Seasonality in European bison habitat selection and movement from reintroduction site in Armeniș Commune in the Southern Carpathian Mountains of Romania

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MEnvSci (Hons) Environmental Science
ENVS 6009 Advanced Research Project
4th May 2017
Word count: 6503

1. Abstract

European bison have been extinct in Romania for over 200 years. Reintroducing bison with a limited gene pool requires the creation of stable and interacting metapopulations across Europe. The potential for human-wildlife conflict needs to be addressed, so knowledge of bison movement behaviour is important. The reintroduction site is in Armeniș Commune, Southwest Romania, where 30 bison have been released; with planned supplementation of approximately a further 10 each year. Spatial and temporal analysis of bison movement and its interaction with temperature was carried out using the location data of one individual that has been introduced. MaxEnt species distribution modelling was carried out using the location data for June 2016 to February 2017, with separate analyses for summer and winter location data. Land cover and NDVI layers were used in the modelling. Initial movement and exploratory behaviour was stepwise whereby, movement from the enclosure occurred in a few phases. The area roamed increased until December before greatly reducing in January and February. Daily movement was highest in September and October, when temperature was average, and dropped by a large amount in January and February. A large movement to a new location was observed at the end of December. MaxEnt models predicted forest edges to be favourable overall with more sheltered, lowland areas predicted to be favourable in winter. The higher altitude, natural grasslands were found to be favourable in the summer. A seasonal shift in range in the winter is driven by temperature and snow cover. In winter, dense snow cover in the natural grasslands hinders movement and feeding so more sheltered, lowland areas provide better food availability. Unsuitable beech forests may be a hindrance to bison movement into the natural grasslands, causing bison to remain where human-wildlife conflict is possible due to the proximity to human settlement.

2. Introduction

2.1. Biology of European bison

European bison *Bison bonasus* are large herbivores of an average weight of approximately 600kg in males and 400kg in females (Krasińska and Krasiński 2013). They live in transient groups based on mutual benefit. There are two genetic lines of European bison; the Lowland line and the Lowland-Caucasian line (Krasińska and Krasiński 2013). The reintroduction programme in Armeniş Commune, Romania, is using the Lowland-Caucasian line. The Lowland-Caucasian line descends from just 12 founding individuals raising the concern of inbreeding, the effects of which are not yet fully understood (Tokarska *et al.* 2011). Therefore, creating interacting stable metapopulations is of vital importance to improve the genetic diversity of the species (Perzanowki and Olech 2006). Bison are a keystone species and, as a large herbivore, they have a role to play in maintaining open grasslands (Johnson and Cushman 2007). Bison also have been found to be seed dispersers and are beneficial in restoring habitats (Jaroszewicz *et al.* 2008). Predators of the bison include the brown bear *Ursus arctos* and wolf *Canis lupus* (Perzanowki and Olech 2006).

2.2. History of European bison

European bison once roamed throughout Europe. During the First World War, they were extensively poached and were extinct in the wild by 1927 when the last free roaming bison in the Białowieża Forest, Poland, died. But in Romania, European bison went extinct much earlier in 1762 (Pucek *et al.* 2004). Bison only remained in wildlife parks and zoological gardens; as a result, only 12 founding animals with known pedigree were suitable for breeding programs for reintroduction (Pucek *et al.* 2004; Tokarska *et al.* 2011).

2.3. Armeniş Commune reintroduction effort

Armeniş Commune is situated in the Southern Carpathian Mountains on the western edge of the mountain range. The release site is a Natura 2000 site surrounding Mt. Tarçu. Land use is primarily forestry and sheep grazing. Land cover is predominantly beech, mixed and coniferous woodland, and large areas of natural grassland at higher altitudes. It is expected and hoped that the bison will move north and east into these natural grasslands, as in the west land use consists of agricultural areas and human settlements with potential for human-wildlife conflict. Releasing bison closer to the natural grasslands is not possible as it is inaccessible by truck which is how the bison are transported to the area.

The first release consisted of 20 bison in June 2016 and a further 10 were released in September of the same year. The population will be supplemented with an additional 10 bison released per year (Vlasakker 2014).

The release has been carried out using a soft release method where the bison are introduced into an acclimatization zone. They are kept there for around a month to become accustomed to the new environment and are then released into a larger rewilding zone to explore further. After a second month, the gates of this enclosure are opened and the bison are able to explore outside the enclosure in their own time and to then roam freely. This allows time to monitor their responses before release when monitoring becomes more difficult (Vlasakker 2014).

2.4. Habitat selection and movement patterns of large herbivores

For many years, European bison were thought to be a primarily forest-dwelling species as this is where they were most regularly recorded. However, the consensus now is that European bison are commonly found in forests because they are a refugee species forced into a suboptimal habitat due to human pressure (Bocherens *et al.* 2014). Preferred habitat has been found to be natural grassland and areas similar to natural grassland (Wołoszyn-Gałęza *et al.* 2016). Larger meadows were found to be utilised more when bison were in larger group sizes (Fortin *et al.* 2009). Areas of comparatively low snowfall were more commonly selected as habitats, showing that snow is also a factor in selection (Fortin *et al.* 2009).

It has been found that bison have a collective decision making process for movement with an adult female often initiating movement (Ramos *et al.* 2015). The number of individuals that follow was found to be dependent on the age and sex of the initiating individual. Collective movement may not always be beneficial to fitness as bison can follow the leader to a location of poor habitat quality (Sigaud *et al.* 2017). Exploratory movement on initial release was found to be on average 539m/month in the first 6 months after release.

2.5. Aim and objectives

The aim of this research was to investigate the movement and habitat selection of European bison in the Southern Carpathian Mountains. This was achieved through several objectives. These were to:

- Study bison movement on a monthly and daily temporal resolution from the location data collected from a GPS collar on one of the reintroduced bison;
- Predict where bison are likely to move based on where they have been thus far using MaxEnt Species Distribution Modelling;
- Study if factors affecting habitat selection are seasonally different using the separate location data for summer and winter; and
- Predict what pressures are likely to be most detrimental to bison population growth and dispersal, in order to create a stable, connected bison population.

Understanding the behaviour of bison in each new location is important because the reintroduction programs are still quite recent and, although studies have been carried out elsewhere, there is little knowledge about how the European bison will react in this new environment. Understanding their initial movement is important in monitoring the success of the introduction (Schmitz *et al.* 2015)

3. Methodology

3.1. Location data

Location, altitude, and temperature data from a Lotek Iridium Track GPS collar (Lotek 2017) on Female bison cip number 11227 (F 11227) was used for all analyses. The period studied was from 1st June 2016, a few days before bison F 11227 was released on the 8th June, to 28th February 2017. This is the only bison that has been released with a GPS collar. The location data will be used to consider trends in movement and habitat selection of bison, not the specific locations that this individual bison travelled to.

3.2. Distance to release location

Distance to release location was done by using the Euclidean Distance tool to create a raster layer with distance to the release location. The Extra Values to Points tool was used to find the distance to the release location for all the location points for bison F 11227 so that average distance to release location could be charted.

3.3. Monthly area roamed

In order to consider the range that is roamed by bison F 11227 in each month, minimum convex polygons were created in ArcMap using the Minimum Bounding Geometry tool. The area of the polygons created was accessible in the attribute table, enabling the change in monthly area roamed to be charted.

3.4. Daily movement analyses

To calculate the distance moved each day by bison F 11227, the distances between the GPS locations given as latitudes and longitudes were calculated using The Spherical law of Cosines with the average radius of the earth given as 6,371km. The value for distances moved each day is an approximation but was tested using ArcMap and was found to be very close to the true value and thus deemed acceptable. The GPS collar records a location every two hours and only the days that had the full twelve data points were used. For each day, the sum of the distances between points was calculated so that for each day of complete data, there was a value for the total straight line distances between each point for that day. This would not be the total distance that bison F 11227 moved each day as movement would not have been in a straight line in the two-hour data collection interval.

3.5. Temperature analyses

The collar on bison F 11227 also measures temperature. Thus, it was possible to analyse this temperature data and determine its effect on the movement and habitat selection of bison. Temperature on the GPS collar was likely to be affected by the body temperature of the animal (Jiang *et al.* 2012). The mean temperature and daily distance moved each month were plotted against each other to see if temperature affected mean distance moved by the bison per month.

3.6. MaxEnt Species Distribution Model (SDM) analyses

MaxEnt is a machine learning species distribution modelling tool. The software uses an algorithm to fit the species presence points to the environmental data layers that are used in the model to predict suitable areas for the species (Elith *et al.* 2011). MaxEnt has several features that it can use to fit the environmental data with the species presence point. This can be done automatically using all the features available to MaxEnt. However, in this study only the linear and hinge features in MaxEnt were used to ensure that smoother, more natural response curves were created which did not over-fit the environmental variables to the species presence points.

It has been found that using an SDM for a species that has had its range severely restricted can create false predictions (Cromsigt *et al.* 2012). With such small amounts of data from just one individual much caution had to be taken.

3.6.1. Study area

The extent of the study area to be used for the MaxEnt SDM was chosen based on locations considered likely for bison dispersal and the distances to which they are likely to disperse in the following years. Fig. 1 shows the chosen study area in the Southern Carpathian Mountains in the Tarçu Mountains Natura 2000 site where are extensive areas of natural grassland in the surround Mt. Tarçu. This is thought to be the best habitat for them to move into as high altitude grasslands were historically found to be their ideal habitat (Bojar *et al.* 2015). The Carpathian Mountains are shaped such that the ideal direction for bison dispersal would be east and north.

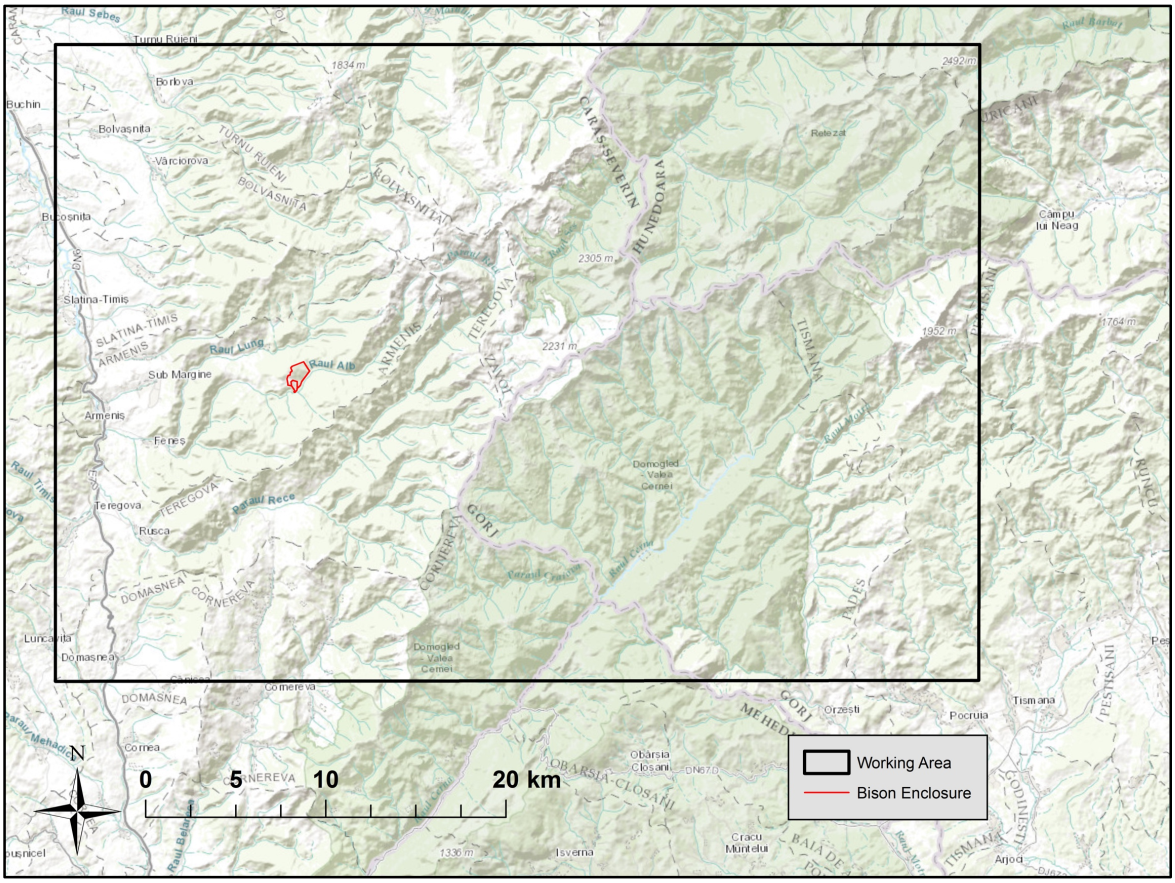

Figure 1. Working area for MaxEnt SDM. Location of the bison enclosure is in the middle west of the working area. Mt. Tarçu and the Natura 2000 area extends to the east of the working area (Basemap sources: Esri, HERE, DeLorme, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, MapmyIndia, © OpenStreetMap contributors, and the GIS User Community).

3.6.2. Environmental layers

Data for digital elevation was found to compromise the model as bison F 11227 has not yet roamed to higher elevations so, when tested, the model predicted that higher altitudes were unsuitable for bison. However, skeletal remains dated at around AD 1550 show that bison diet consisted mainly of grasses from high altitudes (Bojar *et al.* 2015). This suggests that high altitudes are suitable for bison and bison F 11227 simply has yet to roam there.

Land cover data was used for the model because European bison are thought to prefer more open grassland rather than forested areas as was thought for many years. The CORINE Land Cover data (CLC) was used for this purpose as it covers the whole of Europe and accurately details land cover in 44 categories (Copernicus 2006). Bison F 11227 has not yet dispersed to the area which the CLC map considers “Natural grassland”. Most time has been spent in “Land principally occupied by agriculture, with significant areas of natural vegetation” which means that a MaxEnt model would not predict natural grassland to be suitable habitat. The area in which bison F11227 has spent most time is, in reality, largely grassland. This, in conjunction with the findings of Wołoszyn-Gałęza *et al*. (2016) that habitat preference of bison is predominantly areas similar to natural grassland, resulted in choosing "Natural grassland" and "Moors and heathlands" to be reclassified in ArcMap in order that these classifications were regarded the same classification as "Land principally occupied by agriculture, with significant areas of natural vegetation". This was extracted to a polygon and a raster data layer of distance to grassland was created. When this layer and the reclassified land cover layer were run together in MaxEnt, the land cover model was rendered superfluous and thus only the distance to grassland layer was used.

Vegetation plays a large role in the habitat selection and movement of bison as they spend most of their day feeding (Krasińska and Krasiński 2013). NASA MODIS 250m normalized difference vegetation index (NDVI) data was the best data to analyse vegetation as data was available every 16 days at a resolution of 250m (NASA LP DAAC 2017). This meant that there were options as to which specific datasets were used in the case of corruption by cloud cover or other, less common, factors. Data layers from August and February were used. The August NDVI for the grasslands that bison F 11227 has thus far roamed were compared to the values for the grasslands in the study area that bison F 11227 has not yet roamed in order to see if the grassland vegetation is any different in the larger natural grasslands to where bison F 11227 is currently roaming.

Bison tend to avoid busy roads (Wołoszyn-Gałęza *et al.* 2016). Therefore, a layer for proximity to roads was created. This was a binary layer whereby the area close to major roads, based on the nearest that bison F 11227 has until now been to a road, was one category and everywhere else in the study area a second category.

All environmental raster data sets were created at a resolution of 0.0317071 decimal degrees which at the latitude of Romania equates to about 300m. This is suitable because it is higher than 250m which is the resolution of the MODIS NDVI data so that many pixels of the same value were not created.

3.6.3. Species location data

Species location data was all from bison F 11227 from 1st June 2016 to 28th February 2017. This data was processed to have a single point at the midpoint of each pixel of the environmental raster layers where there were one or more location points. This was then captured in a .csv file with the species, longitude and latitude as required by MaxEnt. One .csv file was created with all the species data from June to February, a second .csv file grouped June, July and August data for an analysis of summer habitat selection and a third file grouped January and February data for an analysis of Winter habitat selection.

3.6.4. Model runs

Three MaxEnt models were run, each with five replications and then the mean used for the outputs. The first model used the location data for all months June 2016 to February 2017. It was run with the distance to grassland, MODIS NDVI for August and the binary proximity to roads environmental layers.

The second model was run using the location data for June, July and August 2016. Like the first model it was run with the distance to grassland, MODIS NDVI for August and the binary proximity to roads layers. This was carried out to discover if location selection was different in the summer.

The final model was run using the location data for January and February 2017. It was run with the distance to grassland, MODIS NDVI for February, when there was snow cover, and the binary proximity to roads environmental layers. This was carried out to discover if location selection was different in the winter, particularly to consider whether snow cover had an impact on selection (Fortin *et al.* 2009).

4. Results

4.1. Location data of bison F 11227

Fig. 2 shows all the location points of bison F 11227 in relation to the enclosure which was the location of release. Bison F 11227 spent most time in the area directly west of the enclosure and has also moved into the next valley. The large areas of natural grassland towards Mt. Tarçu are a 5km straight line distance from the release site.

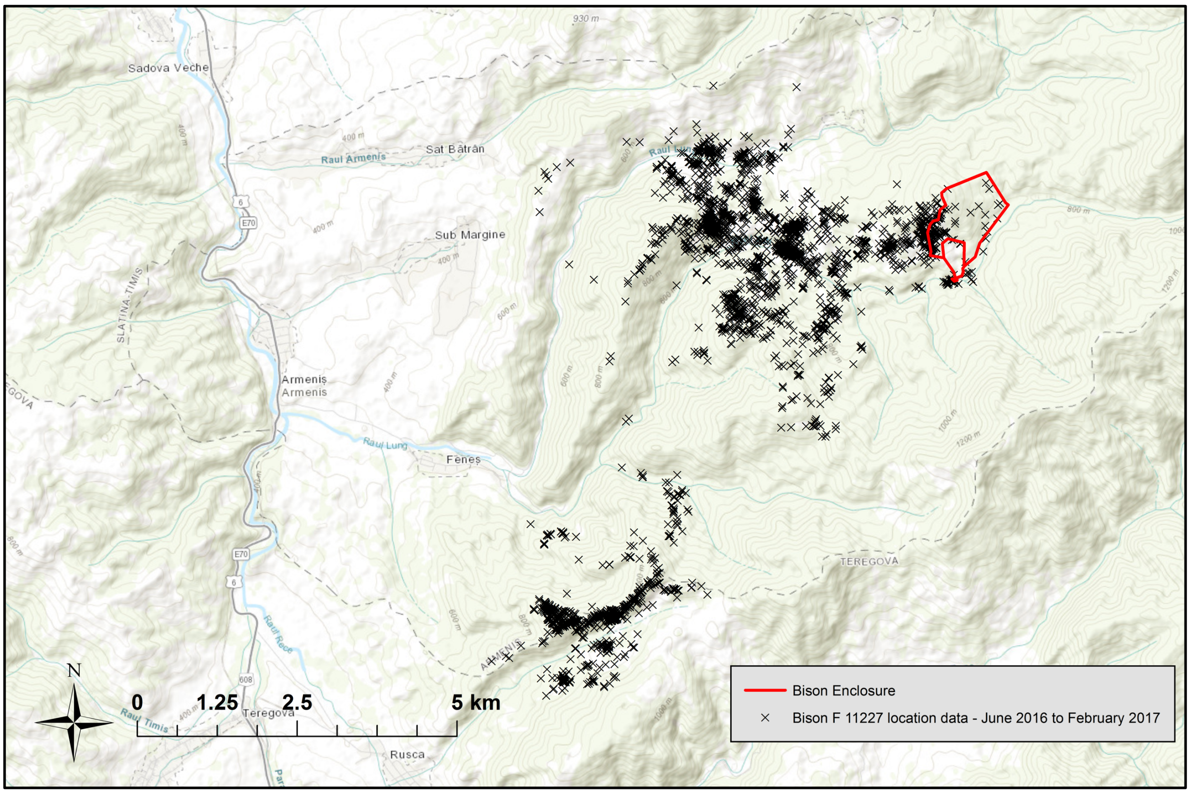

Figure 2. All location points of bison F 11227 represented by cross symbols (x). Location of bison enclosure marked (Basemap sources: Esri, HERE, DeLorme, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, MapmyIndia, © OpenStreetMap contributors, and the GIS User Community).

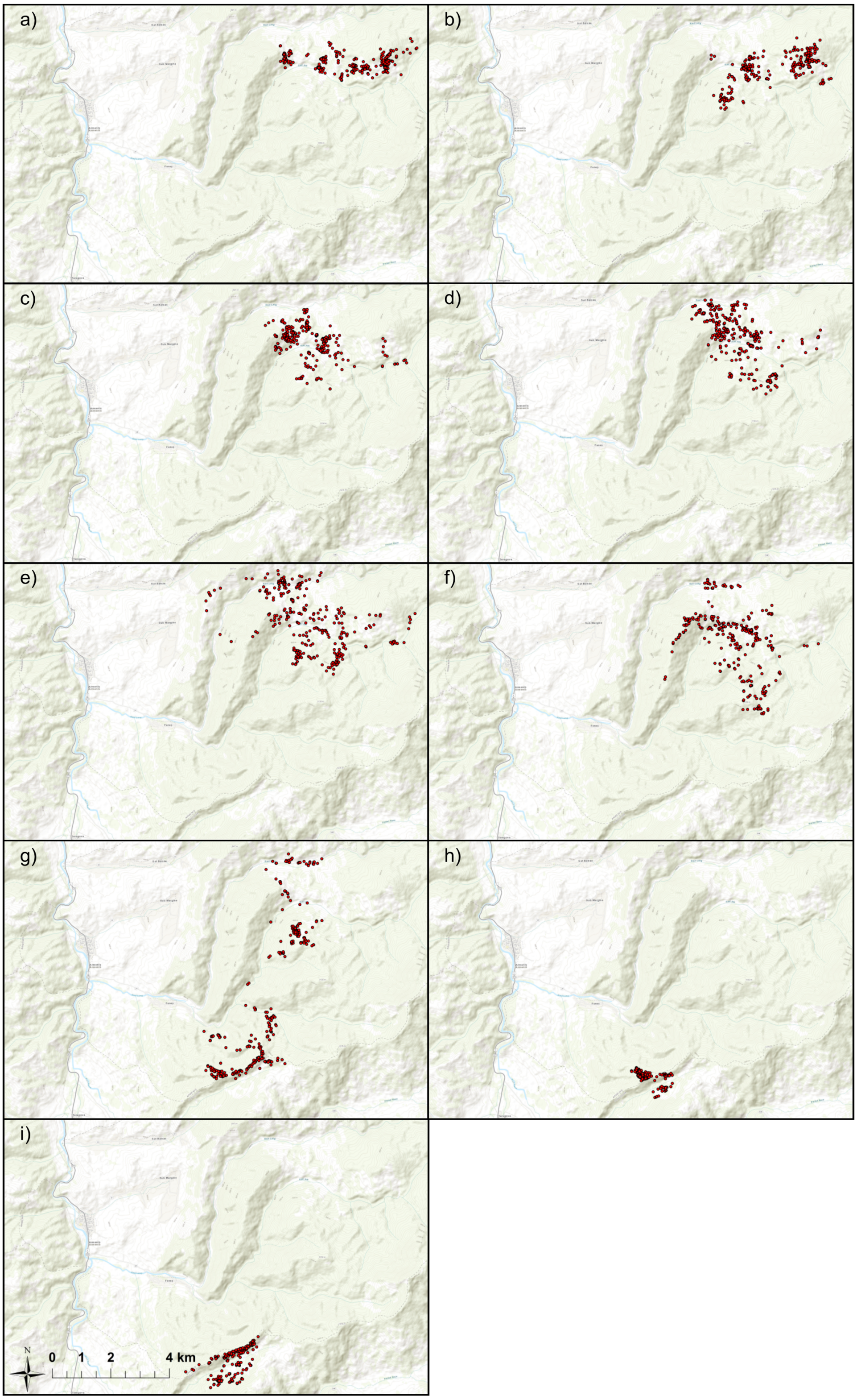

Figure 3. Bison F 11227 location points marked with red points in: a) June 2016; b) July 2016; c) August 2016; d) September 2016; e) October 2016; f) November 2016; g) December 2016; h) January 2017; and i) February 2017 (Basemap sources: Esri, HERE, DeLorme, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, MapmyIndia, © OpenStreetMap contributors, and the GIS User Community).

4.2. Initial movement after release

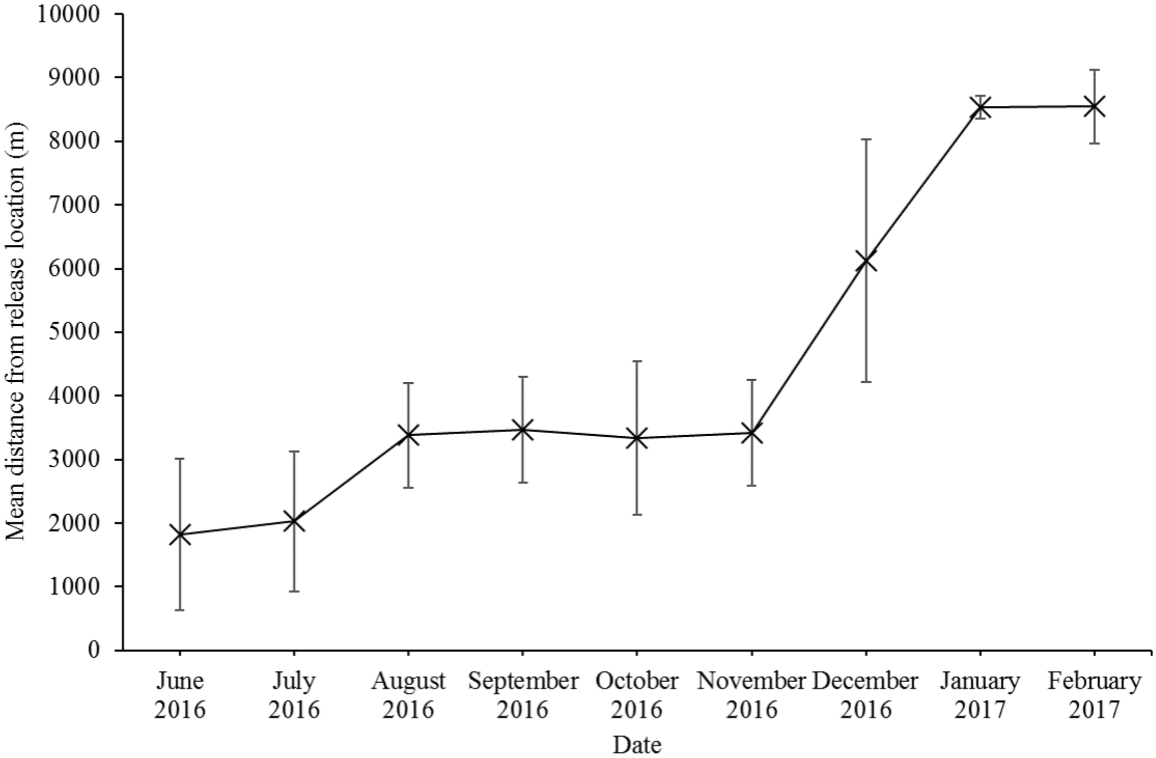

Figure 4. Bison F 11227 monthly mean distance from the release location in metres. Error bars ± 1 s.d. from the mean.

After the release from the enclosure on June 8th 2016, bison F 11227 slowly explored further from the enclosure. Movement was generally outwards from the enclosure and the central point that is roamed around remains in a fairly constant location near to the enclosure from June to November 2016 (Fig. 3). Fig. 4 shows a stepwise movement as distance from release location was, on average, constant in June and July 2016 before increasing in August to just over 3000m; and again, there was little change until December 2016 (Fig. 4). A large movement was seen to the southwest into the next valley in late December 2016 and bison F 11227 remained in this small area throughout January and February (Fig. 3).

4.3. Monthly area roamed

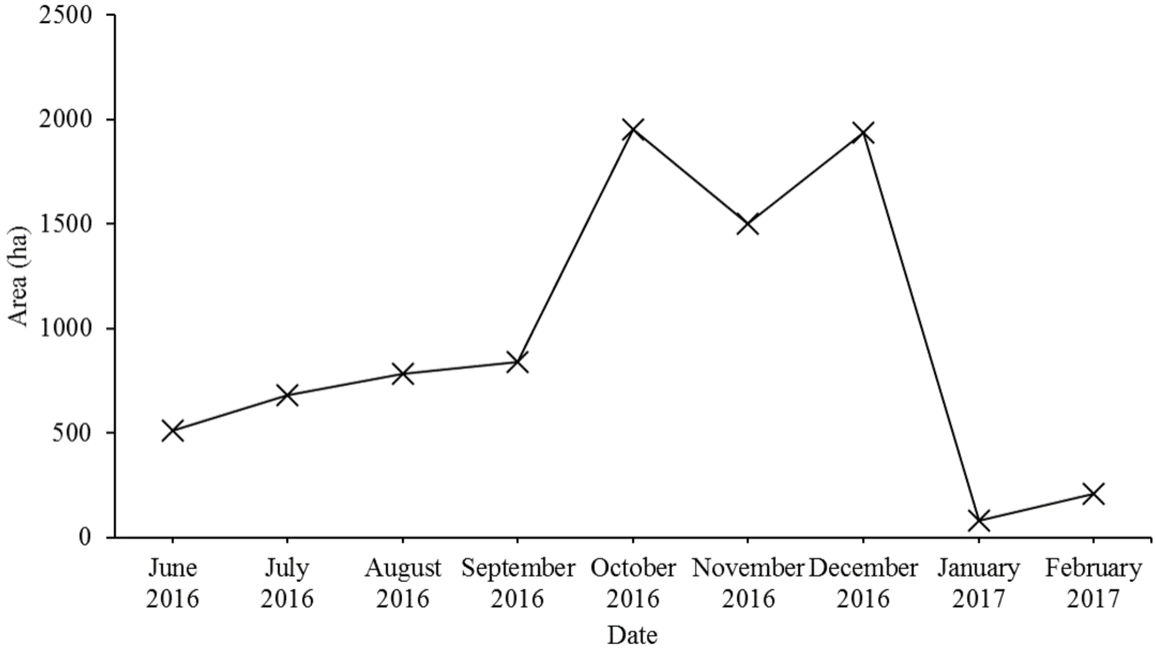

Figure 5. Area of minimum convex polygon representing hectares roamed per month by bison F 11227 from June 2016 to February 2017.

Analysis of the size of area roamed reflects the location change in December 2016. The area utilised by bison F 11227 each month was seen to increase from June to December 2016. In January 2017, the area roamed decreased in size to less than 100 ha before increasing slightly to just above 200 ha in February 2017.

4.4. Daily distance moved

Daily movement of bison F 11227 was initially around 2 km per day when first released. This increased to almost 3 km per day in September and October 2016. The movement per day is significantly reduced in January and February 2017, along with the large reduction in area roamed. The standard deviation in the daily distance moved is also very low in January and February so it is clear that bison F 11227 did not make any long-distance journeys in these months.

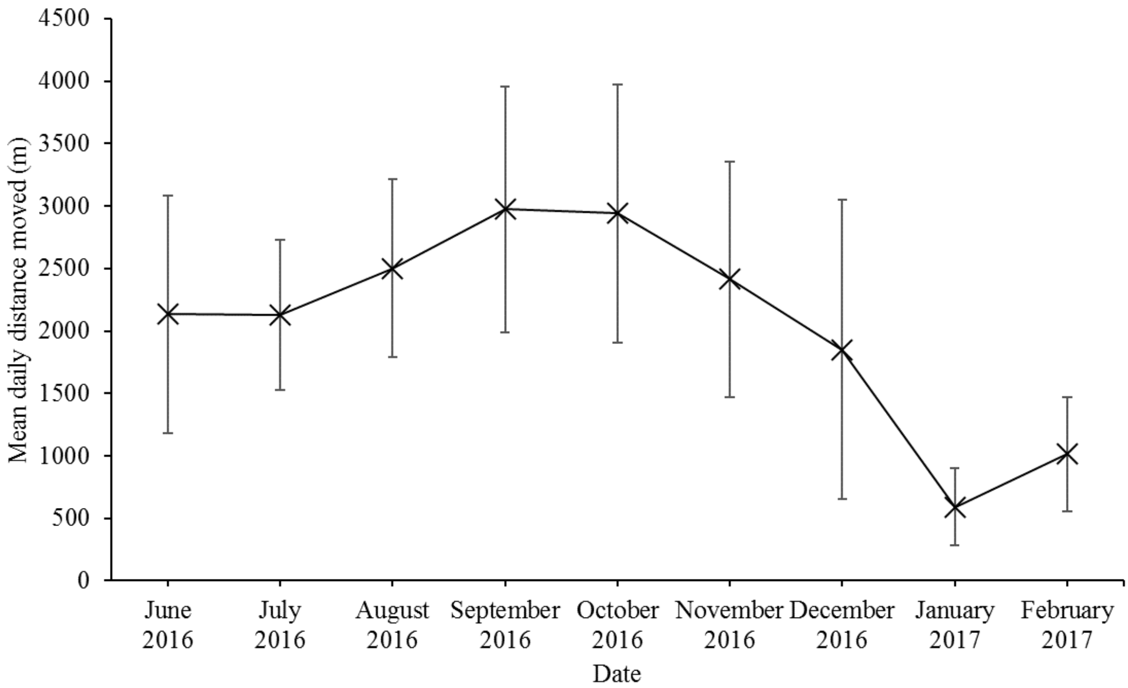

Figure 6. Bison F 11227 mean daily distance moved each month in metres. Error bars ± 1 s.d. from the mean.

Temperature was thought to influence movement of bison. It was found that bison F 11227 tended to move most at average temperatures of 15 to 20°C. At 0°C or below, movement was never more than 400m. This was done by taking the mean of the distance moved in the two hours before and after the time the temperature was logged. Bison F 11227 moved more per day on average during the warmer months (Fig. 7). Greatest average movement per day was in September, at 2,973m. October was similarly high, however was on average 5°C cooler per day than September. The warmest months of June, July and August were all around 22-23°C, and average daily distance moved was 2,000-2,500m. The lowest mean daily distance moved was in January, at 592m; it was also the coldest month with a mean temperature of 2.6°C. Therefore, a weak relationship has been established (R^2 = 0.43) which suggests that bison F 11227 moves more in warmer months than in cooler months.

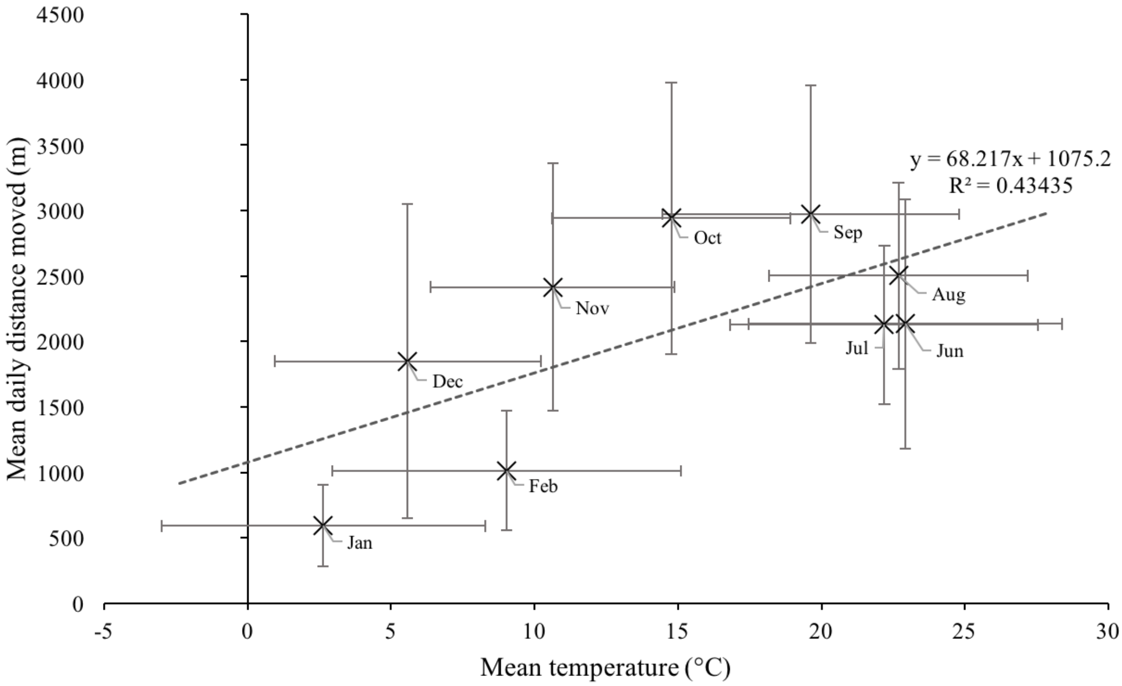

Figure 7. Mean daily distance moved in metres against mean temperature in degrees Celsius for each month. Months are labelled on the graph. Error bars ± 1 s.d. from the mean. Dashed line shows line of best fit with equation and R^2 value.

4.5. NDVI in grasslands

The grasslands that bison F 11227 has thus far been exposed to have a higher mean August NDVI than the rest of the grasslands in the study area (Fig. 8). In the grasslands that bison F 11227 has not roamed, there are some pixels which have a very low August NDVI value, thus creating a large range of values that this individual has not yet been exposed to.

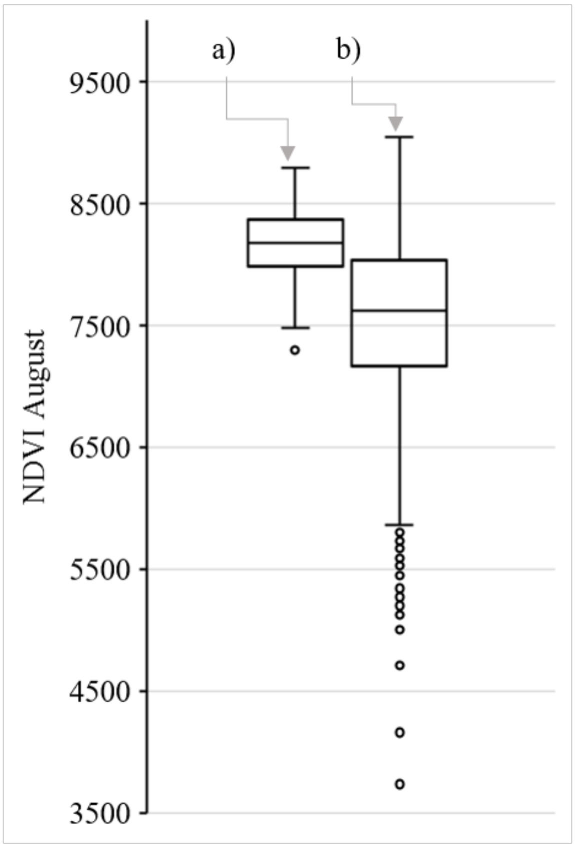

Figure 8. Box and whisker plot of August 2016 NDVI values for grassland in: a) the area that bison F 11227 has roamed; b) the area within the working area that bison F 11227 has not roamed.

4.6. Land Cover

The area that is being studied is made up of a very diverse range of land covers. The majority of land cover is broadleaf, coniferous and mixed woodland with large areas of natural grassland, and moors and heathlands (Appendix I). The "land principally occupied by agriculture, with significant areas of natural vegetation", which is in fact grassland, makes up only a small amount of the study area.

4.7. MaxEnt Species Distribution Modelling

All the MaxEnt models showed that distance to grassland was a very important factor in bison habitat selection whilst NDVI tended to have a lesser effect on the model.

4.7.1. All data

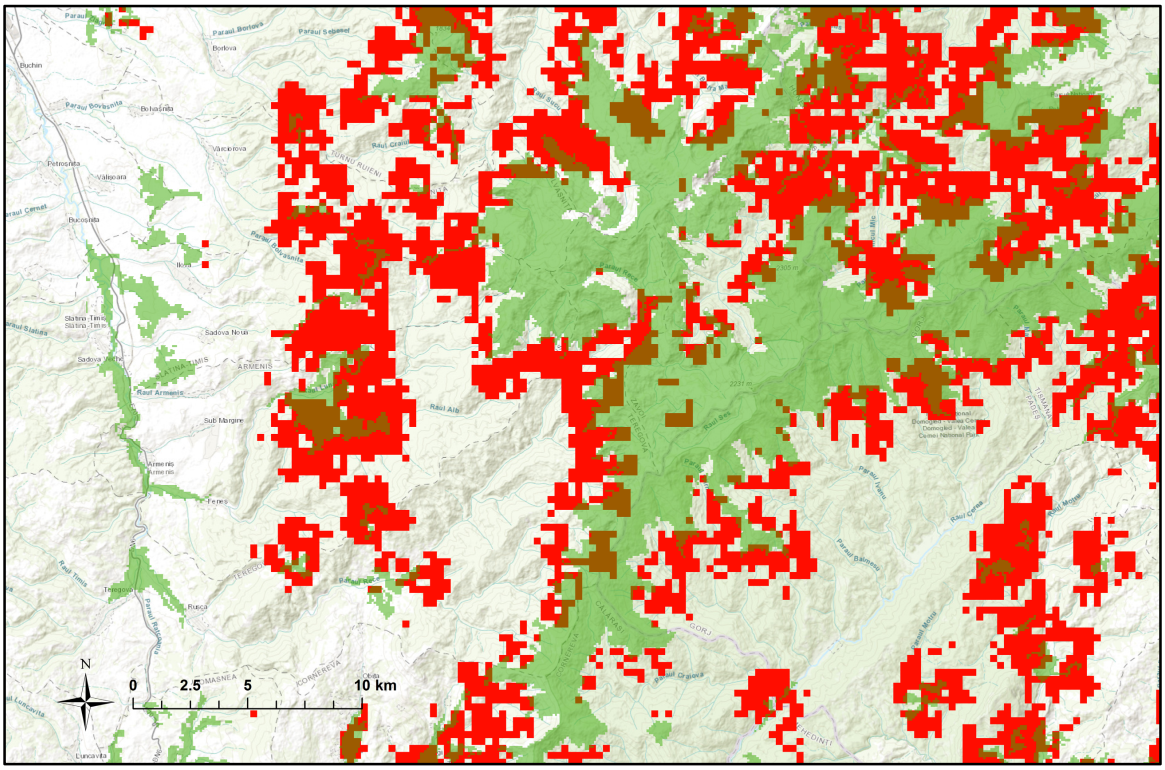

Figure 9. Map of MaxEnt predicted favourable areas based on all location data for bison F 11227 from June 2016 to February 2017. Red represents areas with a value of >0.5 prediction by MaxEnt on a scale of 0 to 1. Green shaded areas show natural grassland and areas similar to natural grassland (Basemap sources: Esri, HERE, DeLorme, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, MapmyIndia, © OpenStreetMap contributors, and the GIS User Community).

MaxEnt has predicted that the most favourable habitat for bison, based on the location points of bison F 11227, is the forest edge. Fig 9 shows that pixels predicted >0.5 by MaxEnt are mostly marginally inside the grassland or on the fringe of the forest. The response curve shows that peak August NDVI was just below 9,000. The response curve for distance to grassland shows that favourable areas are highest in, or very close to, grassland and decrease with distance from grassland. Distance to grassland is the most important factor with a 69.7% permutation importance. August NDVI has a permutation importance of 18.2%, far lower than distance to grassland.

4.7.2. Summer

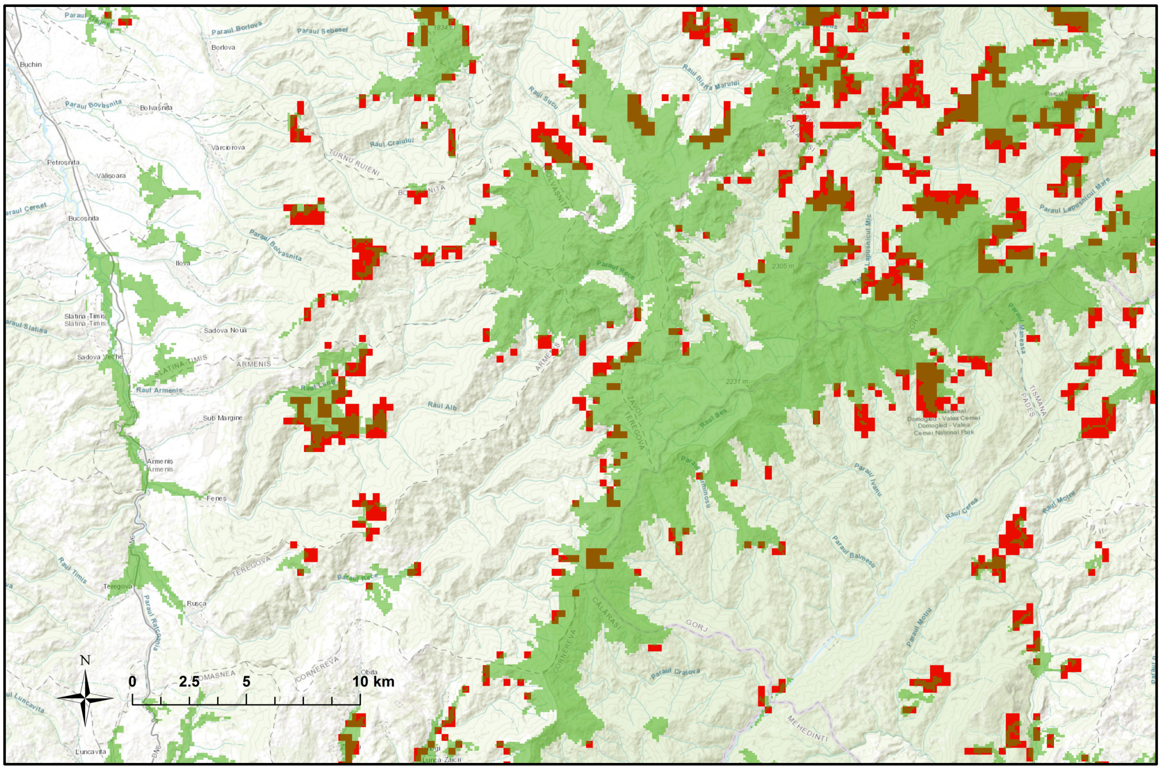

Figure 10. Map of MaxEnt predicted favourable areas based on summer location data for bison F 11227 from June 2016 to August 2016. Red represents areas with a value of >0.5 prediction by MaxEnt on a scale of 0 to 1. Green shaded areas show natural grassland and areas similar to natural grassland (Basemap sources: Esri, HERE, DeLorme, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, MapmyIndia, © OpenStreetMap contributors, and the GIS User Community).

When only the summer location data was considered, the area of most favourable habitat predicted by MaxEnt goes down considerably. The majority of favourable locations are marginally inside the grassland area (Fig. 10). With a permutation importance of 80.3%, distance to grassland is the most important factor and the most favourable areas are at or near to grassland seen from the MaxEnt response curves. It is the lower August NDVI values in the higher altitude natural grassland that MaxEnt predicts to not be suitable for bison F 11227 from the current presence data.

4.7.3. Winter

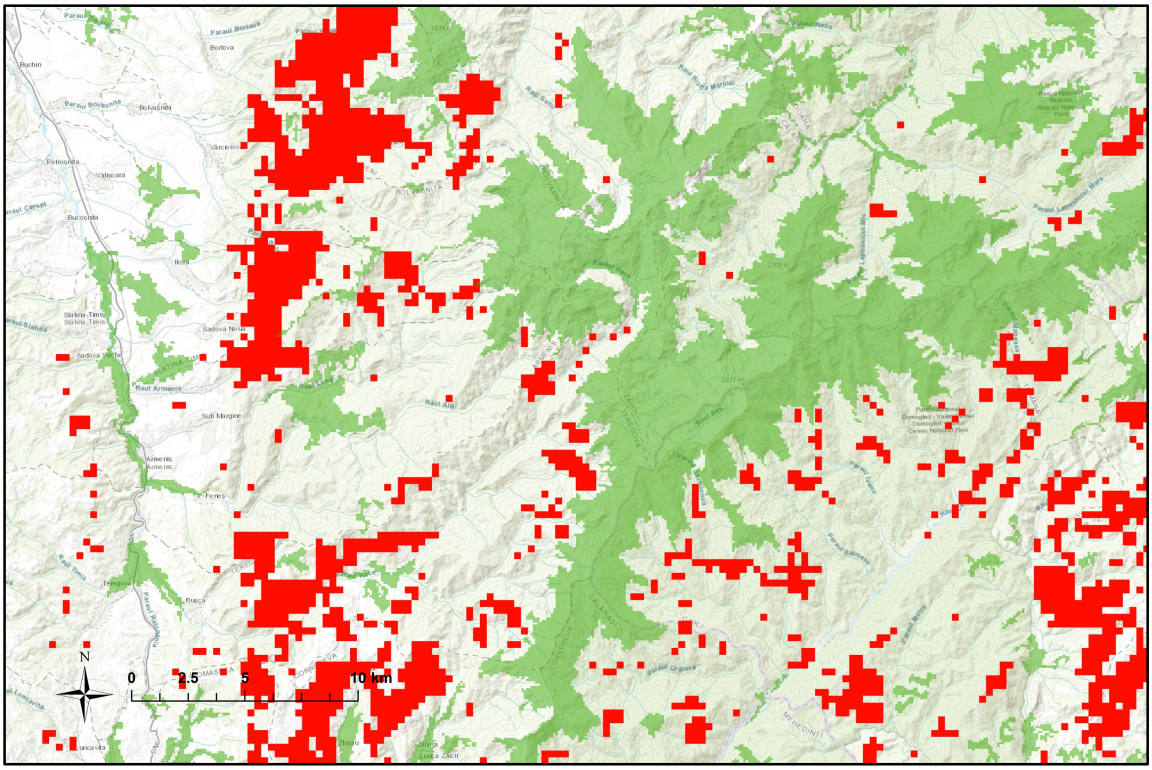

Figure 11. Map of MaxEnt predicted favourable areas based on winter location data for bison F 11227 from January and February 2017. Red represents areas with a value of >0.5 prediction by MaxEnt on a scale of 0 to 1. Green shaded areas show natural grassland and areas similar to natural grassland (Basemap sources: Esri, HERE, DeLorme, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, MapmyIndia, © OpenStreetMap contributors, and the GIS User Community).

When only winter location data was used, there are no favourable locations predicted within the grassland area (Fig. 11). All favourable areas are a slightly within the woodland areas. The response curve for the distance to grassland layer shows this in a peak that is just a small distance away from the grassland area. Therefore, it is just within the woodland that MaxEnt predicts to be the most favourable area. The response curve for February NDVI, with snow cover, shows two peaks in predicted favourable NDVI values, one at about 1,000 and another at about 8,000. The areas that are favourable based on the peak NDVI value of 1,000 have a range of values from 500-2,500. The range that is seen to be favourable from the February NDVI MaxEnt response curve is seen in Fig. 12. The natural grassland areas have very low February NDVI values, which are below 0.

None of the areas that are in the February NDVI range of 500-2,500 are in the higher altitude natural grassland. The grassland area in which bison F 11227 has so far roamed in is within this NDVI range and appears to be the only exception. The woodlands with higher February NDVI values were also not predicted as favourable by MaxEnt with the winter species presence points (Fig. 11).

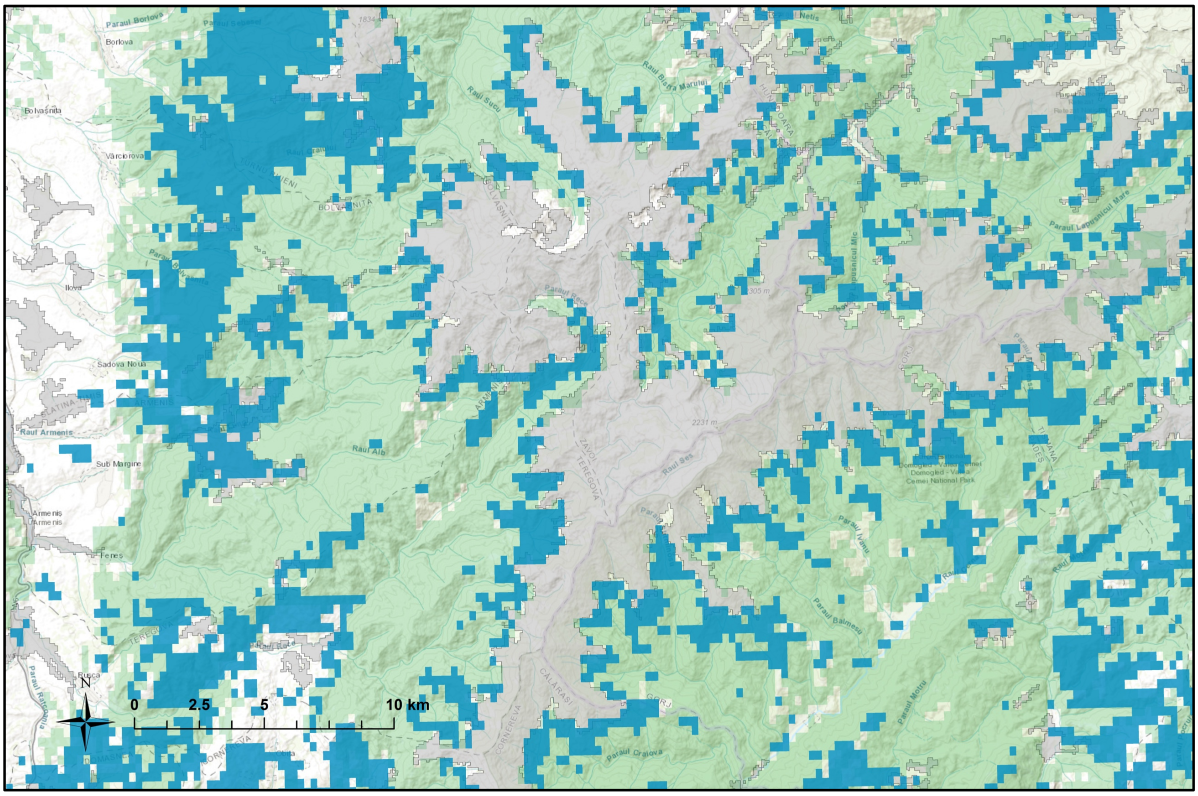

Figure 12. February NDVI values 500-2,500 in blue. The forest areas are shaded in green and the grasslands and areas similar to grasslands shaded in grey that in February are likely to be covered in snow. (Basemap sources: Esri, HERE, DeLorme, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, MapmyIndia, © OpenStreetMap contributors, and the GIS User Community).

5. Discussion

5.1. Exploratory behaviour and winter range

The monthly area roamed increases in area from marginally above 500ha in June to about 2,000ha October to November. This shows exploratory behaviour as bison F 11227 moved further from the release location in search of favourable habitats for feeding (Schmitz *et al.* 2015). In December, when a large amount of movement took place, the range utilised remained high. It appears that bison F 11227 was moving to reach a suitable location in which to spend the months of January and February. This seasonal movement was observed in the Bieszczady Mountains of Poland, where bison had differing winter and summer ranges (Perzanowski *et al.* 2012). Is not yet possible to define the exact nature of this movement to a perceived winter range until more data, from bison F 11227 and more individuals with GPS collars in the future, is available. Bison F 11227 only moved to this winter range at the end of December, however Perzanowski *et al.* (2012) recorded movement from mid October to mid November. This earlier timing could be due to a higher population size as it has been recorded that higher population can cause the movement to the winter range to be earlier (Plumb *et al.* 2009). The winter range was also found to increase in size with higher populations so a similar increase in range may be expected as the population in the Southern Carpathians increases.

The change in location and size of area roamed and the low movement in January and February was prompted by the change in temperature. Snowfall is also considered to be a major factor as was seen to be the case in this study as observed with the low February NDVI values discussed later (Perzanowski *et al.* 2012). Snow may have had an impact in reducing the daily movement as it was greatly reduced in the colder months (Fig. 6). However, without accurate snow cover data, this cannot be confirmed.

5.2. Effect of habitats on bison movement

The CLC maps show that most of the working area is woodland of varying types (Table 1). With the area of "Land principally occupied by agriculture, with significant areas of natural vegetation", which for this study is considered similar to grassland, making up such a small amount of the total grassland (Table 1), and this being the only area of grassland that bison F 11227 has thus far roamed in, it is important that bison start to explore and discover the large expanses of grassland towards Mt. Tarçu. Grassland areas are most favourable to bison and, with an increasing population, bison will require more than just the small area of grassland that they have roamed in until now. However, these areas towards Mt. Tarçu, a 5km straight line distance from the release enclosure, are on the other side of an area that consists of entirely mixed woodlands which are primarily beech. While this is not a long way for bison to roam, it has been shown that beech woodland has previously been avoided by bison in Germany (Schmitz *et al.* 2015). Therefore, this large patch of mixed woodland could be a barrier or hindrance to bison movement. However, once bison do reach the natural grassland, the woodland barrier may be beneficial to preventing human-wildlife conflict as mainly human settlement and agricultural land are found to the west which could be a potential cause of conflict as bison damage crops (Balčiauskas *et al.* 2017). Bison have not always roamed where they have been expected to and this has led to bison moving towards human conflict (Ziółkowska *et al.* 2016). To resolve this, improved habitat connectivity was proposed through creation of corridors.

August NDVI was high in forests and lower in the grassland area. The values were also higher in the grassland area that has been roamed in thus far by bison F 11227 than in the natural grasslands in the rest of the study area. As a result, the MaxEnt models for all species presence points and the model for summer species presence points predicted the grasslands to be largely unsuitable. Despite this, it was possible to see that there was a seasonal change in bison habitat choice.

5.2.1. Seasonal change in movement and habitat choice

It has already been observed that bison tend to have a winter and summer range and that temperature and snow cover tend to drive this shift in range. There are specific, and different, habitat requirements in winter and summer for European bison.

With the MaxEnt model for summer showing forests to be unfavourable habitat, it does appear that there is very little suitable habitat for bison in the summer (Fig. 10). However, it is clear that grassland is in fact likely to be favourable habitat as Fig. 10 shows favourable locations on the very edges of the grassland. These edges are solely highlighted due to the NDVI values of the 'favourable' grassland being different from the grassland area in which bison F 11227 has so far roamed. Therefore, the whole natural grassland area is likely to be favourable. What is clear is that woodland areas are not favourable and this fits with the findings of Schmitz *et al.* (2015) that beech forests are unfavourable habitat.

Already, in the first winter after release, a significant movement has been seen to a more lowland, sheltered area by bison F 11227 (Fig. 11). The MaxEnt model for winter reflected the large effect of snow cover to bison as the February NDVI data on the MaxEnt output showed the natural grasslands as completely unsuitable with very low NDVI values. This is a result of movement, and therefore feeding, being greatly limited (Krasińska *et al.* 2000). As the deepest parts of the forests were still predicted to be unsuitable, the benefits of greater shelter from snow are outweighed by another factor detrimental to bison fitness, perhaps lack of suitable feeding material in the forests. Finding enough food is a challenge for bison in the winter (Krasińska and Krasiński 2013). It is therefore important that there is enough winter foraging area for bison to prevent human-wildlife conflict by from bison damaging agricultural land (Hofman-Kamińska and Kowalczyk 2012). It does appear that there are reasonable amounts of predicted suitable winter areas in the lowland areas near the west of the study area and around in the southeast of the study site on the other side of the natural grasslands (Fig. 11).

5.3. Limitations

Having only one individual with a GPS collar was a major limitation. Interaction with group members and the nature of the fusion-fission dynamics of bison groups could not be studied (Ramos *et al.* 2015). It also meant that anomalous or unusual behaviours could not be identified as there was no comparable data. The MaxEnt modelling was also limited by the small number of species presence points, with data only available from June 2016 in addition to there only being one individual present with a collar. This lack of location data meant that bison were not predicted to roam far into the large expanses of natural grassland. This was due to the difference in August NDVI values between the grasslands that bison F 11227 has roamed in thus far and the other areas of grassland in the study area (Fig. 8).

The study of the effect of temperature on movement was limited by the fact that body temperature would have had an impact on the temperature results. There are studies to limit this effect on GPS collars (Jiang *et al.* 2012). This effect would not have been constant because in different positions and at different ambient temperatures, the collar would have been affected differently.

5.4. Future studies

There is potential for a weather station or temperature monitors to be set up that would allow a more precise study of the effect of temperature on bison movement. Also, monitoring snow cover would give a more accurate idea of its true effect on movement of bison. Diet studies would enable greater understanding of feeding habits of bison that have been found to be so significant to bison movement. Once greater numbers of bison are introduced, the impact of the added numbers and interaction between individuals could show how increased numbers would alter collective bison movement. Ongoing study could be done as the population of bison in the Southern Carpathian Mountains increases. With more GPS collars, the group behaviour and the nature of the fusion-fission dynamics in this population of bison could be observed (Fortin *et al.* 2009). The group dynamics of habitat use could also be studied. For example, American bison have been found to stay in larger group sizes in grassland (Fortin *et al.* 2009). More study is required to know whether wildlife corridors may be needed in order to improve connectivity of suitable bison habitats to prevent bison moving towards human settlement where human-wildlife conflict may arise (Ziółkowska *et al.* 2016).

6. Conclusions

Bison introduction in Romania is a long-term project which is in its early stages. Knowledge of movement and habitat will help towards the overall success of the project.

Both bison range and movement is clearly affected seasonally; both are greatly reduced in the winter. The winter range is in a different location to the area roamed during summer months and appears to be in a more sheltered lowland area, as the grassland areas are unsuitable due to their greater exposure to the elements, lower temperatures and high snow cover. Favoured habitat in winter is lowland areas just within the forest, while in summer the favoured habitat is grassland.

Bison reintroduction relies on the creation of stable, connected metapopulations. To this end, connectivity is of high importance to ensure that bison can disperse into favourable habitats and, once populations have settled, for movement between populations to occur. There is a large area in which it is suitable for bison to roam in the study area. Connectivity between populations may become an issue, however, as bison are likely to turn to agricultural land and human settlements if they are blocked from accessing the natural grasslands by thick beech forests. This is detrimental to bison movement but it is also detrimental as it may increase human-wildlife conflict. It is essential to ensure connectivity and movement into favourable bison habitat. There must also be enough winter range as the bison population increases to prevent the need for to bison to use agricultural land for shelter.

In the future, when bison approach carrying capacity and are limited to a greater extent by food availability, it will be interesting to observe how they begin to disperse as the lack of food is likely to initiate higher dispersal rates. However, if this is the case, connectivity to favourable habitats will remain an issue.

More studies of a similar nature should be carried out when more individuals are released with GPS collars to monitor bison movement as it is recognised that this study was greatly limited by using only one individual's location data. Studies of interactions could then also be added, as bison do respond to the behaviour of other nearby individuals.

7. Acknowledgements

Thanks goes to the WWF Romania team for their great assistance. In particular to Adrian Hagatis, Alexandru Bulacu, Georg Messerer and Oana Mondoc. Also to the bison rangers Matei Miculescu and Daniel Hurduzeu. Thanks also for the assistance of Nick Huisman, fellow intern at the WWF Research Centre in Feneș village in Armeniș commune. The MODIS NDVI 16-Day L3 Global 250m data was retrieved from the online Earthdata system, courtesy of the NASA EOSDIS Land Processes Distributed Active Archive Center (LP DAAC), USGS/Earth Resources Observation and Science (EROS) Center, Sioux Falls, South Dakota, https://search.earthdata.nasa.gov.

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Appendix I

Area in hectares of different land cover types in the study area from the Corine Land Cover map (Copernicus 2006).

Land Cover	Code	Area (ha)
Discontinuous urban fabric	2	800
Mineral extraction sites	7	158
Sport and leisure facilities	11	27
Non-irrigated arable land	12	1987
Fruit trees and berry plantations	16	5881
Pastures	18	8924
Complex cultivation patterns	20	3467
Land principally occupied by agriculture, with significant areas of natural vegetation	21	4864
Broad-leaved forest	23	39083
Coniferous forest	24	22563
Mixed forest	25	44563
Natural grasslands	26	26940
Moors and heathland	27	10634
Transitional woodland-shrub	29	6819
Beaches, dunes, sands	30	170
Bare rocks	31	1343
Sparsely vegetated areas	32	2499
Water courses	40	73
Water bodies	41	266