Environment & Heritage Series

Developments in hare survey methodology

- As applied to the NI Irish hare survey 2007

Quercus Project QU07-01

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Executive Summary

1. The Northern Ireland hare survey was undertaken during late-winter 2007 (Reid *et al*. 2007a). Here was compare a new survey protocol comparable to the Hare Survey of Ireland 2006/07, developed for the Republic of Ireland (Reid, *et al.* 2007b), with the standard Northern Ireland hare survey approach.

2. Conventional long-line point transect methodology and analysis provided a pre-breeding estimated mean Irish hare density in Northern Ireland during 2007 of 4.03 hares.km^{-2} (95% CI 2.81-5.79) giving a total abundance of 57,100 hares (95% CI 39,800-82,000; Reid *et al*. 2007a). Using conventional distance-analysis estimates, relative abundance counts and an index of population change, we conclude that the hare population of Northern Ireland was higher during 2007 than during 2006 but has not changed significantly.

3. Sources of substantial negative bias were identified in the Northern Ireland hare survey approach including consistent sampling bias and the non-uniform distribution of hares relative to survey points located on roads. Not accounting for these sources of bias may underestimate hare densities by up to 50%. A custom Distance-sampling approach involving a new short-line point transect method and innovative analyses were developed by the University of St. Andrews to solve inherent problems associated with surveying hares.

4. Custom Distance-sampling analysis of short-line point transect data provided a pre-breeding estimated mean Irish hare density in Northern Ireland during 2007 of 7.99 hares.km^{-2} (95% CI 4.18-14.46) giving a total abundance of 113,200 hares (95% CI 59,300-204,800). The comparatively wide confidence interval obtained using this methodology is largely due to limited sampling effort; greater investment of effort, comparable with the Northern Ireland hare survey approach, would substantially increase confidence in the results.

5. The new field survey and analytical techniques developed here represent a substantial improvement in the estimation of absolute hare density. Nevertheless, relative temporal change in estimated mean density from conventional analyses

may be used as a measure of variation in actual hare abundance due to deployment of standardised survey and analytical techniques between 2002 and 2007.

6. We make the 5 recommendations for action:
   a. Regular surveys of Irish hare abundance are necessary to establish the extent and pattern of annual fluctuation.
   b. Annual deployment of the standard Northern Ireland hare survey long-line point transect methodology should be supplemented by occasional surveys utilising a short-line point transect methodology and custom Distance analysis, similar to that developed by Reid *et al*. (2007b). Deployment of short-line survey methodologies and analyses should be synchronous with hare survey effort in the Republic of Ireland. The suggested monitoring strategy will allow temporal change in the hare population of Northern Ireland to be described annually, punctuated by occasional reference points of estimated density, both regionally and at an All-Ireland scale.
   c. Conservation policies, such as the Irish hare Species Action Plan, would benefit from revision at regular intervals to account for emerging scientific information regarding the biology and status of the species.
   d. Research on the population biology of Irish hares remains necessary. There is insufficient information on the most basic aspects of demography such as survival and productivity, their relationship with intrinsic and extrinsic factors and the spatial scale at which these factors affect population change.
   e. Investigation of the impact of agricultural practices such as mechanised silage harvest on hare survival will provide valuable information on population recruitment.

Contents

Introduction

The Northern Ireland hare survey commenced in 2002 (Preston *et al*. 2003) and has been conducted at annual intervals since 2004 (Tosh *et al*. 2004; Tosh *et al*. 2005; Hall-Aspland *et al*. 2006; Reid *et al*. 2007a). For species of conservation concern, the importance of contemporary monitoring data and its direct application to management is widely recognised (Choudhury, 1999, 2002; Battersby & Greenwood; 2004).

The Irish hare (*Lepus timidus hibernicus* Bell, 1837) is the only native lagomorph in Ireland (Fairley, 2001; Hamill, 2001) and is currently classified as an endemic sub-species of the mountain hare (*L. timidus* Linnaeus, 1758). Nevertheless, it differs phenotypically, behaviourally, ecologically and genetically from other mountain hares and recent research suggests it may warrant full species status (Hughes *et al.* 2006). It is subject to a local Northern Ireland and an All-Ireland Species Action Plan (Anon, 2000; 2005) and is, therefore, one of the highest priority species for conservation action in Northern Ireland.

The Irish hare population was likely to be considerably larger during the mid-19th to early 20th century than at present with land management changes and agricultural intensification initiating population declines during the early 20th century (Reid, 2006; Reid *et al.* 2007b). Historically, Irish hare populations exhibited marked interannual and multiannual fluctuations (Reid, 2006; Reid *et al.* 2007b), with interannual variability remaining a feature of the contemporary hare population estimates in Northern Ireland (Fig. 1; O'Mahony & Montgomery, 2001; Dingerkus & Montgomery, 2002; Preston *et al.* 2003; Tosh *et al.* 2004; Tosh *et al.* 2005; Hall-Aspland *et al.* 2006; Reid *et al*. 2007a). In the Republic of Ireland, between 2006 and 2007, the hare population more than doubled from 3.33 (95% CI 1.97-6.21) hares.km^{-2} to 7.66 (95% CI 4.83-14.29) hares.km^{-2} with the total population increasing from 233,000 to 535,000 hares (Reid *et al.* 2007b). General population declines can be ongoing, despite short term increases. Interpretation of short-term changes can only be made in the context of long-term time-series. Recent population surveys cover an insufficient period to reliably establish population trends.

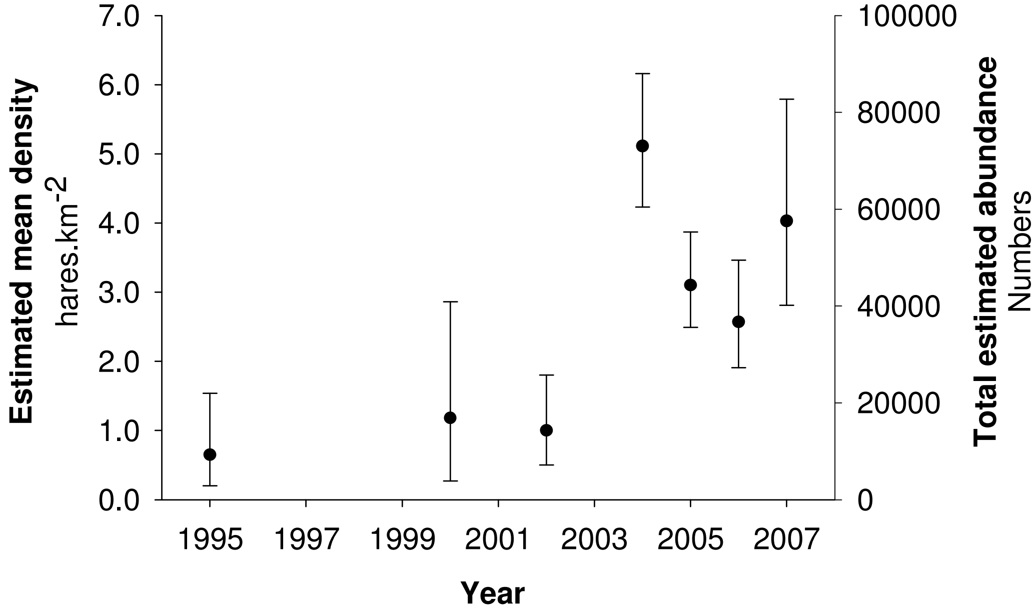

Fig.1 *Estimates of Irish hare mean population density ± 95% confidence intervals in Northern Ireland from 1995-2007 (O'Mahony & Montgomery, 2001; Dingerkus & Montgomery, 2002; Preston et al. 2003; Tosh et al. 2004; Tosh et al. 2005; Hall-Aspland et al. 2006; Reid et al. 2007a).*

Previous hare surveys identified a number of problems in obtaining unbiased estimates of hare density when working from survey points located on roads using Distance-sampling methodology (Tosh *et al.* 2005; Hall-Aspland *et al.* 2006; Reid *et al.* 2007a). These include obtaining statistically independent replicates, accounting for asymmetric survey effort around each survey point due to the presence of hedgerows and the non-uniform distribution of hares relative to roads. Changing survey methodology, however, creates further problems in the comparability of results. The objectives of previous Northern Ireland hare surveys (2002-07) were to:

- Establish the density and abundance of Irish hares in Northern Ireland.
- Add to previous survey data to establish temporal change in the hare population.
- Make recommendations for future work.

In addition to the objectives above, the current study aimed to contrast two different hare survey methodologies; the standard Northern Ireland hare survey used by Preston *et al.* (2003), Tosh *et al.* (2004), Tosh *et al.* (2005), Hall-Aspland *et al.* (2006) and Reid *et al*. (2007a) and that developed by Reid *et al*. (2007b) for the Hare Survey of Ireland 2006/07 that accounts for some of the problems that may lead to biased density estimates.

Methods

Surveys were conducted during mid-late winter (January-March) when ground vegetation was minimal, maximising the detectability of animals. Survey points positioned on line transects following minor roads were spaced approximately 200m apart and surveyed using a 2 x 10^6 candle-power spotlight from a platform on a high clearance vehicle elevating the observer's head height >2 m above ground level, i.e. above most hedgerows. The observer systematically swept the spotlight 180 degrees on both sides of the road twice, working from the area closest to the vehicle towards the horizon. Survey effort for each survey point was taken as a measure of the number of degrees within the observer's circle of vision that were visible and not obscured. For each detection of hares, the survey point location (measured to the nearest 10m using a Trimble Global Positioning System), the cluster size (i.e. number of hares), the radial distance of the cluster from the survey point (measured using a laser range finder; Leica LRF 900 scan) and the bearing of the cluster from the direction of travel (measured using compass binoculars; Tasco, Offshore 54, 7x50mm) were recorded. This was repeated for each survey point along the length of each line transect. Surveys were not conducted until one hour after sunset.

The results of two different sampling methodologies were compared:

<u>Survey method 1 – Long-line point transects</u>

The Northern Ireland hare survey 2007 (Reid *et al*. 2007a) adopted an identical approach to that taken by previous surveys (Preston *et al.* 2003; Tosh *et al.* 2004; Tosh *et al.* 2005; Hall-Aspland *et al.* 2006). The same eight long-line point transects used in previous surveys were resurveyed (Fig. 2). These routes were approximately 100km in length (834km in total) and were originally selected to bisect a representative sample of landscape types characterised by the land classification system (Murray, McCann & Cooper 1992) throughout all six counties in Northern Ireland. One disadvantage of this technique is that habitats are not sampled randomly and individual sample points arranged on long-lines are not statistically independent.

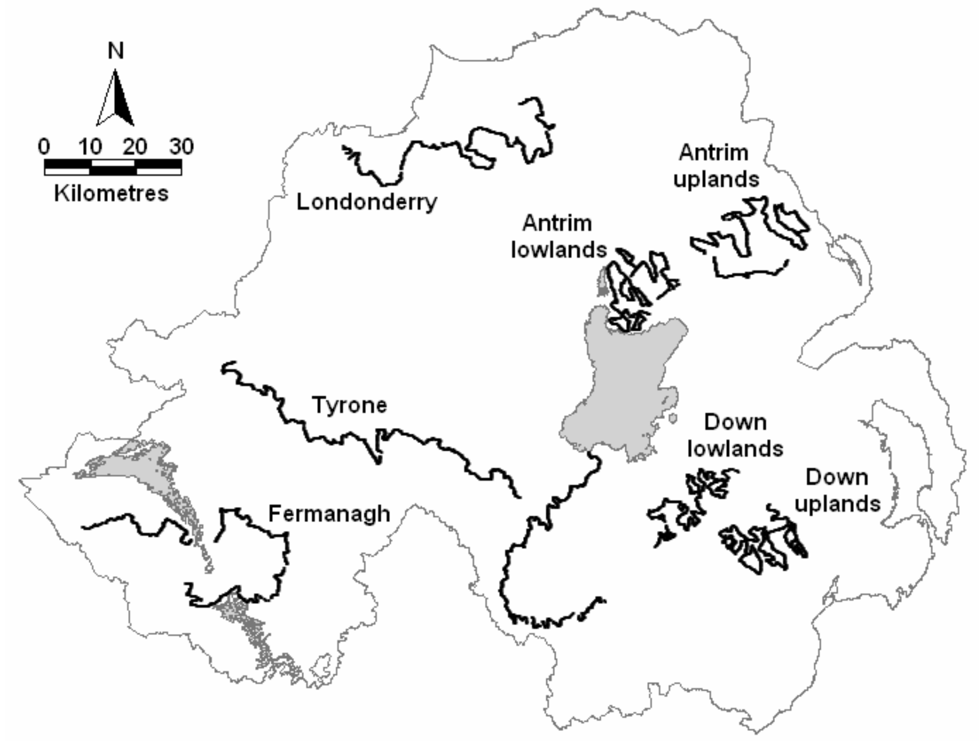

Fig. 2 *Location of long-line point transects used in all previous Northern Ireland hare surveys (Preston et al. 2003; Tosh et al. 2004; Tosh et al. 2005; Hall-Aspland et al. 2006; Reid et al. 2007a).*

For comparability of results the analytical procedure applied by Reid *et al*. (2007a) was identical to that used by previous surveys. Hare density and abundance was estimated using Distance v5 software (Thomas *et al.* 2005). The sample point was taken as the unit for variance estimation with right truncation applied to the upper 10% of sightings. Estimates were stratified by county with three commonly used models constructed for each (Buckland *et al.* 2004), including uniform cosine, half-normal cosine and hazard-rate simple polynomial. The parsimony of each model was evaluated using Akaike's Information Criterion (AIC) with the best model selected on the basis of the lowest AIC value.

Survey method 2 – Short-line point transects

A methodology comparable to that employed by the Hare Survey of Ireland 2006/07 (Reid *et al.* 2007b) was also deployed in Northern Ireland during 2007. For each 10km Irish grid square the most south-westerly 1km^2 grid square that was bisected by at least 1km of minor road was surveyed with each survey square containing 5 sample points approximately 200m apart. One hundred and forty short-line point transects were sampled (Fig. 3). One advantage of this technique is that the uniform non-selective coverage ensures that all habitats are sampled randomly and that a large number of statistically independent replicates are obtained.

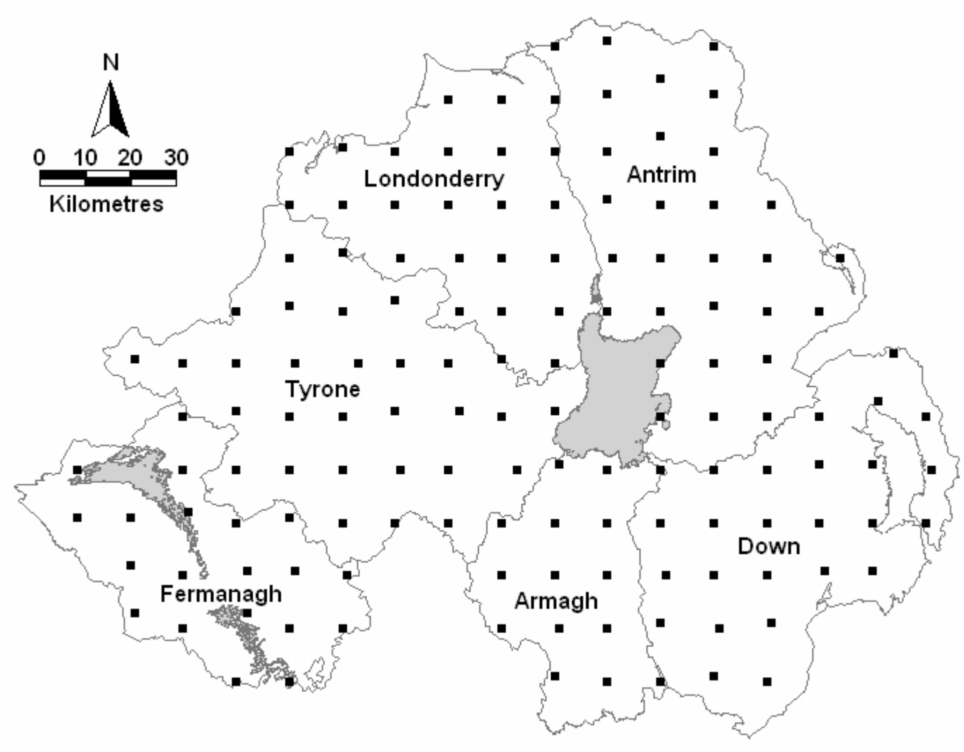

Fig. 3 *Location of short-line point transects similar to those used in the Hare Survey of Ireland 2006/07 (Reid et al. 2007b). Each 1km² survey square contained a 1km long transect.*

Differences in three measures of detection including percentage occurrence, number of clusters and relative abundance of hares between both long-line and short line point transect survey methods were tested for using χ^2 and t-tests.

To estimate hare density and abundance we firstly employed a conventional Distance-sampling analysis identical to that used for the long-line point transect data (see description above). The results of this analysis are directly comparable to those of the long-line point transect method. However, the terrestrial environment does not always fulfil the analytical assumptions of conventional distance-sampling. Previous surveys identified a number of negative biases inherent to hare density estimates produced from point surveys located on roads using conventional distance-sampling analysis (Tosh *et al.* 2005; Hall-Aspland *et al.* 2006; Reid *et al.* 2007a). Conventional analytical approaches do not facilitate the incorporation of information on the probable sources of sampling bias. Consequently, specialist custom Distance-sampling analysis was developed by the University of St. Andrews, Scotland written in the programming language R (CRAN, 2007) to account for sources of sampling bias (Marques & Borchers, 2006; Paxton *et al*. 2007).

Specifically, locating samplers on roads may introduce negative bias as hares may avoid roads. Consequently, the highest proportion of animals may not be detected at or near the sample point but may be some distance from the observer. To describe the pattern of hare distribution with respect to roads, "transfield" transects were walked perpendicular to the road at a random selection of points. These transects extended to the first field boundary or 250m in cases where a boundary was not met. For each cluster of hares detected, the cluster size (i.e. number of hares) and perpendicular distance of the cluster from the transect (and by inference, from the road and field boundary) was calculated using the bearing of the cluster from the direction of travel. The data from night-walked transfield transects were used to provide additional information for estimating hare density gradients relative to the road.

An additional complication is the presence of obstacles such as hedgerows. Whilst total survey effort per point can be easily accounted for, consistent directional bias resulting from less search effort in the area lying parallel to the road may introduce further negative bias. A measure of angular sampling bias was achieved by recording the direction of visible angles within a 360^{o} circle around each survey point. This bias was accounted for by adjusting the relative abundance of hares recorded by the proportion of points where each angle was visible. To ensure all replicates were statistically independent, the sample square, not the sample point, was taken as the unit for variance estimation. Consequently, variation in total survey effort per square was taken as the product of the total number of points per sample square and the mean survey effort per point.

A custom modified Gaussian-based model was written by Marques & Borchers (2006) and Paxton *et al.* (2007) for the Hare Survey of Ireland 2006/07 and further details can be obtained from Reid *et al.* (2007b). The results of the present analysis are directly comparable to those of Reid *et al.* (2007b).

Results

Survey method 1 – Long-line point transects

A total of 247 Irish hares were detected on 8 long-line transects during 2007 (Reid *et al.* 2007a). Not withstanding sources of potential negative bias, the estimated mean pre-breeding density of Irish hares in Northern Ireland during 2007 was 4.03 hares.km^{-2} (95% CI 2.81-5.79) giving a total abundance of 57,100 hares (95% CI 39,800-82,000; Reid et al. 2007a). The mean density was significantly higher than that for 2002 (Fig. 4; Preston *et al.* 2002). The 95% confidence intervals for the estimates during 2004, 2005 and 2006 overlapped substantially with those for 2007, but the mean estimate was lower than 2004 and higher than both 2005 and 2006 (Fig. 4; Tosh *et al.* 2004; Tosh *et al.* 2005; Hall-Aspland *et al.* 2006).

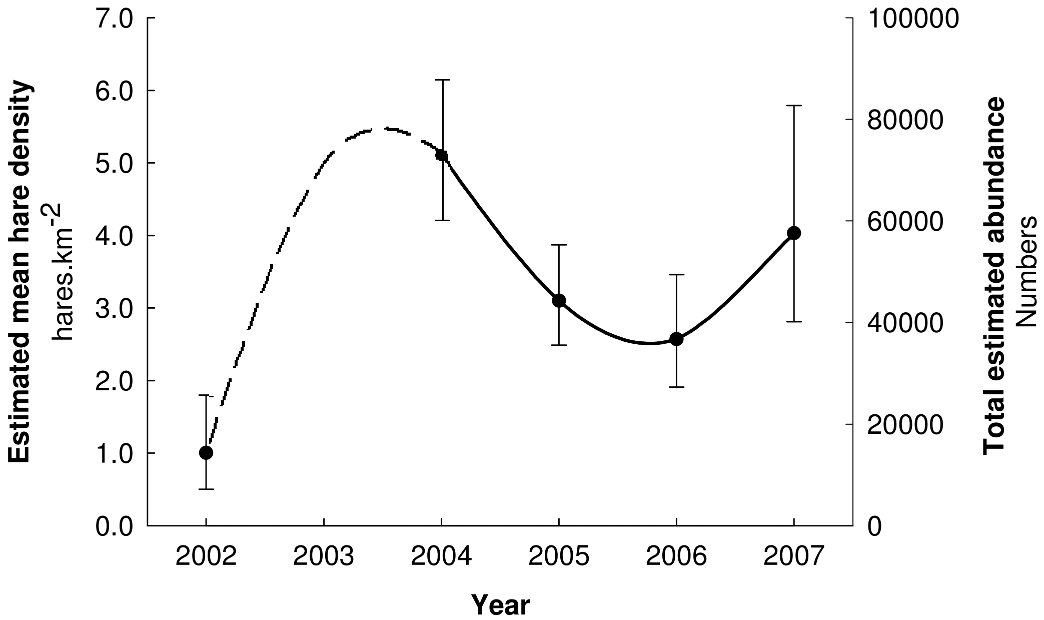

Fig. 4 *Trends in Irish hare density and abundance estimates ± 95% confidence limits during Northern Ireland hare surveys from 2002 to 2007 (Preston et al. 2003; Tosh et al. 2004; Tosh et al. 2005; Hall-Aspland et al. 2006; Reid et al. 2007a). The line through 2003 was interpolated using a cubic regression.*

Survey method 2 – Short-line point transects

A total of 54 Irish hares were detected on 140 short-line transects during 2007. No brown hares were detected during this survey. Percentage occurrence of Irish hares within 1km^2 Irish grid squares was significantly greater using the short-line point transect method than the long-line point transect method (Table 1). Using a conventional Distance-sampling analysis and not withstanding sources of potential negative bias, the estimated mean pre-breeding density of Irish hares in Northern Ireland during 2007 was 4.12 hares.km^{-2} (95% CI 2.47-6.88) giving a total abundance of 57,900 hares (95% CI 34,8700-96,600). These results are entirely consistent with that produced by a conventional Distance-sampling analysis of the long-line point transect survey data.

Survey effort was shown to contain significant and consistent directional or angular bias. The distribution of visible degrees around each survey point was non-uniform $\chi^2_{df=17} = 356.00$, $p<0.001$), with less search effort in segments lying more parallel to the road (Fig. 5). Partly as a consequence of this, and partly because of non-uniform hare distribution, the observed density of hares relative to the survey point exhibited a highly non-uniform distribution with respect to angle from road, with lower frequencies close to the road and greatest numbers being observed directly perpendicular to the road from the survey points (Fig. 6). Using perpendicular distances from the road the distribution of hare clusters exhibited a pronounced shoulder (Fig. 7).

Unlike point transect data, in which animals farther from the road are sampled with lower probability, transfield transect data provided a direct sample from the distribution of distances of hares from the road. Accounting for variation in the total length of transfield transects, the estimated density gradient obtained from both transfield transect data and point transect data combined (accounting for non-uniform angular sampling bias) suggested that the modal density of hares occurred at 130m (Fig. 8).

Table 1 *Descriptive summary of results from the long-line point transect and short-line point transect method using both the survey point or the 1km² survey square as the unit for variance estimation.*

	Long-line point transects	**Short-line point transects**	**Test of difference**
Survey points -			
Sample size (n)	4009	674	
% occurrence (95% CI)	3.29 (2.90-4.40)	4.75 (4.30-6.10)	$\chi^2_{df=1}$ =3.616, p>0.05
$\bar{x}$ detections rate ± s.d.	0.039 ± 0.229	0.047 ± 0.213	$t_{df=4681}$ =0.855, p>0.05
$\bar{x}$ relative abundance ± s.d.	0.062 ± 0.406	0.052 ± 0.241	$t_{df=4681}$ =0.602, p>0.05
1km² survey squares -			
Sample size (n)	896	140	
% occurrence (95% CI)	11.72 (11.00-13.70)	18.57 (17.80-21.00)	**$\chi^2_{df=1}$ = 5.148, p<0.05***
$\bar{x}$ detections rate ± s.d.	0.176 ± 0.575	0.250 ± 0.557	$t_{df=1034}$ =1.409, p>0.05
$\bar{x}$ relative abundance ± s.d.	0.276 ± 0.989	0.400 ± 1.162	$t_{df=1034}$ =1.350, p>0.05

* denotes a statistically significant difference
95% CIs were calculated using the RSXL Resampling Stats™ add-in for Excel© 2002

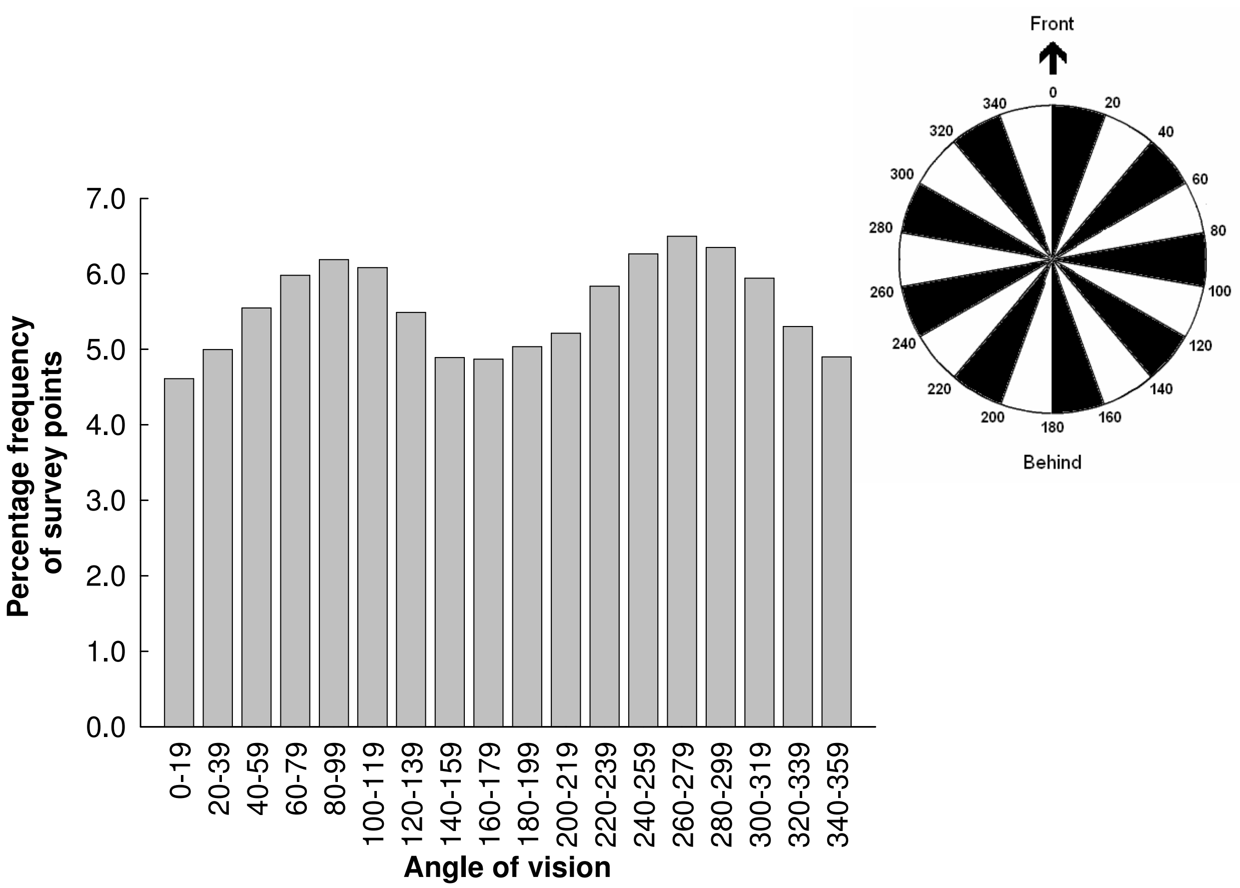

Fig. 5 *Percentage of survey points where angles were visible. Angles between 80-99° were directly perpendicular to the surveyor on the right side of the road and angles between 260-279° were perpendicular to the surveyor on the left side of the road (see insert).*

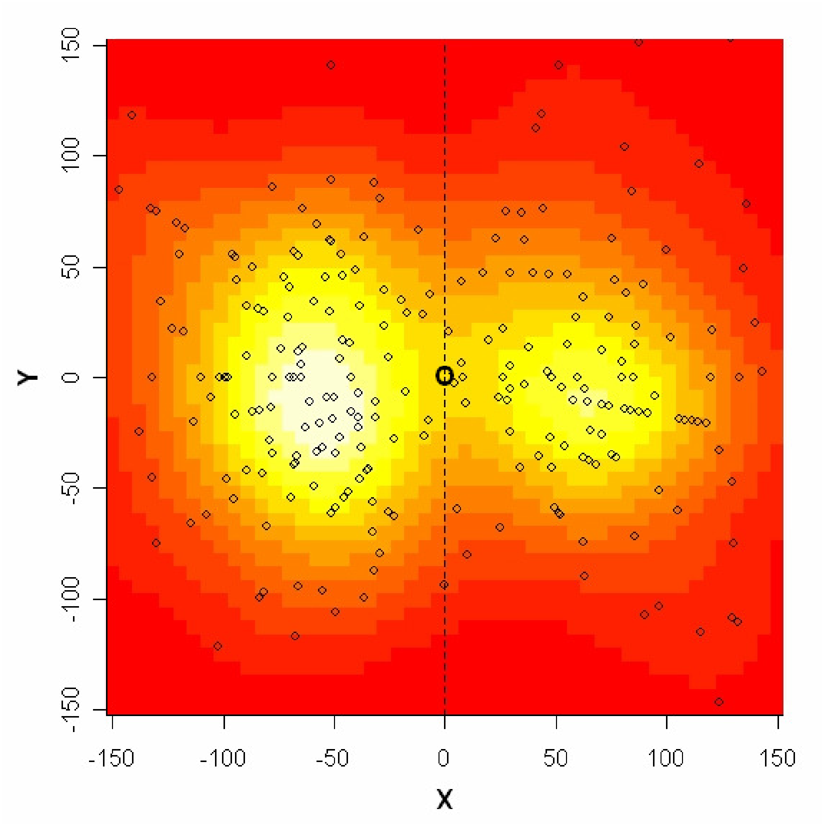

Fig. 6 *The positions of detected hares (small open circles) relative to the survey point (bold open circle at 0,0) and the road (dashed line). The intensity of colour is a smooth representation of the density of hare detections in space, with highest relative densities being white and lowest being red. Note that if the assumptions of conventional Distance sampling had been met a single hotspot of density would lie directly over co-ordinates 0,0.*

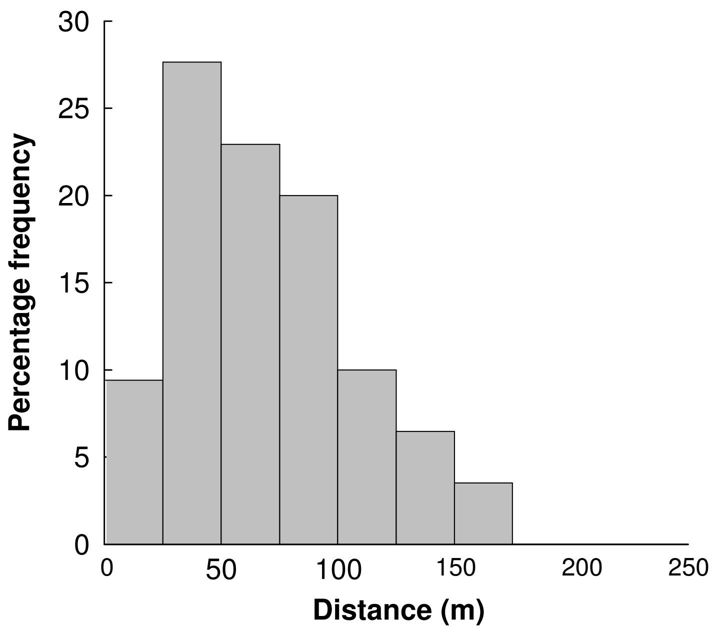

Fig. 7 *Frequency of distances of hare clusters measured perpendicularly from the road.*

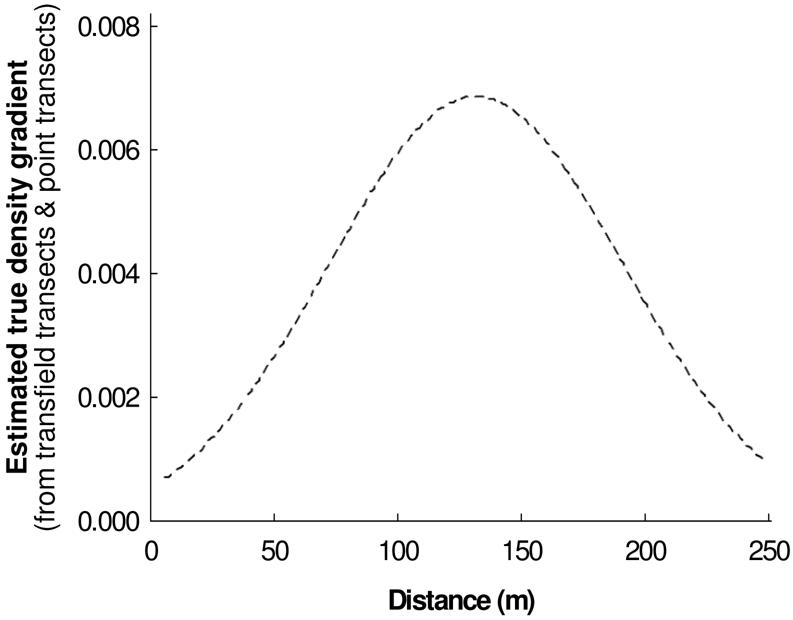

Fig. 8 *The estimated density gradient derived from the joint effect of on-road point surveys and walked transfield transect surveys considered together. Note modal density occurs at 130m from the surveyor.*

The customised Distance-sampling analysis estimated the parameters of both the detection function and density gradient of hares, while simultaneously accounting for the non-uniform angular sampling bias and the observed non-random distribution of hares relative to the road. Accounting for these sources of potential negative bias, the estimated mean pre-breeding density of Irish hares in Northern Ireland during 2007 was 7.99 hares.km^{-2} (95% CI 4.18-14.46) giving a total abundance of 113,200 hares (95% CI 59,300-204,800). The 95% confidence intervals for the estimates from both the long-line and short-line conventional Distance-sampling analyses overlapped substantially with those from the customised Distance-sampling analysis. Nevertheless, the estimated mean density of Irish hares in Northern Ireland during 2007 was considerably greater after sources of negative bias were accounted for than when they were ignored. Failing to account for such biases may underestimate the real density of hares by up to 50%.

Discussion

Distance sampling provides robust estimates of absolute abundance only when the study population and survey design conform to the key assumptions of the analyses.

Conventional Distance-sampling analysis of standard long-line point transect and short-line point transect data provides similar estimates of mean hare density. The long-line point transect method yields a marginally smaller 95% confidence interval. However, 8 times more survey effort was invested in the long-line point transect method. The additional investment of survey effort is not out weighed by a proportional increase in the accuracy of the density estimate.

Conventional Distance-sampling analysis assumes that each sample point is independent; this is not the case as points placed on the same transect (whether 1km or 100km in length) are statistically related. To overcome this problem the custom Distance-sampling analysis assumed that the survey square, not the survey point, was the unit for variance estimation. Consequently, conventional analysis of the long-line point transect method was based on 4009 related samples over 8 independent transects whilst custom analysis of the short-line point transect method was based on 140 truly independent samples. Furthermore, the short-line point transect method provided significantly higher occurrence of hares distributed over a greater and more representative geographical area.

Previous research demonstrated that surveys of hares conducted from roads do not conform to the assumptions of distance-sampling with biased estimates the likely outcome (Tosh *et al.*, 2004; Tosh *et al.,* 2005; Hall-Aspland *et al.* 2006; Reid *et al.* 2007a; Reid *et al.* 2007b). To overcome potential sources of negative bias we developed novel field survey techniques and innovative analytical solutions to the challenges of hare surveys (Marques & Borchers, 2006; Paxton *et al.*, 2007). The level of detail and analysis is, however, rather involved because many of the central assumptions of distance-sampling theory are broken by point surveys of hares conducted from roads. Assumptions relating to measurement of distances and angles were fully met. Critically, however, hares do not distribute themselves uniformly with respect to field boundaries, in this case roads. Furthermore, hedges both in front and behind of the surveyor obscured vision in the portions of the point transects immediately adjacent to the road. Previous researchers have dealt with these biases by left truncation and/or grouping animal detections into bins. Whilst these techniques are commonly applied they are inadequate for dealing with the major biases identified here and would have resulted in yet more flawed estimates of hare abundance.

Despite the analytical complications of working from roads, spotlight counts from minor roads is the only realistic way of surveying enough land to obtain the minimum number of sightings required to estimate density with some degree of precision. In Ireland, particularly rural areas, both road density and traffic volumes are low, especially at night, and recent radio-tracking experience suggests that minor roads were neither avoided nor used preferentially by Irish hares during either the day or night (Neil Reid, pers. obs.). It seems likely that the avoidance behaviour observed was in reference to field boundaries due to predation threat from foxes, rather than roads in particular. However plausible this argument may be, the calculation of hare density and abundance using the custom Distance-sampling analysis based on surveys within the area either side of roads rests on the untested assumption that the density of hares in this strip is not significantly different from that in the wider countryside. If this assumption is wrong, and hares genuinely avoid roads with greater densities beyond the area surveyed, the density estimates provided by the custom analysis will remain negatively biased.

If the underlying assumptions of the custom Distance-sampling analysis of the short-line point transect methodology hold, and we assume that there are no major sources of negative bias remaining, the abundance of Irish hares in Northern Ireland is approximately twice that provided by conventional survey and analytical methodology. The relatively large confidence interval associated with the short-line survey methodology is likely to be a result of low sampling effort. Despite the likelihood that previous surveys of hare density contain substantial negative bias, the interannual fluctuations identified are likely to reflect genuine change in the hare population (Fig. 4). Interpretation of short-term changes should be made in the context of long-term time-series.

The new field survey and analytical techniques developed here represent a substantial improvement in the estimation of absolute hare density. The current estimated density of 7.99 hares.km^{-2} (95% CI 4.18-14.46) in Northern Ireland is entirely consistent with the estimate for the Republic of Ireland during 2007 (7.66 hares.km^{-2}, 95% CI 4.83-14.29; Reid *et al.* 2007b). Irish hare densities have been reported to range from 0.65-126.6 hares.km^{-2} (Jeffery, 1996; Fairley, 2001; Dingerkus & Montgomery, 2002), with the current estimate being comparable to that recorded on mixed farmland during winter in Kildare (6.8 hares.km^{-2}; Whelan, 1985). The estimated abundance of hares in Northern Ireland taken together with the results of the Hare Survey of Ireland 2006/07 for the Republic of Ireland (Reid, *et al.* 2007b), suggest that there were 649,000 hares (95% CI 432,000-1,198,000) in Ireland as a whole during early 2007.

Recommendations

The aim of future monitoring should be clarified prior to the adoption of a particular survey strategy as there are major implications for cost and analytical complexity. If the main aim of future monitoring is to produce accurate estimates of hare density, a methodology that provides widespread coverage with a large number of statistically independent replicates is essential. A custom Distance analysis that accounts for sources of potential negative bias, similar to that detailed here, will be necessary if results are to be reliable. Furthermore, adoption of a short-line point survey methodology with a greater investment of survey effort would provide results comparable to those provided by the Hare Survey of Ireland 2006/07 in the Republic of Ireland (Reid *et al.*, 2007b) allowing the conservation status of the species to be assessed at an All-Ireland scale consistent with the aims of the All-Ireland Irish hare Species Action Plan (Anon, 2005). If, however, the main aim of future monitoring is to establish temporal trends in population change, repeated standardised surveys, such as those already developed in Northern Ireland, are adequate to provide an index of change in hare numbers over time.

One compromise may be to deploy the standard Northern Ireland hare survey long-line point transect methodology annually with occasional surveys utilising a short-line point transect methodology and custom Distance analyses synchronous with the deployment of hare survey effort in the Republic of Ireland. This would allow temporal change in the hare population of Northern Ireland to be described annually punctuated by occasional reference points of estimated density, both regionally and at an All-Ireland scale.

Conservation policies, such as the Irish hare SAP, would benefit from revision at regular intervals to account for emerging scientific information regarding the biology and status of the species. The success of conservation strategies in increasing the Irish hare population should account for natural variation and periodicity exhibited by the species (Reid *et al.* 2007b). Care must be taken not only to establish realistic conservation targets, with some supportable means of achieving these, but also to ensure that the success or failure of SAP measures can be properly evaluated.

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