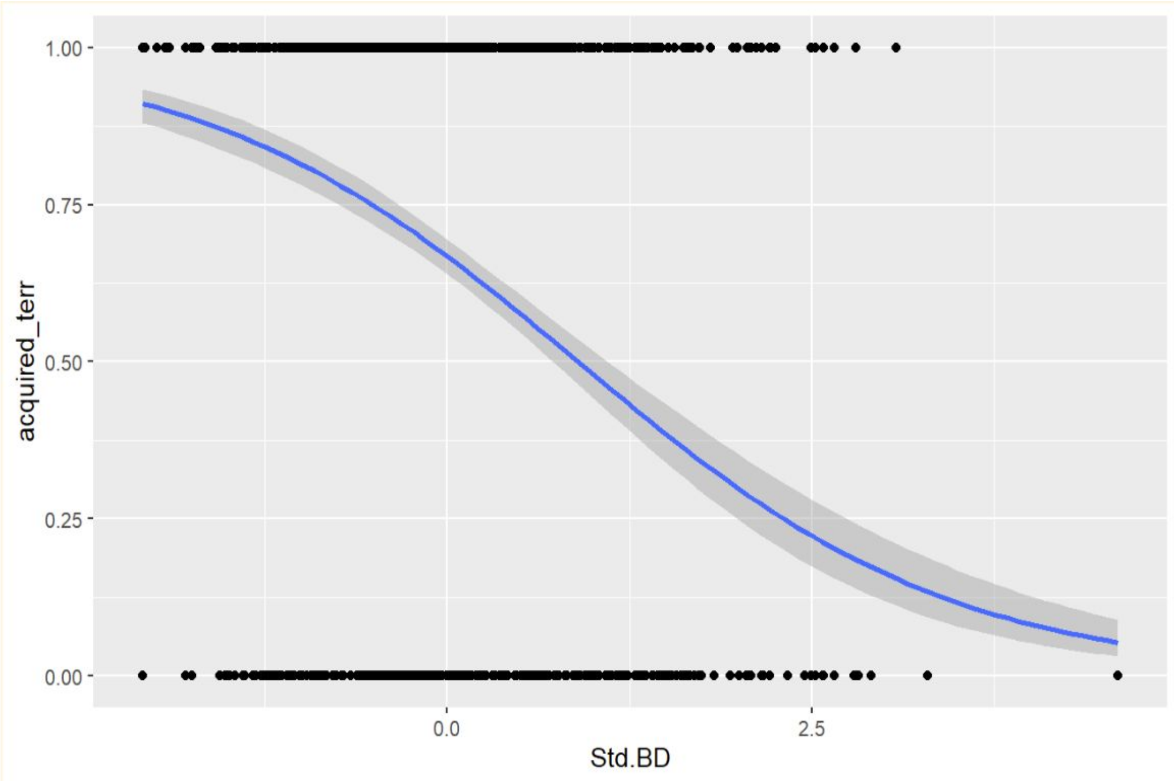
For Prediction 2:

- “Full” model has the lowest AIC
  - Predictors collectively contribute to territory acquisition.
- Among single predictors:
  - Std.BD has the lowest AIC

Conclusion: The null hypothesis that sex is not the biggest factor cannot be rejected.



- The relationship between standardized birth date and territory acquisition
- Birthdate is standardized as the data are collected over decades.
- Squirrels born earlier tend to acquire territory more easily.



Conclusion

Conclusion and Practical Insights

1. **Females squirrels have a higher likelihood of acquiring a territory than males.**
   - Focus on protecting female squirrels could ensure population sustainability

2. **Standardized birth date has the strongest impact on territory acquisition.**
   - Support early-born juveniles by resource management

3. **Predator has the second-strongest impact on territory acquisition.**
   - Manage predator populations to balance survival pressures and competition

Future Work

- Calculate the combined effects by multiplying variables that interact
- Lasso regression
  - A statistical and machine learning technique that combines variable selection and regularization to improve the accuracy and interpretability of a model

Thank you!

Hendrix JG, Fisher DN, Martinig AR, Boutin S, Dantzer B, Lane JE, McAdam AG. 2020. Territory acquisition mediates the influence of predators and climate on juvenile red squirrel survival. Pelletier F, editor. Journal of Animal Ecology. 89(6):1408–1418. doi:10.1111/1365-2656.13209. https://besjournals.onlinelibrary.wiley.com/doi/10.1111/1365-2656.13209.