Dall sheep reproductive success in Alaska and NW Canada

https://github.com/cpf11/FastFajardoPlasynski_ENV872_EDA_FinalProject.git

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1 Rationale and Research Questions

Ungulate populations can easily fluctuate in response to changing environmental conditions (Koizumi and Derocher et al., 2019). Although dall sheep currently have stable population numbers, arctic and subarctic environments are subject to transformation due to changes in climatic conditions affecting snow cover, precipitation, and temperature (Higgins and Cassano, 2009). Changes in these conditions can affect resource availability and vegetation cover, influencing the success and reproductive abilities of herbivore populations (Post and Forchhaammer, 2007). Fluctuations in herbivore populations can result in a bottom up trophic cascade, further impacting community balance and carnivore population numbers (Kagata and Ohgushi, 2005). Because of this, it is important to evaluate reproductive success in dall sheep to ensure stable populations of all organisms in arctic and subarctic North American ecosystems. Assessment of population health will allow conservation planning to take place as needed and will assist in predicting the future of the population as environmental conditions continue to change.

In this project, we will evaluate the effects of environmental conditions on dall sheep reproductive success using multiple linear regression. We aim to identify several factors of statistical significance to create an understanding of how fluctuating conditions will affect dall sheep in the future. We expect that decreased snow cover, decreased precipitation, and increased temperature will have a negative relationship with reproductive success.

Question 1: How do environmental conditions affect Dall sheep reproductive success?

2 Dataset Information

For our analysis, we utilized a dataset called the Arctic-Boreal Vulnerability Experiment (ABoVE): Dall Sheep Lamb Recruitment and Climate Data in Alaska and NW Canada, 2000-2015. We retrieved the data from the NASA Earth Data site using their download data tool. We downloaded the lamb_ewe_ratios_by_mountainunit CSV file, which can be found on the GitHub Repository, under the "Raw" data folder. More information about the dataset can be found in Table 1 and 2.

This dataset consists of sheep population numbers from state and federal monitoring surveys throughout mountain ranges in Alaska and Northwestern Canada during the years 2000-2015. The climate and environmental data were estimated for the fourteen mountain ranges where the sheep were located. Daily snow was estimated using MODIS imagery, and distance to the center of the sheep range, as well as latitude, longitude, and elevation were gathered from the Global Multi-resolution Terrain Elevation Data 2010. Additionally, monthly gridded climate products from the Scenarios Network for Alaska + Arctic Planning (SNAP), were used to estimate average annual temperature, average May temperatures, total annual precipitation, and total winter (October-April) precipitation. The surveys were carried out primarily during the summer using aircraft. As raw sheep counts could not be compared between surveys due to differences in methods, locations, and areas, the variable, Lamb-to-ewe ratio, was calculated, serving as an indicator of recruitment. The dataset therefore contains estimated annual average Dall sheep lamb-to-ewe ratios from each year between 2000-2015.

Detail	Description
Data Source	NASA Earth Data
Dataset Name	Arctic-Boreal Vulnerability Experiment (ABoVE): Dall Sheep Lamb Recruitment and Climate Data in Alaska and NW Canada
Retrieved From	https://daac.ornl.gov/cgi-bin/dsviewer.pl?ds_id=1640
Variables Used	Mountain unit, year, lamb_ewe_ratio, elevation, snow line elevation, snow disappearance, snow cover duration, temp, precip, may temperature, winter precipitation
Date Range	2000-2015

Table 1: Database information

Column name	Description	Class of data	Unit
Mountain unit	14 mountain ranges divided into 24 mountain units for the study	Character	
Year	2000-2015	Double	
Surveys	# of surveys	Double	
Elevation	Mean mountain unit elevation	Double	m
Snow line elevation	Elevation on May 15	Double	m
Snow disappearance	day of year mean	Double	
Snow cover duration	mean days	Double	
Temperature	Annual average temperature for that year	Double	ºC
Precipitation	total annual precipitation for that year	Double	mm
May temperatures	Average temperature in May for that year	Double	ºC
Winter precipitation	Total winter (oct-april) precipitation preceding lambing season in that Year	Double	mm
Latitude	Mean mountain unit latitude	Double	decimal degrees
Longitude	Mean mountain unit longitude	Double	decimal degrees
Distance	from center point of each point of each mountain unit to range center	Double	km
Sheep density	adult sheep/survey area	Double	adult sheep/km2
Lamb ewe ratio	ratio of lambs to female sheep	Double	

Table 2: Raw Dataset Information

#Data Wrangling We first changed the independent variable, year, to a date class using the as.Date function. A pipe function was used to select the independent variables of interest: mountain unit, year, lamb ewe ratio, elevation, snow line elevation, snow disappearance, snow cover duration, temp, precipitation, May temperature, and winter precipitation. The explanatory variables of latitude, longitude, and distance were all removed as mountain unit was the only data necessary to analyze location. Sheep density was removed as an independent variable, as a large amount of data points were missing from this column. The pipe function dropped NA's from the snow line elevation column to ensure that all data points were readable. The remaining variables included in the processed dataset are included in Table 3.

Processed Dataset: Column name | Description | Class of data | Unit ————- | ———-—- | ————- | ————- Mountain unit | 14 mountain ranges divided into 24 mountain units for the study | Character | Year | 2000-2015 | Date | Surveys | # of surveys |Double | Elevation| Mean mountain unit elevation | Double | m Snow line elevation | Elevation on May 15 | Double | m Snow disappearance | day of year mean | Double | Snow cover duration | mean days | Double | Temperature | Annual average temperature for that year | Double | ºC Precipitation | total annual precipitation for that year | Double | mm May temperatures | Average temperature in May for that year | Double | ºC Winter precipitation | Total winter (oct-april) precipitation preceding lambing season in that year | Double | mm Lamb ewe ratio | ratio of lambs to female sheep | Double |

Table 3: Processed Dataset Information

3 Exploratory Analysis

After wrangling the dataset, we created the "Processed" datafile. With our variables of interest, we created a scatterplot matrix to identify patterns within the data. The scatterplot matrix (Figure 1) allows us a better visualization of the relationships within the dataset. To check the dataset for normality, a Shapiro-Wilk test was performed and did not indicate evidence of non-normality (W= 0.99606, p=0.9154). Therefore, we fail to reject the null hypothesis that states the variables are normally distributed.

For further analysis, we plotted time against the dependent variable, lamb EWE ratio (Figure 2), and plotted a histogram of lamb EWE ratio (Figure 3). These figures further signify evidence of normality in the dataset. Finally, the summary tables provide summary statistics for the variables included in the wrangled dataset, and provide a closer look at the summary statistics for Lamb EWE ratio (Table 3 and 4).

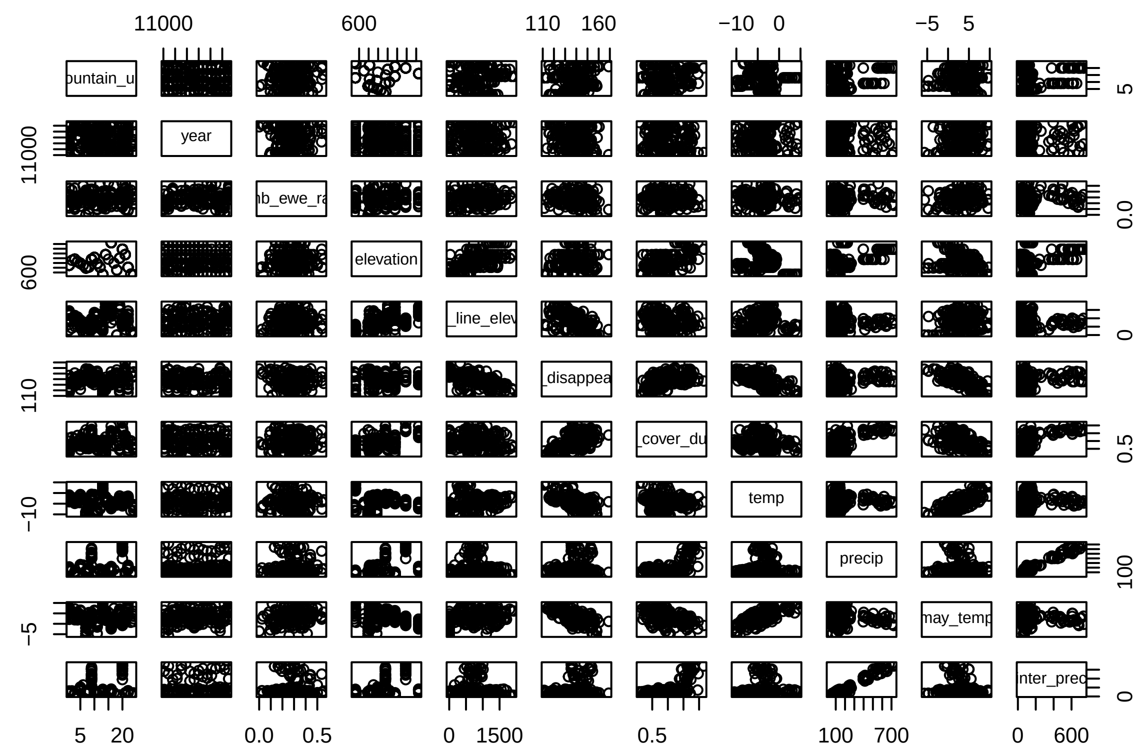

Figure 1: Scatterplot matrix of dataset

```
## Warning in FUN(newX[, i], ...): no non-missing arguments to min; returning Inf

## Warning in FUN(newX[, i], ...): no non-missing arguments to min; returning Inf

## Warning in FUN(newX[, i], ...): no non-missing arguments to max; returning -Inf

## Warning in FUN(newX[, i], ...): no non-missing arguments to max; returning -Inf
```

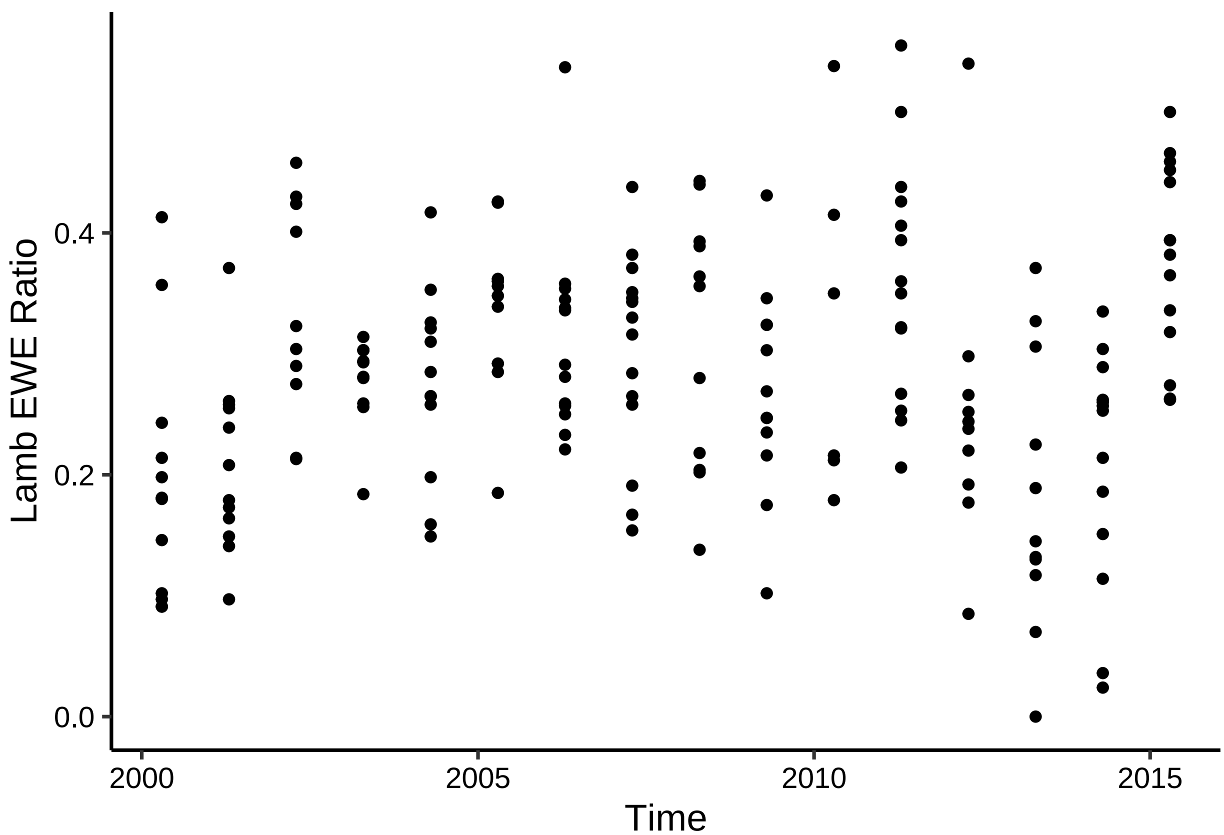

Figure 2: Lamb EWE Ratio over Time

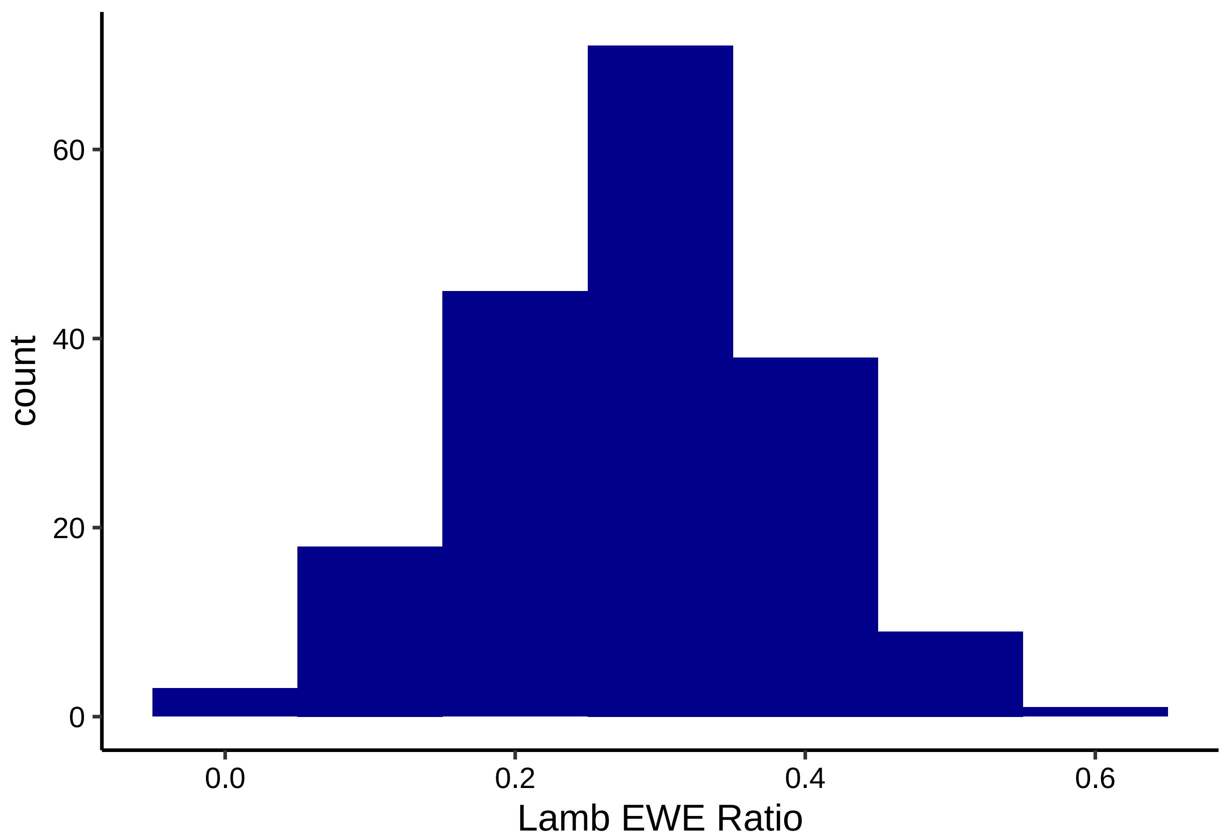

Figure 3: Histogram of Lamb EWE Ratio

Table 3: Table 4:Summary Statistics of Lamb Dataset

	vars	n	mean	sd	min	max	range	se
mountain_unit	1	185	NaN	NA	Inf	-Inf	-Inf	NA
year	2	185	NaN	NA	Inf	-Inf	-Inf	NA
lamb_ewe_ratio	3	185	0.2825135	0.1067934	0.000	0.555	0.555	0.0078516
elevation	4	185	1086.3751243	368.8738171	496.442	1852.819	1356.377	27.1201424
snow_line_elevation	5	185	800.0012432	486.9143092	0.000	1922.125	1922.125	35.7986520
snow_disappearance	6	185	138.2156000	11.1754765	111.319	169.015	57.696	0.8216374
snow_cover_duration	7	185	0.5936703	0.0909945	0.417	0.830	0.413	0.0066901
temp	8	185	-3.9384108	3.0902623	-10.489	4.606	15.095	0.2272006
precip	9	185	188.6173189	169.3793379	30.743	725.153	694.410	12.4530166
may_temp	10	185	3.3103568	2.9746230	-5.690	9.779	15.469	0.2186986
winter_precip	11	185	160.8487784	180.6469450	16.419	738.344	721.925	13.2814275

Table 4: Table 5: Lamb EWE Ratio: Summary Table

mean.ratio	minimum.ratio	maximum.ratio	sd.ratio
0.2825135	0	0.555	0.1067934

4 Analysis

The best model, as chosen by AIC in a stepwise algorithm, included the following explanatory variables: snow cover duration, temperature, and May temperature. The final model indicates that about 7% (adjusted r-squared=0.06929) of the variation in the dependent variable is explained by the independent variables. As indicated by the F-statistic, the variables in the model are significantly different from 0, demonstrating that the linear regression model fits the data better than a model without any explanatory variables (Table 5).

The three explanatory variables were all statistically significant in the final model, indicating that they have a statistically significant effect on lamb ewe ratio. With a one unit increase in snow cover duration, lamb ewe ratio increased by 0.293678 (snow cover duration: estimate = 0.293678, p = 0.86777) (Table 5). This slight positive relationship between lamb ewe ratio and snow cover duration is visible in the plot, with the line of best fit sloping upwards (Figure 4).

With a one unit increase in temperature, lamb ewe ratio decreased by 0.013754 (temperature: estimate = -0.013754, p = 0.00140) (Table 5). Given that this negative relationship between the two variables is very slight, the line of best fit does not demonstrate this negative relationship and instead appears to be a plateau (Figure 5).

With a one unit increase in May temperature, lamb ewe ratio increased by 0.020645 (May temperature: estimate = 0.020645, p = 6.79e-05) (Table 5). This positive relationship between lamb ewe ratio and May temperature is visible in the plot (Figure 5), with the line of best fit sloping upwards. The relationship between these two variables is noticeably more significant in this plot than for the plot comparing lamb ewe ratio and snow cover duration (Figure 4).

Table 5: Table 5: Linear Regression Results

term	estimate	std.error	statistic	p.value
(Intercept)	-0.0143460	0.0860449	-0.1667264	0.8677715
snow_cover_duration	0.2936781	0.1076651	2.7276987	0.0070060
temp	-0.0137539	0.0042377	-3.2456331	0.0013961
may_temp	0.0206453	0.0050624	4.0781286	0.0000679

```
## `geom_smooth()` using formula 'y ~ x'
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## `geom_smooth()` using formula 'y ~ x'
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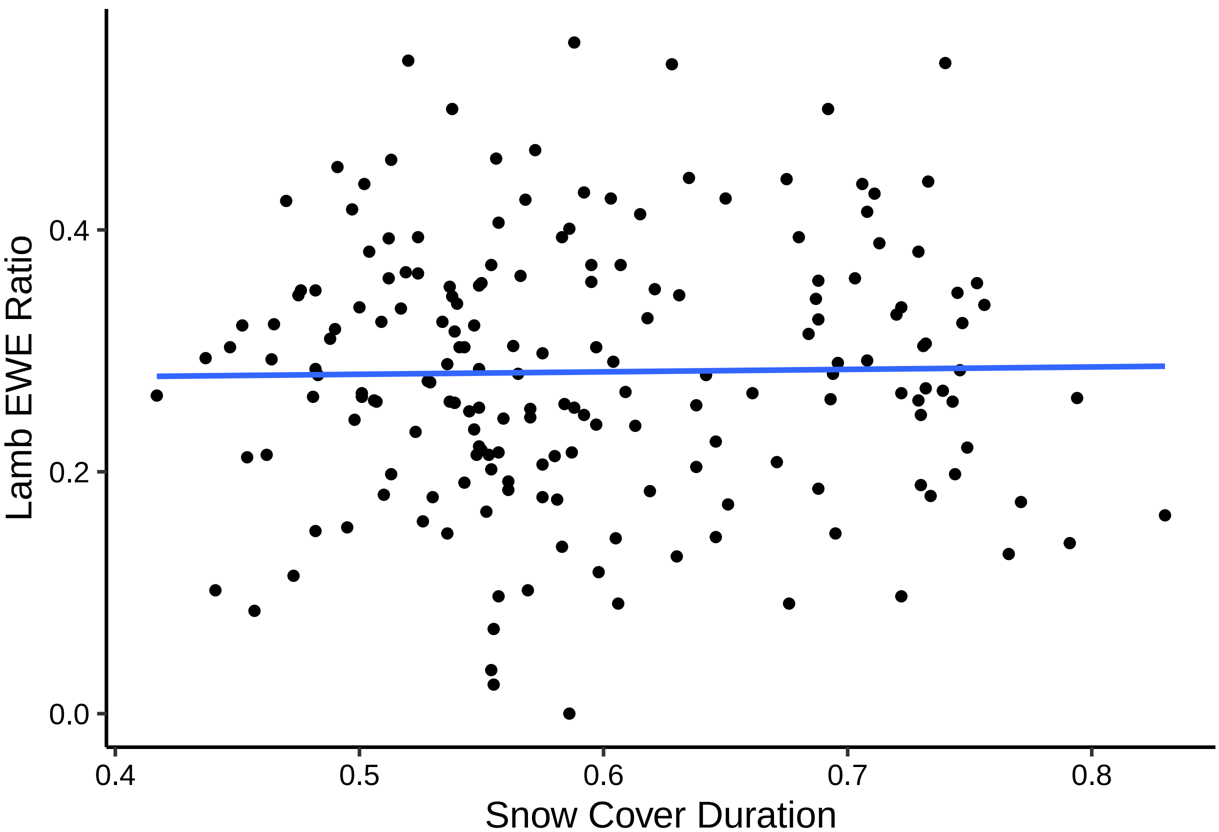

Figure 4: Relationship between lamb ewe ratio and snow cover duration

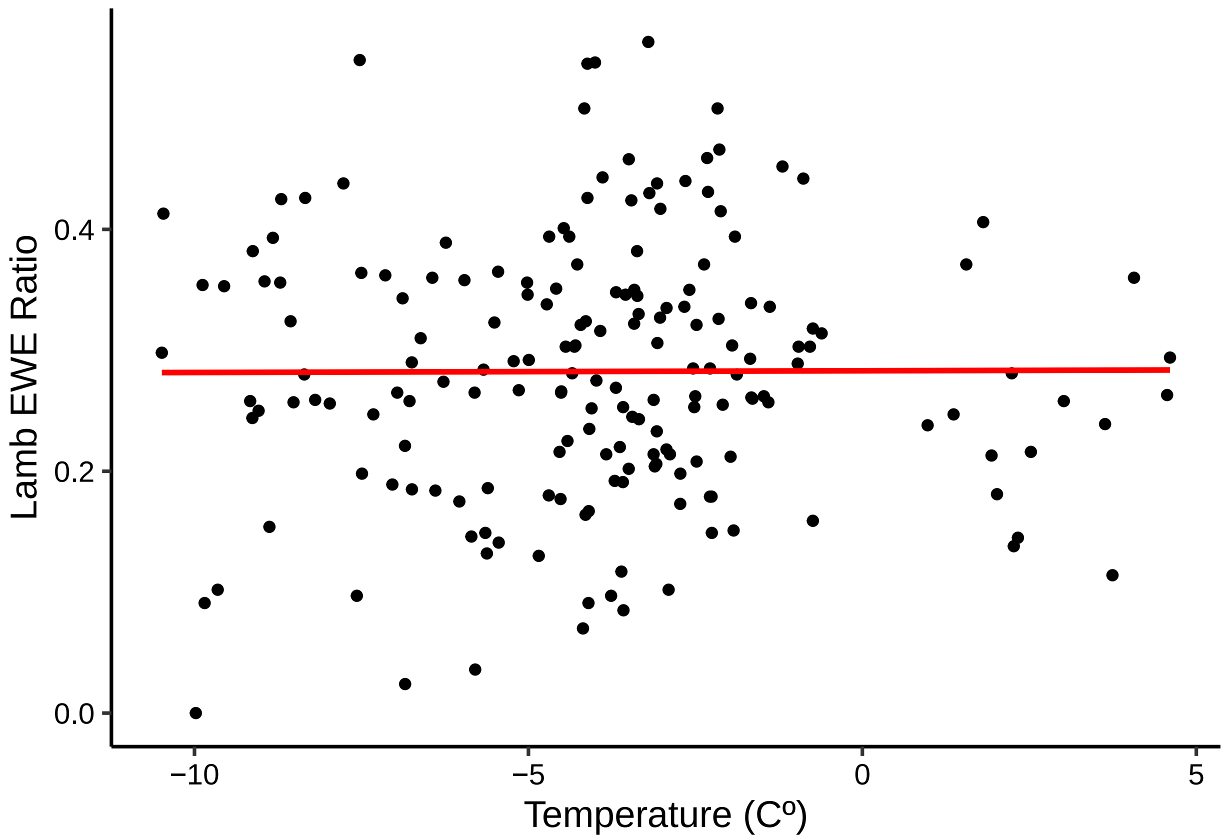

Figure 5: Relationship between lamb ewe ratio and temperature (Cº)

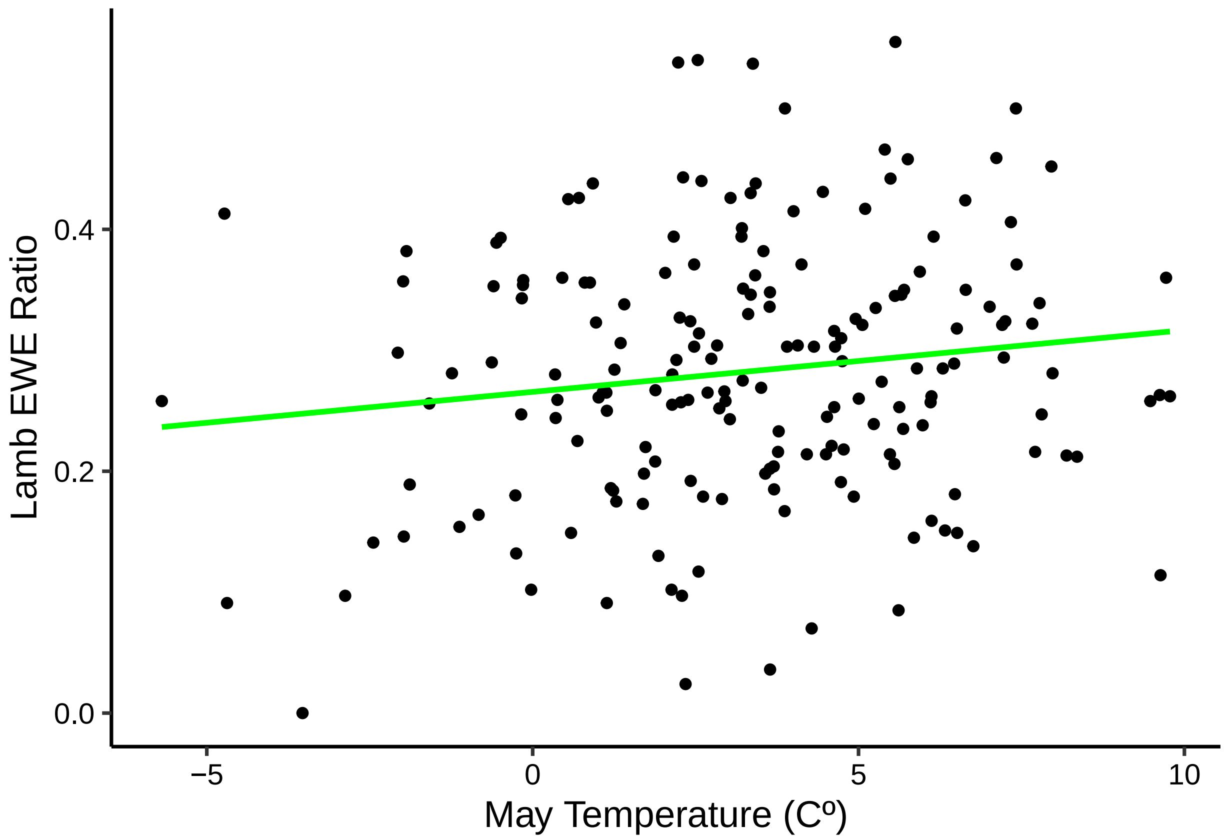

Figure 6: Relationship between lamb ewe ratio and may temperature (Cº)

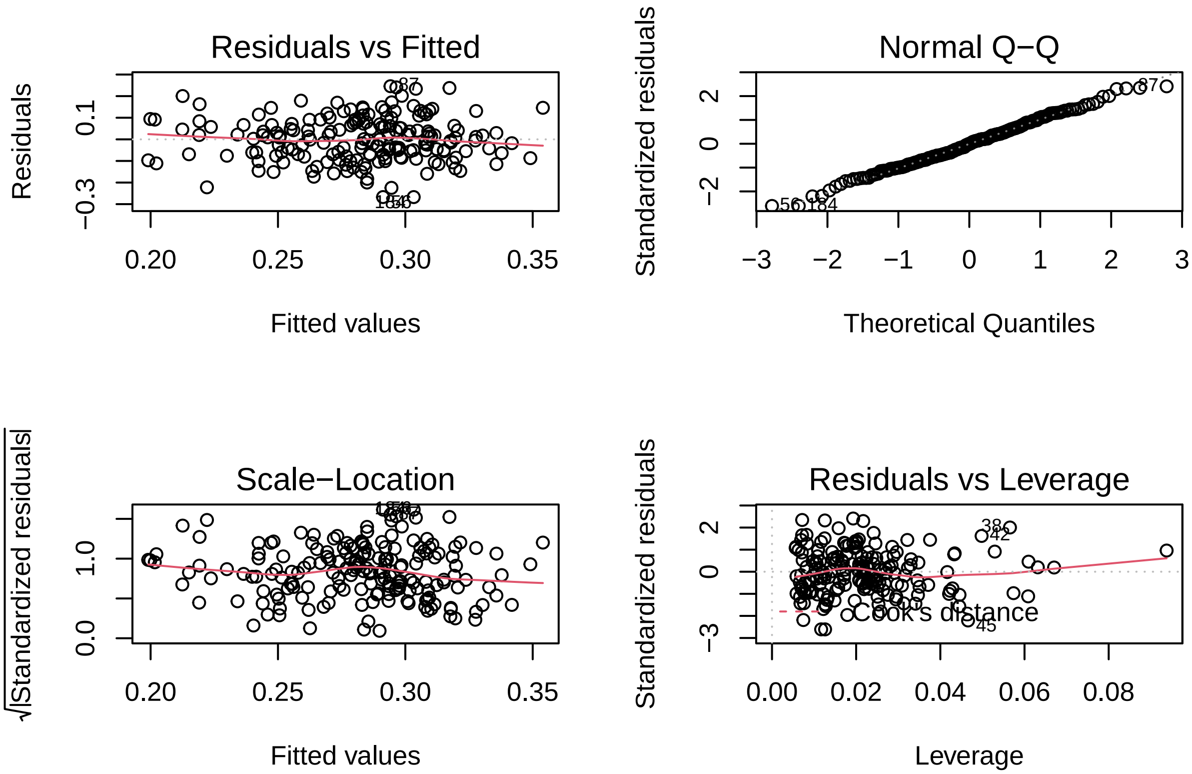

Figure 7: Diagnostic plots of final model

5 Summary and Conclusions

In summary, we found that some climatic conditions have a significant effect on dall sheep reproductive success. Our results indicate that reproductive success is reduced when overall temperatures are high, likely due to adaptations of arctic species to thrive in colder conditions with higher snow cover. This aligns with our findings that reproductive success increases when snow cover duration is longer, indicating again that colder overall temperatures benefit reproductive success of dall sheep. Reproductive success also increased in response to higher May temperature, indicating the importance of seasonal temperature variation for population success. Survivability of offspring likely depends heavily on seasonal vegetation, therefore high temperatures in isolated months such as May are an important factor in maintaining population stability.

Our results provide significant implications for future population management. Arctic environments are experiencing increasing temperatures at substantially higher rates than other areas, a trend that will also contribute to decreased snow cover in Arctic North America (Corell, 2006). As climate change continues to affect environmental conditions, we can expect dall sheep populations to decline in the future due to evidence that increased temperatures and shorter snow cover duration negatively impacts reproductive success. Because of this, it is essential to form population management plans immediately to account for the expected population decline and subsequent trophic cascade. Management plans can include protected natural areas for these populations, potentially at higher elevations and latitudes to accommodate for migration to colder areas as temperatures rise.

6 Future Recommendations

For future research and analysis, more statistical tests should be completed to look for interactions between variables. Additionally, more data could be used in conjunction with this dataset to further analyze our research question. Data on the rate of temperature and snow cover duration change in Arctic North America can be used in conjunction with this data set to estimate how heavily dall sheep reproductive success will be affected in the future.

7 References

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