Signature page

What factors influence horse distribution patterns on Sable Island?

By
Alysha Dupuis

A Thesis Submitted to
Saint Mary's University, Halifax, Nova Scotia
in Partial Fulfillment of the Requirements for
the Degree of Bachelor of Science, Honours Certificate in Biology.

March, 2017, Halifax, Nova Scotia

Approved: Dr. Timothy Frasier

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Abstract

Sable Island is a long, narrow sandbar off the coast of Nova Scotia, Canada. Despite its small size the island has been home to a population of feral horses (*Equus ferus caballus* L.) since the early 1800s. These horses are a valuable study population as they are isolated by law from human interference, and manage to survive in a confined space with limited resources. This study investigates their movement patterns, specifically whether social status and seasonal changes may be influencing variation in movement and distribution among individuals. It was predicted that stallions - male horses that are the designated 'leader' of a band - should have smaller ranges than bachelor horses because their movement may be restricted by their close associations to mares. It was also predicted that range distances would be greater in winter than in summer due to the high winds and limited grazing options on the island during winter. These questions were examined using GPS (global positioning system) data representing the locations of a subset of the horses over a three year period (2008-2010). The results suggest that seasonal changes substantially affect the average position of stallions on Sable Island, likely due to differential resource and shelter availability across the island in different seasons. The data also showed that range was most heavily influenced by individual identity, which indicates that different horses have different range tendencies regardless of their social status or the time of year. However, not all of the variation in distribution and movement of the horses could be attributed to the variables investigated in this study. Further research into other factors and the resource distribution on the island will provide a clearer picture into the dynamics at play within this population.

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Introduction

Individuals within a population often vary in their patterns of movement and dispersal. This can be the result of differences in a number of factors, including social structure and the location and availability of resources (Clutton-Brock, Guinness, & Albon, 1982; Saeki, Johnson, & MacDonald, 2007; Nathan et al. 2008). Analyzing these movement patterns can provide information on the factors influencing population dynamics and ecology, including mating patterns, social organization, and resource limitations (Boitani & Fuller, 2000). In many species, individuals maintain a geographical range within which they perform the majority of their activities. This area of primary use is referred to as an individual's "home range", and represents an important factor shaping distribution and movement patterns within a population (Burt, 1943; Powell & Mitchell, 2012).

In a population there will be variability in the sizes and resource composition of individual home ranges, as well as the fidelity with which individuals remain within them (Campos et al., 2014). These variations represent different responses to the relative costs and benefits associated with establishing, maintaining, and defending a home range (Boitani & Fuller, 2000). The costs involved in maintaining a home range include the energy required to defend and protect that home range, to maintain a mental map of the area and to retain knowledge of the locations of important resources. The most significant benefit to maintaining a defined home range is the reliable access to resources such as food, water sources, and shelter (Boitani & Fuller, 2000). Home ranges are also subject to change as resource availability changes, and individuals may be forced to move to other areas.

Implications of within-population movement and distribution

Loss and fragmentation of animal habitat frequently results from anthropogenic activities, such as resource extraction, as well as the spatial expansion of human residential areas (Northrup et al., 2015). This is a significant threat to biodiversity in such areas (Shirk et al., 2014). These alterations in habitat availability and biodiversity can have a large effect on the habitat selection and dispersal patterns of animals (Northrup, Anderson, & Wittemyer, 2015; Mueller et al., 2011). For instance, Northrup, Anderson, & Wittemyer (2015) found that mule deer (*Odocoileus hemionus)* alter their habitat selection patterns specifically in response to natural gas development. Therefore, it is becoming increasingly important to examine the resource acquisition and spatial needs of animal populations, particularly from a conservation standpoint.

Several life history traits can lead to a population being vulnerable to fragmentation when their habitats are threatened, including small population size, low fecundity, large body size, and small habitat size. This vulnerability is due to the potential for low genetic diversity within the population, inbreeding, and an inability to quickly adapt to changing environmental conditions (Wang et al., 2009). Large populations can also have their size greatly diminished, and become vulnerable to extinction, when the area once available to them becomes lost or fragmented (Prinz, Weising & Hensen, 2013; Iwamura et al., 2013). For example, Heinrichs et al. (2016) used population simulations to mimic real-life animal movement, showing that the combination of habitat loss and fragmentation leads to an exceptionally high risk of extinction.

Due to the fact that changes in animal movement patterns and distribution reflect changes in the ability of an area to meet a population’s resource and spatial requirements, analyzing these patterns can have strong implications for conservation (Wattles et al., 2013). In particular, these patterns can indicate which resources are limiting, and allow conservation efforts to be developed in response (Powell & Mitchell, 2012). For instance, a study on the space use and movement patterns of moose (*Alces alces*) by Wattles et al. (2013) was able to provide insight into which areas used by the moose were in the greatest need of protection. It is also important to consider that if movement patterns differ between seasons, then information on those populations should be gathered evenly across seasons to avoid a seasonal bias in any results (Whitehouse et al., 2008; Quian et al., 2013).

Factors that influence the movement of individuals within a population

Seasonal changes affect which resources are available for use, as well as what resources are needed for survival. The most common changes tend to be in reference to plant communities that do not persist through cold winters but grow again in warmer months. These seasonal changes in plant availability cause their grazers to seek out alternative food sources in the winter and can lead to a shift in home ranges between seasons (Kohler et al., 2004). This phenomenon has been observed in red deer (*Cervus elaphus*) which feed predominantly on long greens in late winter and short greens (more easily digestible and have a higher protein content) during the rest of the year. It appears that during the late winter months the short greens substantially decrease in abundance to a level that cannot sustain the requirements of the red deer population, so they must rely on other plant communities as a food source (Clutton-Brock et al., 1982).

Cold weather and snow in winter months not only affect plant biomass and species availability, but can also directly affect the movement of animals. During the winter there is often a greater need for shelter from harsh weather conditions and the cold, and high levels of snow can make locomotion difficult. This is the case in mule deer (*Odocoileus hemionus*) and elk (*Cervus canadensis*) populations in the temperate mountains of British Columbia, where the high expenditure of energy for movement in the winter due to cold weather and snow causes deer and elk to select different ranges (Poole & Mowat, 2005). This restricted movement in winter is considered to be the main factor influencing range carrying capacity in these populations (Poole & Mowat, 2005). Other weather conditions such as wind, rainfall, and drought can all have a profound effect on the resources used by a population or the level of shelter they require.

Social status, or an individual's position in their population's social system, can affect individual movement patterns as well (Lucas et al., 2009). As Lucas et al. (2009) describe, in a polygynous social system such as that found in the Sable Island horses, one male will mate with several females, forming a family band with them and their young offspring, while other 'bachelor' males move independently. In this type of polygynous mating system, there are three main social statuses that can exist among adults: females in a family band, dominant males that have their own family band, and bachelor males.

It is also important to consider that ecosystems are not static, but rather are constantly changing as species are outcompeted and others emerge. This can result in changes in biodiversity, or the abundance of different species in an area, over time. These changes have a clear effect on the remaining species (Eisenhauer et al., 2016). The non-static species makeup of ecosystems also applies to the plant species that ungulates, such as deer and elk, use as food sources. If the principle food source used by a population is no longer available, then this can lead individuals to leave their typical ranges in search of new food sources. New home ranges or nomadic movement patterns could develop that reflect the shift in resource availability (Eisenhauer et al., 2016).

Statistical methods used to analyze movement

The main goal of any movement model, as noted by Shimatani et al. (2012), is to use an ecological basis and ecological interpretations to reliably explain movement patterns. Aside from home range estimation, which is reliable only with relatively large sample sizes, it is also possible to evaluate the degree and trajectory of movement using a variety of methods (Shimatani et al., 2012). With smaller sample sizes, as is the case in this study, statistical models can be developed to assess range and movement at an individual rather than a population level. This can involve the calculation of average positions in both latitudinal and longitudinal directions in different time periods, and similarly the calculation of maximum range values for individuals.

Study location and population

Sable Island is a long and narrow sandbar off the coast of Nova Scotia that is home to a wide range of species, including a population of feral horses (*Equus ferus caballus*) (Plante et al., 2007). There are no trees on the island; marram grass, sandwort and beach pea, along with a few varieties of shrubs, make up the majority of the plant biomass (Freedman et al., 2016a). Large sand dunes are characteristic of Sable Island, and small ponds are more frequently found on the western half of the island than the east

(Freedman et al., 2016b). While there are indications that the island may have been used as early as 1738 for raising livestock and hunting seals and walruses, the first official recorded project on the island was a life-saving station for victims of shipwrecks in 1801 (Campbell, 1974). The area of the Atlantic Ocean surrounding Sable Island tends to become heavily covered by fog, which made shipwrecks near the island quite common due to its proximity to the transatlantic shipping route between Europe and North American ports (Campbell, 1974). During this time horses were brought to the island from the mainland for use by those stationed there, and for years the horse population was under sporadic human interference, with horses being brought in for breeding and young geldings sent back to the mainland to be sold**.** This active management continued until the 1940s, and the horses were protected by law from interference in 1961 (Frasier et al. 2016**)**.

The horses have a unique ancestry in that the original population was apparently founded by a group of horses of Breton and Norman descent (Plante et al., 2007). This combination of mixed ancestry and isolation has resulted in the population diverging quite significantly from other breeds of horses, but it is not considered a separate breed (Plante et al., 2007). Lucas et al. (2009) found that the genetic variation within the Sable Island horse population was moderate, but somewhat lower than other domestic horse breeds. This is hypothesized to be due to the horses' isolation and adaptation to the island environment (Lucas et al., 2009).

Uzans et al. (2015) estimated the effective population size, which roughly corresponds to the number of effective breeders, of the Sable Island horse population to be just 48 individuals. To provide some context as to the meaning of this estimate, for decades what is referred to as the 50/500 rule has been used to interpret effective population size (Frankham et al., 2014). The 50/500 rule states that an effective population size of less than 50 individuals is not large enough to prevent inbreeding. It also states that an effective population size of 500 is large enough to maintain a population's or species' evolutionary potential over time (Franklin, 1980). A study by Frankham et al. (2014) recommended raising these numbers, as they found support that populations must have an effective size of at least 100 individuals to prevent inbreeding, rather than 50. By these measures, the effective population size of 48 individuals in the Sable Island horses is extremely low, and although the horses currently display moderate levels of genetic variation, this suggests that the genetic variation will decrease quickly over time (Uzans et al., 2015).

Lucas et al. (2009) also found evidence of genetic substructuring in the horses, which refers to slight differences in the genetic variation of a population, across four subdivisions of the island. This could indicate reduced gene flow from one end of the narrow island to the other (Lucas et al., 2009). These findings bring about questions as to how the horses move across the island, and whether their lengthwise movement is somewhat restricted by the fact that the island is so long and narrow.

Study objectives and predictions

This study aims to assess the distribution and movement patterns of a subset of the Sable Island horses over a three year period from 2008-2010. This was assessed using GPS location data collected for a subset of the population each time they were observed. Two potential contributors to distribution and extent of movement will be examined: (1)

social status, and (2) seasonal changes. The social statuses considered in this study are bachelors, which are males without mates and having no consistent ties to other horses, and stallions, which are males with their own family bands. In the case of the Sable Island horses, a family band refers to a small group of horses that spend most of their time together, and typically consist of a stallion, his female mates, and any young offspring they have. It is predicted that bachelors will have a greater extent of movement than stallions because bachelors are not tied down to the requirements of mares or offspring, and stallions may be somewhat territorial and drive bachelors away from their locations. It is also predicted that a greater extent of movement (i.e., range) will be observed in the winter than in the summer due to the harsh winter conditions on the island. The high winds often lead horses to seek shelter behind sand dunes, and limited grazing options during the winter require the horses to travel farther for food. Distribution, as indicated by average position, will also be analyzed with respect to social status and seasonal changes, but no predictions were made on this.

Study Implications

Further knowledge of the seasonal distribution and movement patterns of the Sable Island horses could have implications on future studies of the population. For example, it is important to know if location and distribution data collected in one season are representative of year-round patterns, influencing the necessary timing and number of survey periods. This knowledge is necessary in order to ensure the best quality of data, even as the costs associated with work on Sable Island increase.

Understanding movement and distribution patterns also has implications for the management and protection of the horses. Recommendations have been put forth as to how the horses should be monitored and potentially managed in the future (Frasier et al. 2016). These recommendations specifically include monitoring the island to ensure the horses have adequate environmental resources, and obtaining more information on the horses' risk of extinction, what factors may lead to extinction, how many horses the island can support, and the genetic diversity of the population. As one of few remaining feral horse populations that are both isolated and unmanaged, knowledge of the movement patterns of the horses would also add to the understanding of the natural processes influencing movements at an individual level (Uzans et al., 2015).

Materials and Methods

Creation of Data Set

Wildlife surveys are conducted year-round on Sable Island (Figure 1) by our collaborator, Zoe Lucas, for a variety of ongoing research projects on the island. Survey data collected include identification of individual horses, and documentation of location, social status, band membership, offspring and social behaviours.

For this study, a subset of these data was provided for a three year period (2008-2010). This data set includes: the name/identification of each horse, sex, birth year, and location (GPS coordinates) for each sighting. In cases where the horse's status (stallion, bachelor, tag, and mare) or band information was known, this is provided as well. The social status 'tag' refers to a male horse that has formed an association with a band but is not the band stallion. The data set was entered into a relational MySQL database to ensure robust storage and to ease the process of querying subsets of the data. The data were analyzed using R (R Core Team, 2013) and the R-interface of RStudio (RStudio Team, 2015).

Data for Analyses

Only horses with known social status were used for analysis. Location information was extracted for horses that fit the category of either stallion or bachelor. Stallion data were extracted if individuals were classified as 'stallions' for the entire three year observation period, whereas bachelor data were extracted for individuals who were consistently classified as such for two consecutive years. This time frame was chosen because no horses were classified as bachelors for the entire observation period. All of those classified as bachelors for two consecutive years happened to be in 2008 and 2009.

For seasonal analyses, the months of June, July, August and September were set as summer; and December, January, February and March were set as winter. Fall and spring were excluded because they represent “shoulder” or “transitional” seasons in between summer and winter, and thus location data within them will be heavily influenced by the conditions of each specific year, potentially resulting in an excess of variation during these times. This seasonal division was based on average monthly climate data in the World Forecast Directory (El Dorado Weather Inc, 2017).

Average Position Analyses

For each individual, mean latitude and longitude values were calculated for each year in both bachelors and stallions, as well as for each season in stallions. Season was not considered for the group of both bachelors and stallions due to the limited number of observations available. The time frame analyzed differed between status groups (Table 1). A linear regression was used to assess the importance of individual identity, season (winter or summer), year (2008-2010), and latitude on the average longitudinal positions of stallions. A similar linear regression was used to assess the importance of individual identity, year (2008-2009), status, and latitude on the average longitudinal positions of a subset of stallions and bachelors. Akaike Information Criteria (AIC) were used to compare subsets of the full regression models to assess the impact of each predictor variable on model performance.

Range Analyses

For each individual, maximum and minimum latitude and longitude values were recorded for each year in both bachelors and stallions, as well as for each season in stallions. Again, season was not considered for the group of both bachelors and stallions due to the limited number of observations available. The time frame analyzed again differed between status groups (Table 1). Range was calculated as a single value using the following formula, where lon = longitude, lat = latitude, max = maximum, and min = minimum:

$$\text{Range} = (\text{lon max} - \text{lon min}) + (\text{lat max} - \text{lat min})$$

A linear regression was used to assess the importance of individual identity, season (winter or summer), and year (2008-2010) on the range of stallions. A similar linear regression was used to assess the importance of individual identity, year (2008-2009), and status on the average longitudinal positions of a subset of stallions and bachelors. Akaike Information Criterion (AIC) was again used to assess the impact of each predictor variable on model performance.

Results

Stallions Position

The results of the linear regression used to test the effects of individual identity, season (winter or summer), year (2008-2010), and latitude on the average longitudinal positions of stallions, showed that season and latitude had significant effects (with p-values of 0.00187 and 9.75e-15, respectively), whereas stallion identity and year did not. These parameters explained approximately 50% of the variance in the longitude values, as indicated by the R-squared value (0.5074). The identification of season and latitude as important predictors was confirmed through the analysis of Akaike Information Criterion (AIC), which showed that models without either of these predictors scored substantially worse than when they were included (Table 2). However, removing identity and year as predictor variables did not substantially decrease model performance.

Stallions Range

The results of the linear regression used to test the effects of identity, season (winter or summer) and year (2008-2010) on the range of stallions showed that identity was the most important predictor of range (p-value = 0.0206), whereas the variables of season and year did not have a significant effect on range. The R-squared value for this model was 0.0757, indicating that other untested factors influencing range remain to be identified. The identification of identity as an important predictor was confirmed through the AIC analysis, which showed that models without this predictor scored substantially worse than when it was included (Table 3). However, removing season and year as predictor variables did not substantially decrease model performance.

Stallions and Bachelors Position

The results of the linear regression used to test the effects of identity, year (2008-2009), status (stallion or bachelor), and latitude on average longitudinal position showed that latitude was the most important predictor of longitudinal position (p-value = 1.42e-05), whereas stallion identity, status, and year were not. These parameters explained approximately 45% of the variance in the longitude values, as indicated by the R-squared value (0.4489). The identification of latitude as an important predictor was confirmed through the AIC analysis, which showed that models without this predictor scored substantially worse than when it was included (Table 4). However, removing identity, status and year as predictor variables did not substantially decrease model performance.

Stallions and Bachelors Range

The results of the linear regression used to test the effects of identity, year (2008-2009), and status (stallion or bachelor), on the range of horses showed that identity was the most important predictor of range (p-value = 0.04546), whereas year and status were not. The R-squared value for this model was 0.03437, indicating that other untested factors remain to be identified. The identification of identity as an important predictor was confirmed through the AIC analysis, which showed that models without this predictor scored substantially worse than when it was included (Table 5). However, removing year and status as predictor variables did not substantially decrease model performance.

Discussion

While seasonal changes in location and movement have been well documented in ungulate populations (Clutton-Brock et al., 1982; Kohler et al., 2004; Poole & Mowat, 2005), these results are the first to demonstrate this relationship in the Sable Island horses. As predicted, these data show that the average location of a stallion at a given time is more heavily influenced by season than by the individual identity of the stallion or by the year (Table 2). This suggests that different portions of the island are preferred during different seasons, probably due to differences in the availability of certain resources such as water, forage and shelter across the island. Winters on Sable Island also have characteristically high winds and cold conditions, which could cause the horses to use more sheltered areas with larger sand dunes during the winter than in the summer. Any evidence for this in other populations?

The results of this study indicate that the most important factor in determining range size of both stallions and bachelors is individual identity, more so than season, year, or social status (Tables 3 and 5). This suggests that different horses use the island in different ways and, contrary to what was predicted, regardless of their social status or whether it is winter or summer. For instance, some males may be more inclined to roam over a wide range than others, while some may be more territorial and prefer to stay within a small range and discourage other horses from encroaching on this area.

It is also important to consider that the factors investigated in this study only accounted for at most 50% of the variation in movement. This indicates that there are other variables besides season, identity, year, and social status that are influencing the way the Sable Island horses use the island, as well as how much they move across the island in a given time period.

In conclusion, seasonal changes substantially affected the average position of stallions on Sable Island, likely due to varying resource and shelter availability across the island in different seasons. Range size was most heavily influenced by individual identity, which indicates that different horses have different range tendencies regardless of their social status or the time of year. However, there are additional factors influencing the movement patterns of these horses that were not investigated in this study, including age, band size, and access to mares. The results of this study combined with further research into these factors and the resource distribution on the island will provide a much clearer picture of the dynamics at play within this population.

Tables and Figures

Table 1. A summary of the sample sizes and time frames used in each status category.

Status	Sample Size	Time Frame
Bachelors	12	2008-2009
Stallions	21	2008-2010

Table 2. Results of the Akaike's information criterion (AIC) for each model concerning the average position of stallions, where model.full is the complete regression including all four variables (identity, year, season and latitude), and each other model is lacking the variable noted.

Model	df	AIC
model.id	5	-215.3621
model.year	5	-215.0769
model.full	6	-213.9026
model.season	5	-205.603
model.lat	5	-152.1225

Table 3. Results of the Akaike's information criterion (AIC) for each model concerning the range of stallions.

Model	df	AIC
model.season	4	-235.7153
model.full	5	-235.0299
model.year	4	-233.5579
model.id	4	-231.3414

Table 4. Results of the Akaike's information criterion (AIC) for each model concerning the average longitudinal positions of both stallions and bachelors.

Model	df	AIC
model.year	5	-111.33186
model.status	5	-110.78313
model.id	5	-110.12621
model.full	6	-109.34635
model.lat	5	-90.19048

Table 5. Results of the Akaike's information criterion (AIC) for each model concerning range in both stallions and bachelors.

Model	df	AIC
model.year	4	-112.5494
model.full	5	-110.9629
model.status	4	-109.764
model.id	4	-108.5576

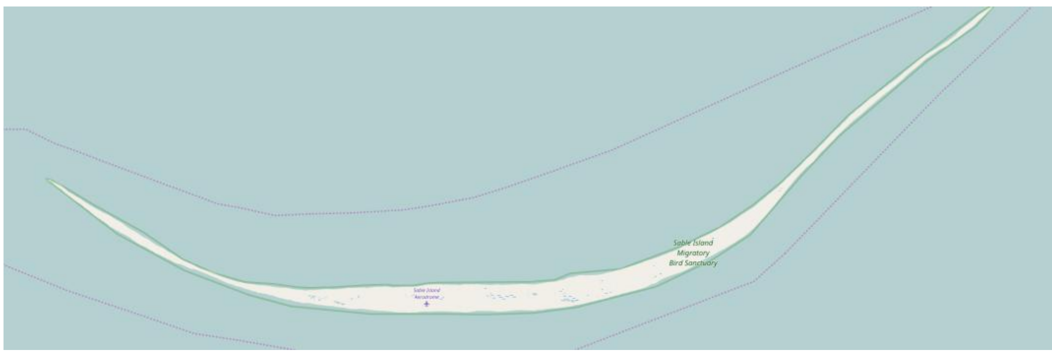

Figure 1. A map of Sable Island, off the coast of Nova Scotia, Canada. Generated using ggmaps in RStudio.

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