MOORS FOR THE FUTURE PARTNERSHIP

CommunityScience

The story so far...

Preliminary data analysis and findings from the Community Science project

June 2018
Prepared for Moors for the Future Partnership
by Stockholm Environment Institute

LOTTERY FUNDED

Overall outcomes

Community Science's vision is to evidence the impact of climate change on the internationally important Blanket Bog habitat in the South Pennine Moors Special Area of Conservation by engaging local communities in environmental monitoring and biological recording – raising awareness of the natural world through citizen science.

Acknowledgements

We would like to thank the many dedicated volunteers that have contributed to the Community Science project whether through collecting, submitting and processing data, helping at engagement events or building and maintaining monitoring equipment. Without their generous contributions of time, this project would not be possible.

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Executive Summary

This report outlines the preliminary data analysis and findings of the Heritage Lottery Funded (HLF), Moors for the Future Partnership Community Science project (CSP). The CSP is engaging with residents and visitors of the Peak District National Park and South Pennine Moors Special Area of Conservation (SAC) to monitor the impacts of climate change on moorlands and the species they support.

Opportunistic monitoring of target species has begun to build up a picture of these species' distributions and all records dated up to the end of 2017 have been mapped within the project area.

Migratory bird arrival dates and butterfly emergence dates from CSP data have been correlated against datasets from Derbyshire Ornithological Society and Butterfly Conservation and show a strong correlation suggesting reliability of the CSP datasets.

Linear regression analysis has shown a significant relationship between swallow arrival dates and winter rainfall in England, with wetter winters corresponding to the later arrival of swallows in the project area.

Data from CSP bumblebee transects shows a strong association between the bilberry bumblebee (*Bombus monticola*) and heath/moorland habitats while the red-tailed bumblebee (*Bombus lapidarius*) and tree bumblebee (*Bombus hypnorum*) appear to be more generalist, being found more evenly across several habitats.

Data from the *Sphagnum* survey has found that the highest mean patch size is in woodland habitats, however with continued data collection from a wider area we might expect this to change.

Heather flowering in the first two years of data collection (2016 and 2017) shows quite consistent timing between years.

Data collected so far on four environmental monitoring sites has shown significant differences in both air temperature and soil surface temperature between sites. Both mean air and soil temperature show a significant decrease with an increase in elevation.

Analysis on rainfall data has shown a negative relationship between total autumn rainfall and the Easting of sites. We have also shown that the number of dry days in autumn increases as you move west to east through the project area.

Water table data analysis has found a significant difference in mean water table depths between sites, with the most degraded site at Edale (Kinder Scout) having by far the lowest mean water table. Rewetting rates were also found to be significantly faster at Edale than at the other three sites.

National Vegetation Classification (NVC) communities have been identified at each of the five monitoring sites that were surveyed in 2017.

Climate change is a long term process so continued data collection will be required for many years to detect changes in the habitats and species being investigated, but data processes have been produced and are available to facilitate analysis in future years.

Introduction

This document outlines the preliminary data analysis that was undertaken in March 2018 using data collected from the first 5 years (2012 – 2017) of the Heritage Lottery Funded (HLF) Moors for the Future Partnership Community Science project (CSP). The overall aim of the project is to engage residents and visitors of the Peak District National Park and South Pennine Moors Special Area of Conservation (SAC) in monitoring the impacts of climate change on the moorlands and species they support.

It should be noted that because data have only been collected over a relatively small number of years, these initial results should be treated with caution and that more robust conclusions may be drawn from data collected in coming years. Data processes to enable future analyses as suggested in this report are available for long-term monitoring.

Climate change is a long term process and many years of data will be required to detect the responses of the upland habitats and species that we are investigating. Whilst records have been gratefully received across a large geographic area, only those within the project area of the Peak District National Park and South Pennine Moors SAC have been included in these analyses.

1. Community Science Opportunistic Monitoring (OM) surveys are quick and simple surveys that ask people to record the date and location of sightings of key species. These will allow us to monitor whether the distribution of species are changing over time and whether the timing of events (e.g. migration times in birds and emergence times in butterflies and amphibian and reptiles) are changing over time and in response to climatic conditions.

   Data collected so far from the OM surveys have allowed us to start to build up a picture of where our target species have been recorded and the timing of life history events. We have also found that swallows have arrived in the project area later in years when there has been a wet winter.

2. CSP Targeted Monitoring (TM) surveys take a more in depth and structured approach – asking people to revisit the same sites regularly and use the same standardised protocols to monitor populations of target species. This enables us to look at changes in species' abundances over time and in response to climatic conditions as well as the timing of events and how these are changing over time.

   Data collected so far from the TM surveys have allowed us to start to build up a picture of the habitat preferences of some of our target species and the timing of life history events.

3. CSP Environmental Monitoring (EM) surveys take place at a network of eight sites across the project area. Teams of volunteers visit these sites regularly to monitor temperature, rainfall, humidity, water table depth and vegetation. This will enable us to look at how the environment of these sites is changing over time and whether sites in different parts of the project area, i.e. with latitude and longitude or elevation, are changing in different ways.

   Initial analyses have been restricted largely to the four sites that have been established for the longest: Edale, Holme, Marsden and Burbage as their data sets cover two full years – 2016 and 2017. Data from the additional four sites which were setup in either 2016 or 2017 will be included in future analysis when more data is available.

   Some significant differences between sites have been found – often in the direction expected – including a decrease in mean temperature with an increase in elevation and an increase in the number of dry days as you move from west to east across the project area. We have also found differences in how water table depth behaves between sites, with Edale behaving quite differently to the other sites, in line with its much more degraded nature. The different vegetation communities supported by the different EM sites have also been identified.

1. Opportunistic Monitoring

Five Opportunistic Monitoring (OM) surveys were developed during the Community Science project. These were designed to be quick, simple surveys that residents of and visitors to the project area could carry out without any prior training. The surveys ask people to record the location and date of sightings of key species via survey postcards, the Community Science website or MoorWILD app. This information allows us to look for evidence of the impacts of climate change on species in the project area. The impacts we are able to examine fall into two broad categories:

- Changes in the distribution of species. As climatic conditions warm, species are expected to shift their distributions further north and further uphill, although changes in rainfall may alter this response. With the results of the OM surveys we can look in particular at changes in the location of species' range boundaries i.e. the northern, southern, upper altitudinal and lower altitudinal limits of species' distributions.
- Changes in the timing of events. As climatic conditions change, species are also expected to alter the timing of events (e.g. timing of migration, timing of spring emergence, timing of breeding). We can use records collected as part of the OM surveys to examine whether the timing of events are becoming earlier or later in the year over time and whether this is related to climatic conditions.

Some of the OM surveys also ask people to record additional information, such as the habitat in which individuals are seen because there may be additional responses, such as changes in the timing of use of particular habitats, which might be expected with climate change.

The following sections outline the specific research questions that each survey was looking to answer and some preliminary results.

1.1 Bird Survey

1.1.1 Research questions

The Bird Survey was launched in 2013 and asks people to record the date, location and number of individuals seen of three species: swallow (*Hirundo rustica*), red grouse (*Lapogus lapogus scoticus*) and curlew (*Numenius arquata*).

Figure 1. The three target species of the Bird Survey: swallow (left), red grouse (centre) and curlew (right).

These data allow us to address the following questions:

Changes in the distribution of species

Firstly, the locations in the project area in which the target species have been recorded can be mapped.

- *Are red grouse southern and lower altitudinal range boundaries changing over time?*
  Red grouse is an upland species that favours cool and moist conditions. It reaches its southern range boundary in the project area and also favours higher altitudes. As climatic conditions warm, it is expected that the red grouse's distribution will shift further north and further uphill to track cooler conditions. Models project that the red grouse will decline or even disappear from the Peak District under future climate scenarios (Huntly *et al.* 2007, Smith *et al.* 2013). We are, therefore, using data from the survey to examine

whether the southern and lower altitudinal range boundaries of the red grouse change over time. Such changes are expected to be gradual and so data will need to be collected over a number of years before analyses can be undertaken and any changes can be detected.

Changes in the timing of events

Firstly, we have compared arrival and departure dates calculated from the Bird Survey with those calculated using data available from the Derbyshire Ornithological Society. This enables us to assess the reliability of dates calculated from our data. The results of this analysis are presented below.

- *Are the arrival and departure dates of swallows in the project area changing over time?*
  Swallows migrate to the UK from Africa in the spring and depart again at the end of the summer. There is already some evidence in the UK to indicate that the arrival of swallows is getting earlier in the year (Huin & Sparks 1998, Sparks *et al*. 2007) and departure dates are getting later (Forrester *et al*. 2007). The data collected from this survey will allow us to track changes in arrival and departure dates of swallows in the project area over time. While these analyses have been carried out to gain some preliminary results, it is likely that data will need to be collected over a number of years in order to detect any significant trends.

- *Are year-to-year fluctuations in swallow arrival and departure dates related to climatic conditions?*
  We can also use data from the Bird Survey to examine whether year-to-year fluctuations in swallow arrival and departure dates are driven by the climatic conditions in that year. We might expect, for example, that swallow arrival dates are earlier in years with warmer springs (as shown in Huin & Sparks 1998) and that departure dates are later in years with warmer summer and autumn temperatures. We use climatic data from England for these analyses because, although a lot of the variation in arrival dates will be dependent on climatic conditions in Africa and mainland Europe, when swallows arrive in southern England, their progress up the country is affected by the climatic conditions they find when they get here because this affects the availability of insects (Huin & Sparks 1998). Again, while these analyses have been carried out to present some preliminary results, it is likely that data will need to be collected over a number of years in order to detect any significant relationships.

- *Are the arrival and departure dates of curlew in the project area changing over time?*
  Curlew – a UK Biodiversity Action Plan (BAP) priority and Amber listed species – move to the project area to breed in spring and depart for their coastal wintering grounds at the end of summer. Some curlew may over-winter within the project area boundary which presents difficulties when trying to establish which sightings relate to the first birds returning in spring to breed. Additional work is needed to accurately identify these arrival and departure dates. However, in future the data collected from this survey will allow us to track changes in arrival and departure dates of curlew in the project area over time but these analyses have not yet been carried out.

- *Are year-to-year fluctuations in curlew arrival and departure dates related to climatic conditions?*
  We can also use data from the Bird Survey to examine whether year-to-year fluctuations in curlew arrival and departure dates are driven by the climatic conditions in that year. However, additional work is needed to accurately identify true breeding bird arrival and departure dates, so these analyses have not yet been carried out.

1.1.2 Results so far

Participation figures

Firstly, we can show the number of records of each species submitted as part of the Bird Survey each year and the total number of individuals of each species that were recorded as part of these records. Figure 2 shows, for records in the project area, that there has been a general increase in the number of records submitted over time. There are also suggestions of other patterns in the data; for example, was 2015 a particularly poor year for curlew? Was 2017 a particularly poor year for swallows? Data from other sources will need to be sought to find an answer to these questions.

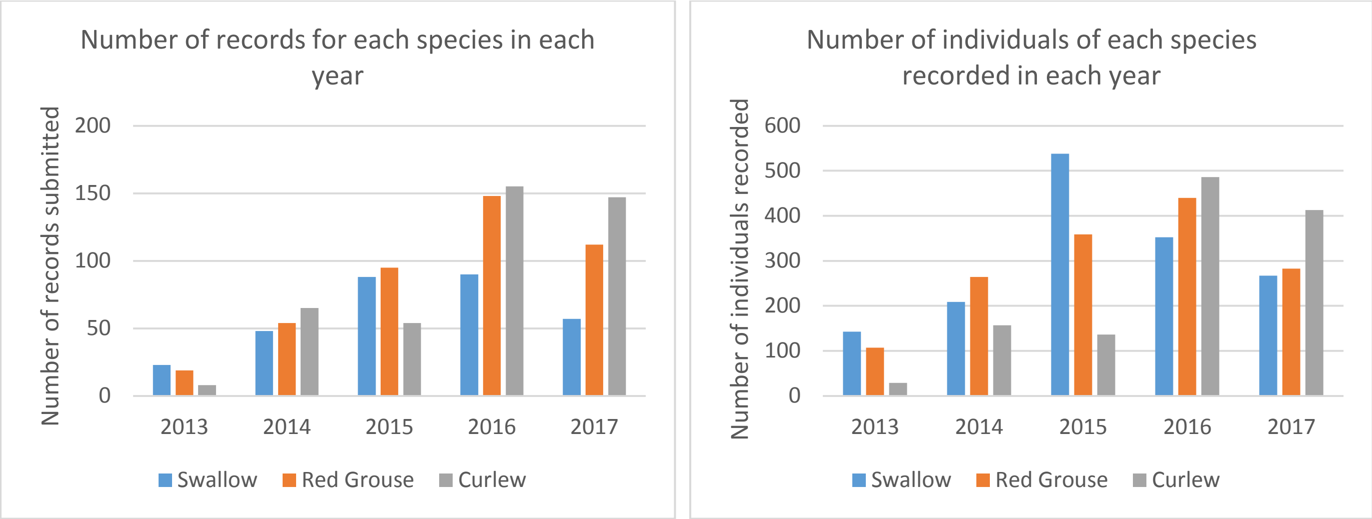


Figure 2. The number of records received from the project area of each species in each year (left) and the number of individuals of each species those records included (right).

Species' distributions

Figures 3-5 show the locations in the project area in which the three target species were recorded from 2013 to 2017 (see Appendix A for distribution maps from individual years).

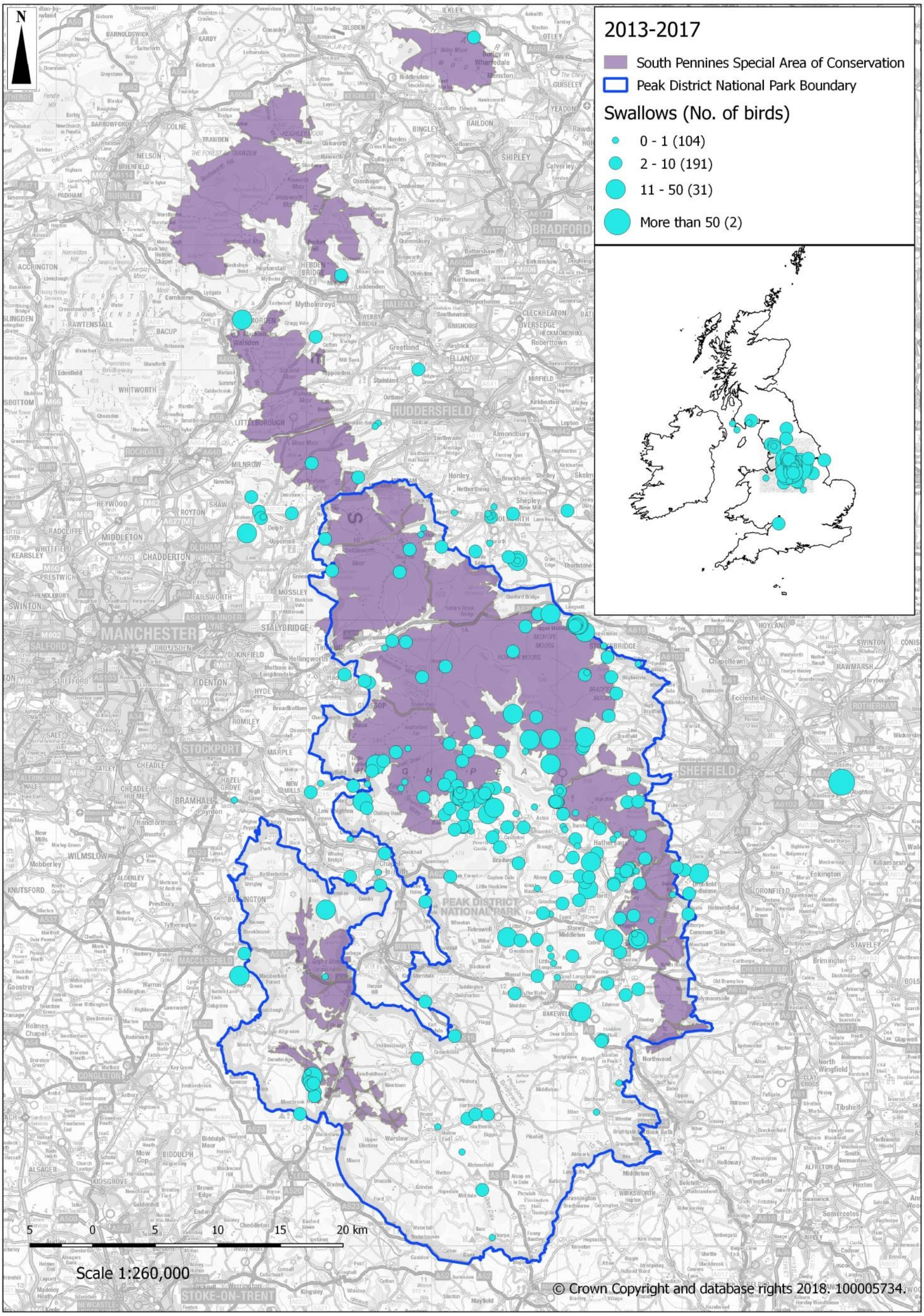


Figure 3. Location of swallow records submitted to the Bird Survey from 2013 to 2017.

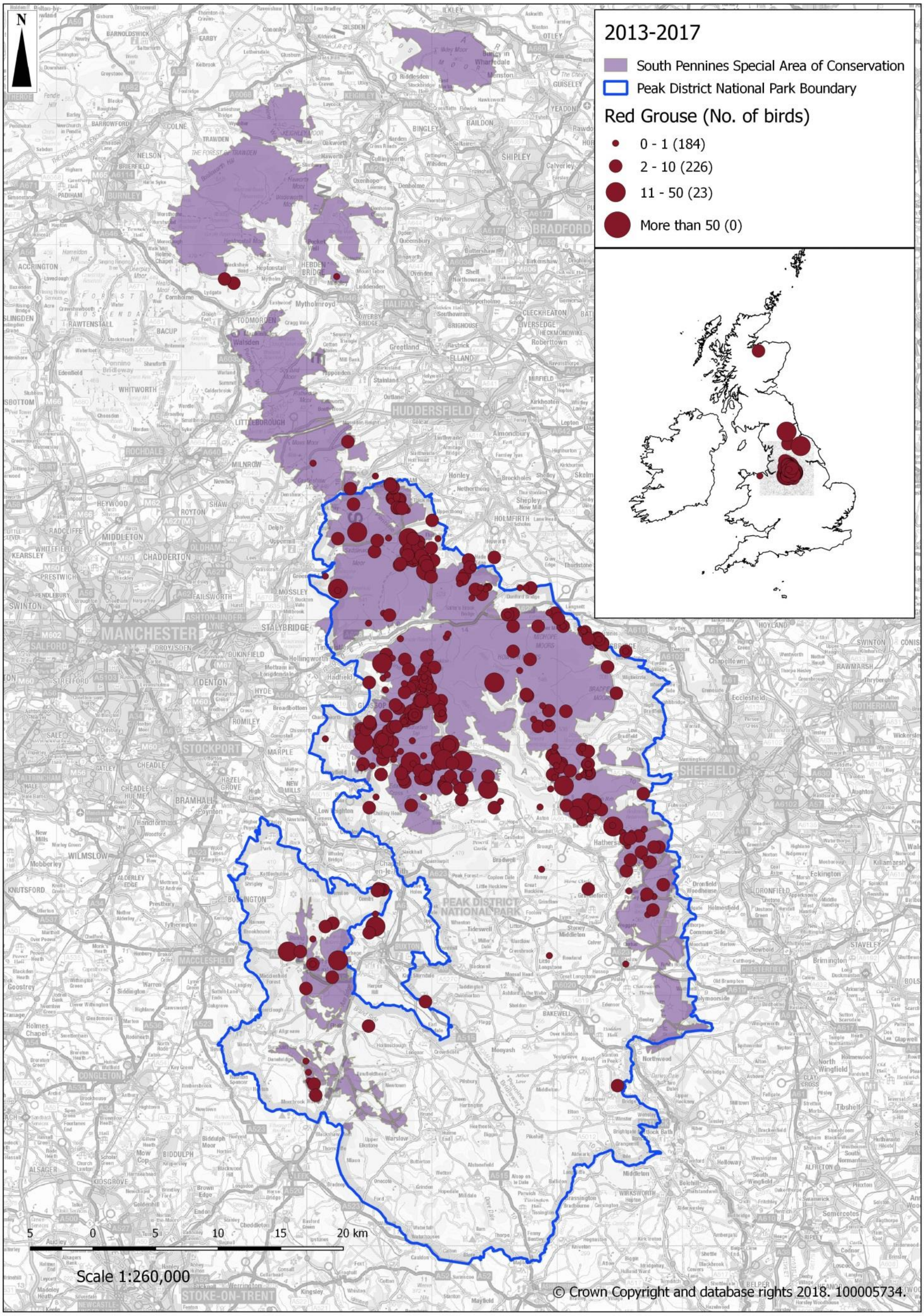


Figure 4. Location of red grouse records submitted to the Bird Survey from 2013 to 2017.

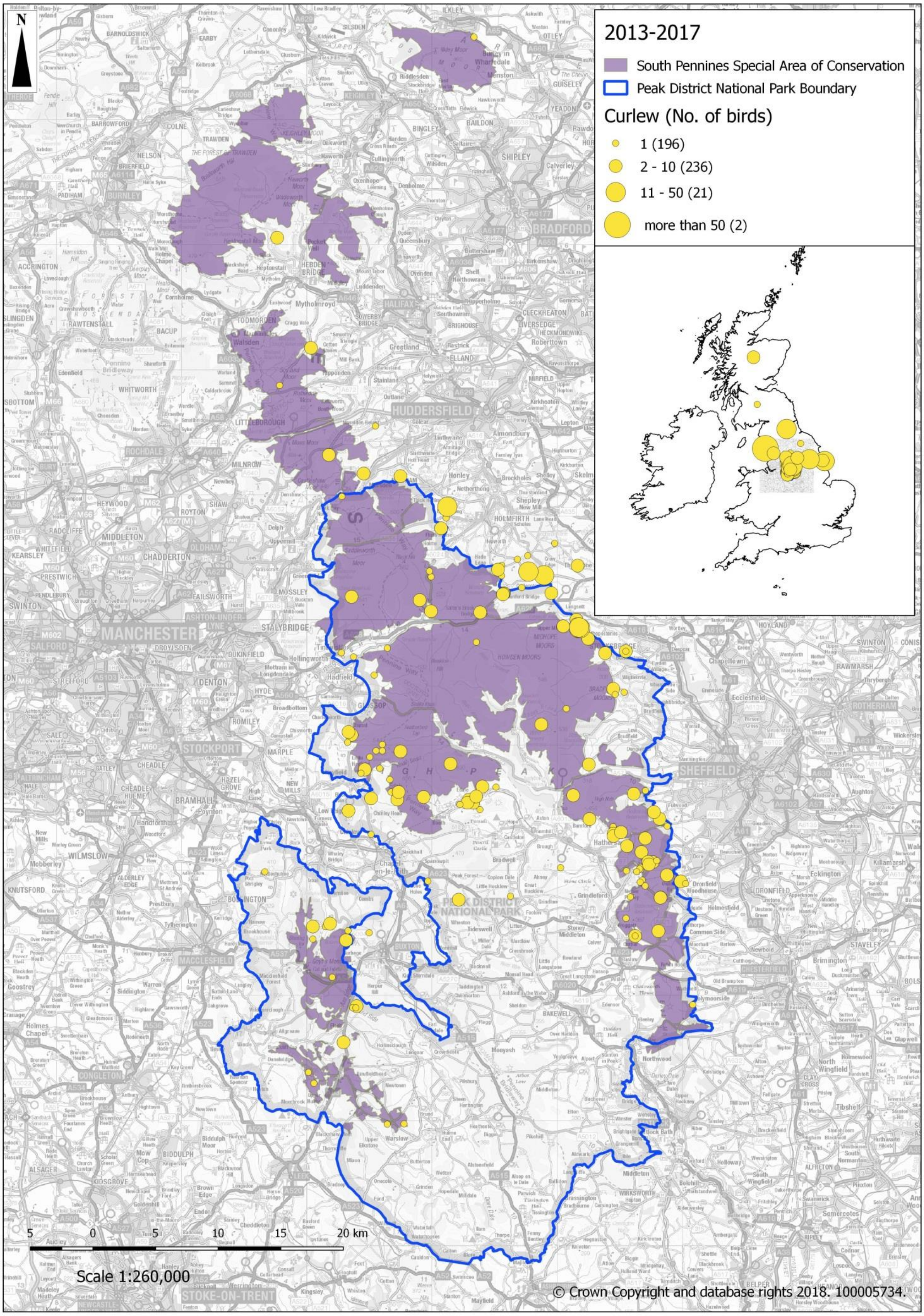


Figure 5. Location of curlew records submitted to the Bird Survey from 2013 to 2017.

The timing of events

There is a strong positive association between swallow arrival and departure dates calculated from the CSP data and the Derbyshire Ornithological Society (DOS) data (arrival dates, Pearson correlation: $r = 0.93$; departure dates, Pearson correlation: $r = 0.81$) (Figure 6) This indicates that the arrival dates recorded in the Bird survey dataset are a reliable representation of bird arrival in the project area. Arrival and departure dates are calculated from both datasets by taking an mean of the first and last five days of the years with records of swallows.

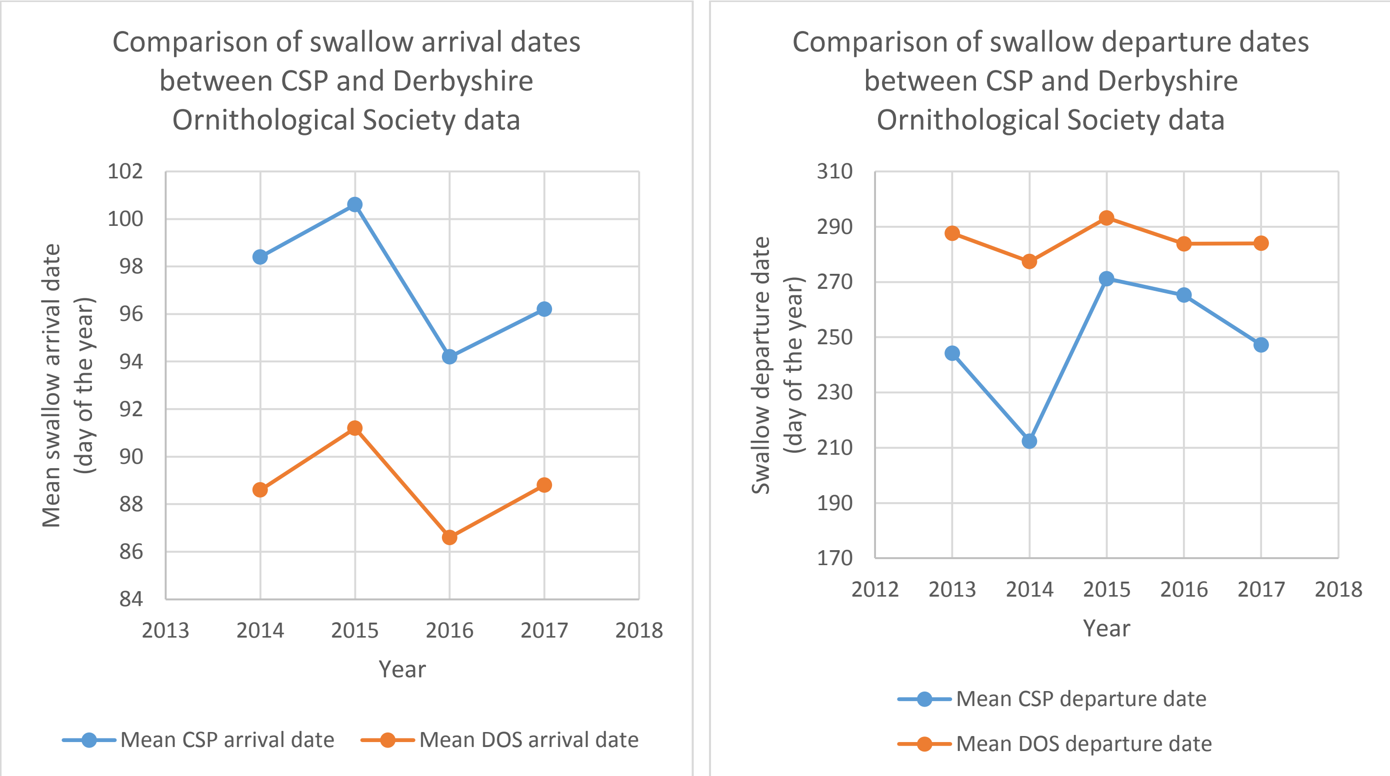


Figure 6. Comparison between swallow arrival (left) and departure (right) dates calculated using data from the CSP and from the Derbyshire Ornithological Society.

Analyses of changes in swallow arrival and departure dates over time have not shown any significant trends so far but data are only available from 2013 to 2017.

We did, however, find a significant relationship between swallow arrival dates and winter rainfall in England (linear regression: $\beta = 0.232$, d.f. = 3, $P = 0.019$) (Figure 7). This is a positive relationship, so swallows appear to have arrived in the project area later in years where there was higher rainfall in December, January and February. This could be because the weather conditions meant that there were fewer suitable days on which swallows were able to make their flight back to the project area.

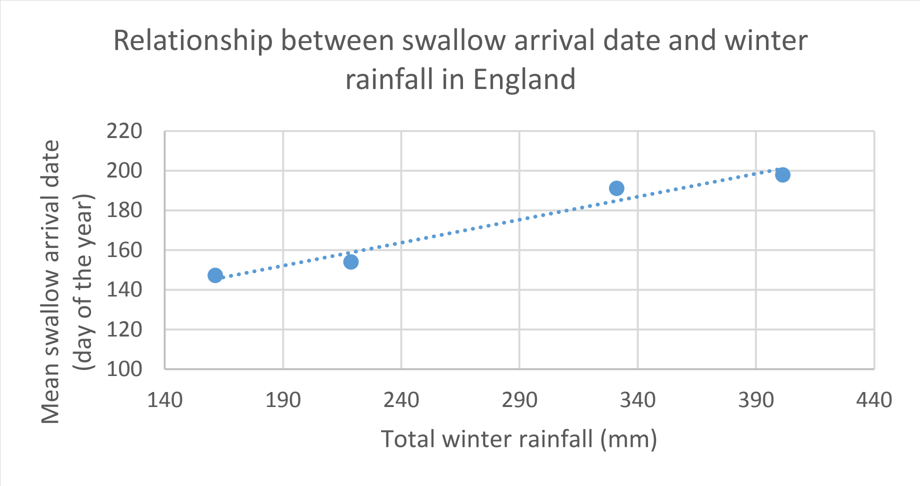


Figure 7. Relationship between the mean arrival date of swallows in the project area and the total rainfall in the preceding winter.

1.2 Butterfly Survey

1.2.1 Research questions

The Butterfly Survey was launched in 2014 and asked people to record the date, location and number of individuals seen of three species: green hairstreak (*Callophrys rubi*), orange tip (*Anthocharis cardamines*) and peacock (*Aglais io*).

Figure 8. The three target species of the Butterfly Survey: green hairstreak (left), orange tip (centre) and peacock (right).

These data allow us to address the following questions:

<u>Changes in the distribution of species</u>

Firstly, the locations in the project area in which the target species have been recorded can be mapped.

- *Is the upper altitudinal range boundary of the green hairstreak changing over time?*
  The green hairstreak has currently been observed up to about 500 m altitude in the project area but might be expected to move further uphill as conditions warm, as has been observed in other species (Hickling *et al*. 2006). Such changes are expected to be gradual and so data will need to be collected over a number of years before analyses can be undertaken and any changes can be detected.

<u>Changes in the timing of events</u>

Firstly, we have compared butterfly emergence dates calculated from the Butterfly Survey with those calculated using data available from Butterfly Conservation. This enables us to assess the reliability of dates calculated from our data, and results of this analysis are presented below.

- *Are the emergence dates of green hairstreaks and orange tips in the project area changing over time?*
  The emergence dates of adult butterflies in the spring and summer are known to be affected by the climatic conditions in a particular year and even conditions in previous years. As climatic conditions have changed over time, several species have shown a trend for earlier emergence dates, including green hairstreaks and orange tips (Roy & Sparks 2000). This seems to be largely driven by warmer spring and summer temperatures. The data collected from this survey will allow us to track changes in emergence dates of green hairstreaks and orange tips in the project area over time. Peacocks are not included in this analysis as they spend the winter as adults. While these analyses have been carried out to present some preliminary results, it is likely that data will need to be collected over a number of years in order to detect any significant trends.

- *Are year-to-year fluctuations in green hairstreak and orange tip emergence dates related to climatic conditions?*
  We can also use data from the Butterfly Survey to examine whether year-to-year fluctuations in green hairstreak and orange tip emergence dates are driven by the climatic conditions in that year. Previous research has shown that emergence dates of green hairstreaks and orange tips are earlier in years with warmer springs (Roy & Sparks 2000). Again, while these analyses have been carried out to present some preliminary results, it is likely that data will need to be collected over a number of years in order to detect any significant relationships.

1.2.2 Results so far

Participation figures

Firstly, we can show the number of records of each species submitted as part of the Butterfly Survey each year and the total number of individuals of each species that were recorded as part of these records. Figure 9 shows, for records in the project area, that there has been a general increase in the number of records submitted over time. There are also suggestions of other patterns in the data; for example, was 2016 a particularly good year for orange tips? Was 2017 a particularly good year for green hairstreaks? Data from other sources will need to be sought to find an answer to these questions.

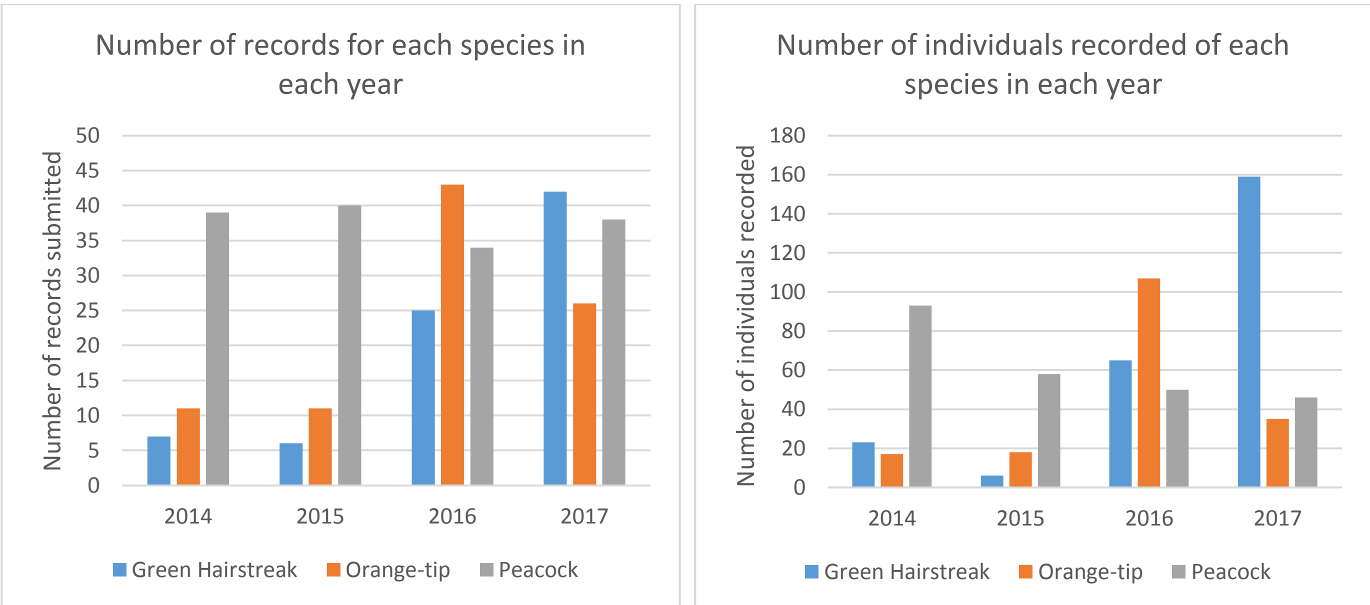


Figure 9. The number of records received from the project area of each species in each year (left) and the number of individuals of each species those records included (right).

Species' distributions

Figure 10 shows the locations in the project area in which the three target species were recorded from 2014 to 2017 (see Appendix B for distribution maps from individual years).

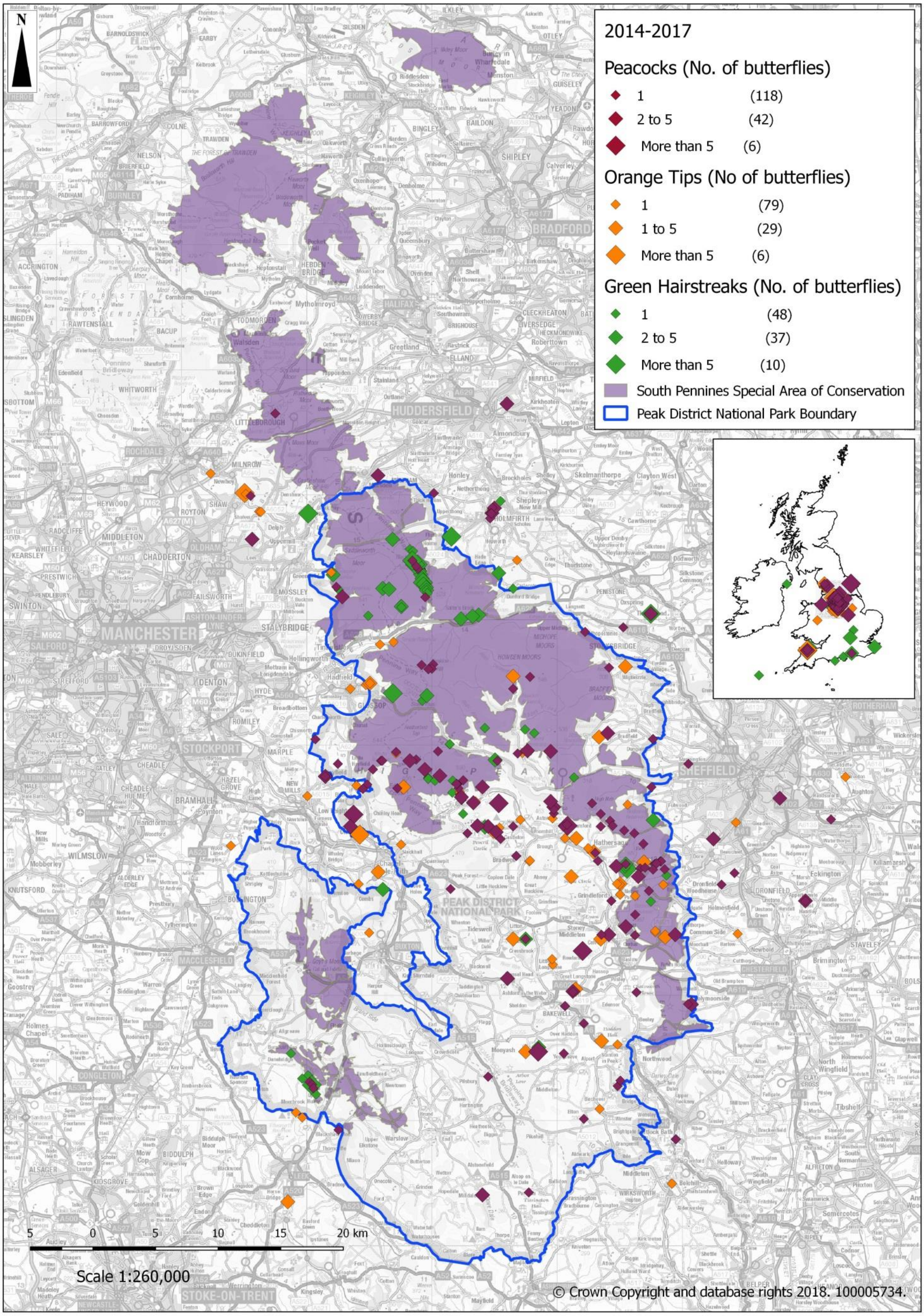


Figure 10. Location of green hairstreak, orange tip and peacock records submitted to the Butterfly Survey from 2014 to 2017.

The timing of events

There is a strong positive association between green hairstreak and orange tip emergence dates calculated from the CSP data and from Butterfly Conservation data (green hairstreak, Pearson correlation: r = 0.99; orange tip, Pearson correlation: r = 0.79) (Figure 11). While CSP emergence dates are consistently later than Butterfly Conservation (BC) emergence dates (which is likely to be due at least in part to the cooler than average UK climate in the CSP project area), annual fluctuations are the same between datasets, suggesting the data is reliable. Emergence dates from Butterfly Conservation were calculated using simply the date of the first reported sighting of the year in the UK and so the date of the first sighting from the CSP data was also used.

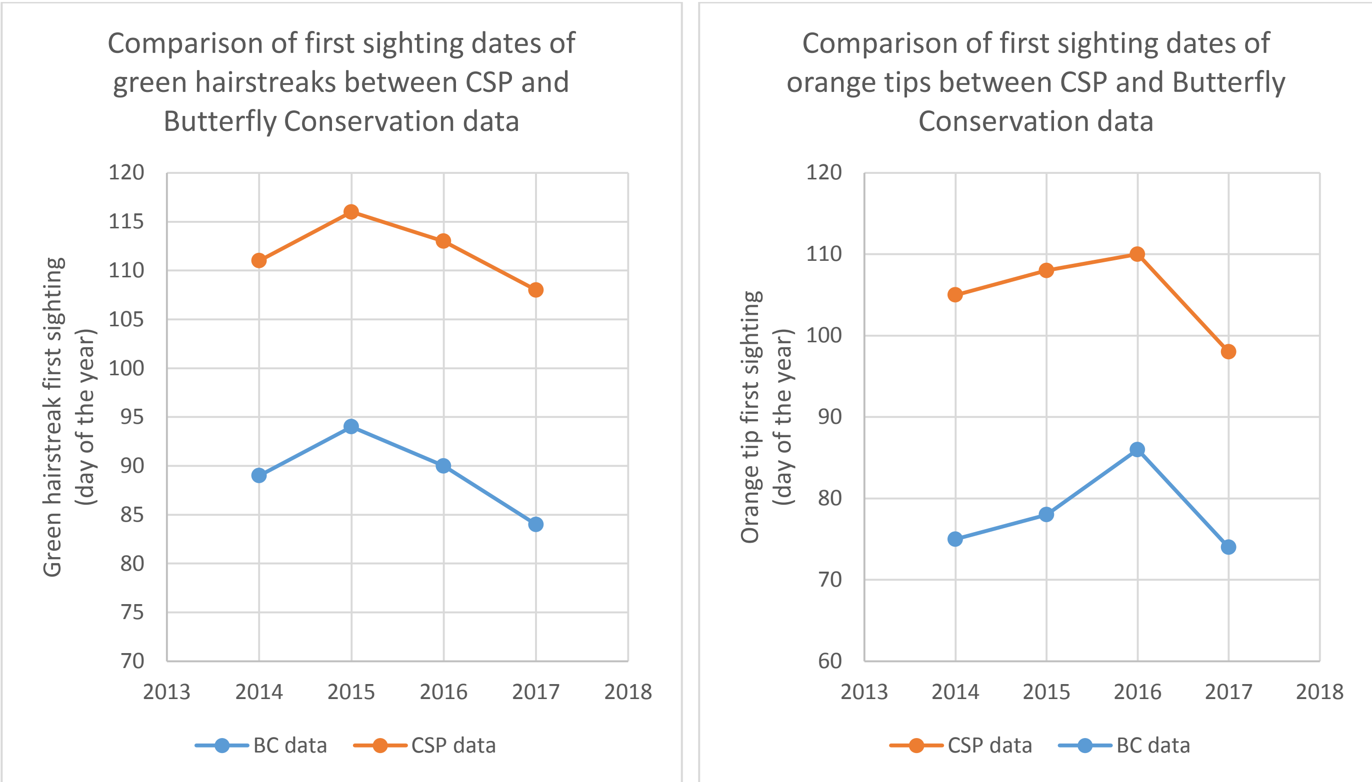


Figure 11. Comparison between green hairstreak (left) and orange tip (right) emergence dates calculated using data from the CSP (orange) and from Butterfly Conservation (blue).

Analyses of changes in green hairstreak and orange tip emergence dates over time have not shown any significant trends over time so far but data are only available from 2014 to 2017. Similarly, no relationships have yet been found between emergence dates of these species and climatic conditions in a particular year.

1.3 Hare Survey

1.3.1 Research questions

The Hare Survey was launched in 2015 and asked people to record the date, location and number of individuals seen of three species: mountain hares (*Lepus timidus*), brown hares (*Lepus europaeus*) and rabbits (*Oryctolagus cuniculus*).

Figure 12. The mountain hare in its winter coat (left), summer coat (right) and transition between the two (centre).

Figure 13. Brown hare (left) and rabbits (right).

For mountain hare sightings, people were also asked to report the individual's coat colour and whether there was snow cover or not. These data allow us to address the following questions:

<u>Changes in the distribution of species</u>

Firstly, the locations in the project area in which the target species have been recorded can be mapped.

- *Are the southern and lower altitudinal range boundaries of mountain hares and the upper altitudinal range boundary of brown hares changing over time?*
  The mountain hare is an upland species that favours cool and moist conditions. It reaches its southern range boundary in the project area and also favours higher altitudes. As climatic conditions warm, it is expected that the mountain hare's distribution will shift further north and further uphill to track cooler conditions (Anderson *et al.* 2009; Acevedo *et al.* 2012). We are, therefore, using data from the survey to examine whether the southern and lower altitudinal range boundaries of the mountain hare change over time. By contrast, brown hares are restricted to lower altitudes in the project area. However, as climatic conditions warm and mountain hare decline they may be able to survive further uphill (Yalden 1971) and so we can use data from the survey to examine if this is the case. Such changes are expected to be gradual and so data will need to be collected over a number of years before analyses can be undertaken and changes can be detected.

<u>Changes in the timing of events</u>

- *Is the degree of mismatch between mountain hare coat colour and snow cover changing over time?*
  Mountain hares change the colour of their coat from brown/grey in the summer to white in the winter so they are camouflaged against bare ground and vegetation in the summer and snow in the winter. However, if snow fall decreases in the future, mountain hares may become increasingly vulnerable to predation if they continue to change their coat colour to white but there is no snow. Research has been done in some closely related species to suggest that mismatch between coat colour and ground cover may increase with climate

change (e.g. snowshoe hares, Mills *et al*. 2013). With the data from this survey, we can look at the timings of coat colour change over time and whether the proportion of sightings where individuals are mismatched with their surroundings is increasing or decreasing over time. Again, data will need to be collected over a longer time period before this analysis can be carried out.

1.3.2 Results so far

Participation figures

Firstly, we can show the number of records of each species submitted as part of the Hare Survey each year and the total number of individuals of each species that were recorded as part of these records (Figure 14).

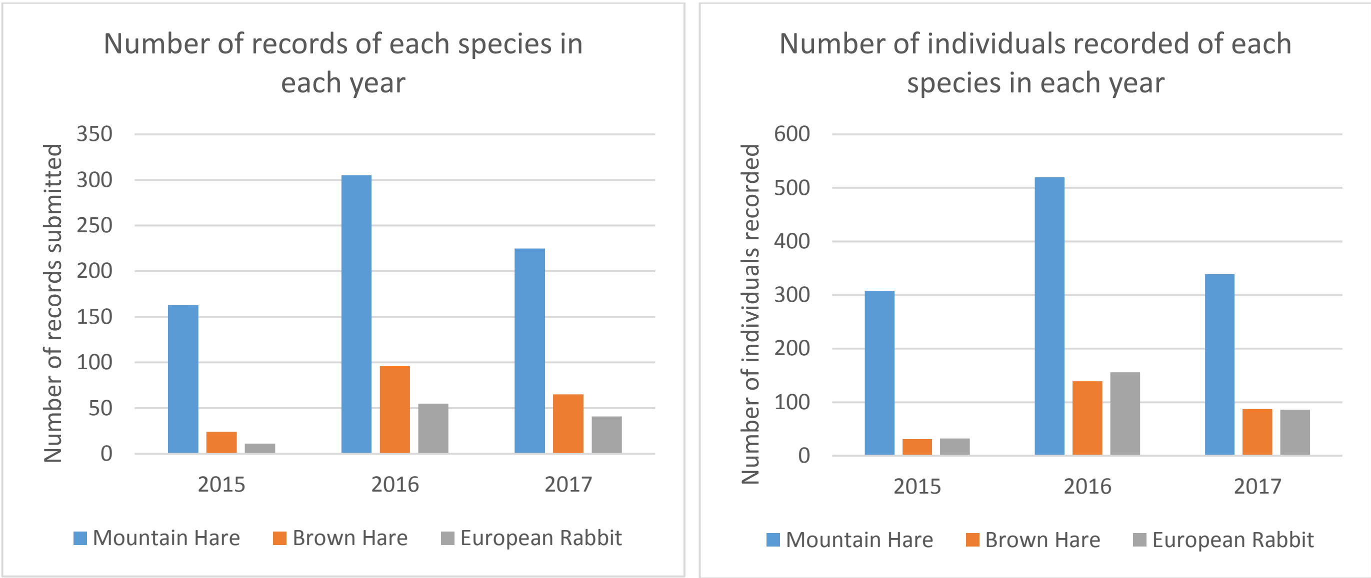


Figure 14. The number of records received from the project area of each species in each year (left) and the number of individuals of each species those records included (right).

Species' distributions

Figure 15 shows the locations in the project area in which the three target species were recorded from 2015 to 2017 (see Appendix C for distribution maps from individual years).

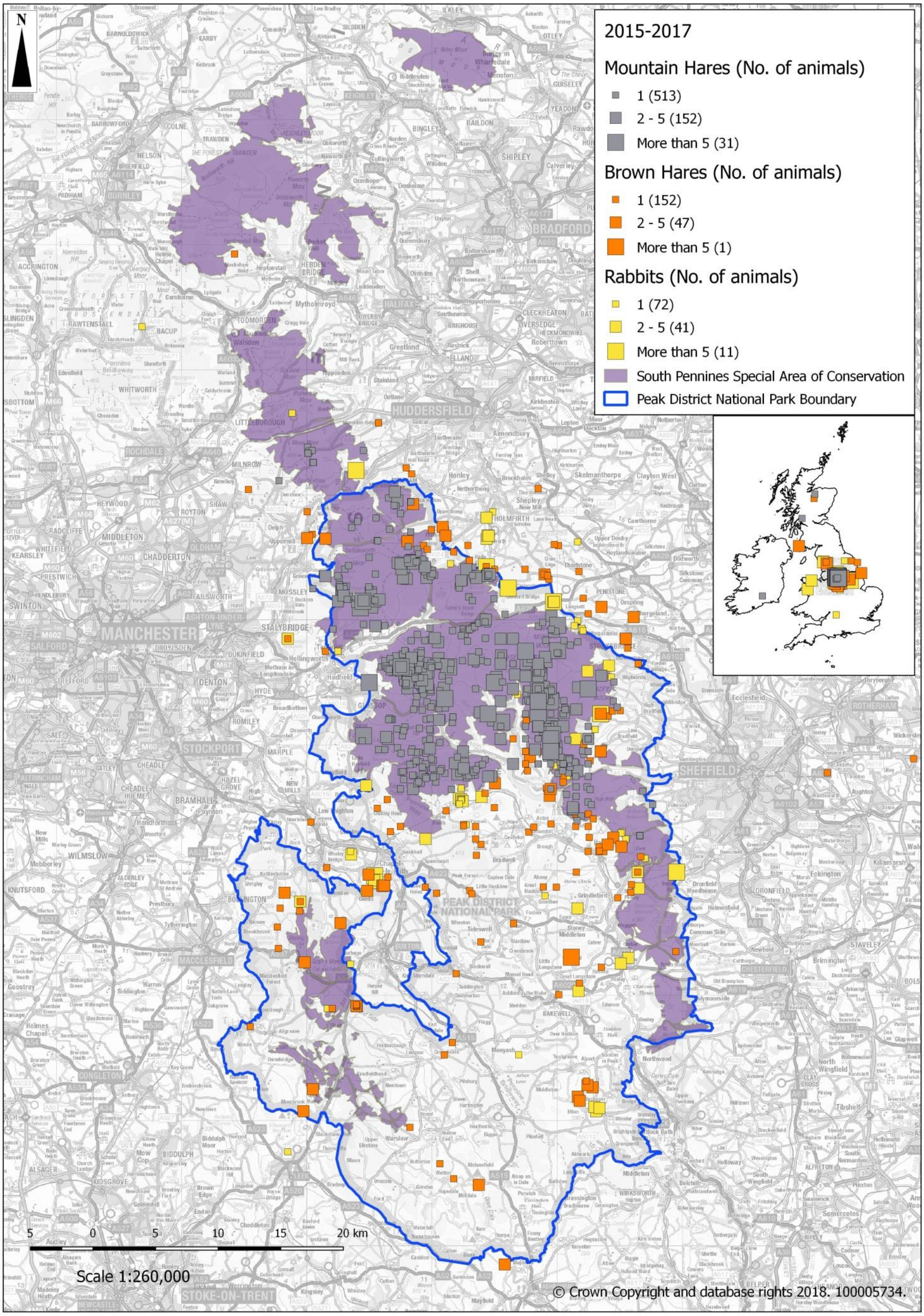


Figure 15. Location of mountain hare, brown hare and rabbit records submitted to the Hare Survey from 2015 to 2017.

The timing of events

Figure 16 shows how the proportion of mountain hares recorded with grey to grey & brown and white coats changes throughout the year. Change to white coats appears to commence in October or November and peak in January or February before a change back to grey to grey & brown by the summer months.

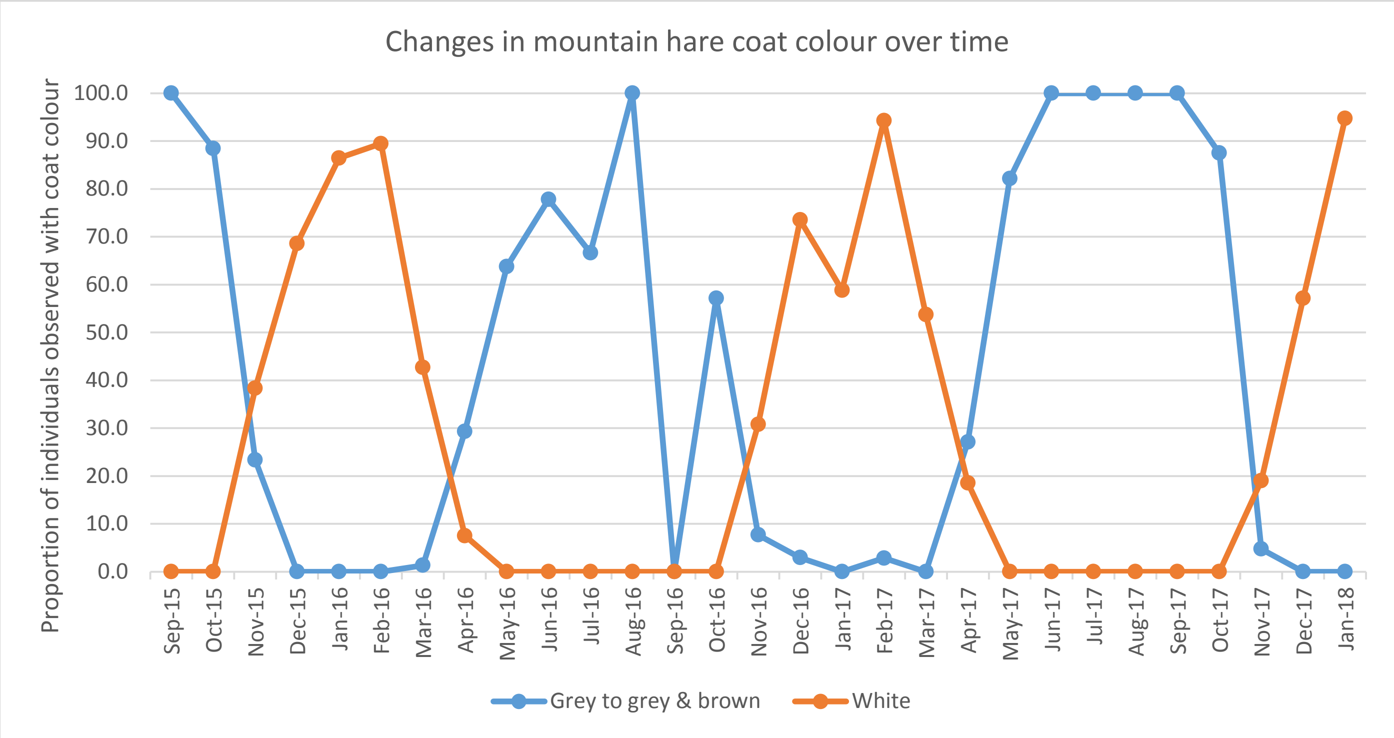


Figure 16. Changes in the proportion of individuals of mountain hare recorded with grey to grey/brown coloured coats (blue) and white coloured coats (orange) over time.

1.4 Ring Ouzel and Redwing Survey

1.4.1 Research questions

The Ring Ouzel (*Turdus torquatus*) and Redwing (*Turdus iliacus*) Survey was launched in 2016 and asked people to record the date, location and number of individuals seen of these species.

Figure 17. Ring ouzel (left) and redwing (right).

People were also asked to record the habitats individuals were seen in. These data allow us to address the following questions:

The distribution of species

The locations in the project area in which the target species have been recorded can be mapped.

- *Can the CSP ring ouzel sightings be used to assist with ring ouzel breeding surveys on the Eastern Peak District Moors?*
  The Eastern Moors Partnership (EMP) manages land on the Eastern Peak District Moors which is particularly valuable as ring ouzel nesting habitat. From the date ring ouzel first return in spring and for the duration of the breeding season, CSP records are shared with the EMP to assist the more comprehensive breeding surveys that they carry out. In 2016, data from the CSP survey was used to help identify a new breeding territory of ring ouzel on the Eastern Moors.

Changes in the timing of events

Firstly, arrival and departure dates can be calculated from the Ring Ouzel and Redwing Survey and compared with those calculated using data available from the Derbyshire Ornithological Society. This will enable us to assess the reliability of dates calculated from our data. As data are only available from two years so far this analysis has not yet been carried out.

- *Are the arrival and departure dates of ring ouzels and redwings in the project area changing over time?*
  Ring ouzels migrate to the UK from Africa in the spring and depart again at the end of the summer, the timing of which might be affected by climate change. Redwings migrate to the UK from Scandinavia in the autumn and depart again in the spring and climate change is expected to lead to later arrival dates and earlier departure dates. The data collected from this survey will allow us to track whether arrival and departure dates in the project area are changing over time. Data are only available from two years so far and so this analysis has not yet been carried out.

- *Are year-to-year fluctuations in ring ouzel and redwing arrival and departure dates related to climatic conditions?*
  We can also use data from the Ring Ouzel and Redwing Survey to examine whether year-to-year fluctuations in ring ouzel and redwing arrival and departure dates are driven by the climatic conditions in that year. The timing of ring ouzel egg laying, for example, has previously been linked to weather conditions, particularly spring rainfall (Beale *et al*. 2006). Again, as data are only available from two years, these analyses have not yet been carried out.

- *How do ring ouzels and redwings alter the habitats they use throughout the year?*
  Ring ouzels move from heather/grassland/grazed pasture in the summer during the breeding period to areas with fruiting trees and bushes in the autumn as they prepare for migration. The time at which this switch occurs might change over time. Redwings may also utilise different habitats throughout the months they are in the UK. Data from the survey can be used to show how this habitat use changes throughout the year and whether this is changing over time. Again, as data are only available from two years, these analyses have not yet been carried out.

1.4.2 Results so far

Participation figures

Figure 18 shows the number of records of each species submitted as part of the Ring Ouzel and Redwing Survey each year and the total number of individuals of each species that were recorded as part of these records.

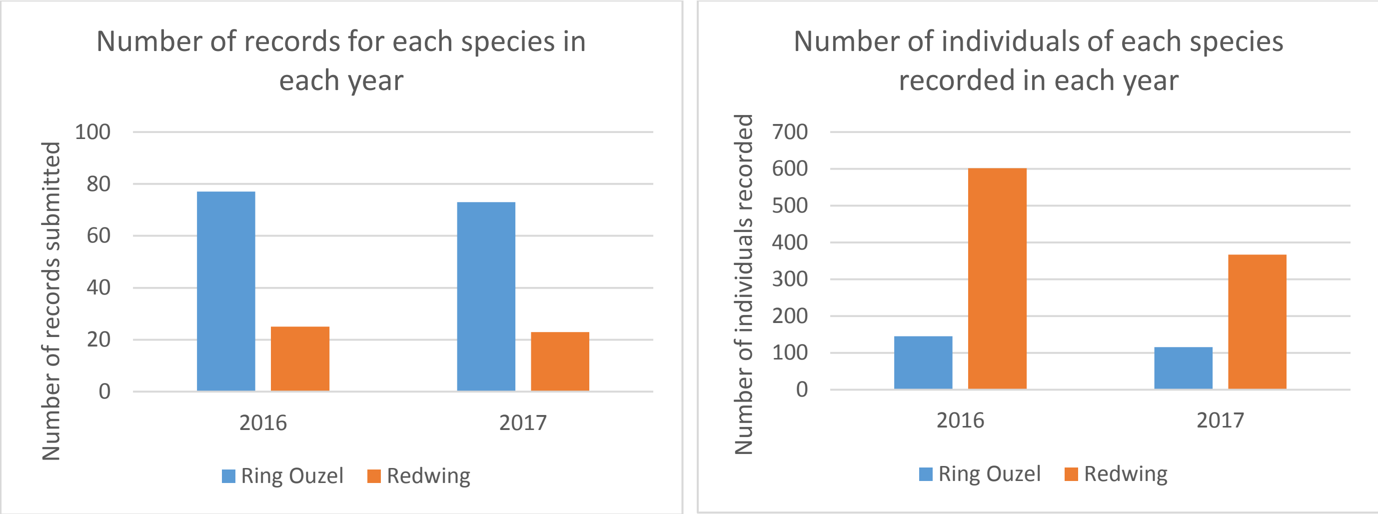


Figure 18. The number of records received from the project area of each species in each year (left) and the number of individuals of each species those records included (right).

Notice that the number of individual redwings recorded is very high in comparison to the number of records submitted. This is because redwings tend to gather in large flocks while overwintering in Britain.

Species' distributions

Figure 19 shows the locations in the project area in which the two target species were recorded from 2016 to 2017 (see Appendix D for distribution maps from individual years).

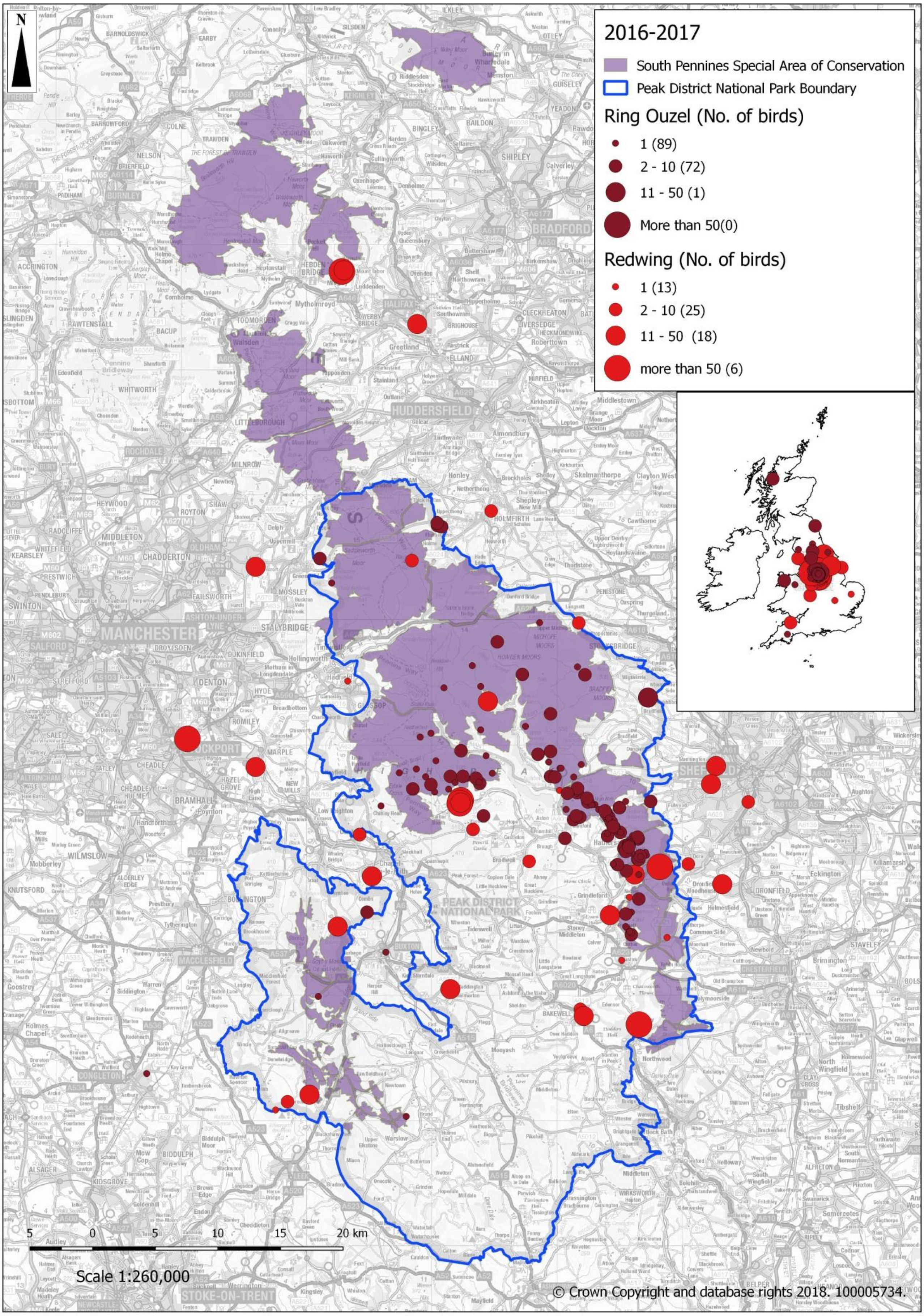
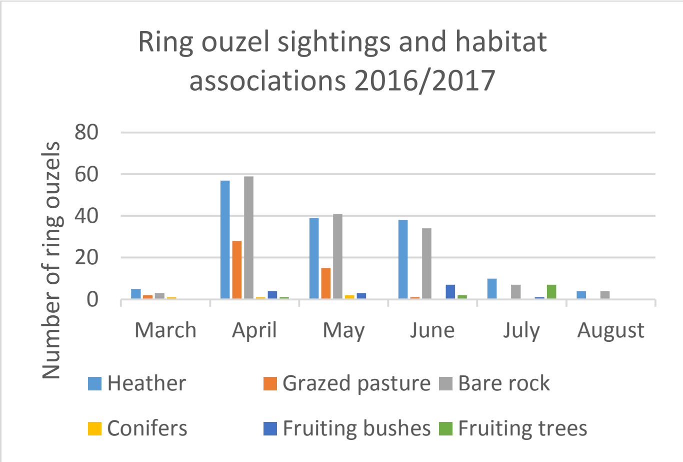


Figure 19. Location of ring ouzel and redwing records submitted to the Ring Ouzel and Redwing Survey from 2016 to 2017.

The timing of events

Although detailed analysis has not yet been carried out on habitat associations due to only two years of data being available, Figure 20 shows when ring ouzels and redwings have been recorded in the project area and in which habitats they have been spotted.



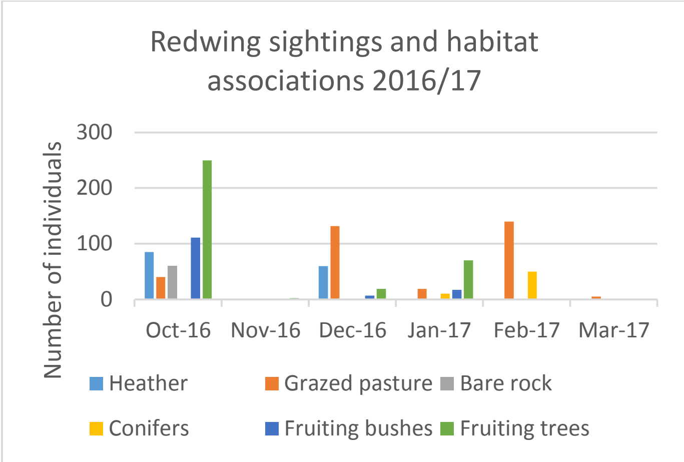


Figure 20. The number of ring ouzels seen in different habitat types and in which months in 2016 and 2017 (both years merged) (left) and the number of redwings seen in different habitat types and in which months at the end of 2016 and beginning of 2017.

1.5 Scales and Warts Survey

1.5.1 Research questions

The Scales and Warts Survey was launched in 2017 and asks people to record the date, location and number of individuals seen of three species: adders (*Vipera berus*), common lizards (*Zootoca vivipara*) and common toads (*Bufo bufo*). People are also asked to record the life stage of the individuals they have seen (juvenile/spawn or adult) and for toads whether they were in water or not.

Figure 21. Adder (left), adult common lizard (centre), juvenile common lizard (right) – note the darker colouration of the juvenile.

Figure 22. Common toad (left), and common toad spawn (right).

These data allow us to address the following questions:

Changes in the distribution of species

Firstly, the locations in the project area in which the target species have been recorded can be mapped.

- *Is the common toad's upper altitudinal range boundary changing over time?*
  Common toads favour warmer conditions and so are restricted to lower altitudes in the project area. As climatic conditions warm, it is projected that the common toad's distribution will shift further uphill (Dunford & Berry 2012). We are, therefore, using data from the survey to examine whether the upper altitudinal range boundary of the common toad changes over time. Such changes are expected to be gradual and so data will need to be collected over a number of years before analyses can be undertaken and changes can be detected.

- *Are adders being seen beyond their known, localised geographical range?*
  There is a well-established but localised population of adders within the project area, on the Eastern Peak District Moors. Anecdotal evidence suggests that there may have been sightings in recent years beyond the confines of the known range. Data from this survey can be used to evidence expansions in the known adder population or identify other potential populations of adders within the project area. Sightings from beyond the known range will be followed up by Derbyshire Amphibian and Reptile Group.

Changes in the timing of events

- *Is the timing of events of the target species in the project area changing over time?*
  The timings of interest in the Scales and Warts Survey are adult adder, common lizard and common toad first sightings; juvenile adder and common lizard first sightings; and toad spawn first sightings, all of which are expected to become earlier in the year as the climate warms. The data collected from this survey will allow us to track changes in these first sightings in the project area over time. Data are so far only available from one year so these analyses have not yet been carried out.

- *Are year-to-year fluctuations in the timings of events of the target species related to climatic conditions?*
  We can also use data from the Scales and Warts Survey to examine whether year-to-year fluctuations in emergence dates are driven by the climatic conditions in that year. We might expect that these events are earlier in years with warmer winters, springs and summers. Previous research has shown, for example, that in years with warmer summer temperatures, the common lizard tends to give birth to young earlier in the year (Le Galliard *et al*. 2010); and in a study of 25 sites in Derbyshire over 12 years, spring migration began earlier in years where the period preceding onset of migration was warmer (Arnfield *et al*. 2012). Data are so far only available from one year so these analyses have not yet been carried out.

1.5.2 Results so far

Participation figures

Figure 23 shows the number of records of each species submitted as part of the Scales and Warts Survey each year and the total number of individuals of each species that were recorded as part of these records.

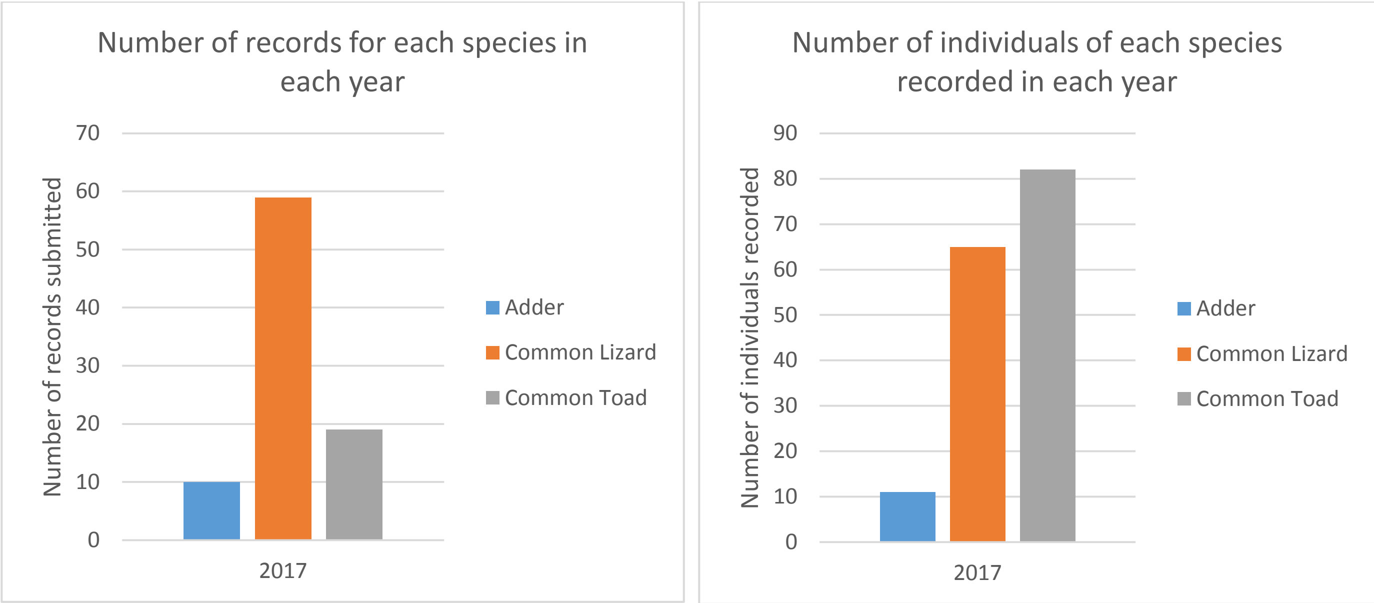


Figure 23. The number of records received from the project area of each species in each year (left) and the number of individuals of each species those records included (right).

Notice that the number of individual toads recorded is quite high in comparison to the number of records submitted. This is likely to be an indication that many of the toad sightings submitted were of animals in breeding ponds in spring, something that analysis in future years will pick up on.

Species' distributions

Figure 24 shows the locations in the project area in which the three target species were recorded in 2017.

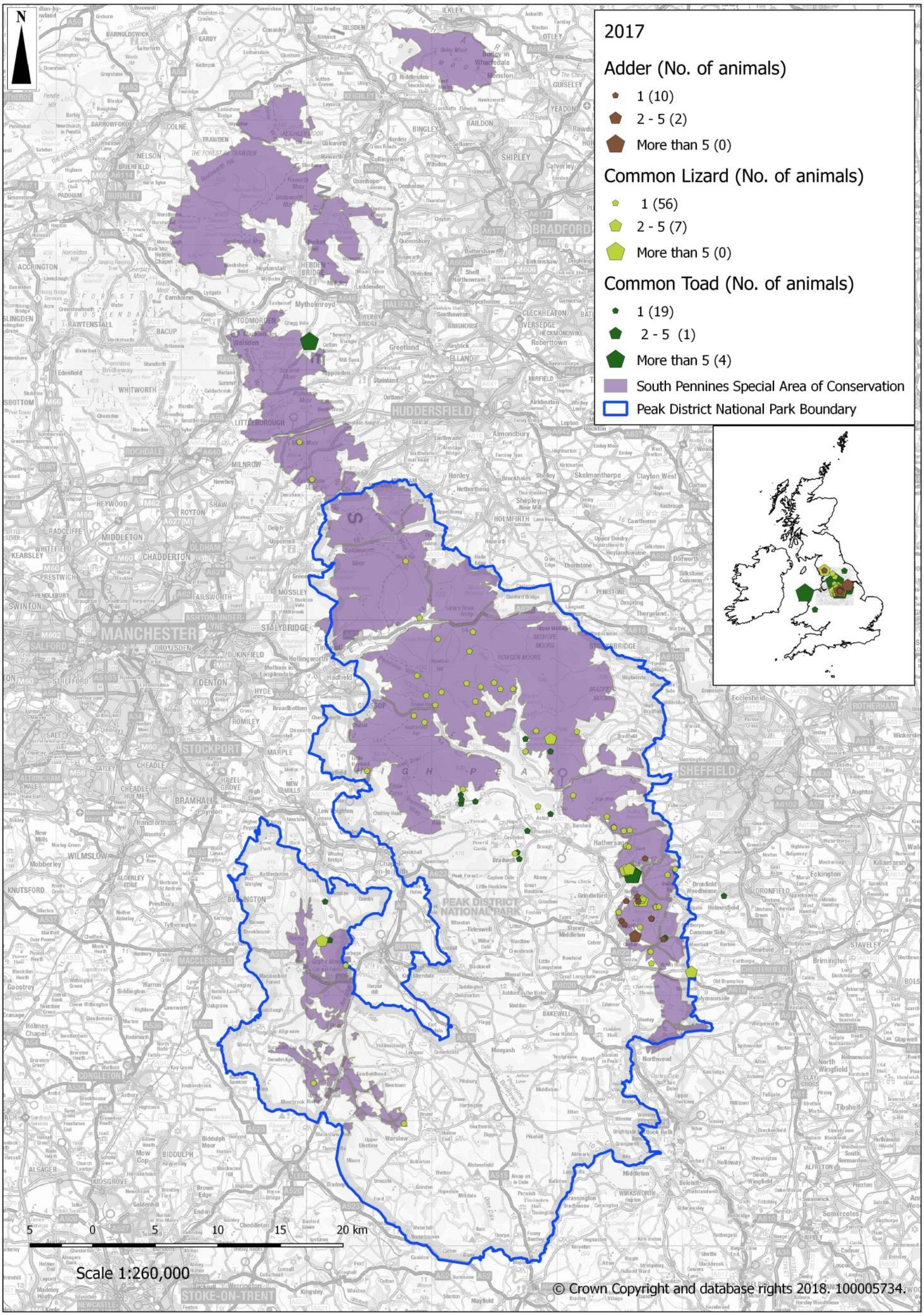


Figure 24. Location of adder, common lizard and common toad records submitted to the Scales and Warts Survey in 2017 (as data collection has only been active for one year).

2. Targeted Monitoring

The Targeted Monitoring (TM) surveys were designed to be more in depth than the OM surveys, requiring training of volunteers in survey techniques and repeated visits to the same sites, using standardised methods to monitor populations of the target species. Many of the surveys are based on a transect methodology in which the same routes are walked repeatedly in order to track populations in the same areas. This allows us to use these data to address the following types of question:

- Changes in population size over time. Repeated visits to the same sites over time allows for an assessment of whether populations in these locations are increasing or decreasing in size over time. It also allows for an assessment of whether year-to-year fluctuations in population sizes are related to climatic conditions in that year. This can give an indication as to how populations will respond to future climatic changes. We can also look at whether there is variation in the project area in these trends over time; for example, are populations at high altitudes increasing in size while populations at low altitudes are decreasing?
- Changes in the timing of events. Data from the TM surveys can also be used to look at whether the timing of events is changing over time.

2.1 Bumblebee Survey

2.1.1 Research questions

For the Bumblebee Survey, launched in 2013 (although here we only consider data from 2015 onwards due to changes in the way recording took place), a number of transect routes have been established (there are currently 40) which people are asked to walk at least once a month every year to record the abundance of three target species: bilberry bumblebee (*Bombus monticola*), red-tailed bumblebee (*Bombus lapidarius*) and tree bumblebee (*Bombus hypnorum*), and the total abundance of any other species they see.

Figure 25. Bilberry bumblebee (left), red-tailed bumblebee (centre) and tree bumblebee (right).

The data collected as part of this survey allows us to ask the following questions:

<u>Changes in the abundance of species</u>

- *Are the population sizes of our three target bumblebee species changing over time?*
  Bumblebees are sensitive to climatic conditions and so changes in climate over time might be expected to have an effect on population sizes. The bilberry bumblebee is an upland species that prefers cool and moist conditions. It might, therefore, be expected to experience population declines in the project area as the climate warms, as has been observed in other parts of its European distribution (Manino *et al.* 2007).
  By contrast, the tree bumblebee is a newcomer to the UK and its spread northwards seems to have been helped by warming climatic conditions. We might expect, therefore, that populations of the tree bumblebee increase in size over time. The red-tailed bumblebee is fairly widespread in the UK but appears to favour warmer lowland areas (NHM, undated) and so, again, we may expect to see an increase in this species in the project area. This analysis has not yet been carried out because data are only available from three years.

- *Are year-to-year fluctuations in the abundance of the target species related to climatic conditions?*
  We can use data from the survey on the annual abundance of the target species to look at whether year-to-year fluctuations in population size are related in climatic conditions in that particular year. If there is a relationship, this may give an indication as to what might happen to these species as the climate changes. For example, if the abundance of a particular species is lower in warmer years we might expect to see a long term decline in this species. This analysis has not yet been carried out because data are only available from three years.

<u>Changes in the timing of events</u>

- *How does the timing of events in the current year compare with previous years?*
  Data from the survey can be used to plot the abundance of each target species throughout the year. This will give an idea of the first and peak emergence time of each species. Data from the current year can be plotted against data from previous years combined to see how they compare.

<u>Changes in habitat associations</u>

- *Is there spatial variation in the types of habitats the target species use?*
  Different habitats provide different microclimates e.g. wetter areas and areas with taller vegetation or a canopy cover tend to be cooler in the summer than dry areas with short vegetation. Some species are able to exploit this microclimatic variation and alter the habitats they use to find their optimal climatic conditions, as has been seen in butterflies (Pateman *et al*. 2012; Pateman *et al*. 2016). Habitat use can, therefore, vary spatially. For example, sites at higher elevations tend to be cooler so species may favour warmer habitats. We can use the data collected from this survey to test whether species vary the types of habitat they are using throughout the project area with latitude, longitude and elevation. Some initial analysis has been done with existing data.

- *Are the target species changing the types of habitat they use over time?*
  As climatic conditions warm, species may also increasingly favour cooler habitats and if conditions become drier they may start to favour wetter habitats than they had previously been using. We can use the data collected from the survey to look at whether we are seeing any trends in changes in habitat associations of the target species over time. Data needs to be collected from more years before this analysis can be done.

2.1.2 Results so far

Participation figures

Firstly, we can show the number and total length of bumblebee transect walks completed each year (Figure 26).

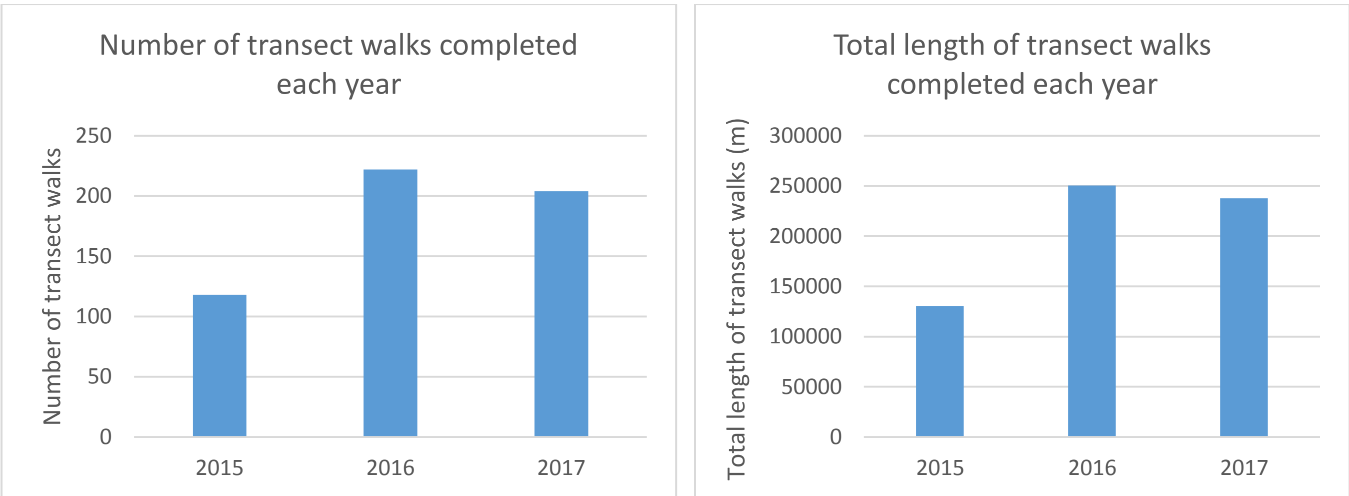


Figure 26. The total number of transect walks completed each year (left) and the total length of these transect walks combined (right).

The timing of events

Figure 27 shows how the abundance of each target species throughout 2017 compares with the mean of previous years. For the bilberry bumblebee, the emergence pattern in 2017 looks fairly consistent with previous years. For the red-tailed bumblebee, it looks as though the peak emergence was earlier in 2017 than in previous years. For the tree bumblebee, the timing of emergence looks similar to previous years but it appears that the overall peak emergence was lower in 2017 than in previous years.

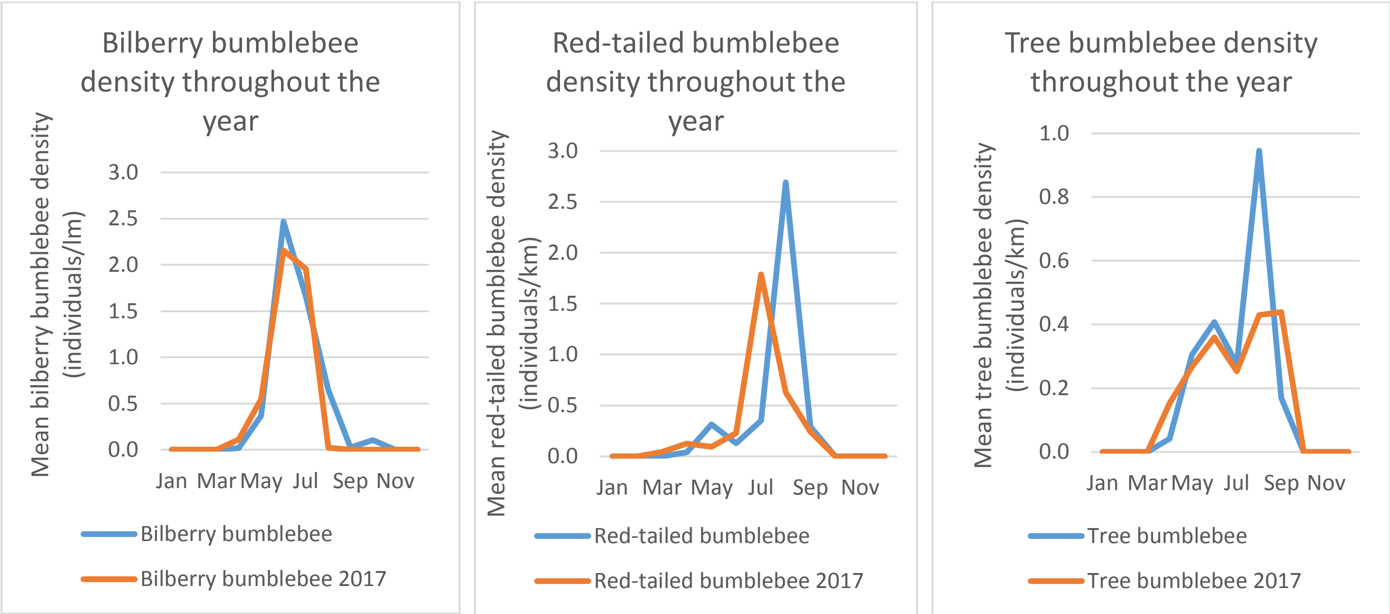
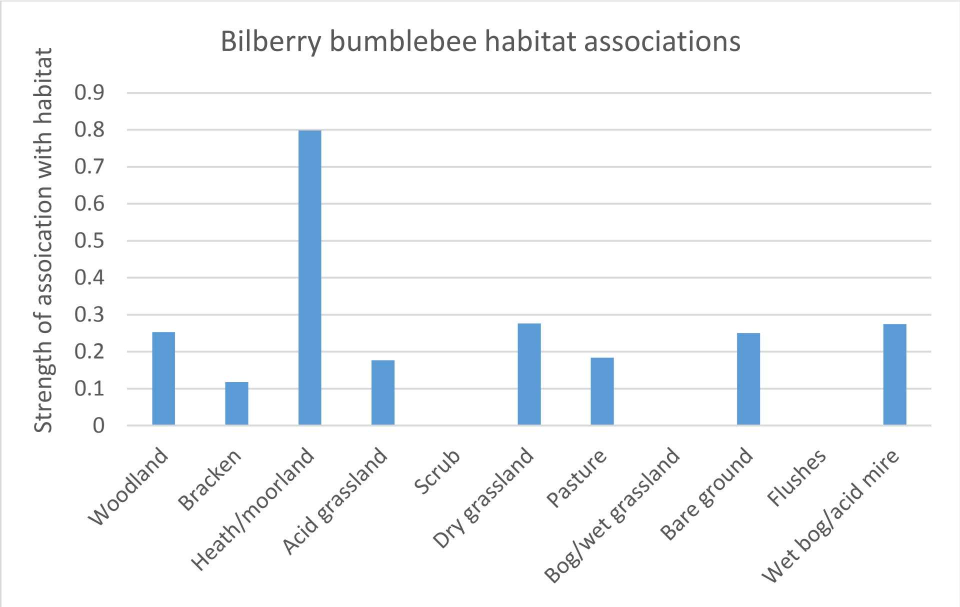
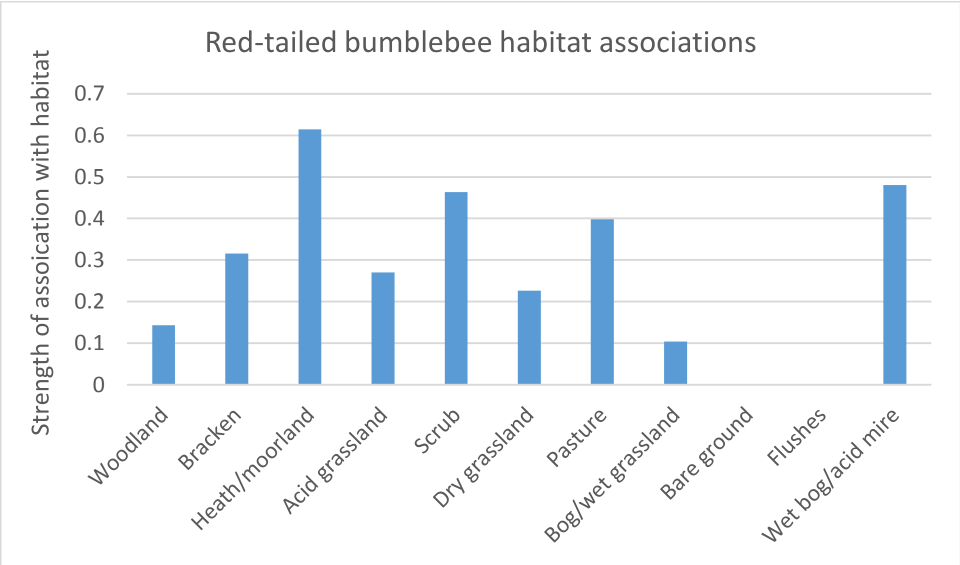


Figure 27. Mean monthly density of bilberry (left), red-tailed (centre) and tree (right) bumblebees recorded across all transects using data just from 2017 (orange) and data from all previous years combined (blue).

Habitat associations

Figure 28 shows the habitat associations of the different target bumblebee species. This measure of habitat association takes into account the relative availability of different habitat types. The higher the number, the greater the strength of the association with the habitat (a measure of 1 would mean the species was only found in that habitat and a measure of 0 would mean that it is not found in that habitat at all). Unsurprisingly, the bilberry bumblebee shows a strong association with heath and moorland whereas the red-tailed bumblebee is more of a generalist and occurs in many different types of habitat fairly evenly, as does the tree bumblebee.





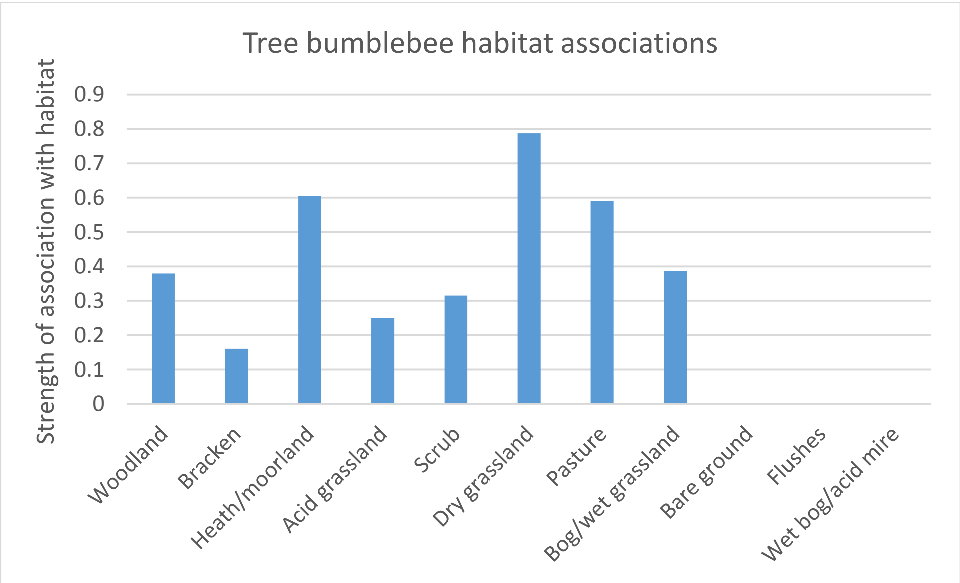


Figure 28. Habitat associations of the bilberry (top), red-tailed (centre) and tree (bottom) bumblebees.

2.2 *Sphagnum* Survey

2.2.1 Research questions

The *Sphagnum* Survey was launched in 2015 and asks people to select a public right of way in the project area to walk and record the location and size of *Sphagnum* patches they see either side of the path. They are also asked to record the type of habitat the patch is in and, if possible, the *Sphagnum* species in the patch.

Figure 29. Sphagnum patches –a dense hummock of mixed species (left), single species patch within a 'lawn' (right).

The data collected from this survey allows us to ask the following questions:

- *How does* Sphagnum *density vary throughout the project area?*
  Sphagnum species require cool and wet conditions in order to grow. We would expect, therefore, for the abundance of *Sphagnum* to vary throughout the project area due to local differences in habitat, soil moisture and other environmental factors. The information on *Sphagnum* patch sizes along transects can be used to calculate and map the average density of *Sphagnum* in 10km grid squares across the project area. This can then be used to look at whether average *Sphagnum* density varies with latitude, longitude and elevation. Data collected from the survey can also be used to look at how *Sphagnum* patch size varies between habitat types. While these analyses have been carried out to present some preliminary results, it is likely that data will need to be collected over a number of years in order to detect any significant patterns.

- *Is* Sphagnum *density changing over time?*
  As *Sphagnum* species require cool and wet conditions to grow, it might be expected that density declines in the project area over time as climatic conditions are projected to warm and become drier. We can calculate the average density of *Sphagnum* in each 10km square across two time periods (e.g. 2015-2024 and 2025-2034) and then test whether there has been an overall increase or decrease in density from the earlier to the later time period. We can also use this information to look at whether there is variation throughout the project area in trends over time. For example, density at the southern edge of the project area might be expected to decline more than those at the northern edge. These analyses have not yet been undertaken as data have only been collected from three years.

2.2.2 Results so far

Participation figures

Firstly, we can show the number and total length of *Sphagnum* transect walks completed each year as well as the total number of *Sphagnum* patches recorded (Figure 30).

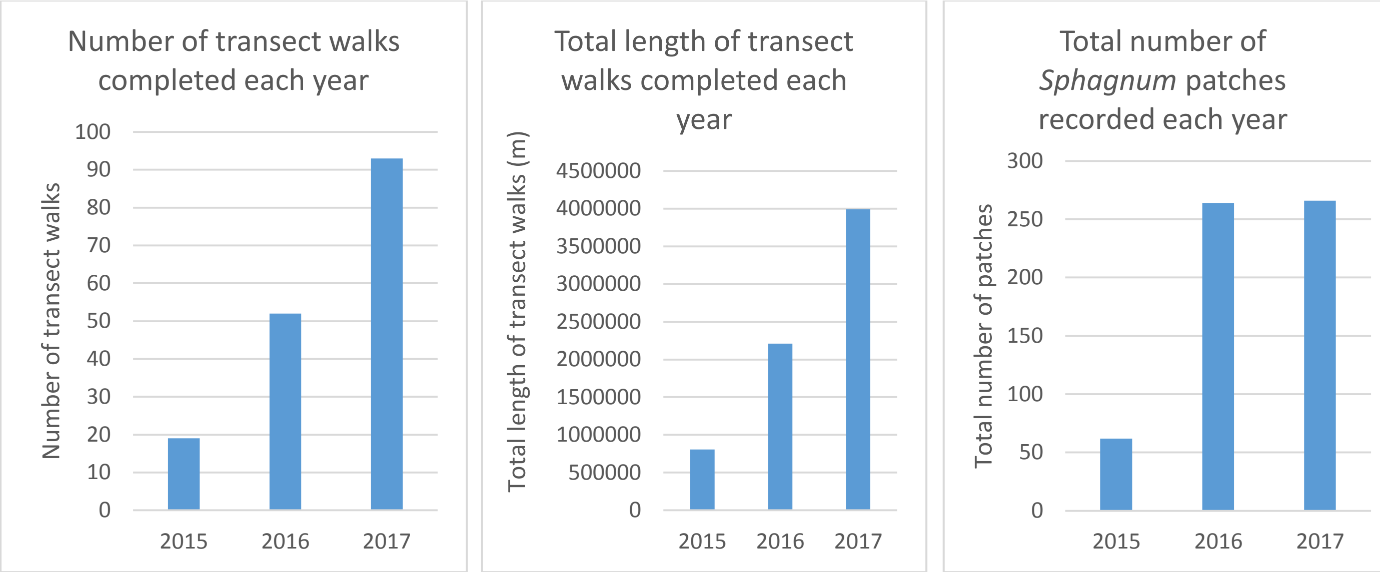


Figure 30. The total number of transect walks completed each year (left), the total length of these transect walks combined (centre) and the total number of *Sphagnum* patches recorded (right).

Sphagnum distribution

The *Sphagnum* data has been represented visually in map form (Figure 31). This map shows where routes have been walked within the project area alongside where *Sphagnum* patches have been recorded.

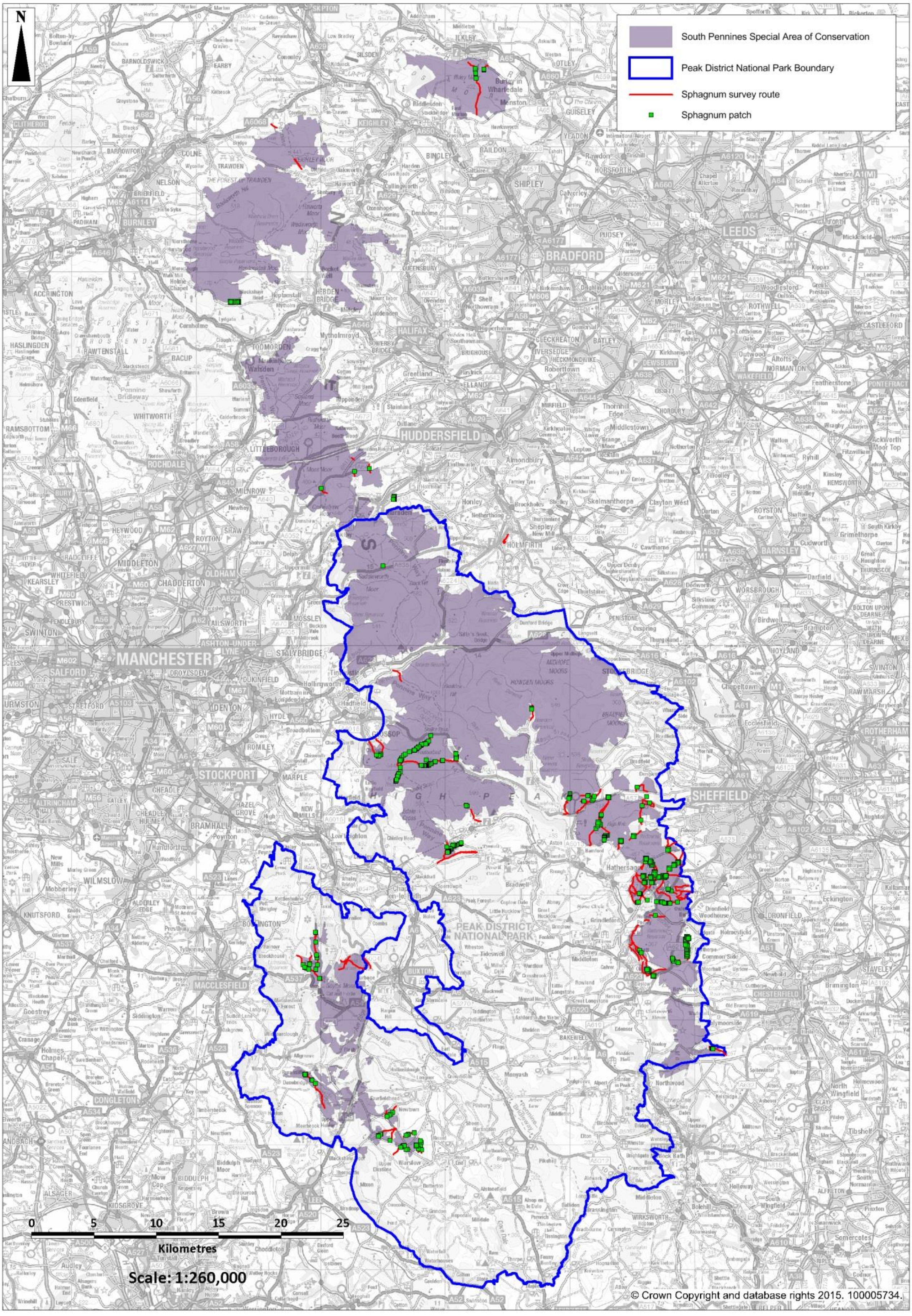


Figure 31. Location of *Sphagnum* survey routes walked and *Sphagnum* patches recorded within the project area from 2015 to 2017.

Sphagnum density

No significant relationship between *Sphagnum* density and latitude, longitude or elevation was found but data have only been collected over three years so far.

Figure 32 shows how *Sphagnum* patch size varies between habitats. Surprisingly, so far the highest mean patch size is in woodland habitats. However, we are still in early days of data collection and so we might expect this pattern to change as more data are collected.

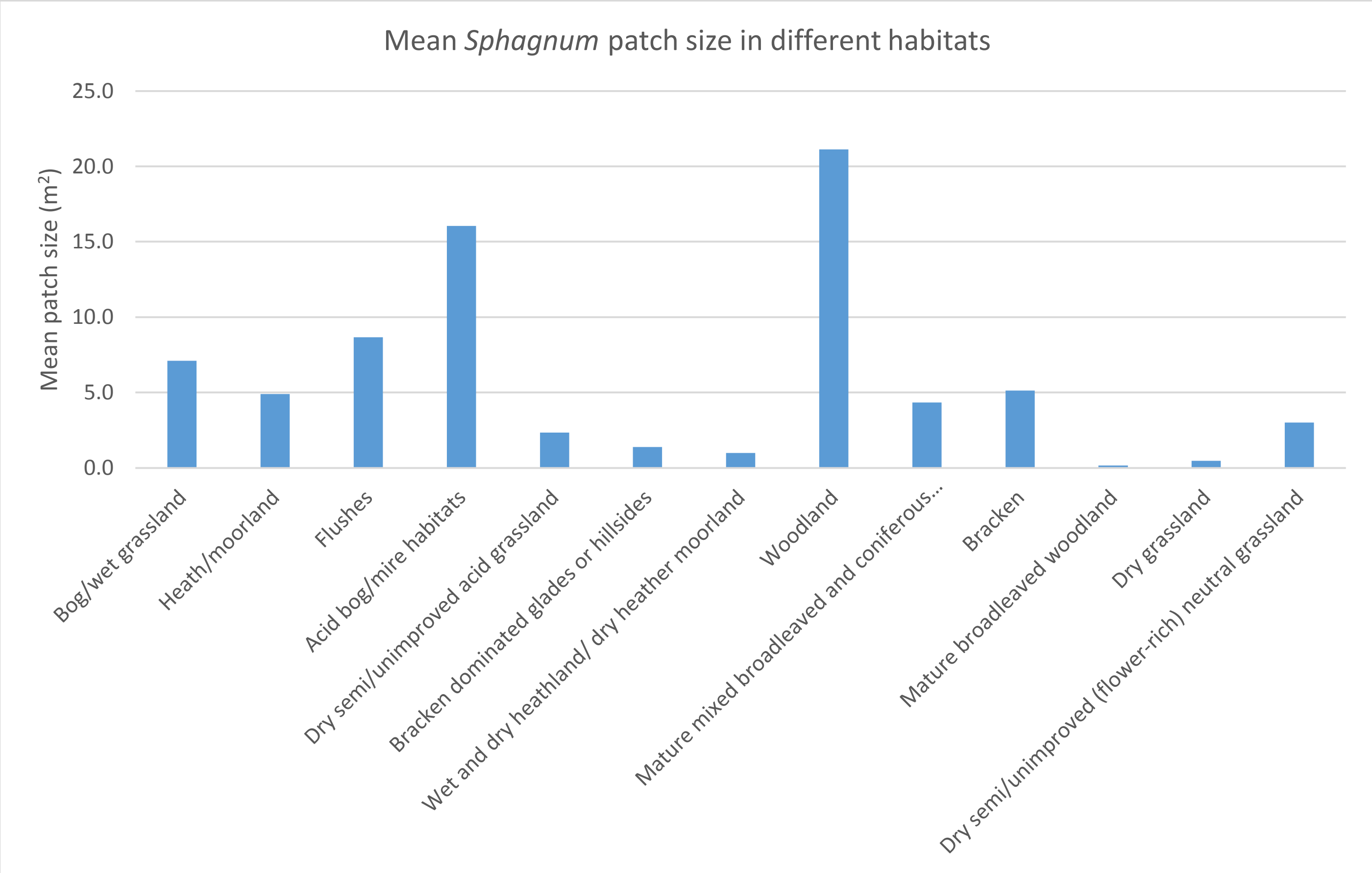


Figure 32. Mean size of *Sphagnum* patches recorded in different habitat types.

2.3 Buds, Berries and Leaves Survey

2.3.1 Research questions

The Buds, Berries and Leaves Survey was launched in 2016 and asks people to walk one of a number of fixed transect routes at least once a month every year and record signs of phenological events (e.g. coming into leaf, coming into flower, fruiting, leaf fall) of four target plant species: heather (*Calluna vulgaris*), bilberry (*Vaccinium myrtillus*), crowberry (*Empetrum nigrum*) and rowan (*Sorbus aucuparia*).

Figure 33. Heather (top left), bilberry (top right), crowberry (bottom left) and rowan (bottom right).

The data collected from this survey will allow us to answer the following questions:

- *How does the timing of events in the current year compare with previous years?*
  Data from the survey can be used to plot the advance of different phenological events for each target species across the year. This will give an idea of, for example, flowering and fruiting times. Data from the current year can be plotted against data from previous years combined to see how they compare.

- *Is the timing of events changing over time?*
  Data can be collated across different time periods to determine whether there is a change in the timing of phenological events over time. Analysis of Nature's Calendar data has revealed that rowan, for example, showed an advance in its leafing time between 2003 and 2014, an observation mirrored in studies in other parts of Europe (Chmielewski & Rotzer 2001). We are interested to see if the same changes are happening at a more local level within the uplands of the South Pennines. The timing of these events is affected by a number of different climatic factors such as temperature and rainfall at different times of year and amount of snow cover in the winter. Responses are, therefore, difficult to predict and may vary between species. These analyses have not yet been undertaken as data have only been collected from two years.

2.3.2 Results so far

Participation figures

Firstly, we can show the number and total length of transect walks completed each year as well as the total number of phenological observations made (Figure 34).

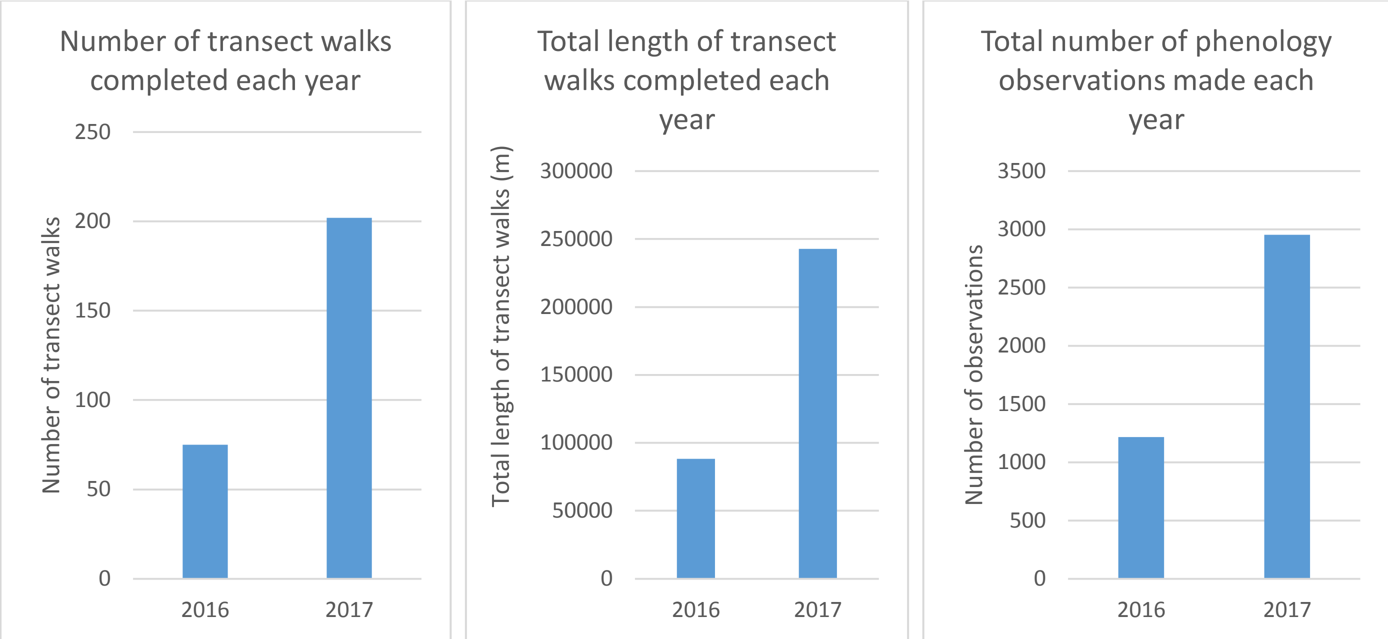


Figure 34. The total number of transect walks completed each year (left), the total length of these transect walks combined (centre) and the total number of phenological observations made (right).

The timing of events

Figure 35 shows an example of a comparison between the timing of events in the current year (2017) compared with previous years. In this case it is the timing of heather flowering and because data have only been collected from 2016 and 2017 the previous years' data is in fact just data from 2016. The figure shows that there is an onset of flowering in July and that flowering begins to stop in September and is finished by December. The timings appear fairly consistent between the two years.

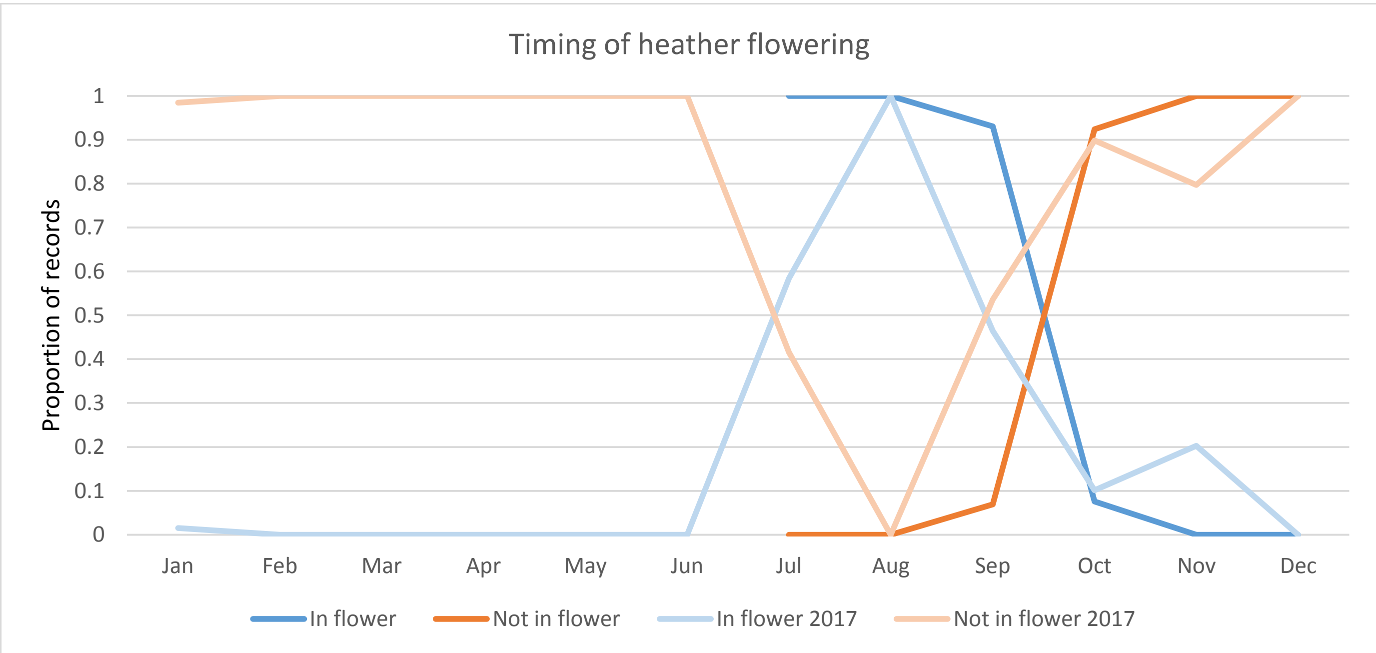


Figure 35. The proportion of heather records in flower (blue) and not in flower (orange) each month in 2017 (pale colours) and across the mean of previous years (darker colours).

2.4 Tails of the Uplands Survey

2.4.1 Research questions

The Tails of the Uplands Survey was launched in 2017 and asks people to visit points along water courses in the project area and report evidence of three species: otter (*Lutra lutra*), American mink (*Neovison vison*) and water vole (*Arvicola amphibius*).

Figure 36. Otter (left), American mink (centre) and water vole (right).

Figure 37. Examples of the signs volunteers look for of the three target species: otter spraint (left), mink footprints (centre) and water vole droppings (right).

The data collected from this survey allows us to answer the following questions:

- *Where are the target species distributed in the project area?*
  The spot surveys allow us to map the distribution of the target species throughout the project area, something that at the moment is poorly understood. The water vole is Britain's fastest declining mammal but the uplands are considered to be a stronghold for them. However, strong empirical evidence to support this is currently lacking. After serious declines in the past, otters are recolonising many water courses across Britain but positive records are still uncommon within the project area. This survey will allow us to pick up early signs of any recolonization within the Peak District and South Pennines. It is also important to track invasive species such as the American mink which could have severe negative impacts on native water voles.

- *Are the species increasing or decreasing in their occurrence in the project area over time?*
  Because we also have records of where evidence of the species was not found, we can calculate the proportion of surveys that found positive evidence of each target species in each year and then use this information to test whether this proportion is increasing or decreasing over time. Because data have only been collected from one year this analysis has not yet been conducted.

- *What are the drivers of variation in occurrence throughout the project area?*
  We can also look at whether there is spatial variation in this change in occurrence – are particular species increasing or decreasing more at certain latitudes, longitudes or elevations, for example? Because data have only been collected from one year this analysis has not yet been conducted.

2.4.2 Results so far

Participation figures

Firstly, we can show the number of positive sightings of evidence of the three species in the first year of the survey, 2017 (Figure 38). Note that some of these records have not yet been fully verified but are possible records that will be investigated further.

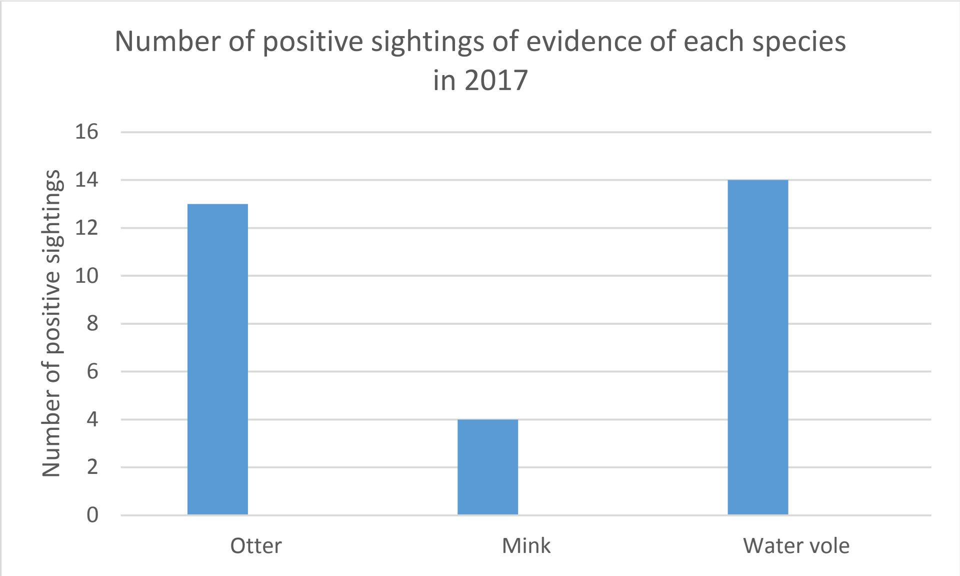


Figure 38. Number of surveys that resulted in positive sightings of evidence of each of the three target species in 2017 (as data collection has only been active for one year).

Target species distribution

The locations where sightings of evidence were recorded have been mapped (Figure 39). This map shows where potential evidence of the presence of the three target species was recorded in 2017, along with sites that were monitored in 2017 but that did not produce any evidence of the species' presence.

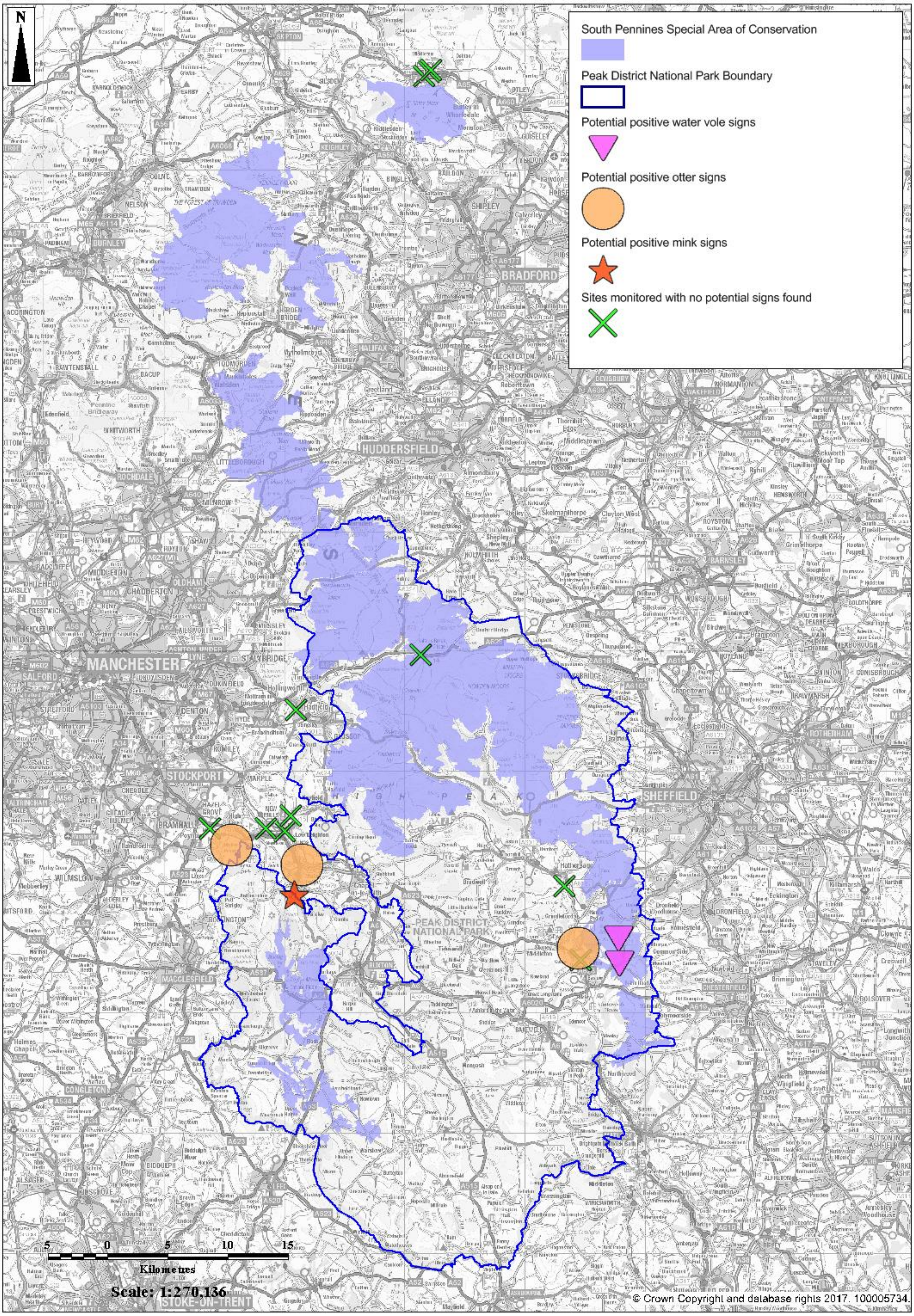


Figure 39. Location of potential positive signs of otter, water vole and mink within the project area in 2017 alongside location of sites monitored with no positive signs recorded.

3. Environmental Monitoring

Eight Environmental Monitoring (EM) sites have been established during the course of the CSP and each site has been setup in the same manner and with the same equipment. This consistent approach allows us to compare environmental conditions across a landscape scale. The first two sites, Edale and Holme, were established in 2014, Marsden and Burbage were added in 2015, the Roaches in 2016, Chatsworth and Holcombe Moor in 2017 and the final site at Crompton Moor in 2018. (Crompton Moor will actually host two sites close together as one of the two has been inoculated with *Sphagnum* moss plugs. The other will act as an untreated control while also feeding into the Community Science climate change study). Table 1 below gives an overview of the sites and the map (Figure 40) shows their geographic locations.

Table 1. Overview of CSP EM sites.

Site name	Set-up date	Elevation (m)	Aspect
Edale	February 2014	603	Gentle south facing slope
Holme	May 2014	540	Gentle west facing slope
Marsden	September 2015	431	Plateau
Burbage	September 2015	420	Plateau
Roaches	September 2016	437	Plateau
Chatsworth	July 2017	334	Plateau
Holcombe Moor	November 2017	400	Plateau
Crompton Moor	March 2018	352	West facing slope

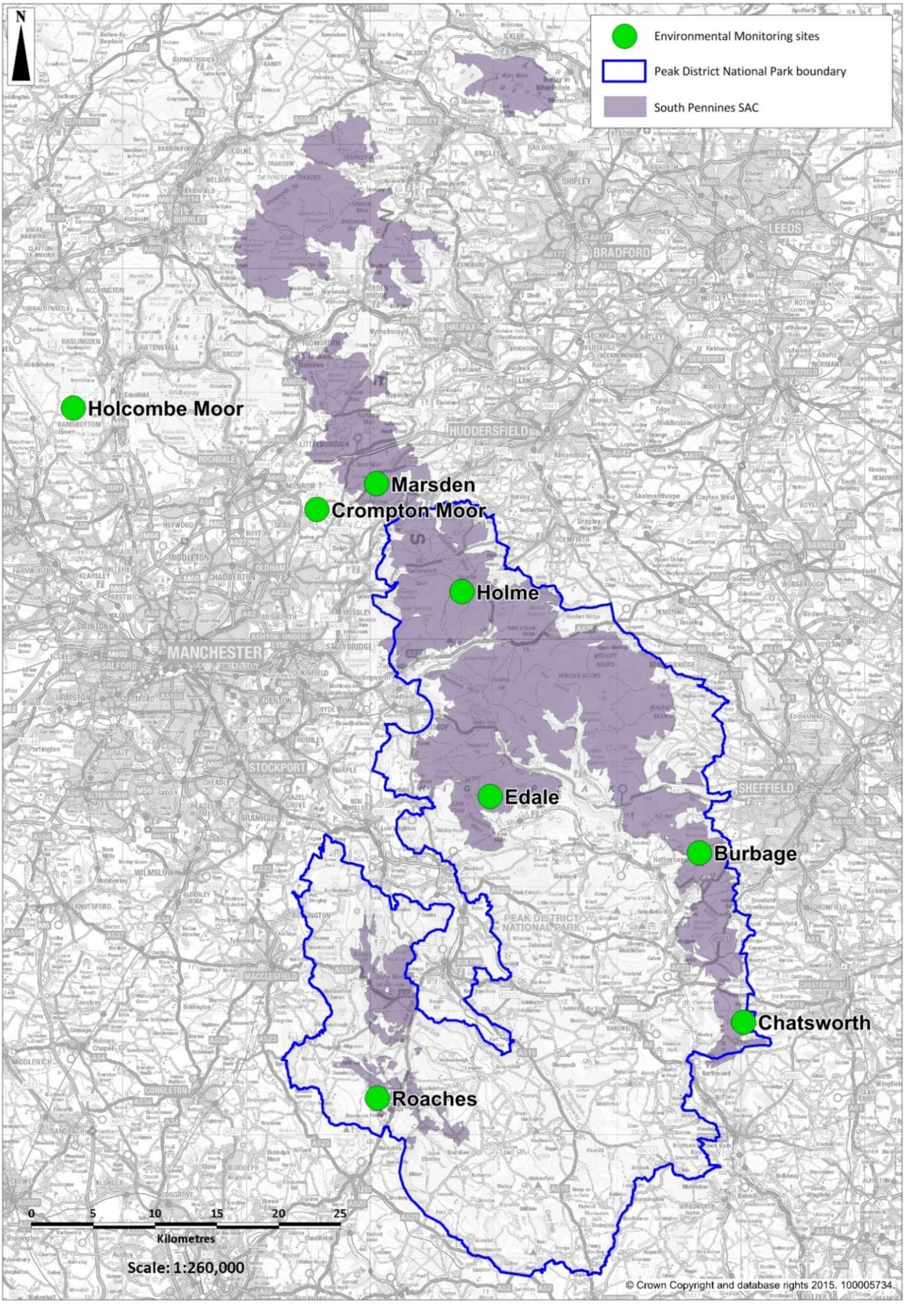


Figure 40. Locations of the Environmental Monitoring sites within the project area.

A number of variables are monitored across 30 quadrats on each site to track the environment and the vegetation of the sites. These variables are:

- Air temperature
- Soil surface temperature
- Rainfall
- Humidity
- Water table depth
- Vegetation composition
- Peat loss/accumulation

The data collected allows us to address the following topics:

- Spatial variation between sites. Data are used to assess how these environmental variables vary between sites and whether there are relationships between these variables and the latitude, longitude and elevation of sites. Initial results from these spatial analyses are presented below.
- Temporal variation. Data are also used to assess whether there are trends in these environmental variables over time, as might be expected with climate change. Data can also be used to assess whether there is spatial variation in these trends. Trends over time in temperature, rainfall, humidity and water table depth may, for example, vary with latitude, longitude and elevation, with consequences for vegetation. As data are only available from a small number of years, these analyses have not yet been completed.

Analyses have so far largely been restricted to data from Edale, Holme, Marsden and Burbage as these sites have been established for the longest time as site setup was staggered over the duration of the project. The four newer sites will be included in future reporting as the datasets begin to build. Analyses have also largely been restricted to using data from the start of 2016 onwards so that sites are being compared using data collected over the same time period.

3.1 Temperature

Two temperature measurements are taken at each EM site.

(1) There is one air temperature logger at each site protected by a solar radiation shield (Figure 41, left) which records temperature above the vegetation. Temperature variables that have been derived from this are mean, daily maxima (maximum temperature recorded in a day), daily minima (minimum temperature recorded in a day) and daily range (difference between the daily maxima and minima). Monthly, seasonal and annual value means for each of these variables have been calculated.

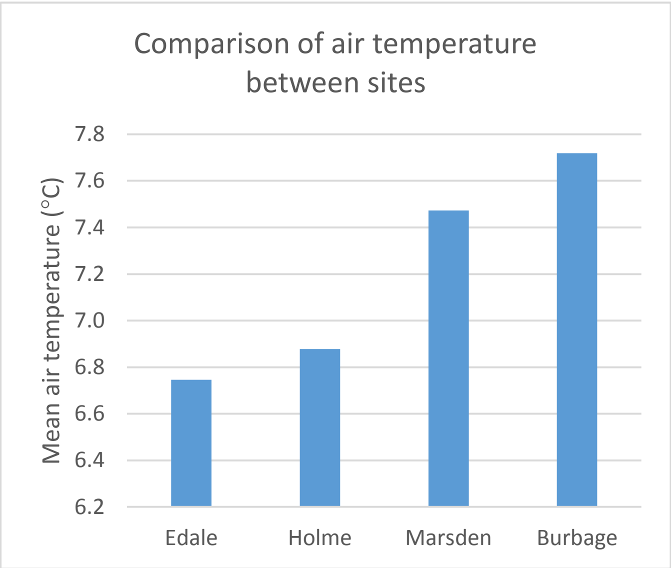
(2) There are also data loggers in 10 quadrats at each site that record the soil surface temperature (Figure 41, right). These have been used to calculate mean monthly, seasonal and annual temperatures at each quadrat and the mean across each site.

Figure 41. Air temperature logger within solar radiation shield (left) and soil temperature logger (right).

3.1.1 Results so far

There is a significant difference in mean air temperature between EM sites (Friedman's statistic = 72.79; d.f. = 3; *P* <0.001) (Figure 42). The temperature in Edale and Holme is lower than in the other sites, with the temperature at Burbage being the highest. The same pattern holds for maximum daily air temperature and daily minimum air temperature.

There is also a significant difference in soil surface temperature between sites (ANOVA: F = 4.194; d.f. = 3; *P* = 0.012) with the pattern being similar between sites: temperature at Edale and Holme is lower than at Marsden, with Burbage having the highest mean temperature.



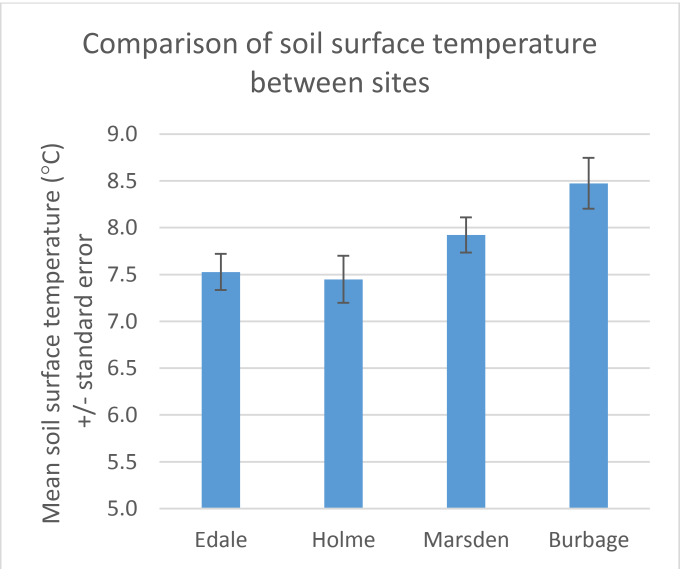


Figure 42. Mean air (left) and soil (right) temperature in different sites.

There is also a significant difference in soil surface temperature between sites when taking data from different seasons separately (Two-way ANOVA, site term: F = 8.00; d.f. = 3; *P* = <0.001) (Figure 43). Again, the pattern is similar with temperature generally being highest at Burbage and lowest at Edale and Holme.

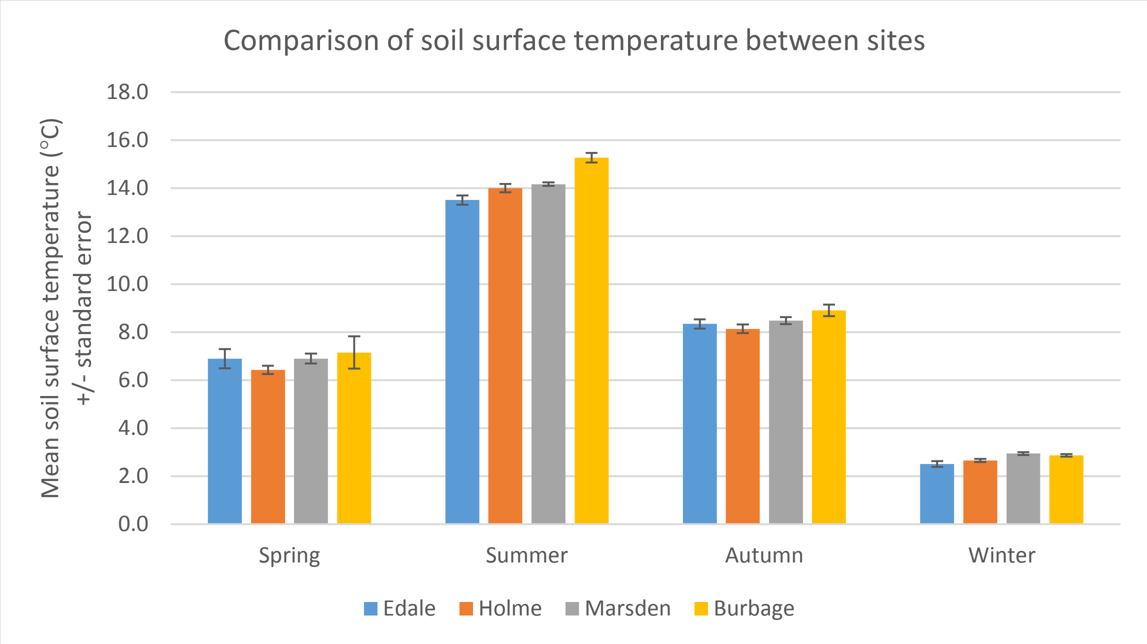


Figure 43. Mean seasonal soil surface temperature at different EM sites.

We found no significant relationship between any of the air temperature variables and latitude and longitude (i.e. air temperature at our sites does not increase or decrease as you move further north or east).

We did, however, find a significant decrease in mean air temperature with an increase in elevation (linear regression: β = -0.005; d.f. = 3; *P* = 0.038) (Figure 44). This provides an explanation for Burbage being the warmest site despite being at similar latitude to Edale, as it is almost 200m lower in elevation.

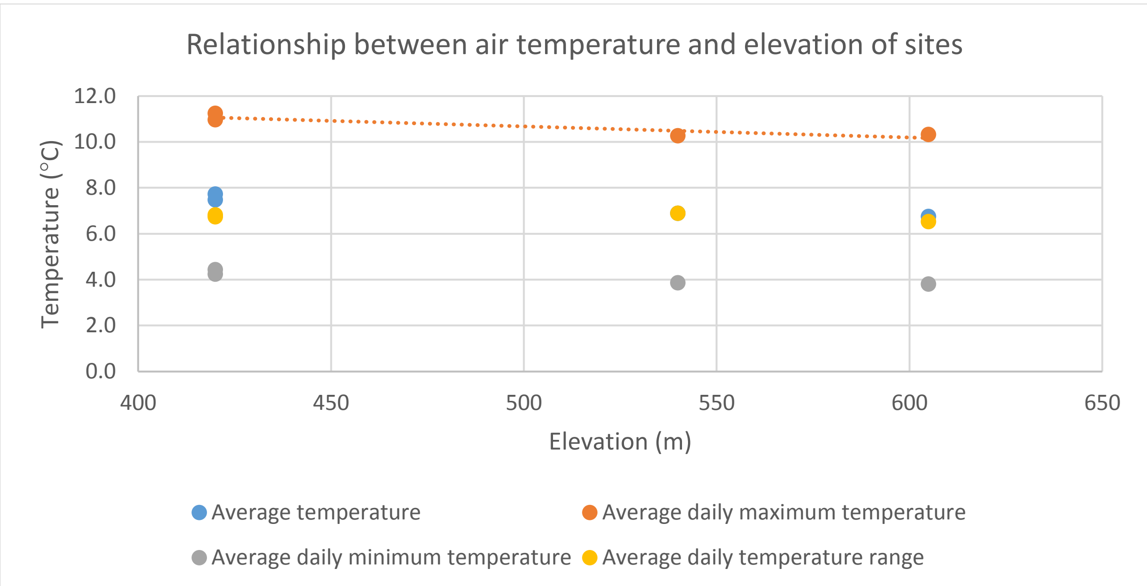


Figure 44. Relationship between air temperature and elevation of EM sites.

For the seasonal air temperature values, there was also no significant relationship between any of the temperature variables and latitude or longitude.

There was, however, a decline in autumn (linear regression: β = -0.005; d.f. = 3; *P* = 0.037) and winter mean temperature (linear regression: β = -0.005; d.f. = 3; *P* = 0.009) with an increase in elevation.

Using the soil surface temperature, the only significant relationship we found was a decrease in mean winter temperature with an increase in elevation (linear regression: β = -0.002; d.f. = 3; *P* = 0.004).

3.2 Rainfall

There is one rainfall gauge installed at each site to monitor rainfall (Figure 45). This data was used to calculate monthly, seasonal and annual total rainfall, number of days without rainfall (as a measure of drought) and percentage contribution to total rainfall of heavy rainfall events (days with more than 20mm rainfall) (as a measure of intensity of rainfall) for each site.

Figure 45. Rainfall gauge.

3.2.1 Results so far

We found a significant difference in total rainfall between the EM sites (Friedman test statistic: 18.60; d.f. = 3; *P* < 0.001) (Figure 46). Rainfall is highest in Holme and lowest in Burbage. We didn't, however, find a difference in the number of dry days or contribution to total rainfall by heavy rainfall events between sites.

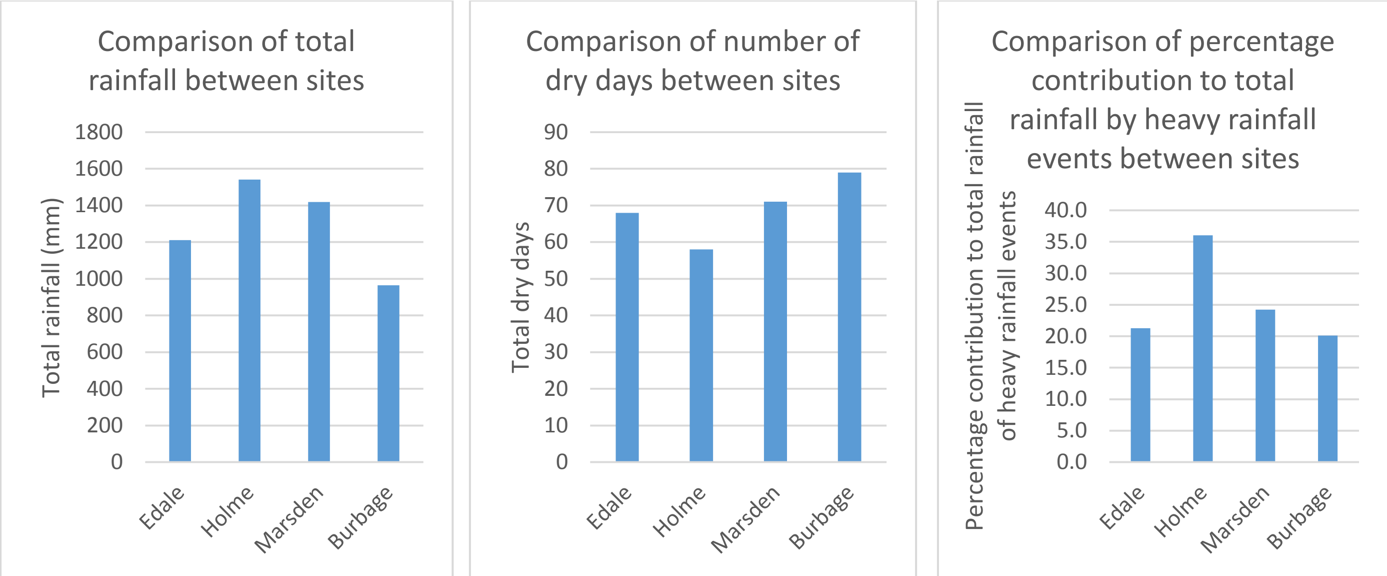


Figure 46. Total rainfall (left), number of dry days (centre) and contribution to total rainfall of heavy rainfall events (right) at EM sites.

We found no significant relationship between any of the rainfall variables and the latitude, longitude and elevation of sites. Analysis of seasonal variables was restricted due to large amounts of missing data.

However, from the data we had available we did find a significant negative relationship between total autumn rainfall and the Easting of sites (i.e. a decline in rainfall as you move from west to east through the project area) (linear regression: β = -0.011; d.f. = 3; *P* = 0.017). In line with this, we found a significant positive relationship between the number of dry days in autumn and the Easting of sites (i.e. an increase in the number of dry days as you move from west to east through the project area) (linear regression: β = 0.0008; d.f. = 3; *P* = 0.030).

We also found a significant positive relationship between the contribution of heavy rainfall events in autumn and the northing of sites (i.e. the contribution of heavy rainfall events to total rainfall increases as you move from south to north through the project area) (linear regression: β = 0.0005; d.f. = 3; *P* = 0.012; winter: β = 0.0003; d.f. = 3; *P* = 0.012).

We found no significant relationships between our seasonal rainfall variables and the elevation of EM sites.

3.3 Humidity

There is one sensor installed at each site to monitor relative humidity, data from which has been used to calculate mean monthly, seasonal and annual relative humidity at each site. This is the same sensor that records air temperature (see Figure 41).

3.3.1 Results so far

We found a significant difference in relative humidity between the EM sites (Friedman test statistic: 53.03; d.f. = 3; *P* < 0.001) (Figure 47). Relative humidity is highest in Edale and Holme and lowest in Burbage.

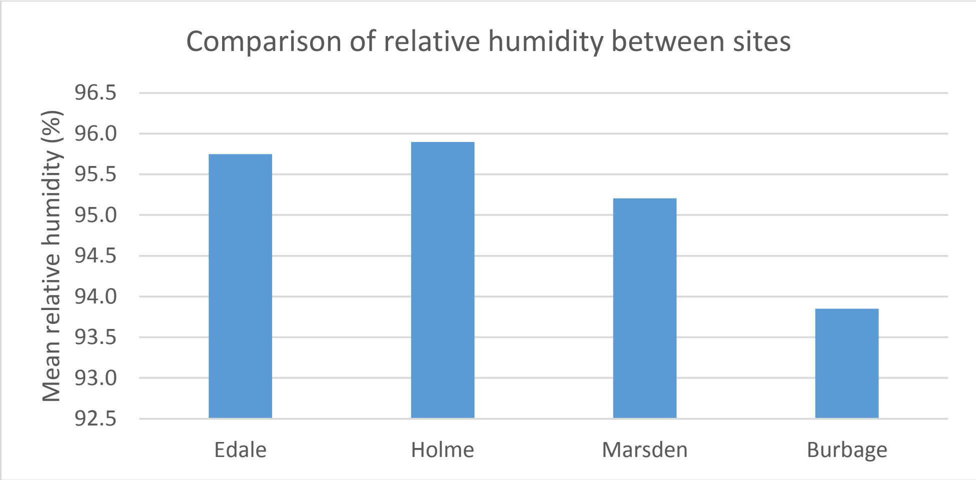


Figure 47. Mean relative humidity on each of the EM sites.

We found no significant relationship between mean relative humidity and the Easting, Northing and elevation of sites. This was also the case when we tested for relationships between Easting, Northing and elevation and the mean relative humidity for each season separately.

3.4 Water table depth

Water table depth is measured in two ways at each EM site.

(1) There is one automatic water table depth logger at each site (Figure 48, left). Data from these have been used to calculate mean monthly, seasonal and annual values of water table depth. They have also been used to calculate drying and rewetting rates at each site. The drying rate is the rate at which the water table depth drops during a period of no rainfall. The rewetting rate is the rate at which water table depth rises with rainfall after a dry period.

(2) There are also data loggers in 15 quadrats at each site where manual water table depth measurements are taken around 12 times a year (Figure 48, right). These have been used to calculate mean average annual water table depth at each quadrat and the mean across each site.

Figure 48. Automatic water table depth logger (left) and measurement being taken from a manual dipwell (right).

3.4.1 Results so far

We found a significant difference in water table depth between sites using data from both automated (Friedman test statistic: 47.60; d.f. = 3; $P < 0.001$) and manual (ANOVA: F = 68.43; d.f. = 3; $P < 0.001$) dipwells (Figure 49). Both sets of data show that water table depth is much lower at Edale than the other sites and appears to be slightly lower at Marsden compared with Holme and Burbage. This is also highlighted in the ongoing water table patterns as shown in Figure xx.

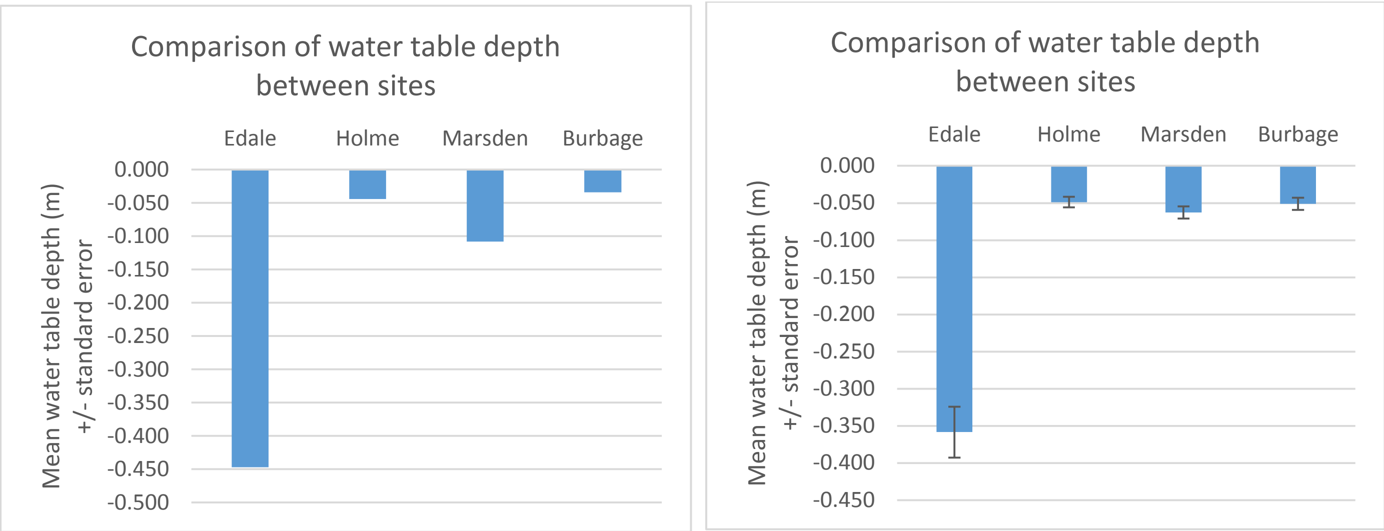


Figure 49. Mean water table depth at EM sites using data from automated (left) and manual (right) dipwells.

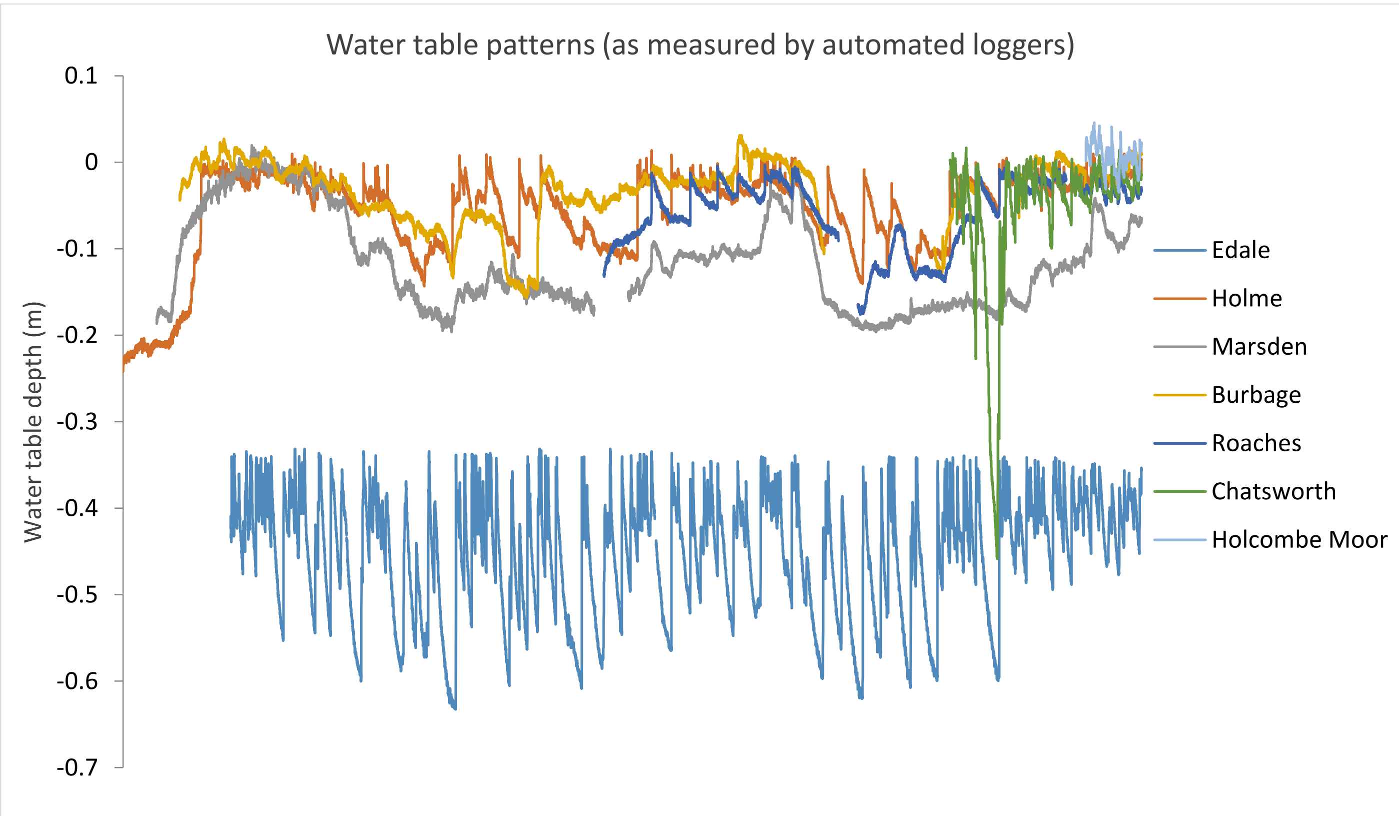


Figure 50. Water table patterns at the seven sites with automated dipwells – from September 2015 to end of December 2017 (note the staggered setup of sites which explains the differing length between series)

We found no significant relationship between mean water table depth and the Easting, Northing and elevation of sites using data from both the automated and manual dipwells. This was also the case when we tested for relationships between Easting, Northing and elevation and the water table depth for each season separately.

We did not find a significant difference in drying rates between EM sites but we did find a difference in rewetting rates (ANOVA: $F = 2.85$; d.f. = 3; $P < 0.001$) (Figure 50). Rewetting was faster at Edale compared with the other sites.

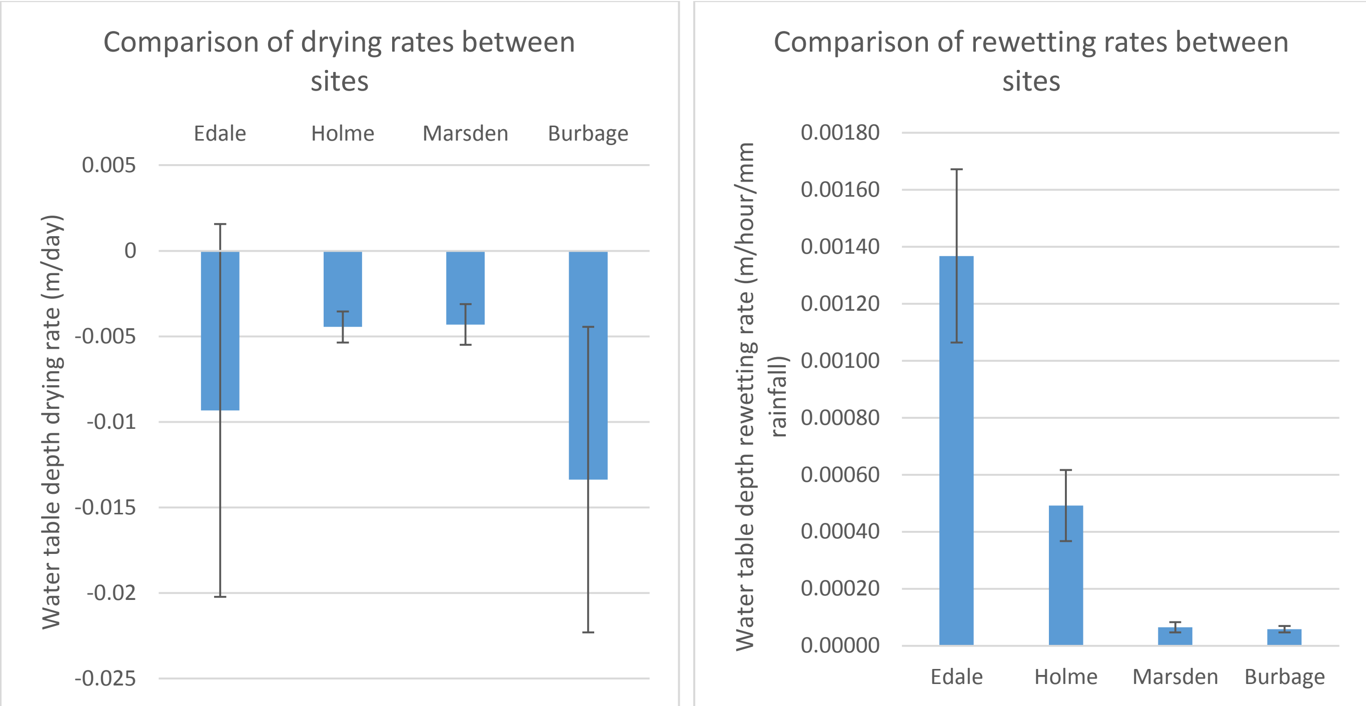


Figure 51. Mean drying (left) and rewetting (right) rates at EM sites.

3.5 Vegetation

Full botanical surveys have been carried out in 30 quadrats in each EM site in each year. This information has been used to calculate the species richness (the total number of species recorded), species diversity (a measure which combines the number of species and how evenly represented those species are), the cover of different types of vegetation and mean vegetation height for each quadrat and each site. The data also allow us to assign each site to a National Vegetation Classification vegetation community. Vegetation analyses have also included data from Roaches as a survey was carried out at that site in 2016.

Figure 52. Example of a vegetation quadrat at the Roaches.

3.5.1 Results so far

We found significant differences in the cover of: bare ground (ANOVA: F = 9.13; d.f. = 4; $P < 0.001$), moorland dwarf shrubs (ANOVA: F = 40.94; d.f. = 4; $P < 0.001$), moorland herbs (ANOVA: F = 3.12; d.f. = 4; $P = 0.017$), grasses, sedges and rushes (ANOVA: F = 29.93; d.f. = 4; $P < 0.001$) and bryophytes and lichens (ANOVA: F = 28.10; d.f. = 4; $P < 0.001$); and a significant difference in vegetation height (ANOVA: F = 13.29; d.f. = 4; $P < 0.001$) (Figure 52).

Overall, Edale and Roaches have a much higher cover of moorland dwarf shrubs (this includes heather, crowberry, bilberry, cranberry and cowberry) than the other sites whereas Holme has a higher percentage cover of grasses, sedges and rushes. All sites have a fairly high percentage cover of bryophytes and lichens except for Marsden. These differences are reflected in the National Vegetation Classification (NVC) communities each site has been classified as:

- Edale: U2b - *Deschampsia flexuosa* (wavy hair-grass) grassland, *Vaccinium myrtillus* (bilberry) sub-community
- Holme: M20 *Eriophorum vaginatum* (Hare's tail cotton grass) blanket and raised mire
- Marsden: H9e *Calluna vulgaris* (heather) - *Deschampsia flexuosa* (wavy hair-grass) heath, *Molinia caerulea* (purple moor grass) sub-community
- Burbage: M20 *Eriophorum vaginatum* (Hare's tail cotton grass) blanket and raised mire
- Roaches: U2b - *Deschampsia flexuosa* (wavy hair-grass) grassland, *Vaccinium myrtillus* (bilberry) sub-community

The NVC communities above fit well with what we know to be present on each site with the exception of Marsden which has only a small amount of both Calluna vulgaris (heather) and *Deschampsia flexuosa* (wavy hair-grass) present. However, vegetation communities in the South Pennines have been heavily impacted by historic industrial pollution and wildfire which may explain why the Marsden community does not have a strong fit with any of the recognised NVC communities.

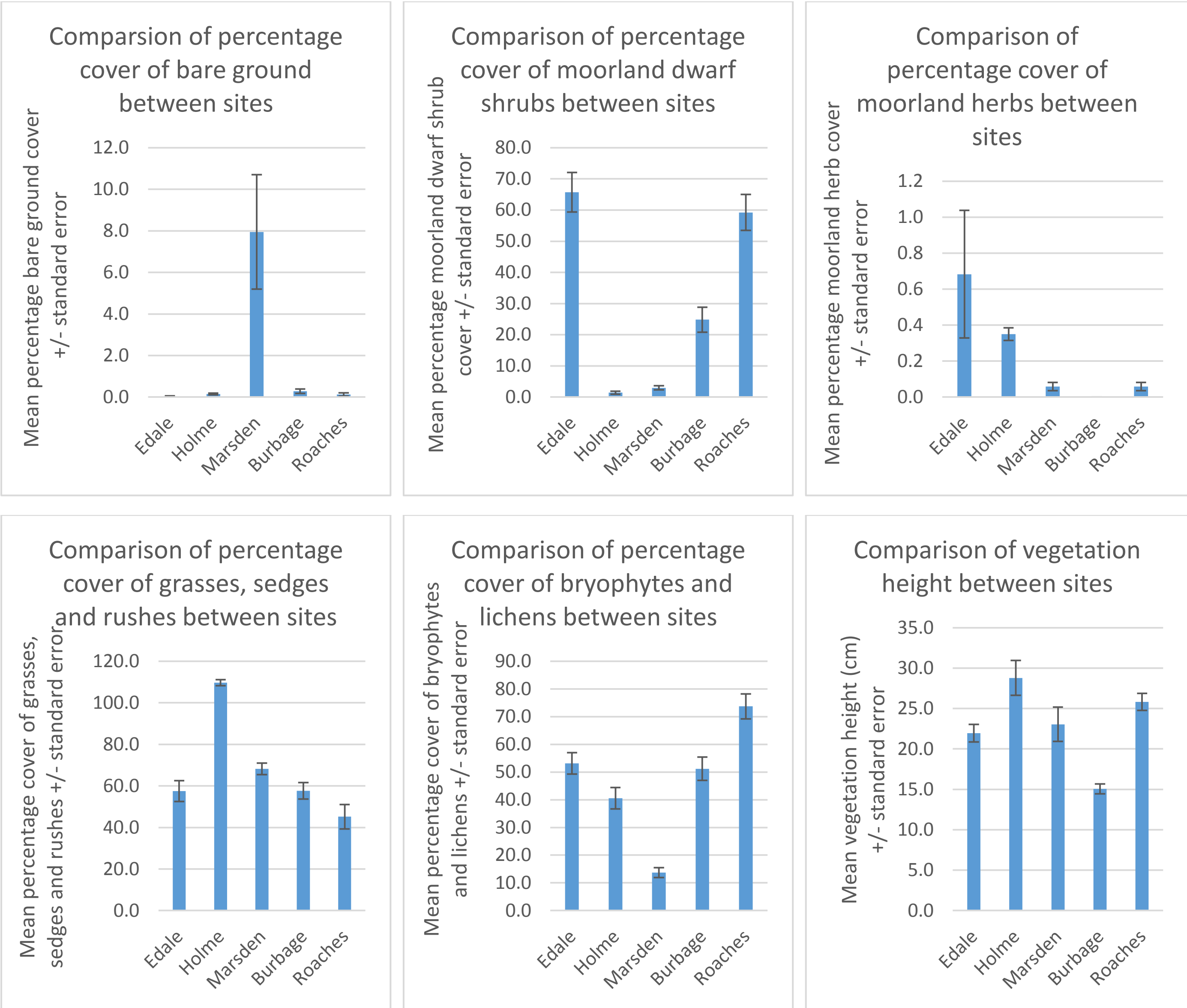


Figure 53. Mean percentage cover across quadrats of bare ground (top left), moorland dwarf shrubs (top centre), moorland herbs (top right), grasses sedges and rushes (bottom left) and bryophytes and lichens (bottom centre) and mean vegetation height (bottom right) on each EM site.

We also found a significant difference in species richness (ANOVA: F = 13.25; d.f. = 4; $P < 0.001$) and species diversity (ANOVA: F = 4.37; d.f. = 4; $P = 0.002$) between sites (Figure 53). Species richness (the overall number of species) was highest at Roaches and lowest at Burbage. Species diversity (which includes a measure of how evenly these different species are represented) was again lowest at Burbage but highest at Edale.

Some historic context for the sites may help shed light on these findings. As the Roaches is located far to the south of the project area, it did not suffer from the historic pollution that severely affected much of the Peak District and South Pennines during and after the industrial revolution. This may be a reason for its higher species richness as a greater number of plant species were able to survive there than further north. Edale currently shows the greatest diversity and this may be partly attributed to its close proximity to areas that have been revegetated with non-moorland species of grass which have drifted on to the site. The variation in topography and peat depth on the Edale site due to historic degradation may also explain why there is a greater abundance of species on the Edale site, as more species can take advantage of the shallower peat and drier, more diverse range of micro-habitats.

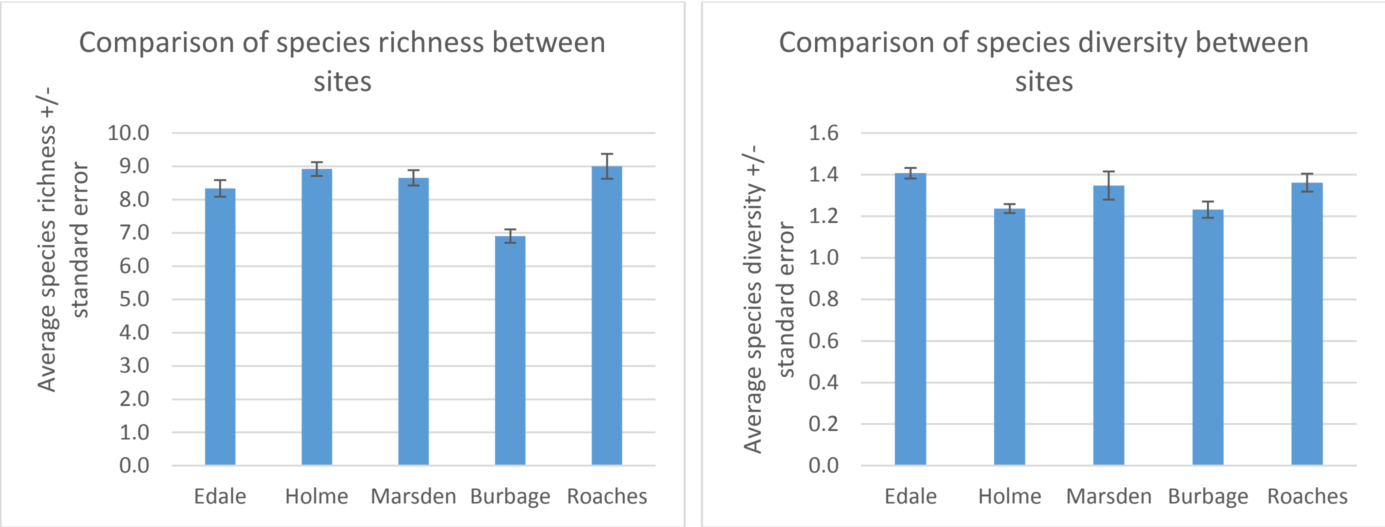


Figure 54. Species richness (left) and diversity (right) at EM sites.

We found a significant positive relationship between the percentage cover of moorland herbs and the elevation of sites (linear regression: β = 0.003; d.f. = 4; *P* = 0.002) (Figure 54). We also found a significant negative relationship between the percentage cover of bryophytes and lichens and the Northing of sites (linear regression: β = -0.001; d.f. = 4; *P* = 0.013) (Figure 54). Finally, we found a significant positive relationship between vegetation height and the mean rainfall of sites (linear regression: β = 0.022; d.f. = 3; *P* = 0.038) (Figure 54).

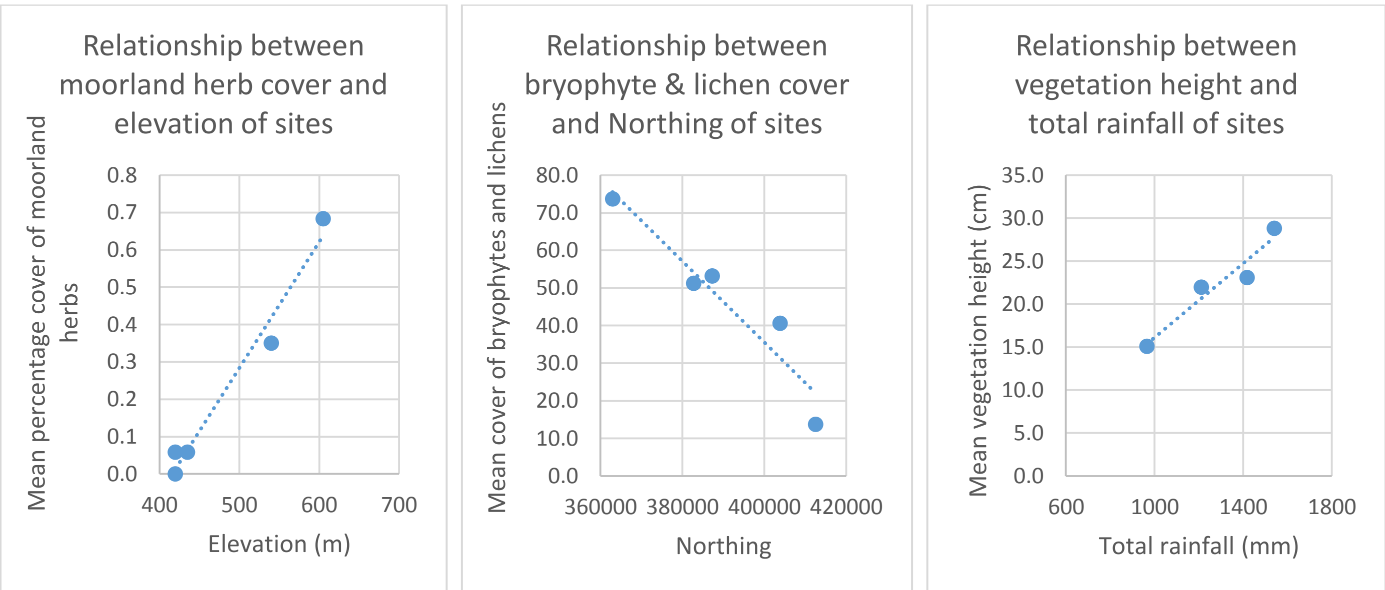


Figure 55. Relationship between percentage cover of moorland herbs and elevation of EM sites (left), bryophyte and lichen cover and Northing of EM sites (centre) and vegetation height and rainfall of EM sites (right).

3.6 Peat accumulation/erosion

Each monitoring site has 10 peat anchors installed. Peat anchors provide us with a long-term method of measuring peat accumulation and erosion. Peat anchors are forced in to the mineral soil layer beneath the peat which keeps them ‘anchored’ in exactly the same place. This gives us a consistent point of reference to measure the peat surface against.

Changes in peat accumulation/erosion on our ‘intact’ sites will take many years, so due to the nature of the data collected from peat anchors analysis on the existing data has not yet been conducted.

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Further information

- Bumblebee Conservation Trust: https://www.bumblebeeconservation.org/
- Butterfly Conservation: https://butterfly-conservation.org/
- Derbyshire Amphibian and Reptile Group: http://groups.arguk.org/DARG/
- Derbyshire Ornithological Society: http://www.derbyshireos.org.uk/index.php
- Eastern Moors Partnership: https://www.visit-eastern-moors.org.uk/
- Heritage Lottery Fund: https://www.hlf.org.uk/
- Moors for the Future Partnership Community Science webpages:

  http://www.moorsforthefuture.org.uk/community-science
- MoorWILD app: http://www.moorsforthefuture.org.uk/moorapps
- Ring Ouzel Study Group: http://www.ringouzel.info/
- Woodland Trust – Nature's Calendar: https://naturescalendar.woodlandtrust.org.uk/