

**Evaluation of
Brown Hare Survey Results
from the West Pennine Moors
and other parts of Lancashire

2005 and 2006**

a report for
the Wildlife Trust for Lancashire,
Manchester and north Merseyside



by

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SUMMARY

1. This report was commissioned by the Wildlife Trust to analyse the results of brown hare surveys carried out in the West Pennine Moors and other parts of Lancashire in 2005 and 2006, and draw comparisons with previously analysed results of data collected in 2002 and 2003 (Skelcher 2003). As in 2003, data was principally analysed using the computer software *DISTANCE 4.0* for estimating population densities
2. 1 km squares within the West Pennine Moors were selected according to their habitat, following analysis by the Wildlife Trust and Lancashire County Council to identify squares which were predominantly lowland valley, upland fringe or moorland. Squares which could be attributed to these habitat types were then put forward for survey of brown hare in the spring of 2003 so that some analysis of hare density in each habitat type could be calculated. Surveyed squares elsewhere in Lancashire were mostly selected in response to an earlier questionnaire issued by the Wildlife Trust and no breakdown of habitats is provided.
3. Using *DISTANCE*, the estimated density of brown hares per 1km square in the West Pennine Moors was 0.95 in 2005 and 0.55 in 2006. This represents an apparent 42% decline from the 2003 density of 1.65 to 2005 and a further decline of 42% to 2006. As in 2003, the lowland valley and upland fringe habitats were found to be the better available habitats for brown hares in this area, having densities in the lowland valley of 1.48 hares per 1 km square in 2005 and 2.72 per 1 km in 2006, and densities in the upland fringe of 2.86 hares per 1 km square in 2005 and 4.17 per 1 km in 2006. This compares with densities of just 0.36 hares per 1 km square in 2005 and 0.67 in 2006 in the moorland habitats.
4. Elsewhere in Lancashire the estimated density of brown hares was 2.56 per 1 km square in 2003 and 5.69 in 2006. The 2005 calculated density suggests a 54% decline in hare numbers from the 2003 figure of 5.56, but a return to slightly above the 2003 figure in 2006.
5. From the data analysed, it appears that the number of hares in the West Pennine Moors is lower than elsewhere in Lancashire. However, it is likely that this difference can at least partially be accounted for by the method in which surveyed squares were selected and the Lancashire sample is likely to over-represent the situation in the county as a whole.
6. The densities calculated for the various West Pennine Moor habitats are mostly lower than the average densities calculated by similar methods from extensive national data in similar habitat categories (Hutchings & Harris 1996). Compared to 1996 national results, the West Pennine Moors could be said to have a low density of hares overall, while the sample of surveyed squares in the remainder of Lancashire could be said to have a high density of hares in all years except 2005.
7. The use of *DISTANCE* to calculate population densities from transect data relies on a number of assumptions, some of which were not necessarily true for the West Pennine Moor and Lancashire brown hare surveys. Ideally, improvements could be made to the survey methodology to increase the reliability of the data. However the methodology actually employed was more practical to execute with limited resources and more easily repeatable with volunteer labour. While there are undoubtedly problems in interpreting the data, it nevertheless provides some indication of hare numbers which is likely to be closer to the true picture than could easily be collected by other methods.

1 INTRODUCTION and METHODS

An extensive survey of brown hares in Lancashire was first carried out by volunteers for the Lancashire Wildlife Trust in the spring of 2002. This survey broadly followed national guidelines for sampling 1 km squares (Hutchings & Harris 1996, Langbein *et al* 1999), but with amendments to facilitate access for ease of future surveying using volunteers (see Appendix 2). Surveyed squares were mostly selected in response to an earlier questionnaire issued by the Wildlife Trust.

In 2003 the survey was repeated, but with additional detailed work being carried out by a contractor and United Utilities staff, in addition to volunteers, within one rural area of Lancashire; the West Pennine Moors Area of Outstanding Natural Beauty. 1 km squares within the West Pennine Moors were selected according to their habitat, following analysis by the Wildlife Trust and Lancashire County Council to identify squares which were predominantly lowland valley, upland fringe or moorland. Squares which could be attributed to these habitat types were then put forward for survey of brown hare in the spring of 2003.

The results obtained from the 2002 and 2003 survey work were analysed to estimate the density of brown hare present in the West Pennine Moors and other parts of Lancashire and to draw comparisons between hare utilisation of the different broad habitats identified within the West Pennine Moors (Skelcher 2003).

Further hare survey work was carried out in Lancashire and the West Pennine Moors in 2005 and 2006 using volunteers and United Utilities staff following the same methodology.

This report was commissioned by the Wildlife Trust to analyse the 2005 and 2006 data and draw comparisons with the previously analysed results of data collected in 2002 and 2003. As in 2003, data was principally analysed using the computer software *DISTANCE 4.0* for estimating population densities (see Appendix 3), which is obtainable from <http://www.ruwpa.st-and.ac.uk/distance/> (Laake *et al.* 1994).

2 RESULTS

The detailed results of the brown hare transect walks carried out between 2002 and 2006 are given in Appendix 5. These results were analysed using *DISTANCE* and a summary of this analysis is provided in Table 1 below. The distribution of surveyed 1km squares throughout Lancashire for each year, together with an indication of hare abundance (0 hares recorded, 1 - 3 hares recorded or 4+ hares recorded), is shown in the subsequent series of Maps 1 - 4.

Table 1: Summary of brown hare survey results

D = estimated density (per km square) calculated by *DISTANCE*; CV = coefficient of variance; LCL = lower 95% confidence limit; UCL = upper 95% confidence limit; ESW = estimated strip width (m) from transect line where it is calculated that the number of animals missed within is equal to the number of animals recorded beyond; ns = number of sample transects analysed by *DISTANCE*; nh = total number of hares recorded from pooled transects; total effort = total length of pooled transects (km); all n = number of 1 km squares for which data was received (not necessarily with sufficient information for analysis by *DISTANCE*); all h = total number of hares recorded from all surveyed squares; hares/km square = density of hares calculated by total number of hares observed per 1 km square surveyed.

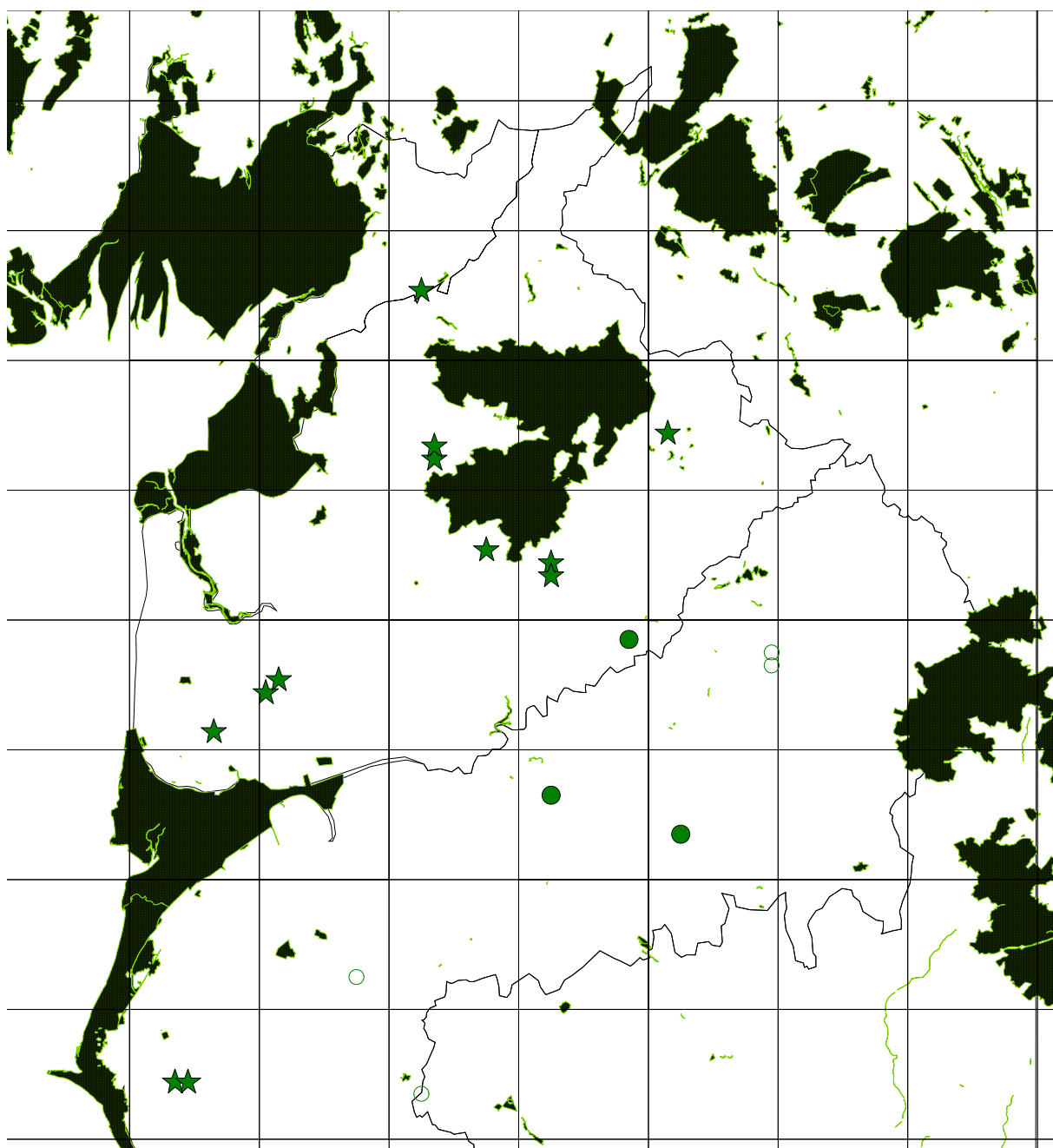
	D	CV	LCL	UCL	ESW	ns	nh	total effort	all n	all h	hares/km sq
West Pennine Moors											
2006	0.55	0.52	0.2	1.5	141.14	22	10	63.7	22	10	0.45
2005	0.95	0.52	0.35	2.56	135.15	28	13	83.6	28	15	0.46
2003	1.65	0.46	0.68	4.02	121.44	24	30	74.95	24	30	1.23
WPM Valley											
2006	2.72	0.91	0.41	18.09	(10)	7	1	18.4	7	1	0.14
2005	1.48	0.68	0.39	5.56	79.17	10	7	29.9	10	7	0.7
2003	1.45	0.66	0.38	5.47	200.37	10	17	29.25	12	19	1.58
WPM Fringe											
2006	4.17	0.98	0.31	56.53	(10)	4	1	12	4	1	0.25
2005	2.86	0.76	0.49	16.63	20	6	2	17.5	6	2	0.33
2003	1.41	0.66	0.36	5.52	120.48	8	8	23.6	8	8	1
WPM Moorland											
2006	0.73	0.82	0.15	3.5	149.98	9	6	27.5	9	6	0.67
2005	0.36	0.99	0.06	2.29	199.98	9	4	27.5	9	4	0.44
2003	0.59	0.64	0.14	2.46	223.21	5	5	19.1	5	5	1
WPM Mixed											
2006	1.15	0.47	0.02	60.15	149.98	2	2	5.8	2	2	1
2005	0					2	0	5.8	2	0	0
2003	0					1	0	3	1	0	0
LANCASHIRE											
2006	5.69	0.3	3.14	10.32	193.42	20	132	60	21	132	6.29
2005	2.56	0.68	0.61	10.74	120.18	8	18	29.3	10	27	2.25
2003	5.56	0.45	2.1	14.7	146.69	9	42	25.75	10	49	4.9
2002	7.54	0.31	3.97	14.3	132.1	17	93	46.7	17	93	5.47

Map 1: Distribution of hare records in surveyed squares throughout Lancashire in 2002

- Stars indicate 4 or more hares recorded on a single 1 km square transect.
- Solid circles indicate 1, 2 or 3 hares recorded on a single 1 km square transect.
- Hollow circles indicate 1 km square surveyed but no hares recorded

Grid lines shown at 10 km intervals

Green shading shows extent of Sites of Special Scientific Interest in Lancashire

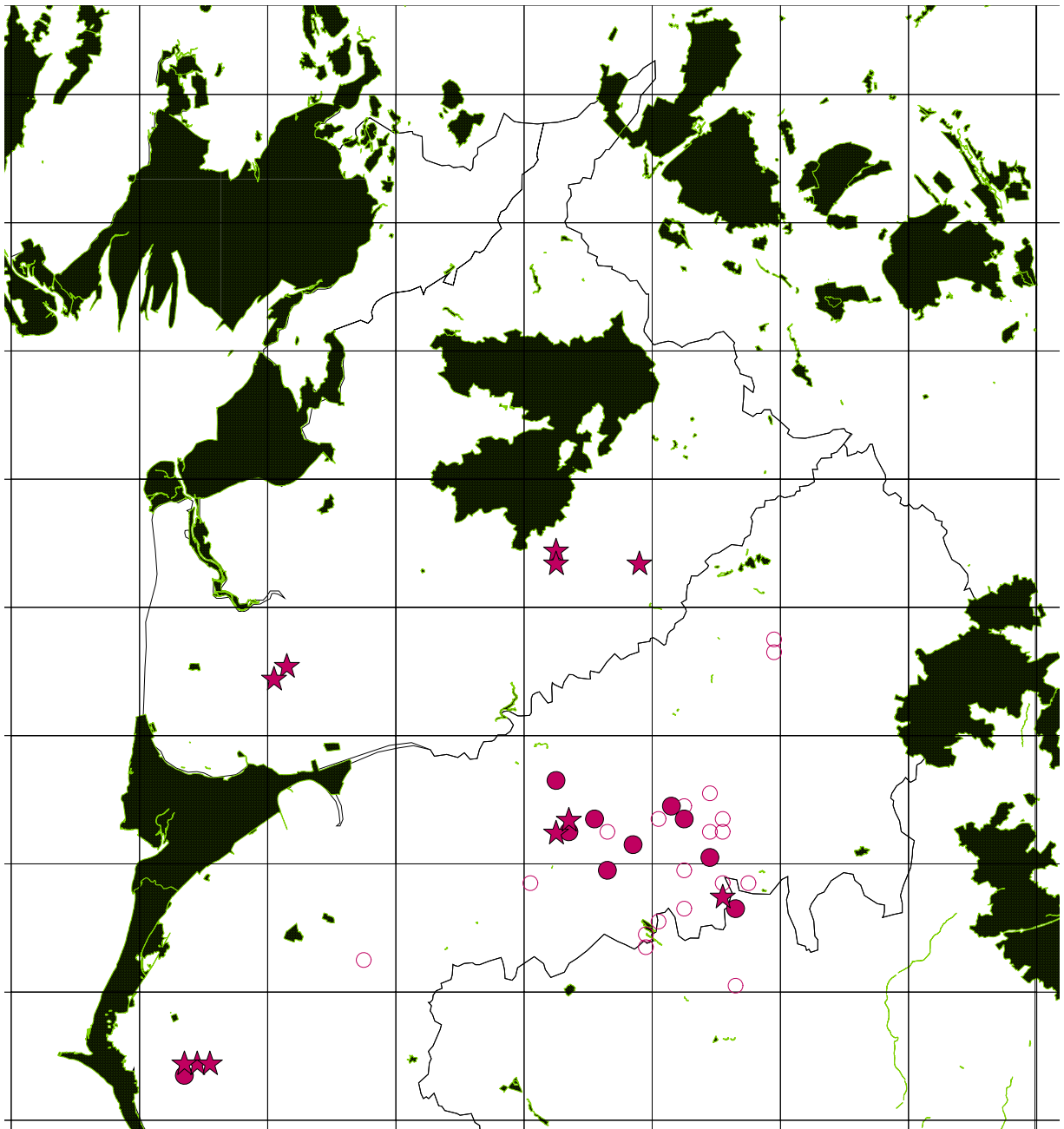


Map 2: Distribution of hare records in surveyed squares throughout Lancashire in 2003

- Stars indicate 4 or more hares recorded on a single 1 km square transect.
- Solid circles indicate 1, 2 or 3 hares recorded on a single 1 km square transect.
- Hollow circles indicate 1 km square surveyed but no hares recorded

Grid lines shown at 10 km intervals

Green shading shows extent of Sites of Special Scientific Interest in Lancashire

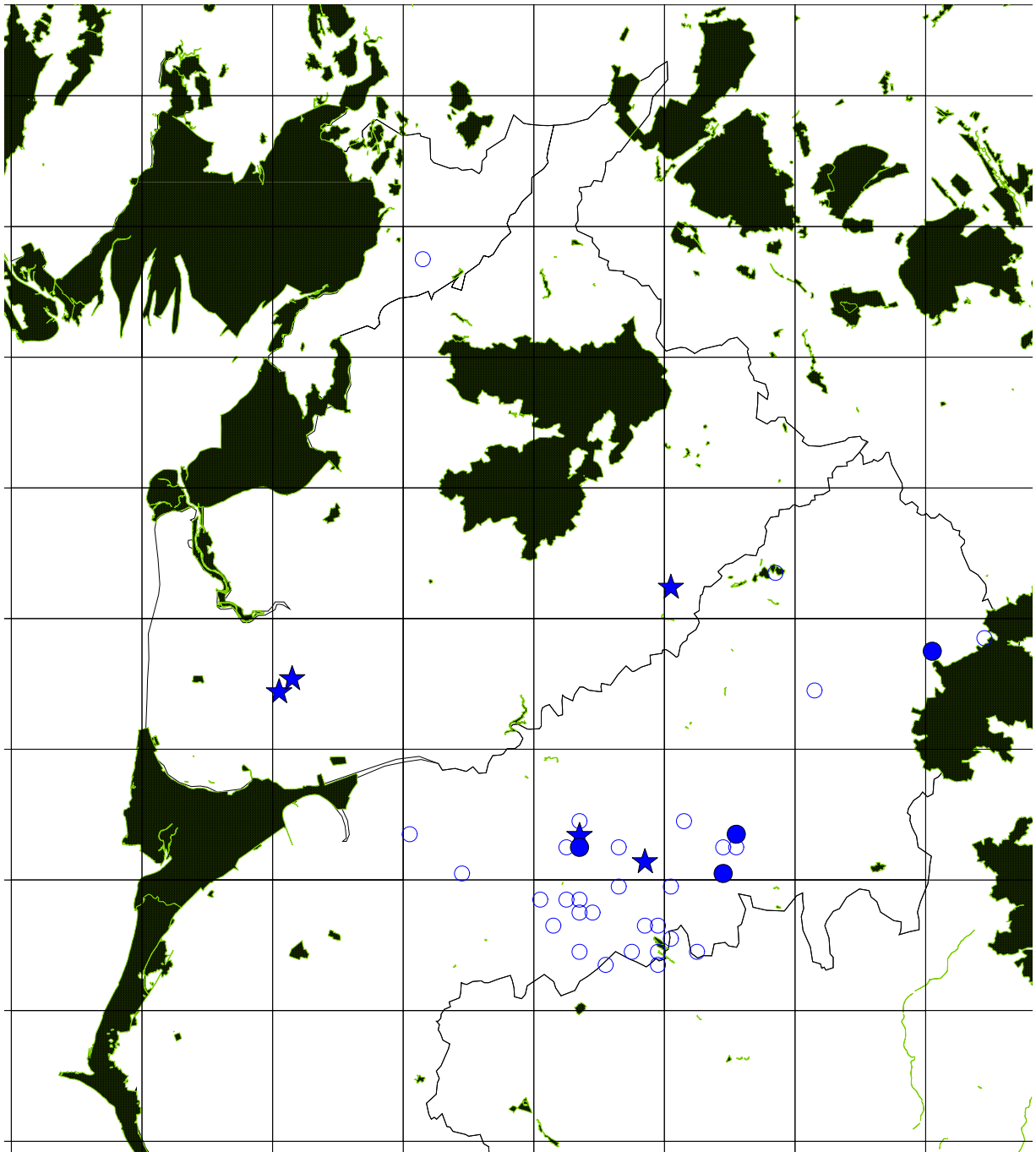


Map 3: Distribution of hare records in surveyed squares throughout Lancashire in 2005

- Stars indicate 4 or more hares recorded on a single 1 km square transect.
- Solid circles indicate 1, 2 or 3 hares recorded on a single 1 km square transect.
- Hollow circles indicate 1 km square surveyed but no hares recorded

Grid lines shown at 10 km intervals

Green shading shows extent of Sites of Special Scientific Interest in Lancashire

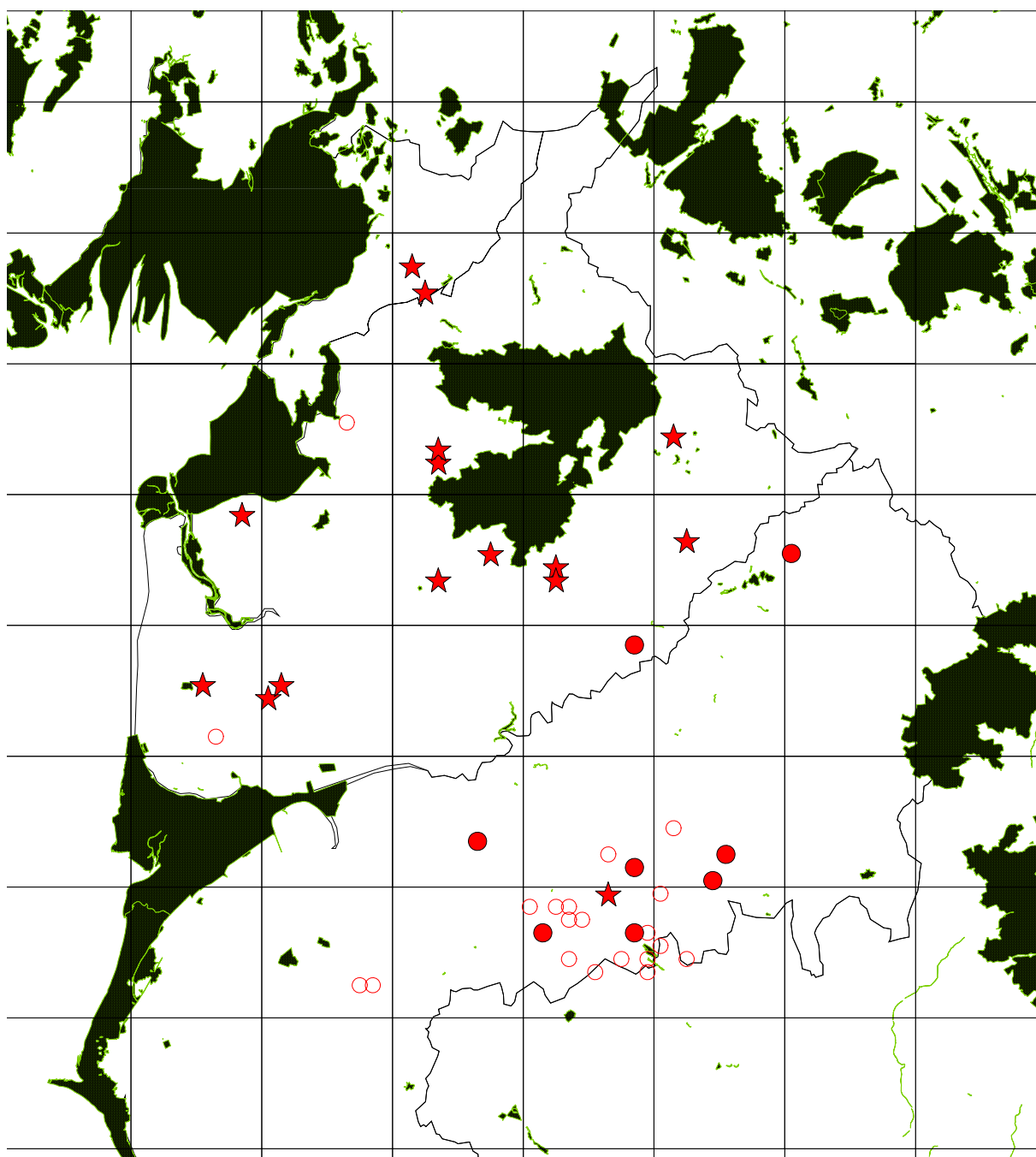


Map 4: Distribution of hare records in surveyed squares throughout Lancashire in 2006

- Stars indicate 4 or more hares recorded on a single 1 km square transect.
- Solid circles indicate 1, 2 or 3 hares recorded on a single 1 km square transect.
- Hollow circles indicate 1 km square surveyed but no hares recorded

Grid lines shown at 10 km intervals

Green shading shows extent of Sites of Special Scientific Interest in Lancashire



From the above table, it can be seen that, on average, 0.46 hares were seen per 1 km square surveyed in the West Pennine Moors in 2005 and 0.45 per 1 km square surveyed in 2006. Using *DISTANCE*, the estimated density of brown hares per 1km square in the West Pennine Moors was 0.95 in 2005 and 0.55 in 2006. This represents an apparent 42% decline from the 2003 density of 1.65 to 2005 and a further decline of 42% to 2006.

Elsewhere in Lancashire, 2.7 hares per 1km square were recorded in 2005 and 6.29 hares per 1 km square in 2006. The estimated density in these squares, calculated using *DISTANCE*, was 2.56 per 1 km square in 2003 and 5.69 in 2006. The 2005 calculated density suggests a 54% decline in hare numbers from the 2003 figure of 5.56, but a return to slightly above the 2003 figure in 2006.

Using *DISTANCE* to compare different habitats in the West Pennine Moors in 2003 suggested that the lowland valley and upland fringe habitats were the better available habitats for brown hares in that area, supporting densities of 1.45 and 1.41 hares per km square respectively, while moorland supported just 0.59 hares per km square. This assessment was further supported by the 2005 and 2006 figures which showed densities in the lowland valley of 1.48 hares per 1 km square in 2005 and 2.72 per 1 km in 2006, and densities in the upland fringe of 2.86 hares per 1 km square in 2005 and 4.17 per 1 km in 2006. This compares with densities of just 0.36 hares per 1 km square in 2005 and 0.67 in 2006 in the moorland habitats.

It should be noted that the 95% confidence limits for the estimates calculated by *DISTANCE* are fairly large. The estimate calculated from the 2006 West Pennine Moors data could only be given as being between 0.2 and 1.5 hares per km square with 95% confidence and between 0.35 and 2.56 for the 2005 data. The estimate calculated from the 2006 Lancashire data fell between 3.14 and 10.32 hares per km square with 95% confidence and between 0.61 and 10.74 for the 2005 data.

Note that data could only be analysed by *DISTANCE* if full details of the transect route length were provided along with the perpendicular distances from the route of hares recorded. This information was sometimes not complete on record sheets supplied by volunteers, hence the discrepancy in the sample numbers shown in Table 1 above (i.e. **ns** c.f. **all n** and **nh** c.f. **all h** as shown in Table 1).

3 DISCUSSION

As in 2003, the 2005 and 2006 results would initially appear to show that the density of hares in the West Pennine Moors is well below the average density for the rest of Lancashire. However, it is likely that much of this difference can be accounted for by the method in which surveyed squares were selected. Squares in the West Pennine Moors were selected, more-or-less, at random, based on different habitat criteria rather than any previous knowledge of hare presence. In contrast, the more widely spread Lancashire squares were selected in response to an earlier questionnaire carried out by the Wildlife Trust.

While some negative results were reported to the questionnaire, it is likely that many people would only respond if hares were present. In an extensive national survey, no hares were recorded in 62% of the squares surveyed (Hutchings & Harris 1996) but in Lancashire no hares were recorded in only 30% of squares in 2002, 12% in 2003 and 19% in 2006. This compares with the proportion of squares in which no hares were recorded in the West Pennine Moors of 72% in 2006, 78% in 2005 and 63% in 2003, which is much more in line with the national average. Only in 2005 were there 60% of surveyed squares with no hares in the remainder of Lancashire, when the calculated density of 2.25 hares per 1 m square was appreciably less than in other years. Thus, the Lancashire sample, in general, is likely to over-represent the situation in the county as a whole, while the West Pennine data is likely to be a better reflection of numbers within the AONB.

In Britain, brown hare are typically associated with agriculture and are replaced, ecologically, in some upland areas by the mountain hare. It is therefore not surprising that the density of hares in the West Pennine Moor survey was found to be higher in the lowland valley and upland fringe habitats than in upland moorland. Interestingly, the total number of hares recorded per each 1 km square in moorland in the West Pennines was similar to, or often exceeded, totals in other habitats in each of the surveyed years, but it seems likely that visibility would be better in open moorland and so the observation width within which hares might be expected to be seen is likely to be much greater. This factor will have been accounted for in the *DISTANCE* calculations and hence the lower moorland density figures suggested.

The densities calculated for the various West Pennine Moor habitats are mostly lower than the average winter densities calculated by similar methods from extensive national data (Hutchings & Harris 1996) of 8.77 hares per km square in arable land, 3.57 in pastoral land (perhaps comparable to the West Pennine Moor lowland valley habitat), 2.5 in marginal upland (perhaps comparable with upland fringe) and 1.15 in upland (moorland). The exception is the higher density calculations for the upland fringe in 2005 and 2006, though these are drawn from very small samples and the margin of error is very high. Tapper 1991 lists spring densities for individual study sites around Britain, ranging from 1.5 per km square up to 134 hares per km square in Suffolk, and includes mention of 28.5 hares per km square in Altcar, Lancashire.

Hutchings & Harris (1996) categorised 1 km squares nationally as having a high density of hares where the density was more than 3 and a low density where the density was less than 3. On this basis, the West Pennine Moors could be said to have a low density of hares, while the sample of surveyed squares in the remainder of Lancashire could be said to have a high density of hares in all years except 2005.

It should be noted that analysis of the West Pennine Moors data is also not without problems. Firstly, the margin of error given by *DISTANCE* is reasonably high and the true density of hares could be up to 4 hares per km square within the 95% confidence limits in 2003, up to 2.6 hares in 2005 and up to 1.5 in 2006. The margin of error becomes greater for analysis of individual habitats

as the data-set becomes smaller. The margin of error principally suggests that the data-set is not large enough, and the more information which can be fed into a survey of this type, the greater the accuracy of estimates is likely to be. In addition, there are a number of factors in the survey design which could adversely affect calculations, which are discussed in Appendix 4.

While, ideally, improvements could be made to the West Pennine Moor and Lancashire survey methodology to increase the reliability of the data, the methodology actually employed was more practical to execute with limited resources and more easily repeatable with volunteer labour. While there are undoubtedly problems in interpreting the data, it nevertheless provides some indication of hare numbers which is likely to be closer to the true picture than could easily be collected by other methods.

4 REFERENCES

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Appendix 1: A brief natural history of brown hare in Britain and Lancashire

1.1 Brown Hares in Britain

In Britain, the brown hare is widespread, locally abundant (notably in East Anglia, Hutchings & Harris 1996), but vulnerable to modern farming methods and showing signs of general decline (Morris 1992).

The brown hare is a species of open habitats, principally found on farmland. It is replaced, ecologically, by the mountain hare in upland Scotland, north Wales and in parts of the southern Pennines where farmland or open grassland gives way to heather moorland. Brown hares are most abundant in arable areas where cereal growing predominates. Pasture is also frequented, though high densities of livestock will deter hares from some grasslands. Woods, shelterbelts and hedgerows are frequently used as resting areas during the day particularly during winter. Food includes grasses, herbs and arable crops (Tapper 1991).

Brown hare are normally nocturnal but activity extends into the mornings and evenings during summer. There is no evidence of territorial behaviour and no obvious pattern to the distribution of home ranges. Results from radio-tracking suggest that a range of around 20-40 ha is average. Within home ranges, activity shifts from place to place between seasons, which is probably related to changing food supply and cover. On bare arable land, hares may dig themselves into a form during the day, which presumably provides shelter and protection from predators. About 3 litters of young are produced between February and October. The litter size is typically 1 to 4, with smaller litters early and late in the season (Tapper 1991).

A recent nationwide study estimated the winter population of brown hares in Britain to be just over 800,000, which is only 20% of the estimated population 100 years ago (Hutchings & Harris 1996). It is believed that the decline was particularly notable over a 20 year period from the early 1960s.

As a game animal, the brown hare receives only limited legal protection through the Ground Game Act (1880) and Hare Protection Act (1911) but, because of its significant decline in population, it was identified in the *UK Biodiversity Action Plan* as a 'Priority Species' and is also included in the local biodiversity action plans (North-West Biodiversity Steering Group 1999; Serjeant 2001)

1.2 Brown Hares in Lancashire

In Lancashire, brown hare appear still to be widespread but they are believed to be in decline (Serjeant 2001). Good information exists on the distribution of hares, but the lack of systematically collected data make assessment of the population size difficult. However, a marked decline has certainly occurred throughout the county. In less favourable areas, such as east Lancashire, this appears to have happened in the 1970's and early 1980's, and hares may now be completely absent in some areas. In the more suitable lowland plain, a population fall appears to have taken place later, in around the late 1980s, or even early 1990s in the case of the Fylde (Serjeant 2001).

Local strongholds for the brown hare appear to be around west Lancashire and the former mosses of the Lancashire coastal plain. To a lesser degree, the upland pasture fringe of the Forest of Bowland also seems to be important (Serjeant 2001).

Appendix 2: Guidelines for hare survey work issued by the Wildlife Trust

GUIDELINES FOR HARE SURVEY WORK IN WEST PENNINE MOORS

3rd DRAFT 31/03/03

Equipment Checklist:

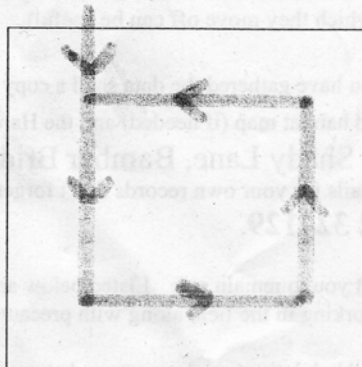
'Clean' Map of your 1km square
Habitat Map
Hare Data Sheet
Clipboard
Pencil
Rubber
Binoculars
Walking boots
Watch

The 'Transect':

You are asked to try to record the number of brown hares in your square counted during a single visit. The best way to do this is to walk around a set route that crosses your square in such a way so as you get a good view of as much of the land in the square as possible. The route is known as a 'transect'. The basic idea is to walk the transect and mark on the map the locations of any hares you see, filling in the hare data form as you go.

The ideal transect around a one kilometre square looks like the route on the right here:

However, we appreciate that it will be difficult (if not impossible) to walk around your square in this fashion while keeping to linear features on the ground. All we ask is that you plan a route that is as close to the 'ideal' as the terrain, rights of way, etc will allow. When you have decided your transect, please mark it on your 'clean' map. If you need to go out of the square in order to link up with a footpath that will bring you back into the square, this is OK but remember not to record hares that are outside the square.



Your Square:

Unless you know the square very well, we advise that you visit the area a few days before you walk the transect to decide on the route this should take. If possible, the transect should follow linear features such as footpaths, bridleways, roads, field edges, hedgerows, tracks through woods, riverbanks, etc. Avoid walking across the middle of fields especially if these contain crops.

It is best to stick to Public Rights of Way or 'PROWs' (footpaths, bridleways) if you can. Where we have the information, we have marked the PROWs on your 'clean' map. These appear either as thickened black lines on the map or as a series of dots thus:



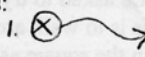
IF THERE ARE ANY AREAS OF PRIVATE LAND THAT YOU NEED TO CROSS BUT WHICH DO NOT HAVE PROWs, THEN YOU SHOULD ARRANGE PERMISSION TO WALK ON THESE STRETCHES OF LAND.

Lancashire County Council's West Pennine Moors Officers are liaising with local landowners and tenants and are writing to as many as possible to inform them of the hare survey. If you need to check landowner information (e.g. to find out who you need to speak to in order to obtain access permission), you should contact **Martin Dollimore** on 01254 699662.

We rely very much on the good will of farmers and landowners to conserve hare populations so permission should be obtained from relevant landowners before walking across an area where there is no public right of way. When you speak to them, please remember to ask the landowner if there are any hazards on the route that you should be aware of (e.g. steep slopes).

Use this preliminary visit also to check the details shown on the Habitat Map. If any details have changed (e.g. a new area of woodland has been planted on former grassland) then please alter the habitat map accordingly and send it back with your hare data sheet (see below).

General Advice:

1. The following points should be borne in mind when walking your transect:
 - Do not survey in wet or windy conditions or if the visibility is less than 200m because of mist/fog
 - Try to time your walk around so that it takes place during the three hours after dawn or the three hours before dusk (around 6 – 9am or 4 – 7 pm during the spring)
 - Allow two hours to conduct the survey
 - Do not wear bright clothes, make a lot of noise or take dogs with you
 - Please record the time you start and end the transect on the Hare Data Form
 - Walk the transect at a slow but steady pace and stop regularly to scan in front of you and to your sides. In order to maximise your chances of seeing hares that are at rest it may be useful to get into the habitat of using your Binoculars to scan a field three times from side to side, spending a few minutes observing the area carefully.
 - Mark the location of any hares you see on the 'clean' Map with a cross. If the hare is moving (which is more than likely!) mark where the hare goes by using an arrow from the cross like this:

 - Record details of each sighting on your Hare Data Form
 - Try to record each individual hare only once. (Hares sometimes circle around and so noting the direction in which they move off can be useful).
2. Once you have gathered the data send a copy of the 'clean' Map (with the transect and sightings marked), the amended habitat map (if needed) and the Hare Data Form to: **Tony Serjeant, Lancashire Wildlife Trust, Shady Lane, Bamber Bridge, Preston, Lancashire. PR5 6AU.** (If you want to keep details for your own records don't forget to make a copy for yourself!). Any queries telephone Tony on **01772 324129.**
3. We want you to remain safe. Listed below are a wide variety of general hazards that you might encounter when working in the field along with precautions to reduce the risks:
 - Undulating/rough terrain and steep slopes. Select appropriate footpath/route. Wear appropriate footwear with good soles and ankle support.
 - Weather. Ensure you are aware of the forecast prior to your work. This is of particular importance in the winter or when visiting remote or high moorland areas.
 - Dense vegetation. May obscure hazards such as holes, burrows, tree stumps or fencing. Work with care in such conditions.
 - Protruding stems. Take care when bending to survey vegetation to avoid injuries to eyes.
 - Cross streams or rivers only by footbridges or other purposely built structures. Avoid any structures that appear damaged or poorly maintained.
 - Poorly maintained footpaths, stiles, etc. avoid if possible and report to appropriate agencies.
 - Secluded sites. If in doubt err on the side of caution and do not walk alone. Inform another person of where you are going, your route and estimated time of return and arrange for them to contact the authorities if you do not contact them to say you have arrived back safely.
 - 'People' Hazards. (Might include poachers, strangers in isolated sites, irate owner/occupier, people with dangerous dogs, etc.)
 - (a) Exercise good judgement and assess the situation
 - (b) Avoid confrontation and withdraw if threatened
 - (c) Record incident and inform appropriate authorities
 - (d) Carry mobile phone if possible
 - (e) Operate lone working system
 - (f) If in doubt do not work alone
 - People with firearms. If shooting is legal make yourself known audibly and visibly. If illegal, withdraw and report to authorities.
 - Railways. NO fieldwork on active railways.
 - Hypothermia. Wear appropriate warm and waterproof clothing. Carry extra clothing and high energy food (e.g. chocolate).
4. Remember to enjoy yourself!

Appendix 3: Analysis of data using *DISTANCE*

The calculations made by *DISTANCE* are based on the concept that the probability of detecting an animal decreases as its distance from the transect line increases. At its simplest, the assumption is that all animals within a given distance of the transect route will be seen but outside this zone animals may be missed, so that the area of consideration is $2wL$, where w is the width or distance from the transect line within which all animals are expected to be recorded and L is the length of the transect route (or total length of all transect routes from pooled data). The density of animals is then calculated by the number of animals seen within the chosen width of the transect route divided by the above calculated area. Sightings of animals beyond the set width are not included in the analysis.

DISTANCE recognises that seeing all hares within the set belt width is unlikely and thus mathematically estimates the probability of detecting an animal that is a certain distance from the transect line. The population density is calculated using the equation:

$$P = \frac{N}{2L_0 \int_0^w g(x) dx}$$

where P = population estimate; N = number of animals sighted in each transect line (or pooled group of transect lines) and L = length of the transect line (or total length of pooled group of transect lines).

The detection function $g(x)$ is obtained by fitting a curve to the frequency distribution of detection distances. The definite integral of this function is referred to as the *effective strip width* and defines the width at which the number of animals seen outside this strip equals the number missed inside it.

Appendix 4: Reliability of using *DISTANCE* to analyse Lancashire and West Pennine Moor hare data

The use of *DISTANCE* to calculate population densities from transect data relies on a number of assumptions; including that animals directly on the line of the transect route will never be missed and the further away the animal is from the route, the greater the probability that it will be missed. These assumptions were not necessarily true in the Lancashire survey.

Because most of the transects used public rights of way, the route itself will often be unsuitable hare habitat (e.g. tarmacked road), while hares may further avoid land in the near vicinity of the route where there is a high level of public activity. In addition, visibility close to the path may sometimes be obscured by walls, hedges, banks etc, while visibility into the distance across open fields may be extensive. Thus, in many cases, hares may be more likely to be seen at distance in the fields away from the survey route. These factors are likely to lead to an underestimate when using *DISTANCE* to calculate density.

Variability in visibility between different habitats should be accommodated within *DISTANCE* in calculating the appropriate observation width.

The survey of hares by transect walks and estimate of population density by *DISTANCE* has been recommended by Hutchings & Harris, 1996, and Langbein *et al* 1999. In these surveys, however, 1 km squares were surveyed by strictly following routes 100 m within the perimeter of the square and undertaking walks at mid-day during winter, so as to disturb resting hares, rather than searching for active hares in the morning or evening. Thus, walks followed routes which, in themselves, were entirely representative of the surrounding habitat and hares would be much more likely to be flushed on or close to the transect route than they would at greater distance.