Pilot study

Detecting changes in deer numbers in space and time

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Abstract

- Red deer in the highlands represent an important case study on the role of human activity on the range use of wild animal populations.
- Before embarking on a larger study of this issue it is necessary to investigate whether available management information can be used to detect changes in deer distribution and culling patterns.
- This pilot study focused on North Chesthill Estate and its immediate neighbours in the North Sub Group of the Breadalbane Deer Management Group (BDMG).
- North Chesthill Estate is especially of interest since it is ringed by four Munros that are popular with hill walkers and it encompasses a SSSI. This area is also subject to a Section 7 agreement to reduce grazing pressure on these priority habitats. The combination of these elements has led to conflicts between the legitimate objectives of landowners and the public benefits these landscapes provide.
- We collated historical count and cull data and analysed this to a) assess trends over time in deer numbers and their spatial distribution; b) investigate the relationship between deer and sheep numbers, and patterns in deer habitat preferences across the study area; c) compare observed counts against predictions from deer population models informed by reported culling levels; and d) compare observed deer density against predictions from a GIS based habitat preference model (DeerMAP) using the count data.
- Deer numbers have been increasing over the study area. Within North Chesthill, distributions of stags and hinds have changed, and stag (though not hind) numbers have clearly declined. Whilst North Chesthill has maintained its sheep flock, neighbouring estates have considerably reduced their flocks over the last 14 years.
- Distribution maps indicate that deer are increasingly recorded on lower slopes and on the margins of the study area. This may be in response to the reduction of sheep, allowing deer access to grazing areas previously used by sheep. In addition, there is some evidence that deer are making more use of heather moorland although the data are inconclusive.
- Within North Chesthill, culling has increasingly taken place on the Western and Eastern beats since 2007, whereas culling rates in the central area have fallen.
- Given the observed cull and count data, and using reproduction and mortality rates from the literature, predictions from the deer population dynamics model indicate that, across the study area, the population should be in decline; in contrast, counts remain high. However, within North Chesthill, the models predict a stable but higher than observed population for the western sub-area indicating that, given the parameters used, there should be more deer on this beat.
- The analysis of the available management information has provided some evidence for changes in deer distribution over time, although it is not possible to determine what has caused these changes. Whilst it is plausible that sheep removal may have been one factor, it remains to be tested whether hill walking throughout the year, especially in summer and autumn, may also lead to changes in stag distribution on North Chesthill.
- Given these results, a further study is required to provide evidence to inform the conflict between recreation and sustainable wildlife management. The study should be explicitly designed to test how hill walkers and livestock management influence deer range use and the consequences for managing these habitats.

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4. Introduction

The highlands are an iconic feature of Scotland; the open moorland and mountain landscapes are valued and enjoyed by both residents and visitors. These landscapes also provide the resources for a range of activities such as hill farming, deer stalking, game birds, forestry and fishing, which support the economy in these rural areas. In recent years, a number of drivers of change have affected deer management in the uplands. These broadly fall into three areas. First, there has been an increasing policy emphasis on managing grazing impacts, especially for priority habitats. This has led to pressure to decrease large herbivore densities. The deer population in Scotland has increased in recent decades for a number of reasons, not least because of a reduction in winter mortality due to less severe winters (Irvine, et al., 2007). Furthermore, the introduction of Single Farm Payment has led to a reduction in the density and distribution of sheep in the uplands (Waterhouse et al, 2008[2]; Irvine, 2011) and, coupled with grazing management plans under Section 7 of the Deer (1996) Act, has led to a decrease in wild and domestic herbivore densities in some areas. Second, culling and fencing associated with increased woodland planting has affected deer numbers and distribution. Third, trends in recreation coupled with the Land Reform (Scotland) Act 2003 have led to increasing numbers of people accessing rural areas to walk in the mountains. These changes have led, in some cases, to conflicts between the legitimate objectives of landowners and the public benefits these landscapes provide.

This pilot study is intended to identify whether available management information on deer and sheep numbers can be used to detect changes in deer distribution and cull numbers. This represents a preliminary step in developing further research on the impact of human activity on the range use of wild animal populations. The study area is a highland estate in Perthshire and the immediate neighbouring land holdings. This area attracts hill walkers because of a number of Munros on the properties. Here, we use historical count and cull data, as well as habitat maps, to assess trends in abundance, culling levels, distribution and habitat preferences of red deer (*Cervus elaphus* L.) across this area. Specifically, the main objectives were to i) collate the available red deer cull and count data and analyse trends in numbers over time, ii) correlate changes in sheep numbers with deer count information, iii) compare observed population trends against models that predict population size based on the cull and count data and iv) use a GIS based deer habitat preference model to explore how the preferred areas of deer range compare with observed deer distributions. Evidence that deer range use departs from expected patterns is discussed in relation to potential causes that may include changes in sheep numbers, increase in recreational users and deer management activities such as supplementary feeding.

The study area consists of a number of estates, which are part of the Northern sub-group of the Breadalbane Deer Management Group (Figure 1).

[2] http://www.sruc.ac.uk/info/120484/support_to_agriculture_archive/54/2008_farmings_retreat_from_the_hills

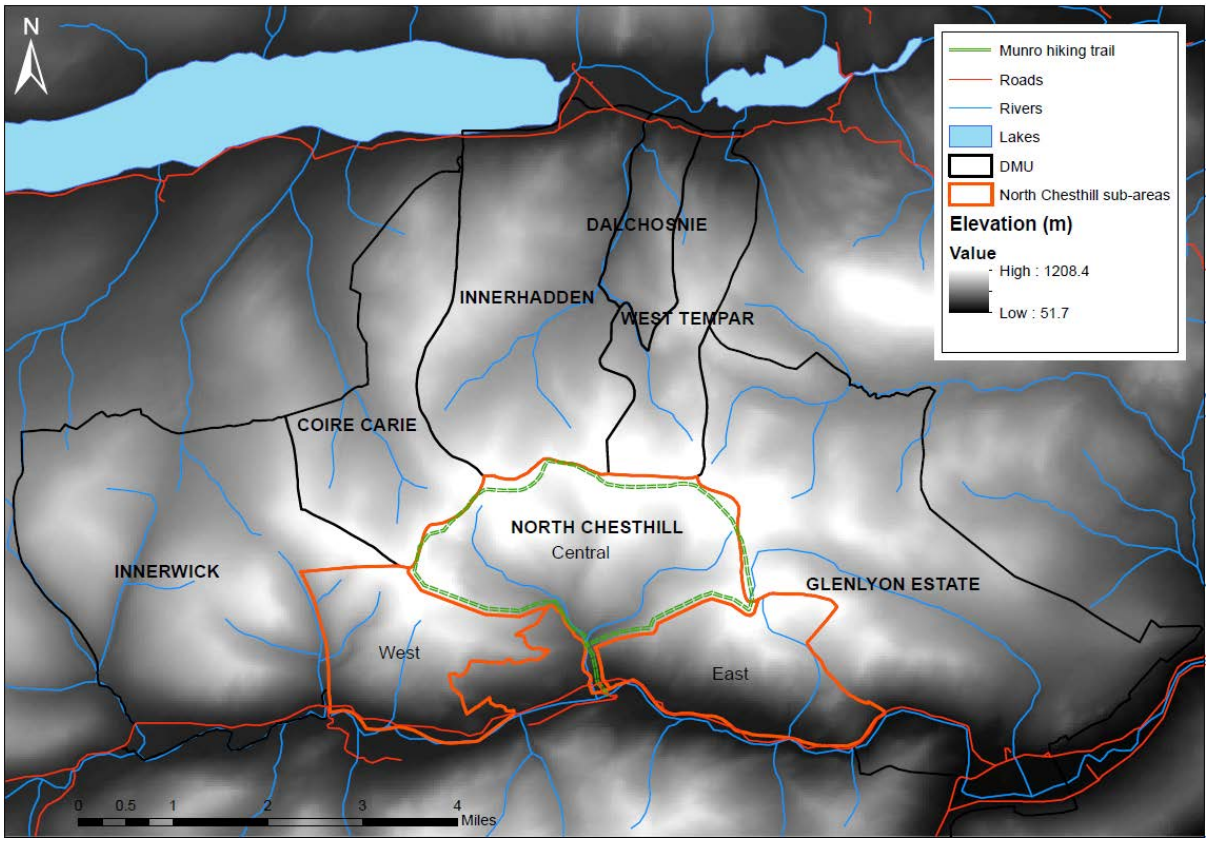


Figure 1: Study area. The southern boundary of the selected area (DMU) is assumed to be an effective barrier due to a combination of the road, river and deer fencing along the valley bottom.

The central estate is North Chesthill (2750 ha or 23% of the study area) and is bordered by Glenlyon (25%), Innerwick (20%), Innerhadden (14%), Coire Carie (9%), West Tempar (6%) and Dalchosnie (3%). The organisation of DMG into sub-groups reflects local knowledge on what is generally accepted as discrete sub-populations of red deer that inhabit the Breadalbane Deer Management Group (BDMG). Whilst stags range over all of these areas, hinds are believed to remain mostly in the same sub-group.

North Chesthill estate management objectives include sheep and cattle farming, fishing, deer stalking, forestry and game birds. The estate encompasses the greater part of the Carn Gorm and Meall Garbh SSSI, a site designated for its montane habitats and the species of nationally rare arctic-alpine plants growing on the summits. This area is subject to a Section 7 agreement which has led, in particular, to a reduction in sheep numbers to reduce the grazing pressure on these priority habitats. Of particular relevance to this project is that the property is ringed by four Munros very popular with hill walkers (Clements, 2014): Carn Gorm, Meall Garbh, Carn Mairg and Meall na Aighean. Although the Land Reform (Scotland) Act 2003 was enacted only recently, unrestricted access to land for recreational purposes is a long-standing tradition in Scotland. Informal counts of vehicles parked at Invervar attests to the popularity of the area. During summer weekends, there are often between 10 and 17 cars and even some minibuses. In recent years, the increasing popularity of hill walking has come into conflict with deer management and stalking

activities, especially during the stag stalking season, from 1st July to 20th October (but mostly September and October). Hinds are stalked later, from 21st October to 15th February. There is very little supplementary feeding for deer in the study area. A few mineral blocks are provided and there are some feeding sites on Meggernie and Lochs, both located beyond the western boundary of our study area (Clements, 2014). Glenlyon used to provide winter feeding for stags between 2003 and 2008 because of the very poor conditions of the deer and the very few mature stags due to the shooting regime in previous years (pers. comm, Iain Wotherspoon of Glenlyon estate).

Within the DMG, North Chesthill is the only estate farming sheep, with a flock of about 950 ewes and gimmers. In winter they congregate on the lower part of the hills to seek refuge from the weather, but they disperse to higher altitude to graze in the spring and summer and range onto neighbouring land. Neighbouring estates used to keep sheep but these are now largely absent. Despite the potential competition for grazing between deer and sheep, North Chesthill estate maintains a sheep flock to diversify their source of revenue and to compensate partially for the increasingly difficult deer stalking (Lockett, 2014).

5. Methods

5.1 Counts, culls, habitat and geographical data.

- Counts

There are four years since 1987 when deer counts are available. In 1987 (17-23 February) and 1999 (19 January) counts were made on foot. In 2008 (1 March) and 2011 (17 March) counts were carried out by helicopter. The James Hutton Institute (JHI) and Scottish Natural Heritage (SNH) supplied the georeferenced data. Because the 2008 count only classified stags, we estimated the hind and calf numbers based on the ratio in the same data categorized by age and sexes in another database supplied by JHI. Thus, the total number of stags, hinds and calves for 2008 per estate is right, but their exact spatial distribution is unknown.

Further counts from March 2002, 2004, 2006 and November 2012 do not have accompanying spatial data, apart from an indication of the estate on which the deer were observed. Consequently, it is impossible to use this data to investigate factors such as habitat preference. Data from 2012 were proportionally distributed among stags, hinds and calves since hinds and calves were not classified (as in the 2008 data). In addition, deer surveyed on Dalchosnie estate in 2004 were included in the count for Innerhadden. The total number was reallocated to both estates according to historical proportions (
Table 1). It is also worth mentioning that deer recorded on Slatich and Ruskich have been included in North Chesthill count as these three areas form the North Chesthill Deer Management Unit (DMU) for the purposes of recording count data.

- Cull

Paper based records for the North Chesthill stag cull were combined with hind and calf cull data that was already computer based. The cull data cover the stalking seasons from 1998 to 2013 (2014 for stags) and mostly include general locations for the culls. However, hinds and calves culled in 1998, 1999, 2000, 2001, 2002 and 2010 were not recorded with geographical information so they were distributed among the three sub-areas according to historical proportions. Additionally, the BDMG supplied estate level cull data for the neighbouring land holdings for the years 2005 to 2013.

Table 1: Summary of original count data quality.

Years	Georeferenced data	Deer classified as stags, hinds & calves	Comments
1987	X	X	
1999	X	X	
2002		X	
2004		X	Dalchosnie & Innerhadden counts reported together
2006		X	
2008	X		
2011	X	X	
2012			

- Habitat

The Land Cover of Scotland map from 1988 (LCS88) was updated in ArcGIS with the National Forest Inventory Scotland data from 2011. Since the land cover terminology is not always the same, the data have been summarized in 14 categories: arable, bracken, felled woodland, good rough grassland, heather moorland, improved grassland, montane, others, peatland, poor rough grassland, rock and cliffs, waters and woodland. Habitat information was extracted through ArcGIS.

- Geographical data

For the purpose of spatial analyses, additional information was digitized in ArcGIS from information drawn on an OS map by North Chesthill estate's owner. This included the cull locations and the paths used by hill walkers to access the four Munros. To explore range use by deer within the estate in relation to areas accessed by walkers over time, the estate was divided into three sub-areas. The central zone includes the four Munros and its boundary has been delimited as the edge of a 100m buffer along the path. The east and west areas are thought to be relatively unused by walkers. Shapefiles of deer fences were provided by SNH and their status as porous or deer proof was updated according to landowner knowledge. The estates boundaries used for this study are the Deer Management Unit boundaries as defined by SNH.

5.2 Red deer population dynamics model

Differences between observed and predicted deer numbers over time were determined using the *Red deer population dynamics model, open hill version 3.1* (copyright © by Forest Research, 2008). The Visual Basic model was developed as a tool to help managers assess the impact of different culling levels on deer populations. It uses specified values for fecundity and mortality (which we based on relevant literature), and accounts for recorded cull numbers. We used the model to evaluate differences between observed counts and predicted abundance. Cull data for Dalchosnie, Innerhadden and West Tempar estates are regularly reported jointly, so the pooled cull proportion for these three estates was used for the individual model runs.

The population model was run for each estate separately, for the sub-areas of North Chesthill, and for the entire study area. Initial population size was taken from the 1999 count (no cull data were available for the 1987 count year). The model then predicts the population size each year for the following 10 years. The predictions were run a second time starting from the 2004 count and a third time starting from the counts in 2008.

The reproduction rate for a low performance population was set at 0.391 for hinds aged 3 or over (Ratcliffe, 1987), which was deemed reasonable since the average calf-hind ratio calculated on the count data is 0.326. The over-winter survival rate for a low performance population is 0.77 for calves, 0.97 for deer aged 1 or over (Ratcliffe, 1987) and 0.2 for deer aged 9 or over. The calf sex ratio was assumed to be 1:1, which is supported by the limited available cull data in which calf sex is recorded.

5.3 DeerMAP

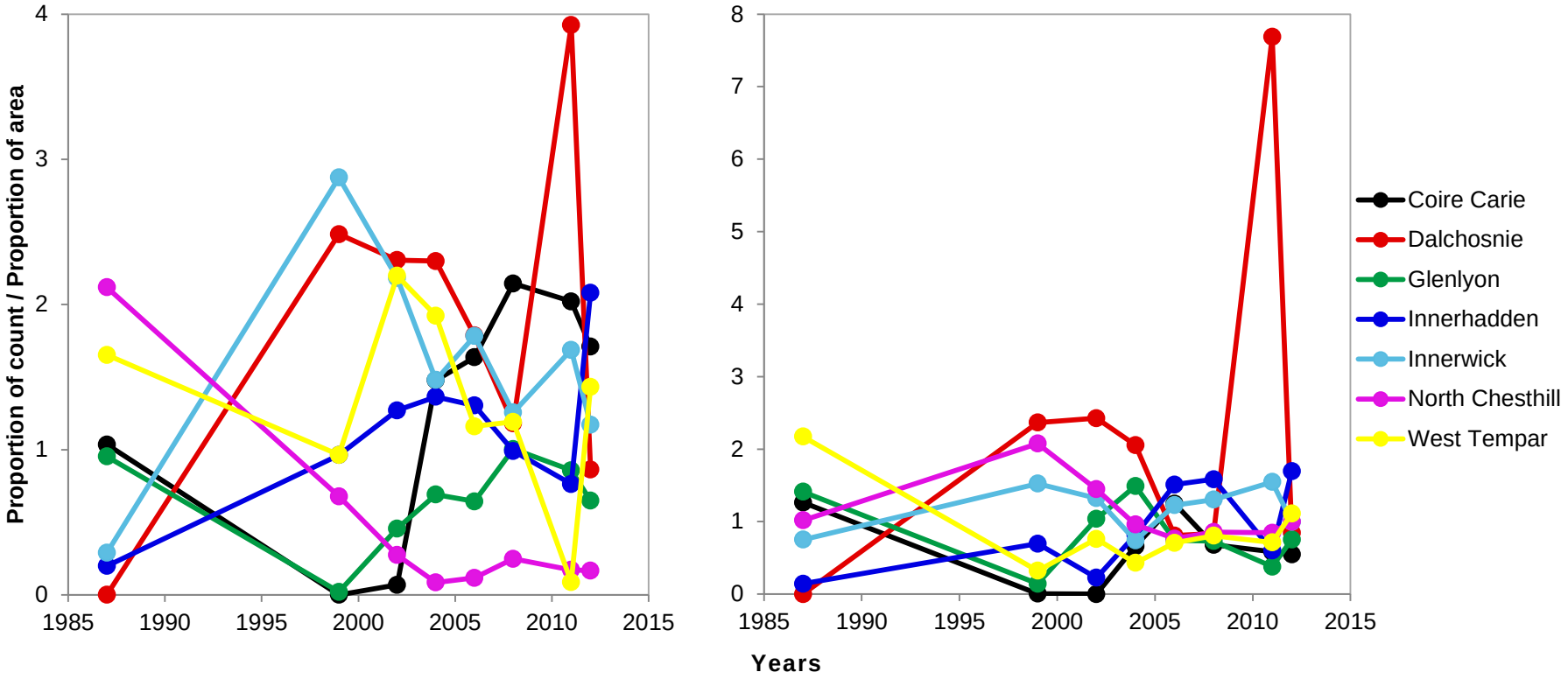
DeerMAP (*Deer Movement and Abundance Predictor*) is a model run in ArcGIS to produce maps of predicted red deer distribution depending on habitat (forage and shelter), topography, fenced areas, paths and weather conditions (Irvine, et al., 2009). DeerMAP predicts deer distribution for both summer and winter for stags and hinds, producing maps to show where deer would prefer to be, given habitat characteristics. Differences between these predictions and observed distributions may indicate that unmodelled factors are influencing deer range use.

6. Results

6.1 Deer counts

For the purpose of our analyses, hinds and calves were plotted separately from stags as the two groups occupy different areas in winter. The overall stag count for this group of estates has increased from 139 to 997 with a peak at 1123 in 2011. Hinds and calves have increased from 1253 in 1987 to 2241 in 1999. In subsequent years, the counts fluctuate between 1611 and 1831 except in 2006 when the count was 1323. The consensus in the BDMG is that the population was growing, especially in the North sub-group, until 2011-2012 (Clements, 2014).

The count data were plotted against time and displayed as a relative density (proportion of all the surveyed deer that were counted on an estate, divided by the proportion of the study area covered by that same estate). A value of 1 indicates that an estate holds a share of deer proportional to its size. Only North Chesthill shows a decline in the relative stag density without any sign of recovery (Figure 2). The general trends observed on each estate for hinds and calves are similar and the proportions for North Chesthill have remained more constant.



a.Stags b. Hinds and calves.

Figure 2: Stags (a) and hinds and calves (b) relative density per estate from 1987 to 2012. The relative density is expressed as the proportion of deer divided by the proportion of the study area. A relative density of 1.0 suggests that the estate has a share of the overall deer population in proportion to the estate's size.

6.2 Sheep counts

Sheep ownership statistics from IACS and JAC were supplied for the BDMG (Figure 3), but since the flocks used to graze on open hills and wander a lot, the data must be interpreted with caution. In general, sheep numbers have declined in the last 14 years and there are virtually no sheep on neighbouring ground to North Chesthill now, except wanderers from further afield and from the North Chesthill flock. The remaining sheep are probably not on the open hill but on in-bye land (pers. comm, Victor Clements of Native Woodland Advice).

The drop in sheep numbers that is observed in 2003 (Figure 3) is unexplained and might reflect an artificial removal of sheep for management purposes by Glenlyon estate.

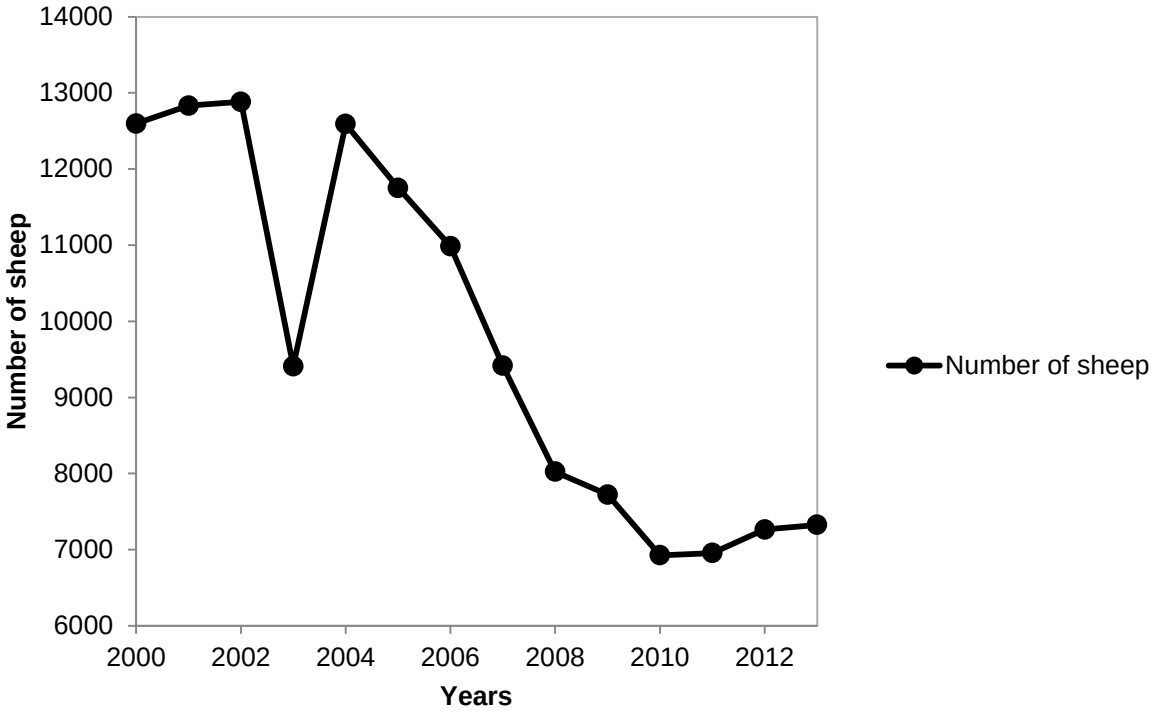
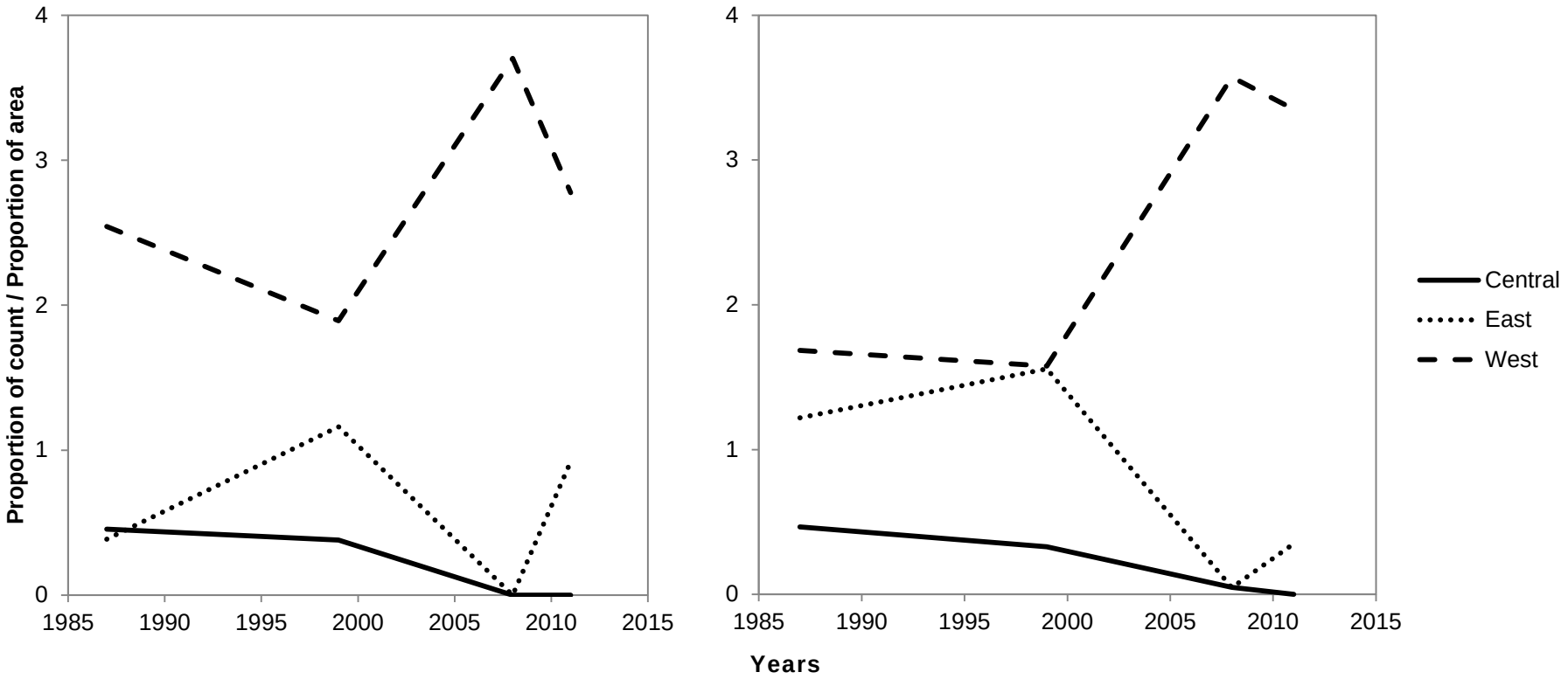


Figure 3: Number of sheep for the BDMG from 2000 to 2013.

6.3 Deer counts on North Chesthill estate.

Deer within North Chesthill are mainly found in the western sub-area of the estate in winter; this aggregation seems to increase over time (Figure 4). In the central sub-area, the winter stag count has always been low. There were 14 and 16 stags counted in the central area in 1987 and 1999, and none were surveyed in 2008 and 2011. Hind and calf counts increased from 62 to 160 before the millennium and went down to 7 and 0.



a.Stags b. Hinds and calves.

Figure 4: Stags (a) and hinds and calves (b) relative density per sub-area of North Chesthill estate from 1987 to 2012. The relative density is expressed as the proportion of deer divided by the proportion of North Chesthill estate area. A relative density of 1.0 suggests that the sub-area has a share of the overall deer population in proportion to the sub-area's size.

6.4 Deer distribution

Distribution maps of the counts show that stags were mainly reported in the centre of the different management units in 1987, but increasingly recorded towards the margins of the study area with time (Figure 5). Glenlyon has been providing supplementary feeding between 2003 and 2008, which may explain the cluster of stags in the easternmost corner of the estate. Furthermore, the observed stag distribution in winter does not correspond to what is expected according to DeerMAP. The GIS model predicts a high density in the centre of North Chesthill and another hotspot in Glenlyon, yet no stags have been seen in those areas. Most observed clusters are in zones where very few or no stags are expected to winter.

The distribution trend is similar for hinds and calves: they are evenly distributed amongst the estates in 1987, however the clusters line up in parallel with and just north of the Glenlyon river in 1999 and then concentrate in the western sub-area of North Chesthill, the southern part of Innerwick and along the border of Innerhadden and Dalchosnie (Figure 6). In contrast, the prediction maps provide a better match to the observed distribution of females and calves. Nevertheless, some areas predicted by DeerMAP to be highly preferred are devoid of deer.

Since the count data are merely snapshots of how deer were distributed on the day they were surveyed, an examination at the estate level of how the predictions compare to the actual counts reveals that, aside from the first count, North Chesthill should support more stags in winter (Figure 7). In most years, the other estates actually host more stags than expected, or numbers similar to those expected, and may be benefitting from the current drivers that affect stag distribution. That trend seems to be inverted for hinds and Innerwick invariably has more hinds than expected (Figure 8). Apparently, the southern part of Innerwick and western area of North Chesthill are favoured by hinds and calves in winter.

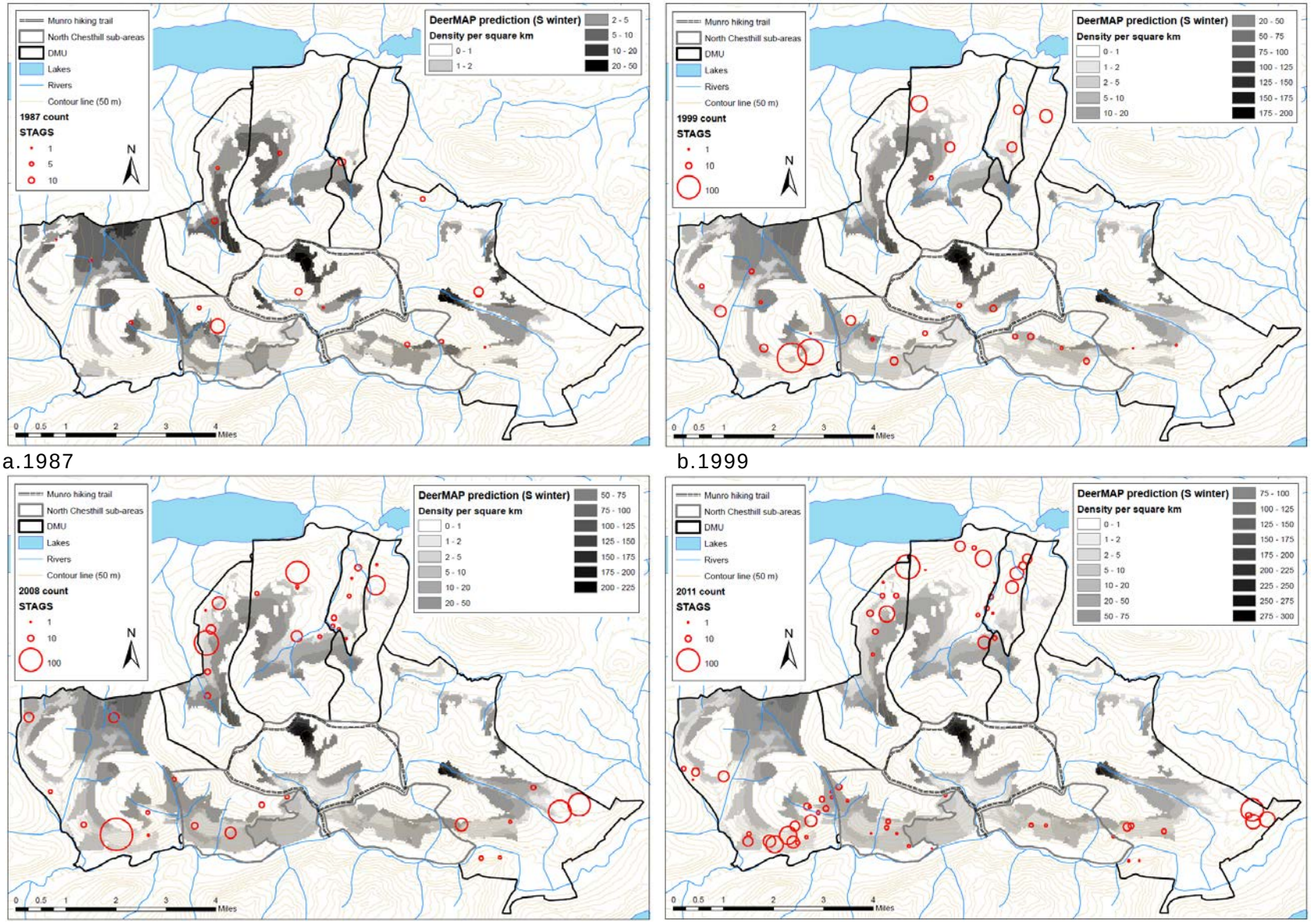
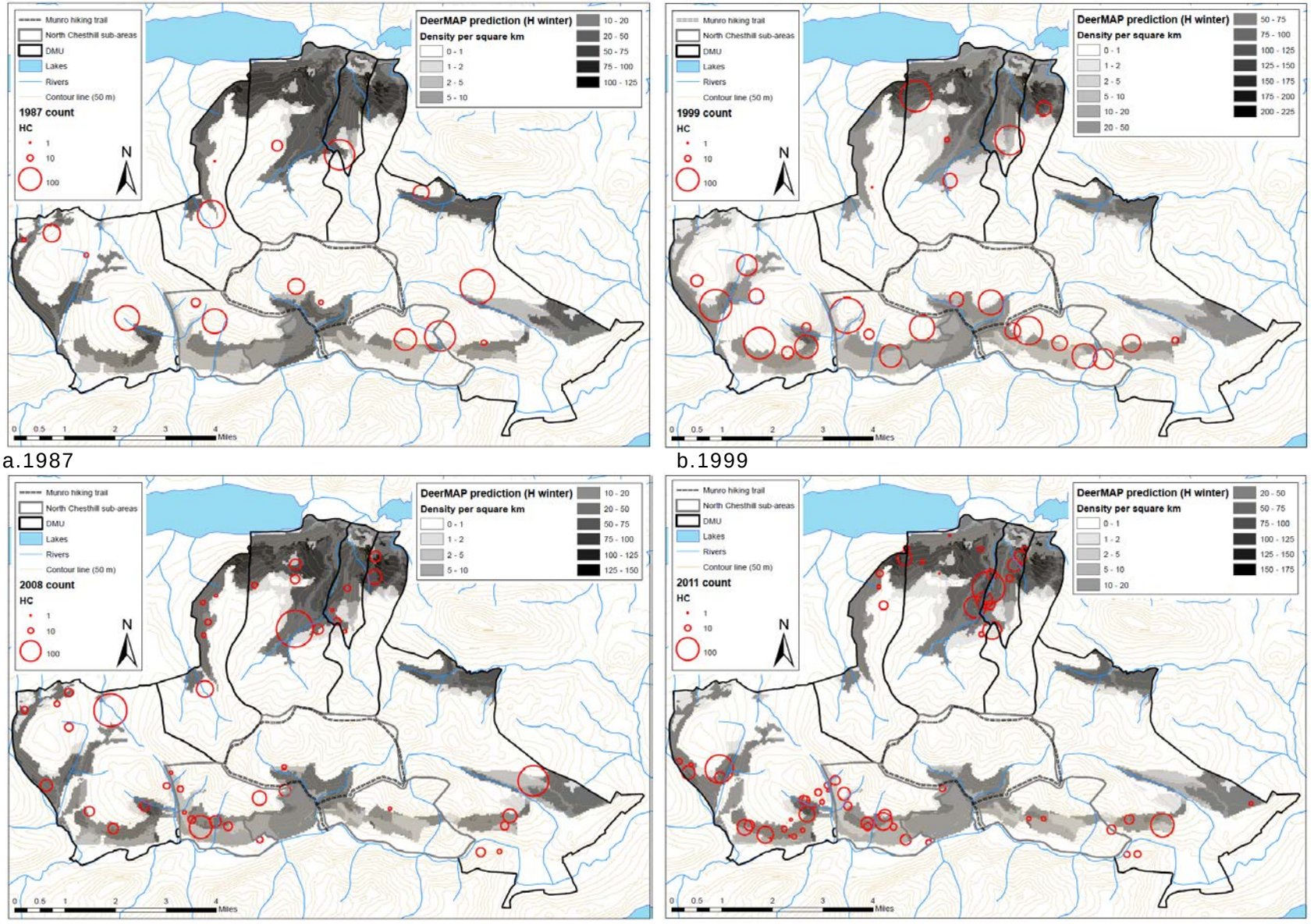


Figure 5: Stags distribution across the study area and DeerMAP prediction for winter in 1987, 1999, 2008 and 2011. Flannery appearance compensation applied and minimum value corrected to standardize symbol sizes between years.



a.1987 b.1999

c.2008 d.2011

Figure 6: Hinds and calves distribution across the study area and DeerMAP prediction for winter in 1987, 1999, 2008 and 2011. Flannery appearance compensation applied and minimum value corrected to standardize symbol sizes between years.

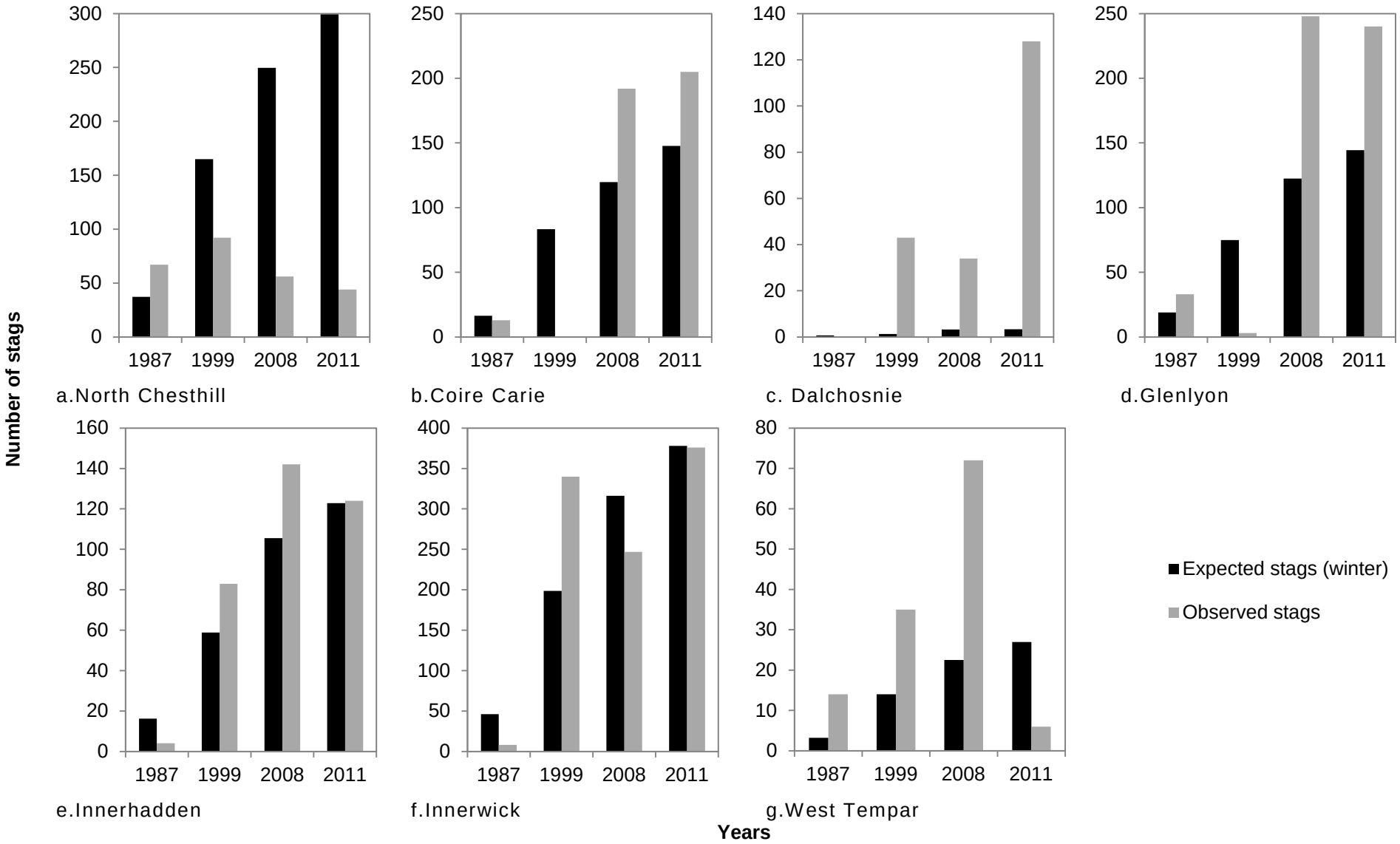


Figure 7: Expected and observed stag count per estate according to DeerMAP in 1987, 1999, 2008 and 2011.

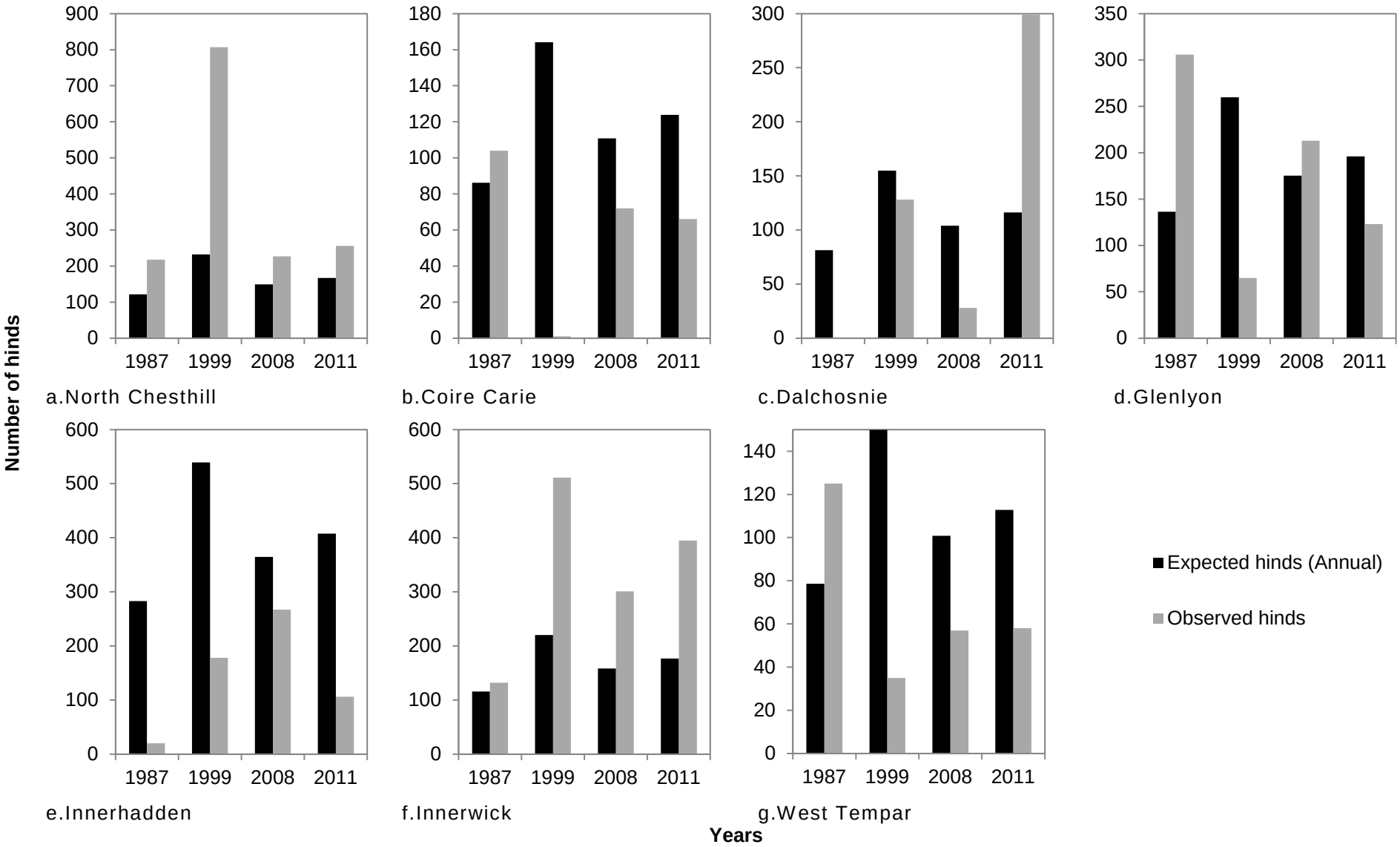
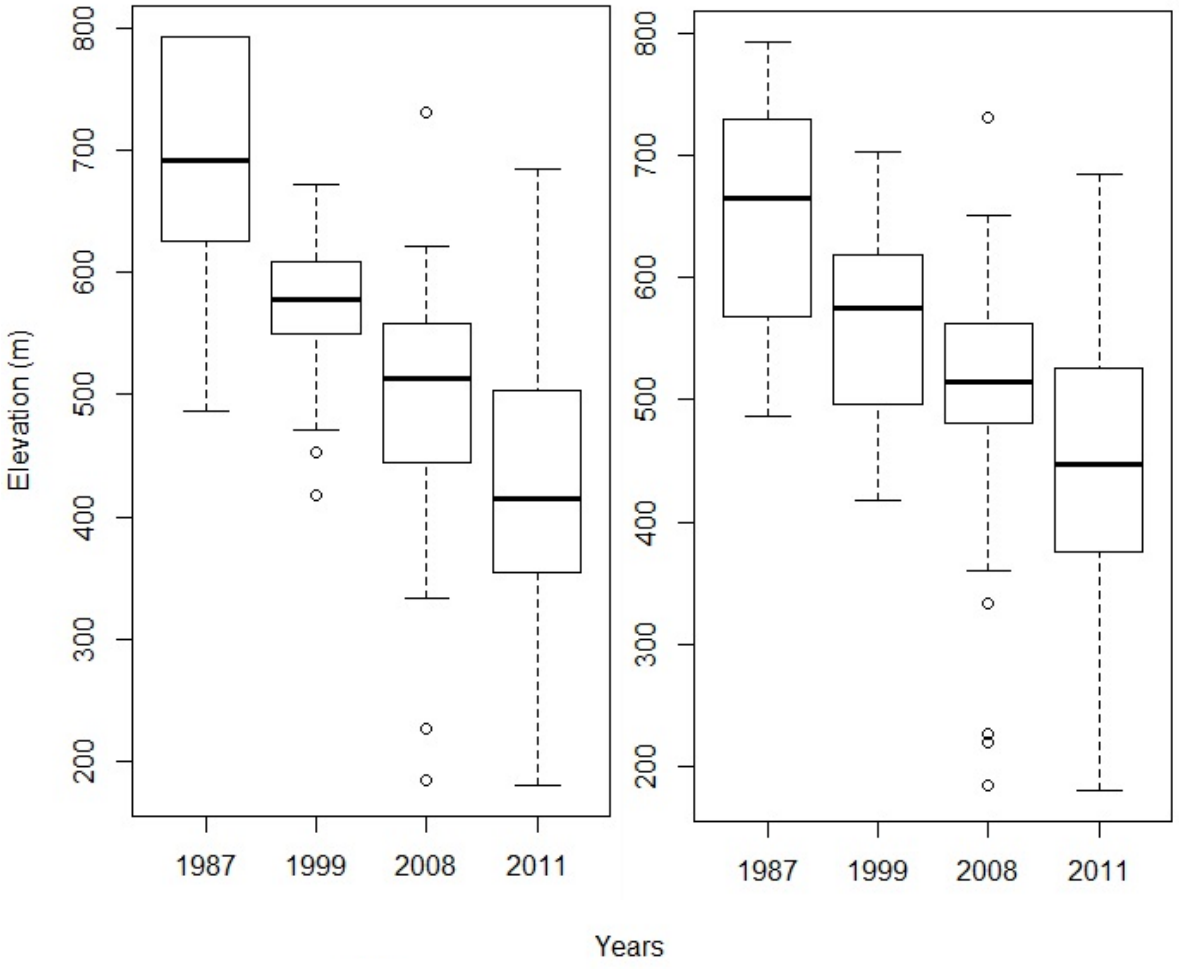


Figure 8: Expected and observed hind count per estate according to DeerMAP in 1987, 1999, 2008 and 2011.

Altitudinal distributions suggest that deer are using the hills differently with time. Although they are still found at higher altitudes, both males and females are now more commonly found on lower ground during the dates when they were counted (Figure 9).

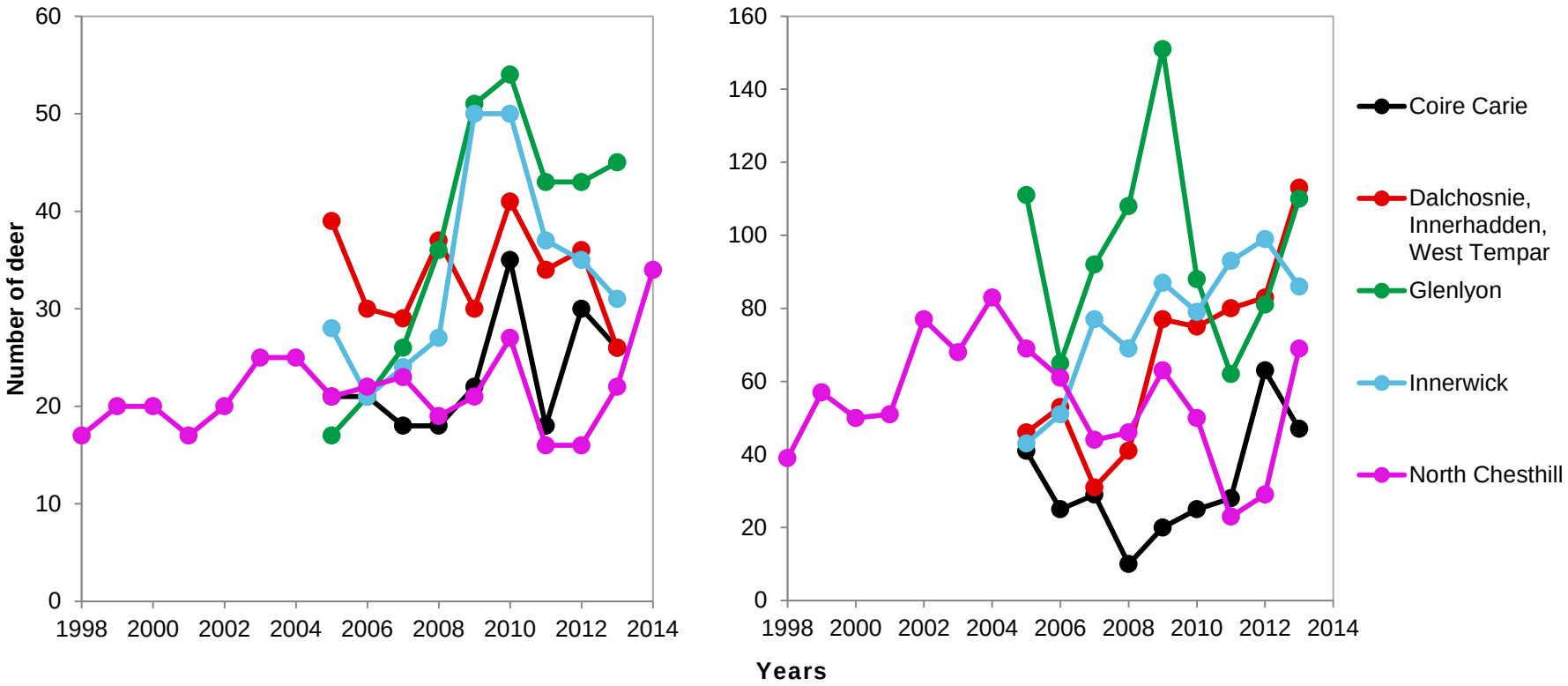


a.Stags b. Hinds and calves.

Figure 9: Elevation (m) at which stags (a) and hinds and calves (b) were counted for the entire study area in 1987, 1999, 2008 and 2011.

6.5 Cull data.

Cull data from 2005 to 2013 were available for each estate although Dalchosnie, Innerhadden and West Tempar often report their cull data together. However, North Chesthill data were also available from 1998 to 2005 (as well as 2014 for stags). There was an increase in cull numbers in 2008 and 2009 (Figure 10) consistent with the consensus of BDMG members that the population was growing at the time (Clements, 2014). The total number of deer culled in the study area has fluctuated between 115 and 207 for stags and 255 and 425 for hinds and calves.



a.Stags b. Hinds and calves.

Figure 10: Cull numbers for stags (a) and hinds and calves (b) per estate from 1998 to 2013 (2014 for stags).

Even though no count data are available to shed light on the stag distribution during the stalking season, a prediction map was produced using DeerMAP (Figure 11) which indicates that the preferred areas and therefore the highest stag densities would be expected to be on and around the summits at the centre of the study area. The hiking trail followed by most hill walkers goes through some of these areas.

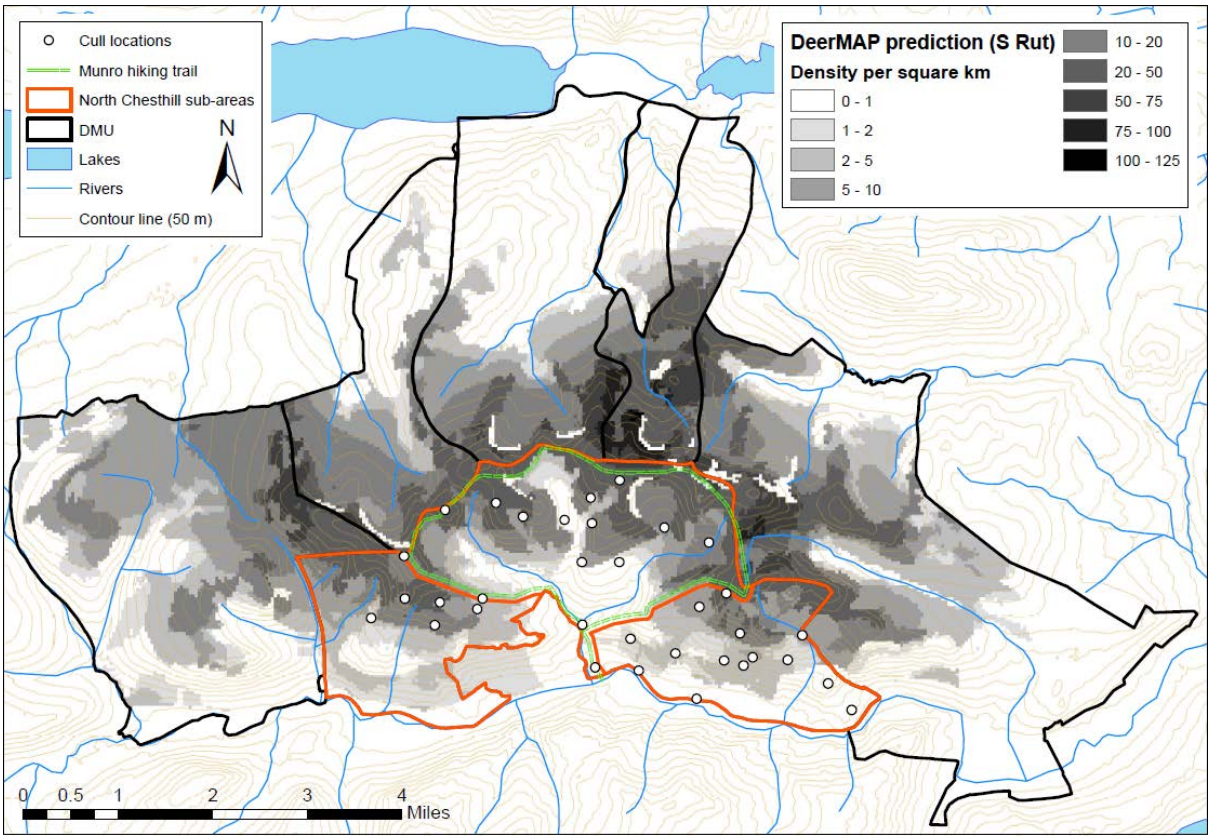
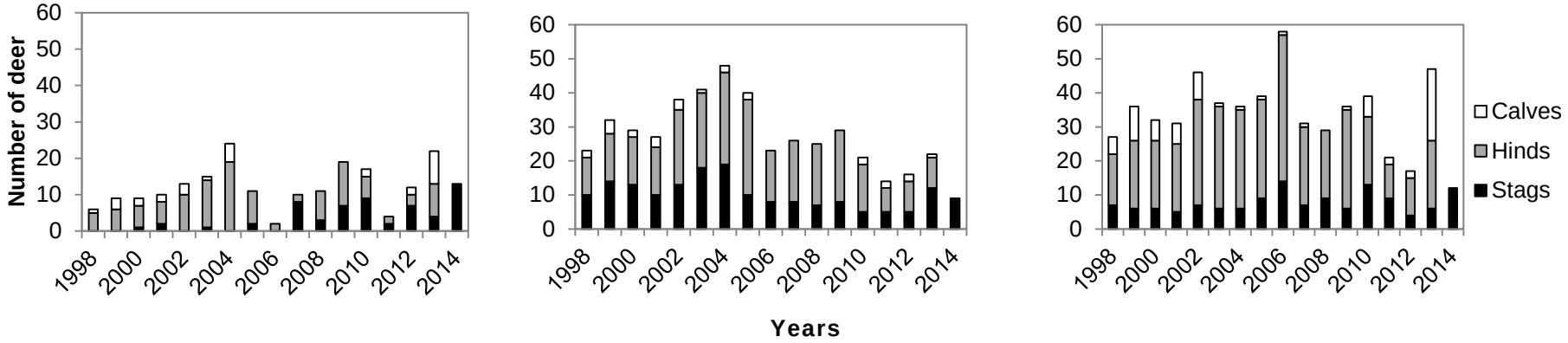


Figure 11: DeerMAP prediction of stag distribution during summer in 2011 and cull locations on North Chesthill estate.

Most stalking activities take place in the more accessible central and eastern sub-area of North Chesthill (Figure 12). Getting carcasses out of the western sub-area is logistically difficult because of the topography and because access to the road is prevented by two smaller properties (Slatich and Ruskich). Nevertheless, more stags have been culled in the western zone since 2007 than in previous years. In the central sub-area, culling has declined after four of the best years from 2002 to 2005. Stalking success has remained high in the eastern zone, except for two low years in 2011 and 2012. According to North Chesthill management, a reduction in disturbance in 2014 resulted in an exceptional stag season, which bucked the current downward trends, especially in the central area of the estate.



a.West b.Central c.East

Figure 12: Cull numbers per sub-areas of North Chesthill estate for stags, hinds and calves, from 1998 to 2013. At the time of writing, only stag data are available for the 2014 stalking season.

6.6 Vegetation data.

The study area is mostly covered by heather moorland, montane and peatland habitat (Figure 13 and Figure 14). Of the individual estates, Dalchosnie has the highest proportion of heather moorland and North Chesthill has one of the lowest. However, North Chesthill has the largest proportion of grassland at 35%, closely followed by Glenlyon at 29%. The western sub area has a variety of habitats, whereas the central area has a larger proportion of montane habitat and the eastern area has mostly good rough grassland (Figure 14). A comparison of the 1988 LCS map with the National Forest Inventory Scotland data from 2011 reveals that woodland coverage has increased by 4% for the study area. Glenlyon has increased its woodland coverage by 7%, North Chesthill 5%, Innerhadden 3%, Innerwick 2%, Dalchosnie and West Tempar 1%. On North Chesthill estate, woodland coverage increased by 1% in the western and central areas and by 17% in the east. According to the estate management, the woodland in the eastern sub-area successfully attracts deer (pers. comm, Alastair Riddell of North Chesthill estate).

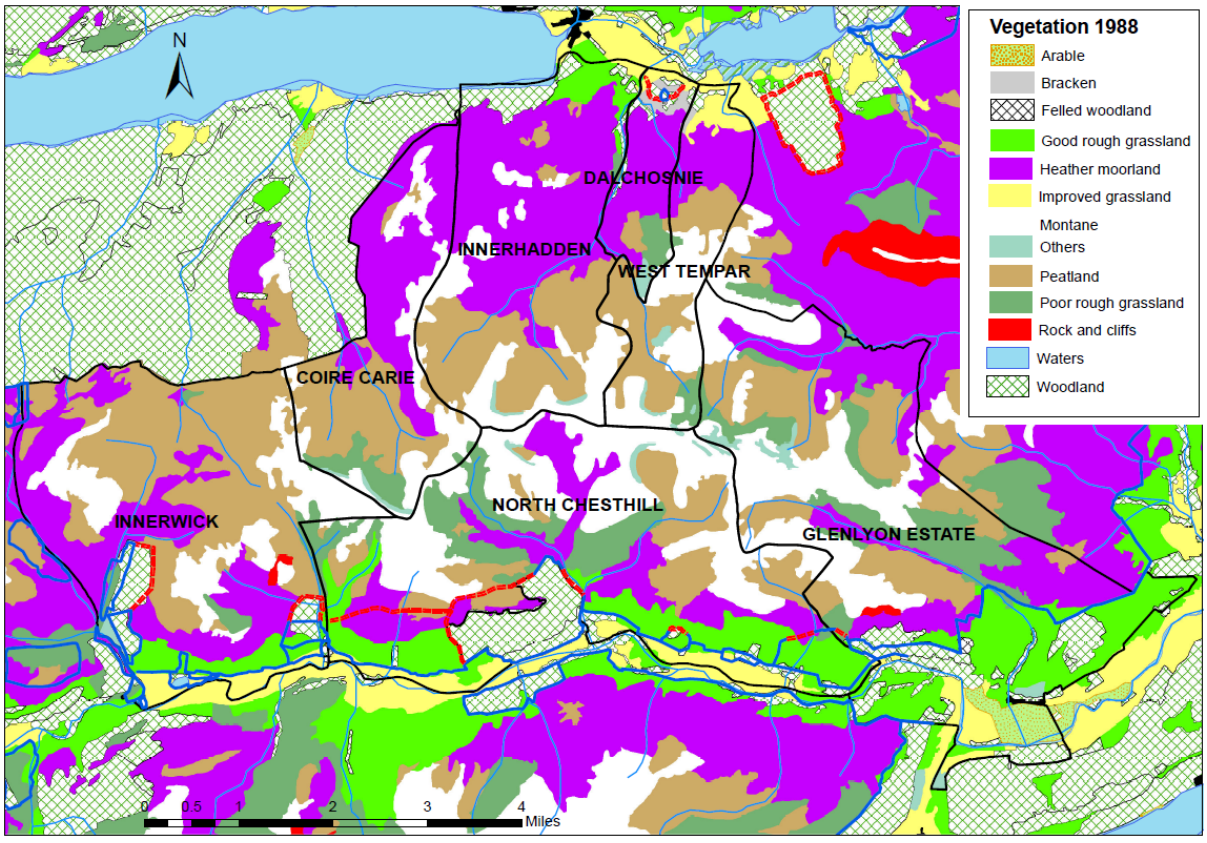
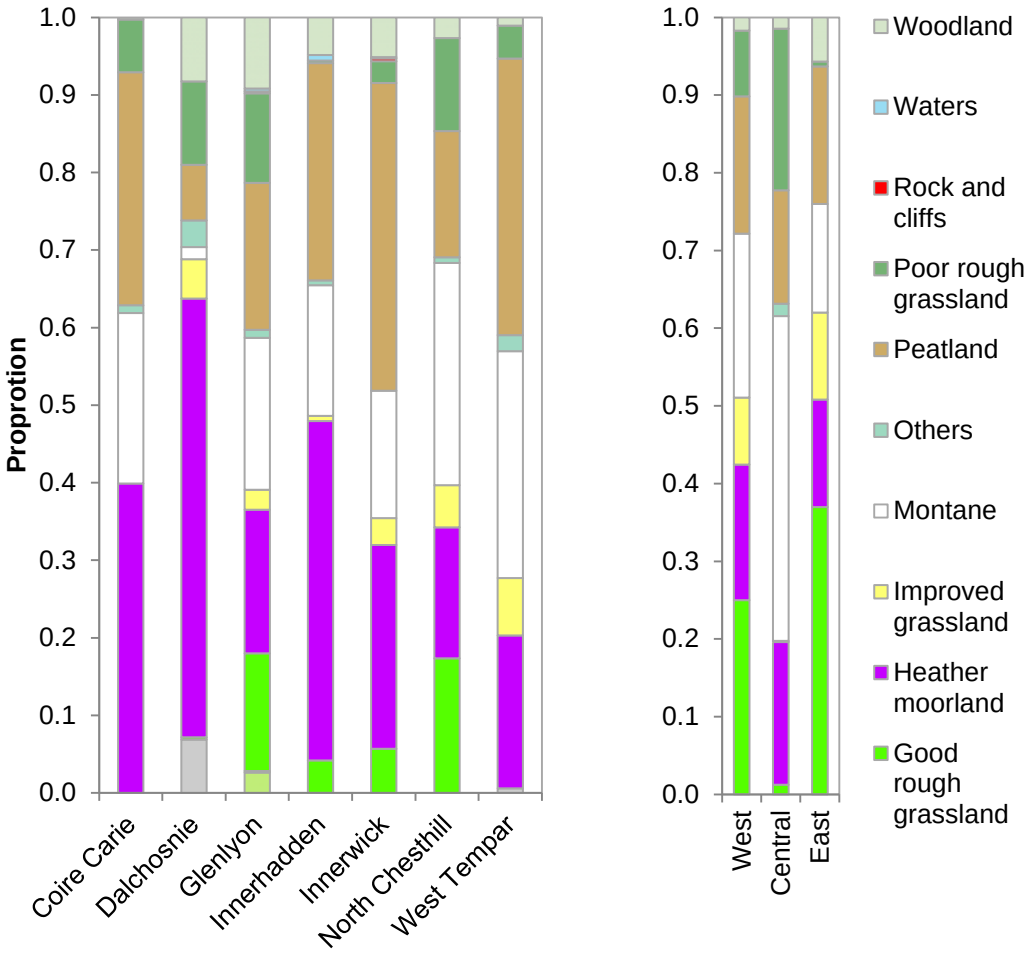


Figure 13: Land cover Scotland (1988).

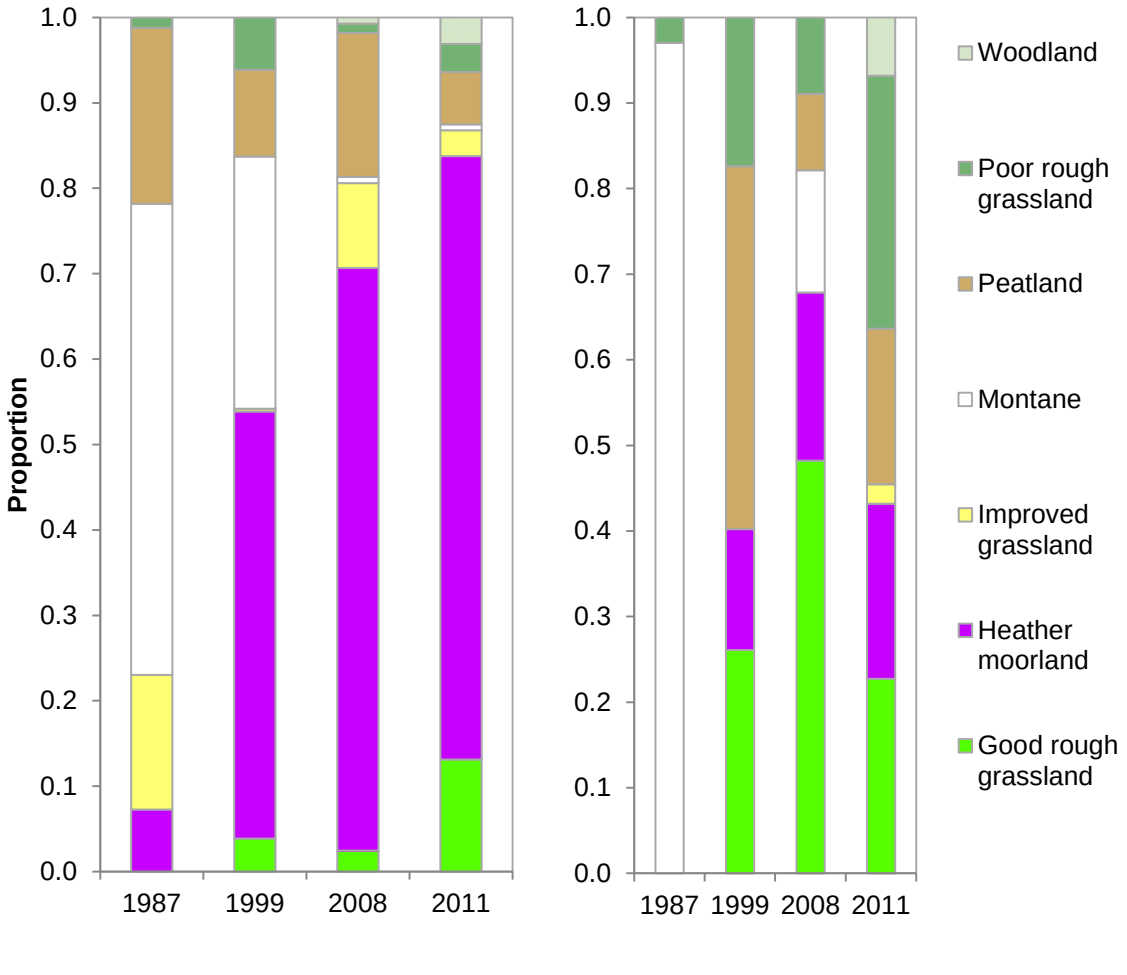


a.Estate b.North Chesthill sub-areas

Figure 14: Proportion of each type of habitat per estate (a) and sub-areas of North Chesthill Estate (b) (LCS1988).

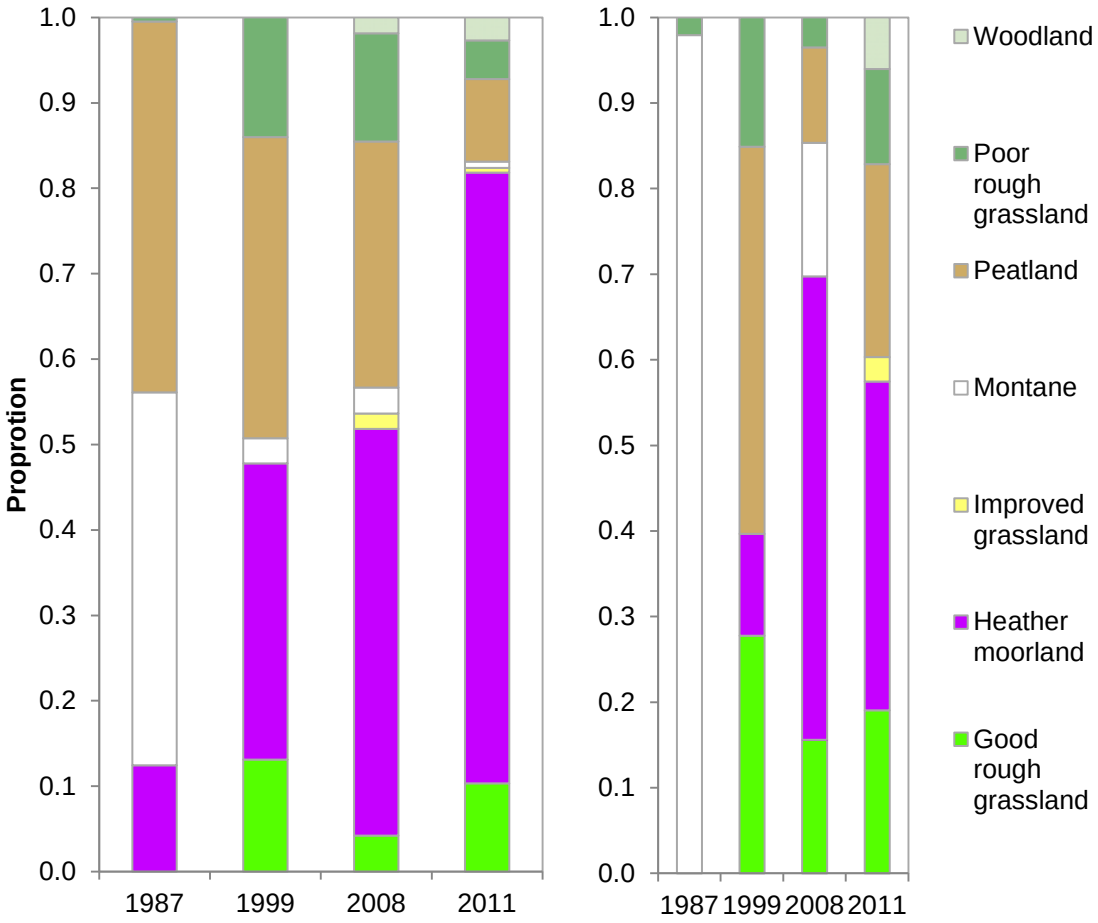
Habitat preferences were determined by extracting habitat information associated with the count locations. In 1987, stags were mainly located on montane and peatland habitat but have progressively shifted towards heather moorland and montane habitats in 1999 and concentrated in heather moorland in 2008 and 2011 (Figure 15).

Hinds and calves moved from montane and peatland habitat in 1987 towards heather moorland and peatland in 1999 and 2008 (Figure 16). In 2011, they were predominantly found in heather moorlands. On North Chesthill, both males and females were almost exclusively found in montane habitats during the first count but have been distributed in a variety of habitats since. These findings must be viewed in light of the fact that count data are very limited and several indeterminate individuals have been distributed among sex and age classes according to historical proportions.



a.Study area. b.North Chesthill.

Figure 15: Proportion of stags counted per type of habitat, for the entire study area (a) and for North Chesthill (b), in 1987, 1999, 2008 and 2011.



a.Study area. b.North Chesthill.

Figure 16: Proportion of hinds and calves counted per type of habitat, for the entire study area (a) and for North Chesthill (b), in 1987, 1999, 2008 and 2011.

6.7 Red deer population dynamics model

The outputs produced by the red deer population dynamics model (Appendix A) consistently predict that, based on reproduction and mortality rates from the literature as well as the count and cull data, the population should be declining. The exception is the western sub-area of North Chesthill, where the population should remain fairly stable. In general the observed counts are below the predictions in the western area of North Chesthill indicating that, given the culling regime and the parameters used for reproduction and mortality, there should be more deer in this area. In contrast, observed counts on the other estates are generally above the predicted population sizes, indicating that, for the culling levels applied to these areas and the likely reproductive and natural mortality rates, there are more animals in these areas than would be expected.

7. Discussion

We used the management (or operational) data on red deer populations collected by or on behalf of estates to determine if those data can be used to detect trends in deer numbers and distribution over time. The rationale for this analysis is that there is a perception among land managers that the pattern of deer range use has changed. Evidence for a change in range use is an important first step in any further studies that set out to determine the causes and drivers of change that may include human disturbance, changes in grazing livestock or habitat related changes. This study demonstrates that there have been changes in deer numbers and distribution but that these effects are difficult to interpret because of the nature of the data.

Overall, the abundance of deer increased slightly but not all estates have benefited from the population growth. Most notably, North Chesthill has seen a decline in the numbers of stags wintering on the estate. Relationships between sheep and deer densities are difficult to establish from the data available because the open hill landscape allows sheep to move freely; consequently, sheep are not necessarily grazing on the estate to which they belong. Furthermore, remaining sheep might be kept on in-bye land. It is therefore highly speculative to attempt to draw conclusions from the sheep ownership data for each estate, but it does appear that the overall number of sheep in the study area has declined over the time period that this study covers.

Distribution maps show that stags are increasingly found towards the edges of the study area, but not in the areas predicted by DeerMAP. The decline in stags predicted by the population model could, conceivably, be due to using an incorrect value for the reproductive rate. However, the value we used (Ratcliffe, 1987) is supported by the calf proportions found in the cull data. A possible explanation for the higher numbers of observed stags compared to the model predictions could be that the current stag culling levels are only possible because of immigration of males from areas outside the study area during the rut, attracted by the relatively stable and high hind population.

Predictions for hinds and calves are more accurate than those for stags and the more recent counts fit better with DeerMAP predictions. The GIS model prediction assumes a free distribution (deer disperse according to habitat characteristics) in the absence of sheep, and there is a suggestion that hinds and calves might be moving onto grounds previously grazed by sheep.

From the georeferenced counts, it appears that deer of both sexes and age classes have increasingly been wintering at lower altitude and more often in heather moorland. Unlike hinds, stags are known to prioritize quantity over quality of forage in the winter. Previous studies of red deer in Scotland have shown that males eat more heather than females, who also feed on grasses (Staines, et al., 1982). Although both sexes were predominantly counted in heather moorland, hinds might be attracted to North Chesthill because of the higher proportion of grassland (although note that the central zone on North Chesthill has a low proportion of good rough grassland coinciding with low numbers of deer).

Woodland cover in the study area has increased but it is difficult to assess how this might affect deer distribution, since the only georeferenced data we have come from surveys conducted over a week or a single day in winter. We do know, though, that some of these wooded areas are accessible to deer because some fences are porous to deer. The need to seek shelter from the wind is the most limiting factor for distribution on open hills in winter (Munro, 1962; Staines, 1976 cited in Hester, et al., 1998; Grace, et al., 1979; Conradt, et al., 2000). Therefore, it is to be expected that deer are counted at lower altitude and might even be omitted from the counts if they are seeking shelter from radiative loss of temperature in the wooded areas. Moreover, males have been found to be more sensitive to wind speed, decreasing mean temperature and increasing monthly rainfall; consequently, males are more likely to seek better-sheltered areas to forage (Conradt, et al., 2000).

Surprisingly, deer have been counted increasingly at lower altitudes over time. In the West Highlands, sheep tend to graze at lower altitude, excluding deer from the preferred swards and pushing them to graze at higher altitude (Osborne, 1984). The reduction of sheep flocks might explain partly why deer have been roaming at lower altitude and in different habitats in later years if those were previously inhabited by sheep (DeGabriel, et al., 2011). According to North Chesthill management, the grazing has considerably improved in the southern end of Innerwick estate following the removal of sheep from the hill, which may explain the high numbers of deer counted in that area.

8. Conclusion and recommendations

The distribution of deer in the study area covered by this pilot study does appear to have changed. In winter, deer have moved away from the mountainous centre of the study area to the lower grounds of the periphery. Given the limited historical data available, explanations for this change in distribution are necessarily speculative and it is impossible, at this stage, to pinpoint the drivers of those changes. Sheep may be at least partially implicated, because de-stocking sheep affects deer distribution, as the deer move onto newly available areas.

The wealth of operational data being gathered by or on behalf of estates has the potential to shed light on deer population trends, but it is critical that this information is collected in a consistent and systematic way. Since the data available at this point have been gathered in winter, we cannot answer any questions related to stag movements during rut and the impact of hill-walkers on their distribution, which is one of the main concerns at North Chesthill estate. Other issues raised by the estate are that human disturbance might also have an effect on hinds because if these are displaced to other areas, their calves will not return as hinds (de-hefting). In the long run, it might mean that fewer hinds in the central sub-area of North Chesthill will attract fewer stags. However, in the last two seasons (2013 and 2014) there has been an influx of deer to this sub-area as the rut approaches. Anecdotal evidence also suggests that deer are less inclined than formerly to cross the ridges that the Munro trail follows back into North Chesthill.

In summary, the trends in deer distribution detected in this study support the development of a more comprehensive study focusing on these issues. Behavioural observations of deer, sheep and hill-walkers using a range of GPS technologies and

questionnaires could shed light on the sensitive situation where ecotourism and stalking activities co-occur within the same landscape.

9. Acknowledgments

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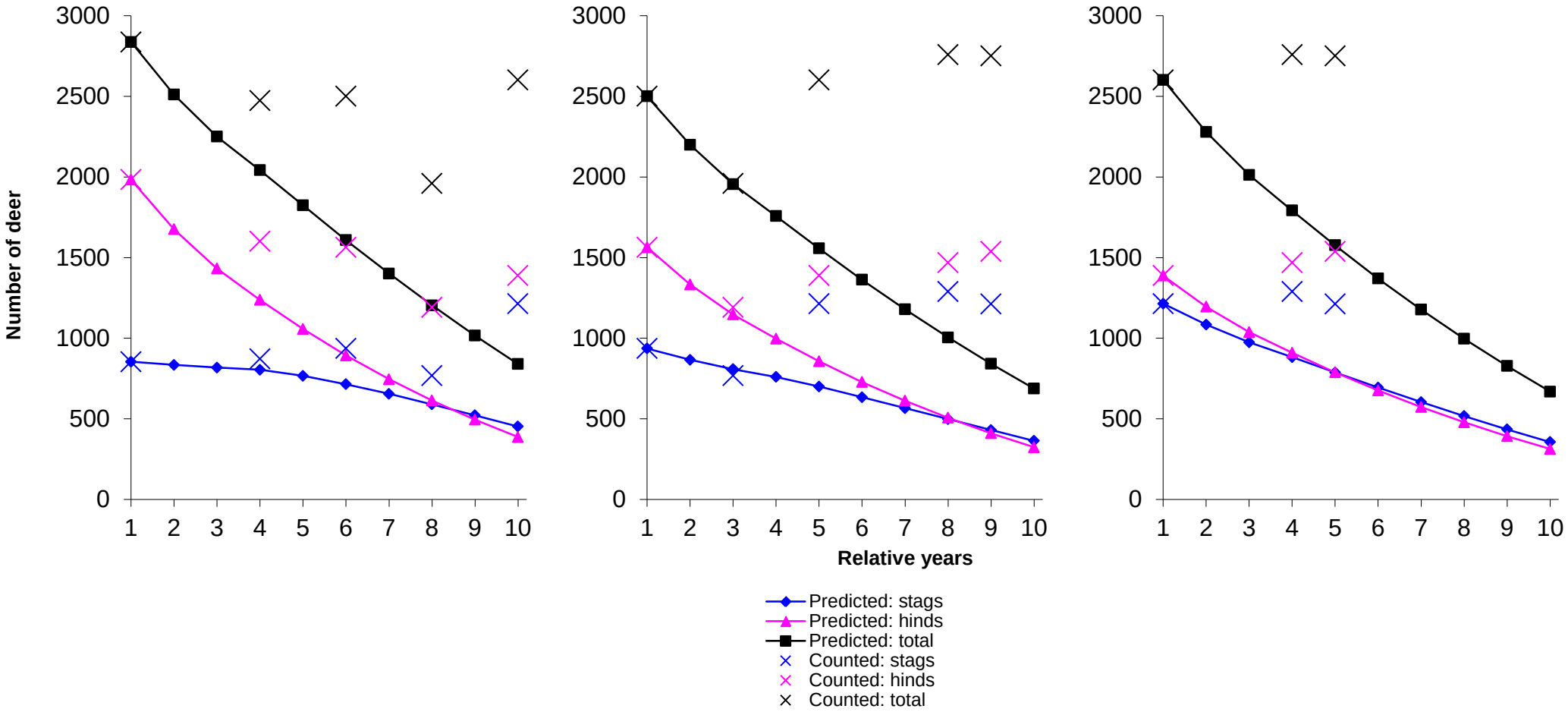
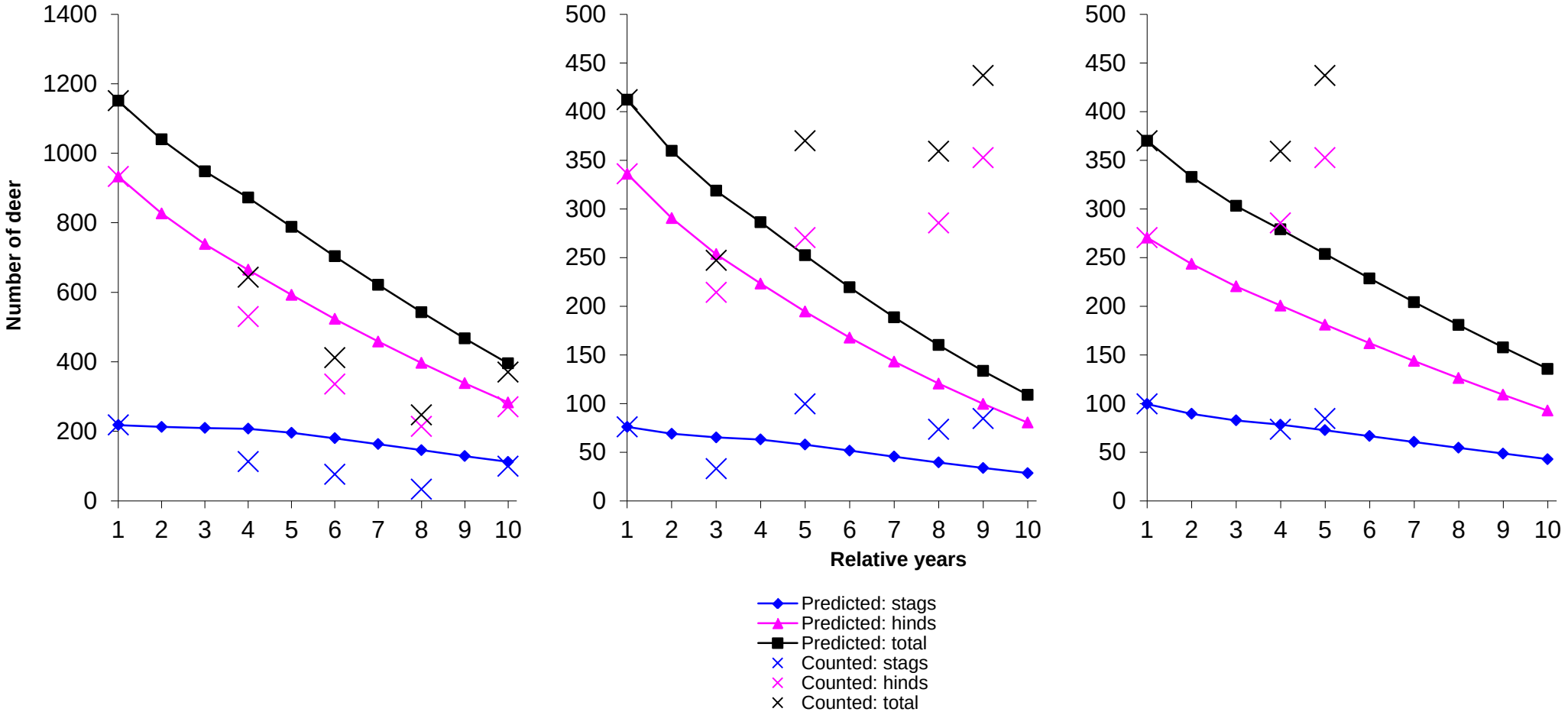
11. Appendix A: Red deer population dynamics model outputs.



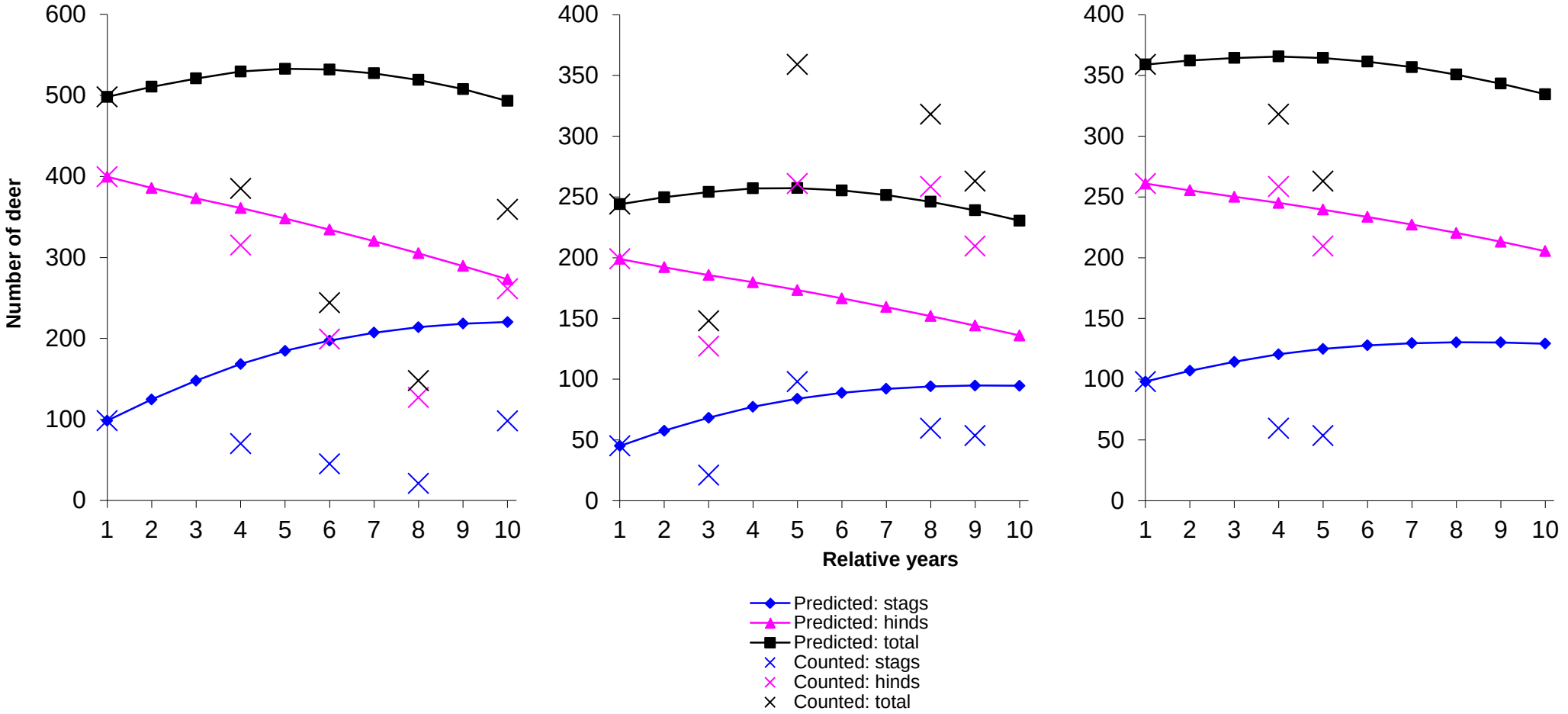
a. Initial year 1999 b.Initial year 2004 c.Initial year 2008

Red deer population dynamics model outputs for post winter mortality for the entire study area.



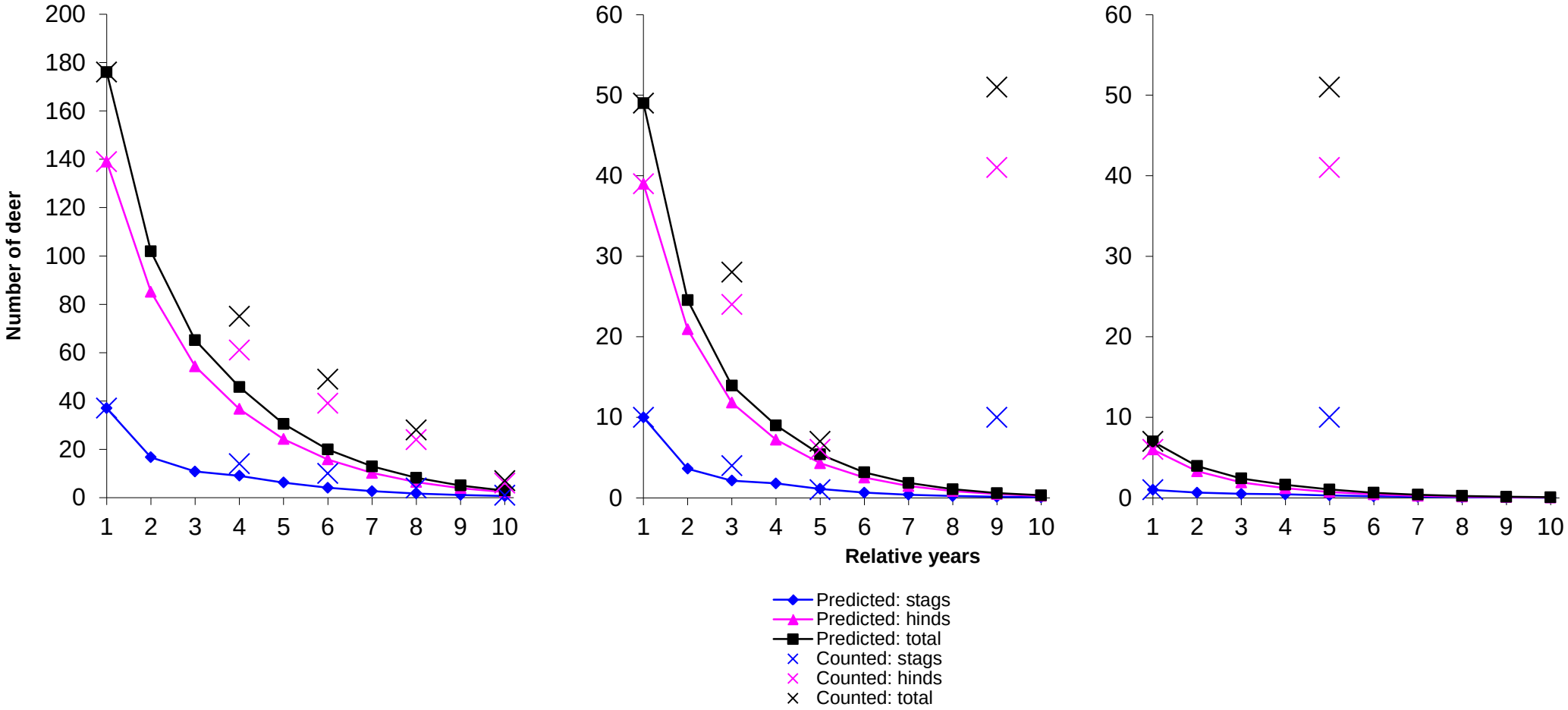
a. Initial year 1999 b.Initial year 2004 c.Initial year 2008

Red deer population dynamics model outputs for post winter mortality for North Chesthill estate.



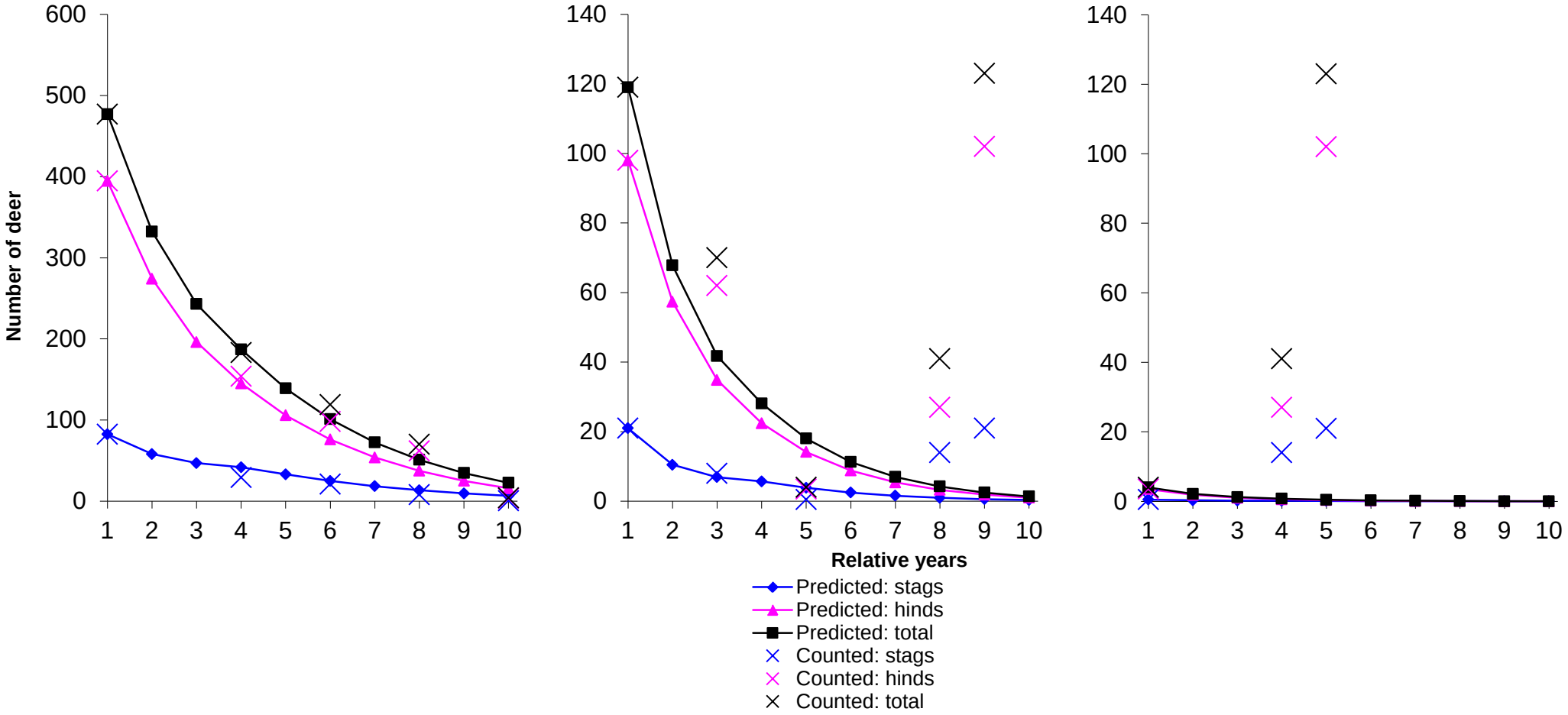
a. Initial year 1999 b.Initial year 2004 c.Initial year 2008

Red deer population dynamics model outputs for post winter mortality for the west sub-area of North Chesthill estate.



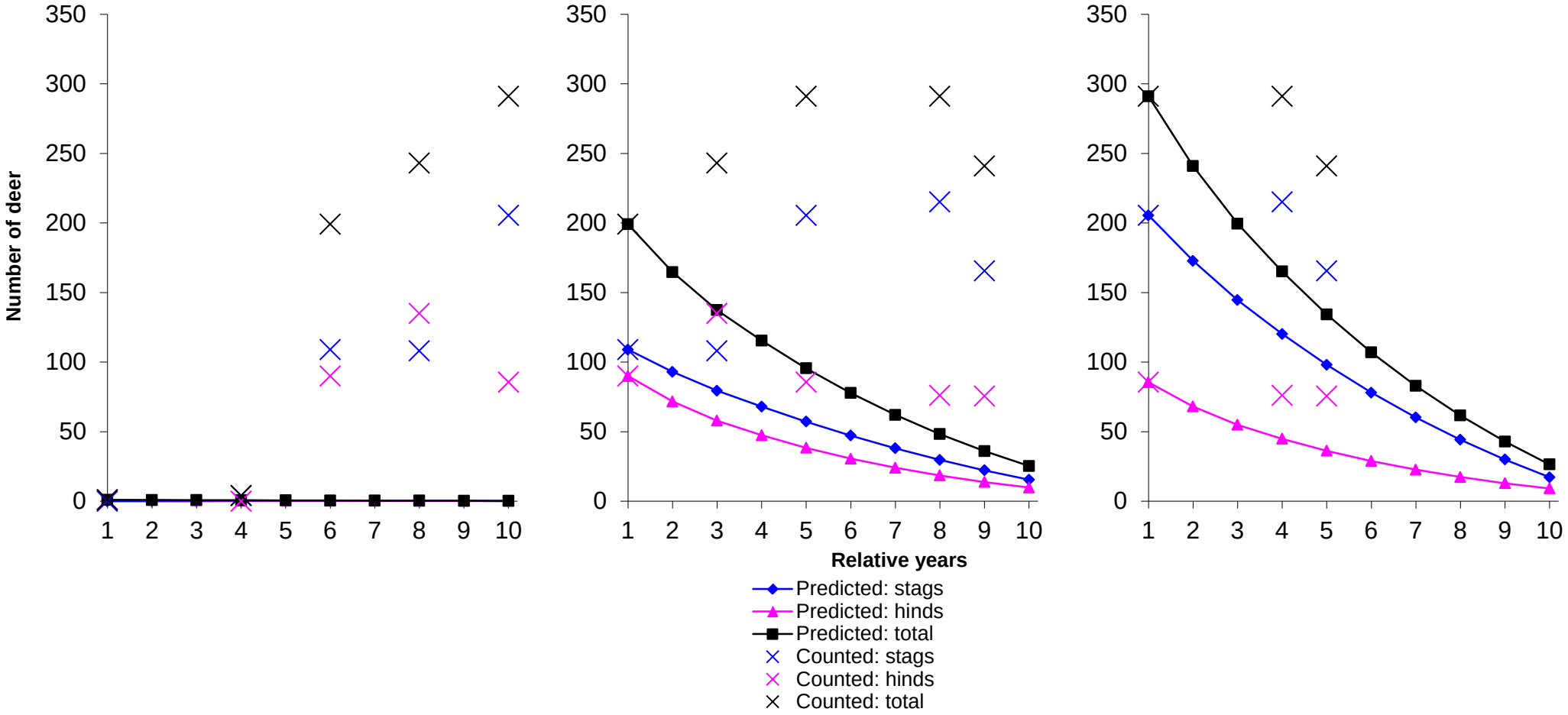
a. Initial year 1999 b.Initial year 2004 c.Initial year 2008

Red deer population dynamics model outputs for post winter mortality for the central sub-area of North Chesthill estate.



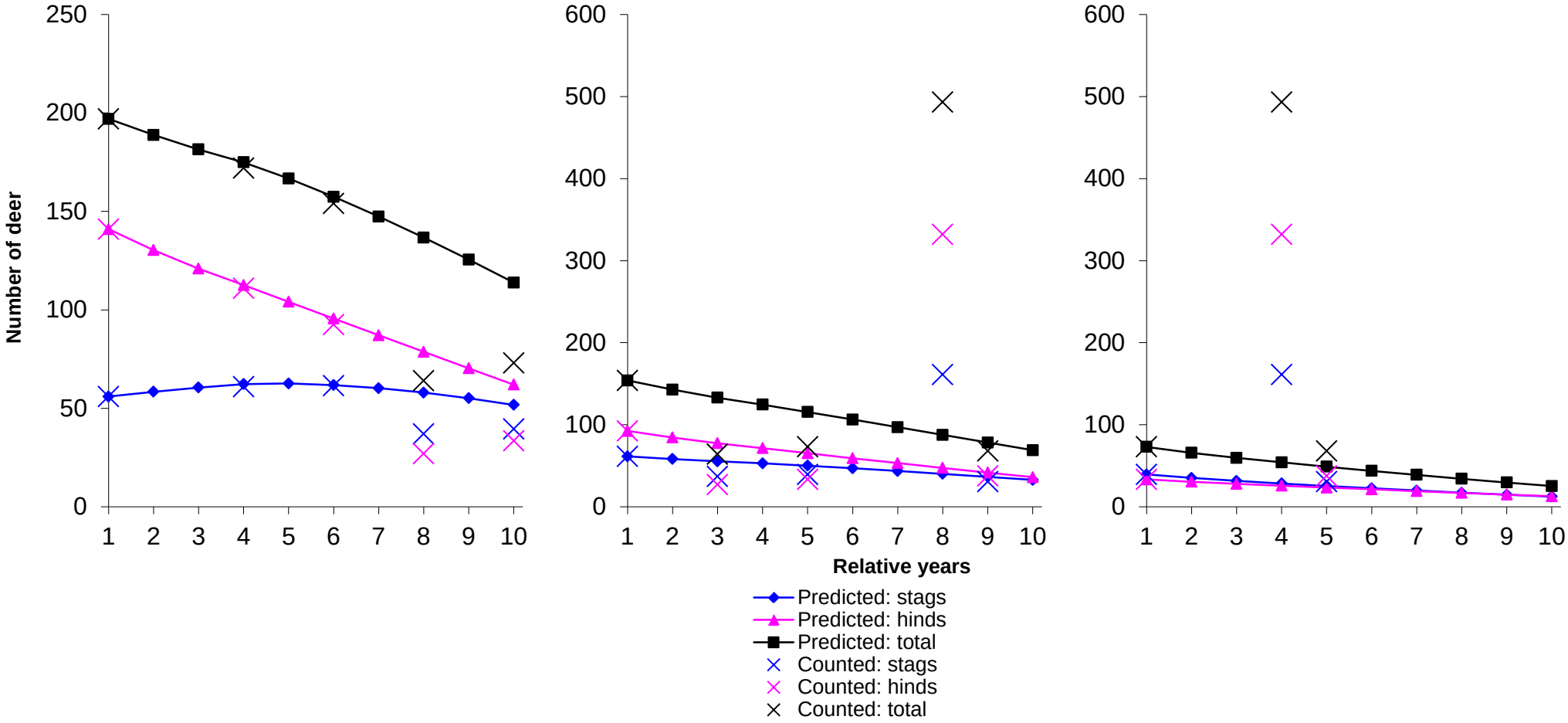
a. Initial year 1999 b.Initial year 2004 c.Initial year 2008

Red deer population dynamics model outputs for post winter mortality for the east sub-area of North Chesthill estate.



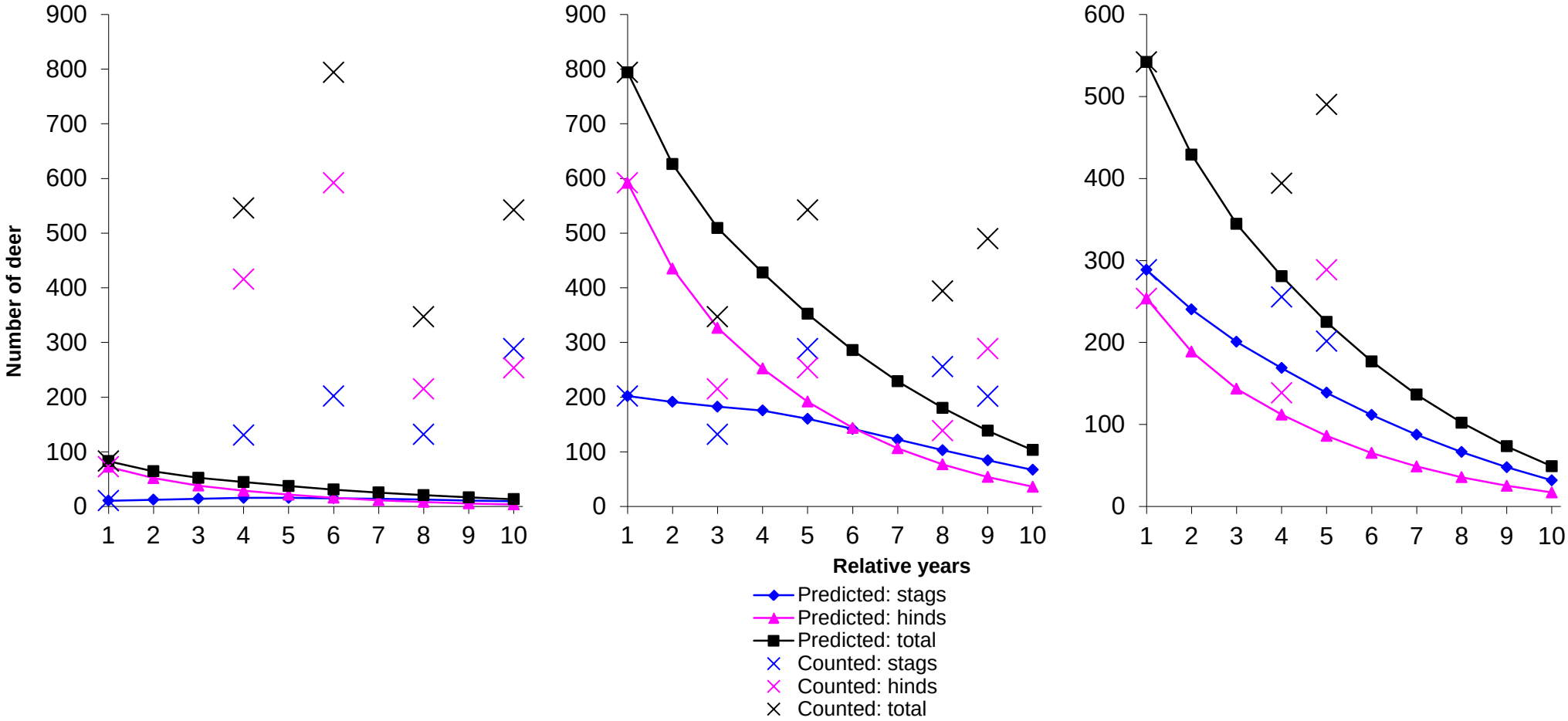
a. Initial year 1999 b.Initial year 2004 c.Initial year 2008

Red deer population dynamics model outputs for post winter mortality for Coire Carie estate.



a. Initial year 1999 b.Initial year 2004 c.Initial year 2008

Red deer population dynamics model outputs for post winter mortality for Dalchosnie estate.



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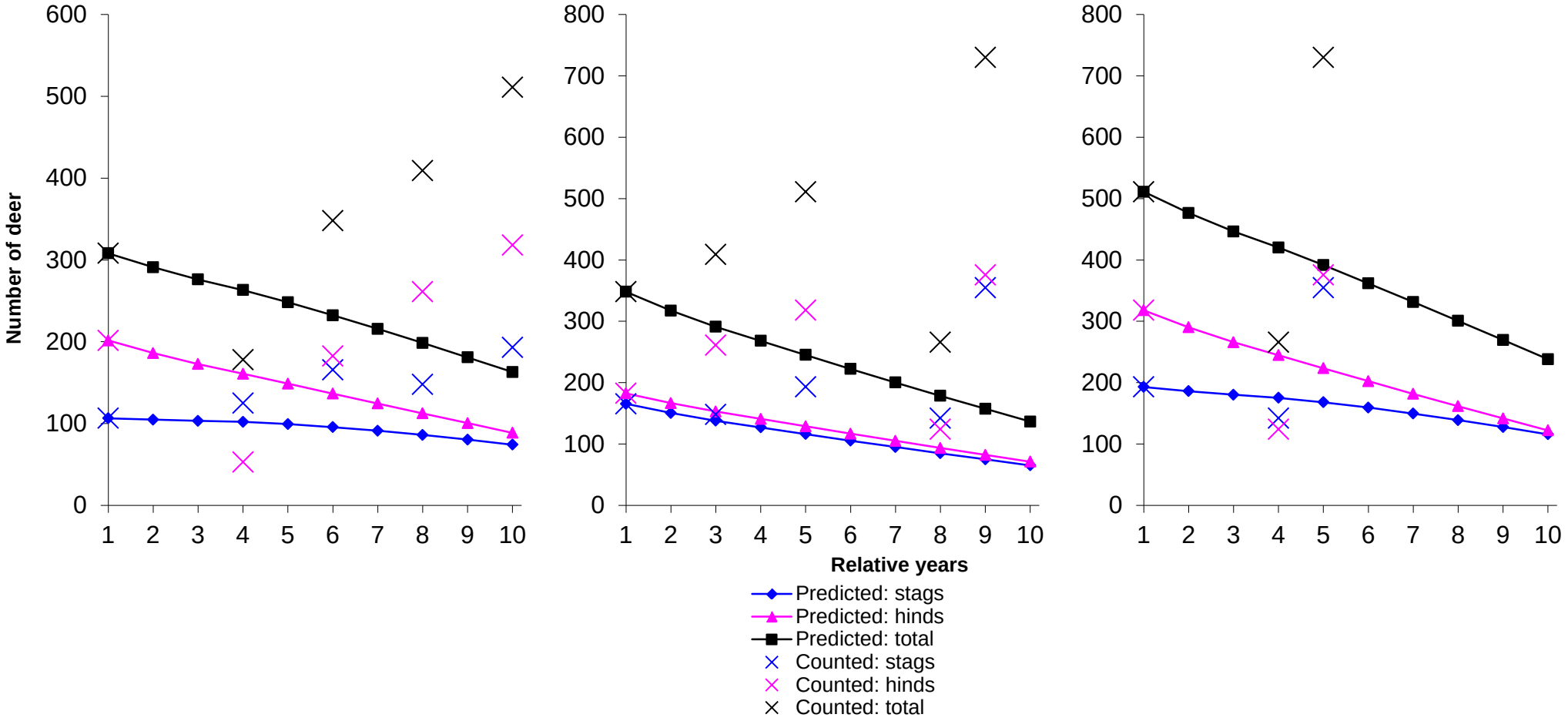
Red deer population dynamics model outputs for post winter mortality for Glenlyon estate.



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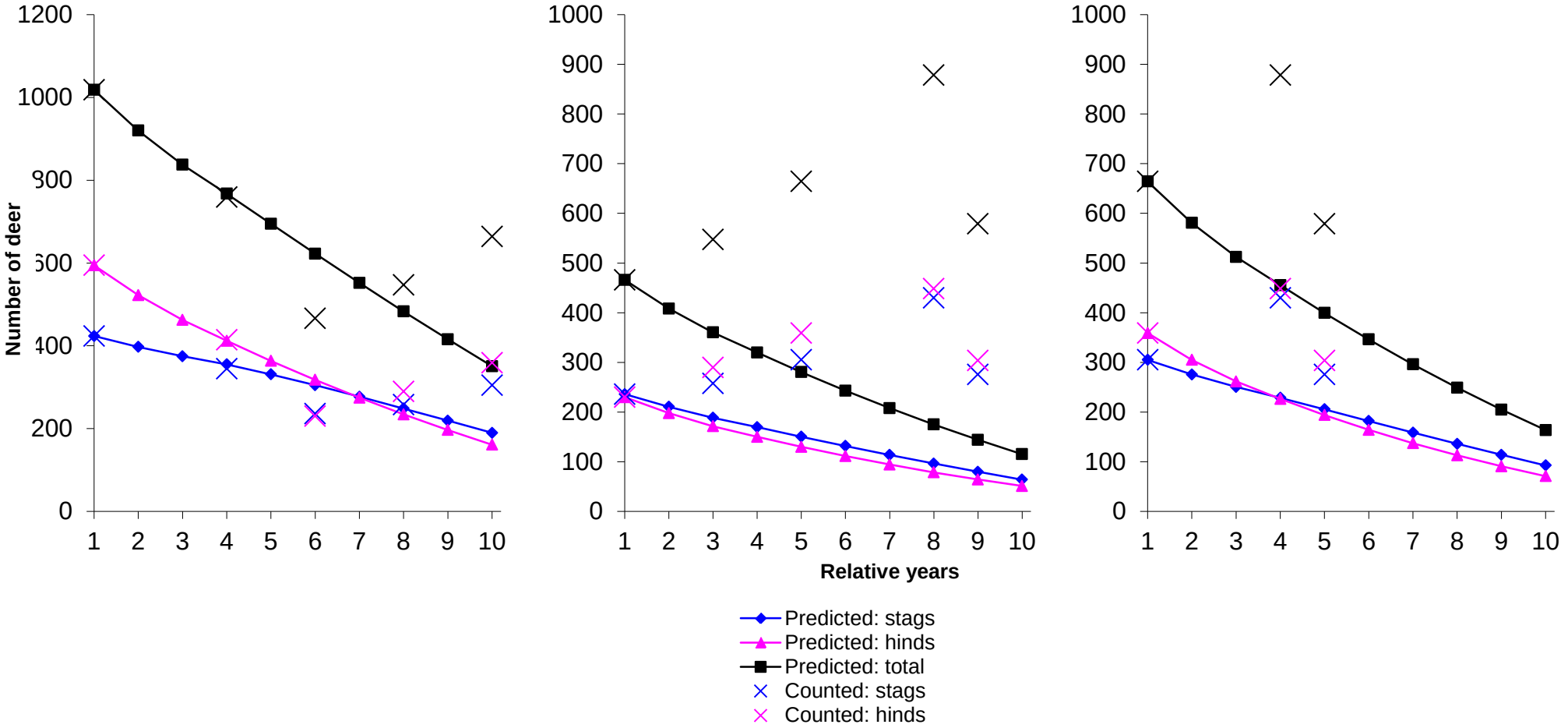
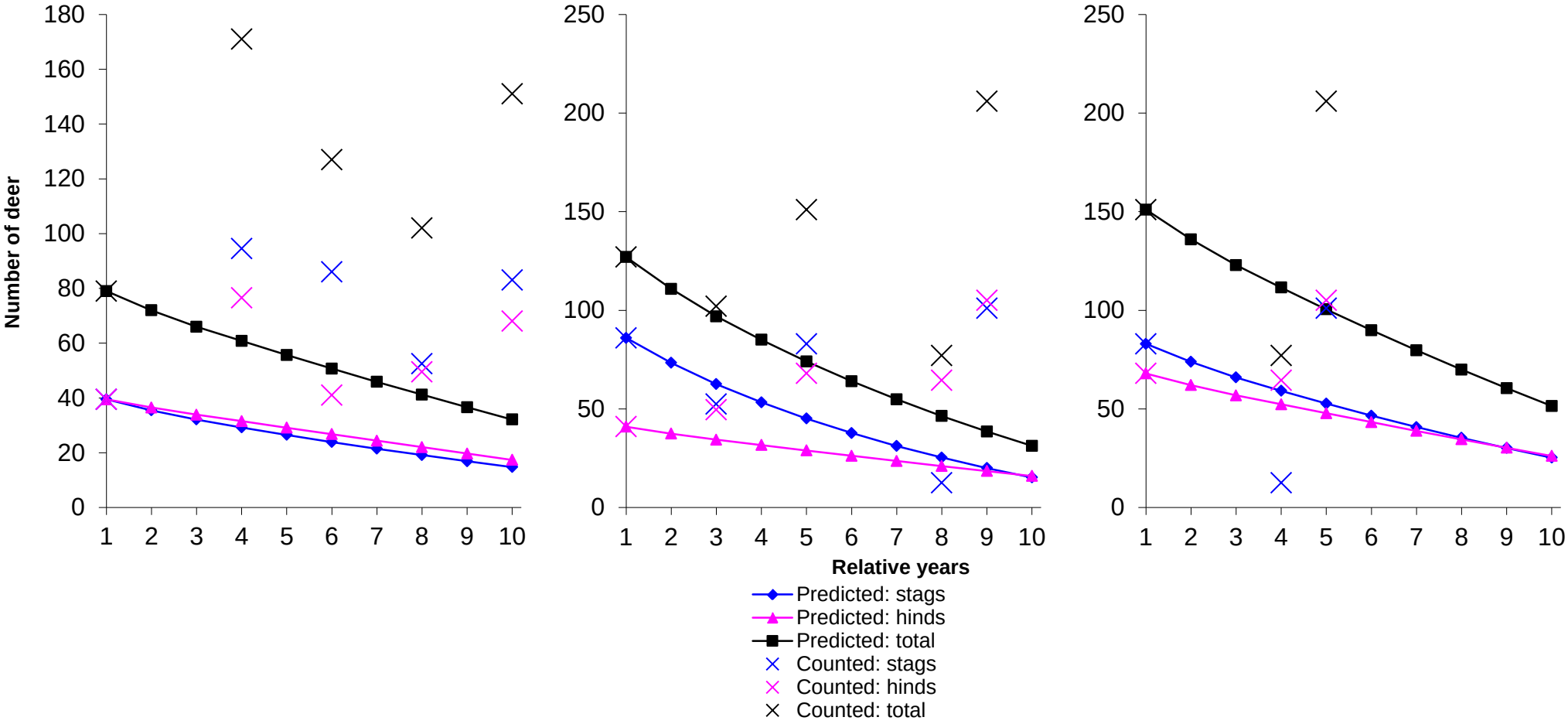
Red deer population dynamics model outputs for post winter mortality for Innerhadden estate.



a. Initial year 1999 b.Initial year 2004 c.Initial year 2008

Red deer population dynamics model outputs for post winter mortality for Innerwick estate.



a. Initial year 1999 b.Initial year 2004 c.Initial year 2008

Red deer population dynamics model outputs for post winter mortality for West Tempar estate.