Swedish University of Agricultural Sciences
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Six years of estimating roe and fallow deer density with distance sampling at the Koberg estate

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Abstract

Data about the big ungulates, particularly the European fallow deer (*Dama dama dama*) and the European roe deer (*Capreolus capreolus*) have been collected at the Koberg estate (Västra Götaland County, Sweden) using distance sampling as the inventory method. The project has been running for six years (2007 – 2012) and this is the fist time where all data from all years has been merged in one study. The main aims of this study was: (1) to investigate if the fallow deer and the roe deer density have decreased or increased during this period, (2) calculate the encounter rate, (3) investigate the quality and credibility of the estimated densities based on the results, (4) determine however the distance sampling method (line transect sampling) was the most suitable inventory method at Koberg and (5) to descriptively consider if the density estimates indicate reasonably similar trends as expected from the variation in the number of dead animals each year. The software used to analyze all field data was Distance 6.0. The results showed large variations in both species over the years with variable reliability. It was an expected result that the fallow deer density decreased in both areas after the hunt 2007/2008. But it was not an expected result to indicate such low density values for both species. Even if the result did not establish fully reliable estimates was this study not a waste. It still indicates population increases or decreases and the total number of individuals (*N*) with a known uncertainty in the whole area which is important information for the hunters and landowners for planning following years hunting.

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Introduction

Free-ranging European fallow deer (*Dama dama dama*) have been present at the Koberg estate (Västra Götaland County, Sweden) since 1920 and they are believed to derive from approximate 20 animals located near the Koberg castle (Count Niclas Silfverschiöld unpubl.). Fallow deer and the European roe deer (*Capreolus capreolus*) are together with wild boar (*Sus scrofa*) and moose (*Alces alces*) the most hunted game species on the Koberg estate. To efficiently and sustainably manage and balance the densities of large game species in relation to other land use, it is important to keep track of how populations changes. With distance sampling, it is possible to investigate both trends of changes in population density and the exact number of animals over a longer period using the collected fieldwork data. Sometimes it is sufficient to determine trends i.e. whether the population increases or decreases from one year to the next. Usually the landowners and hunters have more use of knowing the exact number of animals on their property to plan the following years hunting quotas. Many different methods are available to make population counts e.g. aerial or pellet counts by plot, strip or distance sampling (Buckland *et. al*. 2001). At the Koberg estate a distance sampling monitoring program was initiated in 2006 to estimate the roe deer and fallow deer population sizes. The method was selected based on the limitation in the other inventory methods e.g. traditional pellet counts are not possible to perform since it is to difficult to separate fallow deer dung from roe deer dung and it does not give any information about the species group composition such as sex and age (Carlström & Nyman 2005). Aerial counting is normally an expensive method that is difficult to use for small deer species and group living species on top of that a helicopter at low altitude might frighten the fallow deer and roe deer and it only gives an occasional picture of the population size (Bergström & Sand 2004). Distance sampling therefore has many advantages compared to plot counts and strip transect sampling because of its flexibility and efficiency in relation to effort. The method distance sampling can be applied in several ways combining different inventories made from ground as dung - , vegetation - or cue counting, but it can also be combined with aerial counting. The most commonly used and the method used to estimate the density in this study at the Koberg estate is thus the line transect sampling.

The encounter rate is a concept commonly used in distance sampling. It describes the observed number of animals detected per unit effort. However, the dominant source of variance in line transect sampling is usually the encounter rate variance according to Fewster *et. al.* (2009). In this survey is the encounter rate thus used to gain a conception about whether the chosen transect lengths was sufficiently long to optimize the detection probability in relation to effort. Either could transect length be increased and the number of transects decreased or vice versa. The dominant source of variance in line transect sampling is usually the encounter rate variance according to Fewster *et. al.* (2009) The encounter rate is the expected number of animals detected per unit effort. In this survey, the encounter rate is used to gain an outset whether the transect lengths are sufficiently long or if each transect needs to elongates to increase the detection probability g (*y*).

Aim

The aim of this study is to analyze all collected data from these six years and to: (1) determine if the fallow deer and roe deer density has changed over the years (2) calculate the encounter rate (3) investigate the quality and credibility of the estimated densities based on these results, (4) compare the distance sampling method, line transect sampling, with other inventory methods and determine if the used method was the most suitable for the survey at the Koberg estate and (5) to descriptively consider if the density estimates indicate reasonably similar trends as expected from the variation in the number of dead animals each year. For instance in the hunting season of 2007/2008 was a hunting experiment performed in an attempt to decrease the fallow deer population in one part of the study area. Did the population size and density decrease as a consequence of the increased hunting bag?

Material and methods

Study species

The European fallow deer (fallow deer) introduced in Europe after the last glacial period but it was not until year 1570 that it was introduced in Sweden. The fallow deer is, due to their characteristic herding behavior, relatively easy to keep in captivity and was initially kept in enclosures near bigger estates (Carlström & Nyman 2005). It is a medium- sized gregarious ungulate and the males are larger then the females with a body weight between 70-100kg and a shoulder height around 70-90cm, whereas the females weight is between 35-60kg and shoulder height around 70-80cm. (Putman 1988). Its main food consists of grass but may as well eat herbs, leaves, buds and occasionally even seaweed if available (Carlström & Nyman 2005).

The European roe deer is a native species to Sweden and can be found nationwide except in the mountain areas up in the north. They live solitary or in small groups. Their body weight is between 20-30kg, shoulders height 70-75cm and length 70-75cm as well. The European roe deer (roe deer) are always looking for food with high nutritional content and high digestibility, i.e. food with less fiber. A selection of their food preferences are berry bushes and heather (*Calluna vulgaris*) in winter. Among the deciduous trees mainly sallow *(Salix caprea*), birch (*Betula sp*), aspen (*Populus tremula*), ash (*Fraxinus excelsior*) and rowan (*Sorbus aucuparia*) is preferred and among herb-plants can fireweed (*Epilobium angustifolium*) and wood anemone (*Anemone nemorosa*) be included (Cederlund & Liberg 1995).

Hunting statistics

Parallel with the survey, data about the number of dead animals has been collected. This data has been compared with the results from this distance sampling survey to estimate if it gives fairly similar trends. Year 2007/2008 was a hunting experiment performed in an attempt to decrease the fallow deer population and the substantial density decline of fallow deer 2007/2008 (particularly in the northern area) can be explained by this experiment.

To determine if the results from the distance sampling survey are reasonably accurate or not, I chose to compare them with the reported bag statistics from the Koberg estate (2006-2012). This data have been collected through the research project with assistance from hunters and the residents at the Koberg estate (Kjellander unpbl.). All causes of death e.g. hunting, traffic, starvation or predation are in this study merged and compiled for each hunting season (Fig. 15 and 16).

Study area

Koberg estate is sited around 20 km south of Trollhättan in Västra Götaland County, Sweden. The estate is in total 9134 ha but the actually study area is only 8489 ha divided in two parts; north (2756 ha) and south (5377 ha) by the fenced national highway 42 intersecting the estate (Appendix 1 and 2). Around 79 % of the area is covered by different types of forest, 16 % consist of arable land and pastures, lake, pounds, parks, and gardens around houses 3 % and mires and marshes 2 % (Svartholm 2010). All arable land in the northern area is commercial farming while all arable land in the southern part is managed as game fields. Supplementary feeding was applied all winters at both areas at the estate and during the harsh winters 2010 and 2011 was intense supplementary feeding probably the contribution to that the fallow deer and roe deer populations did not collapse.

Distance sampling

According to Thomas et. al. (2010), distance sampling could be described as comprising a set of methods in which distances from a line or point to detections are recorded, from which the density and / or abundance of objects is estimated. Objects are usually single animals or animal groups (termed clusters), but may be plants or inanimate objects. The fundamental idea of distance sampling is therefore relatively simple. A known number of lines, also called transect, or points are randomly placed to cover the whole survey area. These transects are then surveyed in two different ways. Either by an observer walking along the transect, recording the distance, angle, perpendicular distance, position and other measurement to the object of interests (Marques, T. 2009). The principle is therefore basically the same as for a traditional strip transects sampling (Buckland *et. al*. 2001). What distinguishes them is that in line transect sampling there is no specific transect width (w) but the observer is still traveling along a line of a certain length (L) but now also recording all the sighting distance or more accurately the perpendicular distance from the center line to each object of interest (Fig. 1).

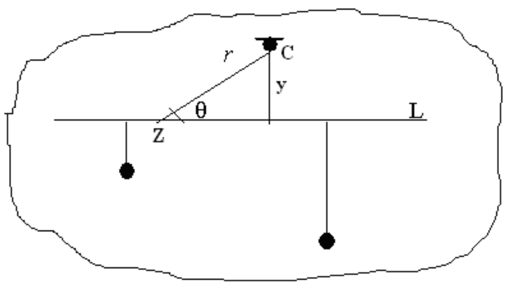
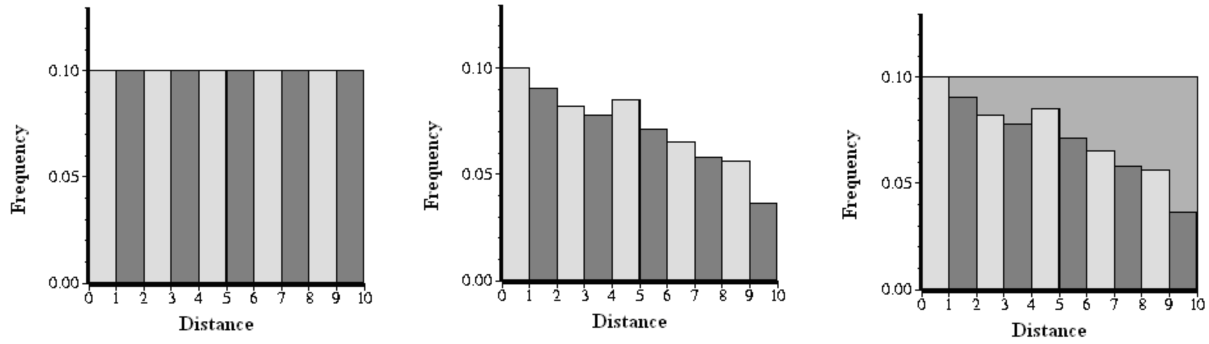


Figure 1. Line transects sampling with an undetermined width. L = line transect length, Z = position of observer, C = position of object, r =sighting distance, y = perpendicular distance, θ = sighting angle

The key to distance sampling analyses is to fit a detection function, g (y) to the observed distances, and use this fitted function to estimate the proportion of objects missed by the survey when the proportion of detected objects (P_a), is known. (Thomas *et al.* 2002.) Density is then calculated as:

$$D = \frac{n}{2wLP_a}$$

The detection function, g (y), where y refers to the perpendicular distance to the object and n refers to the number of observed animals, generally decreases with increasing distance to the transect or point, but the context $0 \leq g\ (y) \leq 1$ is a fundamental assumption (Buckland *et. al.* 2001). Assuming an area that have been surveyed and all objects has been detected, that will result in a uniform histogram (Fig. 2A). A more realistic outcome is that not all objects has been detected, this will instead generate a histogram where, g (y), is decreasing relative to the observed distance (Fig. 2B). The correction for undetected objects based on the measurements taken out in the field) e.g. distances to detected objects) is the inversed integral of the detection function g (y) (Fig. 2C).



A B C

Figure 2. (A) A uniform histogram where one can assume that all objects in the area have been observed. (B) A histogram where the detection function, g (*y*), decreases relative to the increasing distance from the transect line. (C) The detection function decreases relation to the increasing distance and the shadowed area shows the correction from undetected objects.

To correctly estimate density with distance sampling three fundamental assumptions has to be fulfilled to generate unbiased estimates (Thomas *et al*. 2010):

1. Objects on the line are detected with certainty.
Objects directly on the line are 100% detected, g (*0*) =1, and further away from de line decreases the probability of detection substantially (Buckland *et al*. 2001).

2. Objects do not move.
All measurements are made from the objects initial location, before it was affected by the observer (Buckland *et al* 2001).

3. Measurement are exact
All angles, distance, objects, sex and other necessary measurement are measured with accuracy without any errors (Buckland *et al*. 2001).

Data collection

The collection of field data has been running for six years in the Koberg study area, around one month each spring, and the basic approach has been the same every year. Each study area (north and south) had from the start 40 transects with a length of 1000m each that was randomly placed to cover the whole area. The northern area have always had 40 transects but at the southern area have the number of transects increased to 45 since 2008. All the 85 established transects (*k*) has as far as possible been surveyed twice each year and occasionally three times especially in 2007. But 2012 is an exception since all transects were only surveyed once, due to limited resources. In 2007 it was immediately discovered that while an observer was just walking and transporting him/her self and not formally performing the survey, from one transect to another, animals were still observed, but not included in the survey as they were not seen from a formal transect. Therefore in 2010 this transport walking was also included in the survey as improvised transects named "new lines" (k_n) to ensure that as much distance as possible was surveyed and as many animals as possible were observed (Tab. 1). However, these "new lines" could vary in length (193 – 1200m) and could be in any direction as it was the shortest way between the car and the starting point or end point of a standard transects, or the shortest way between the end of the first standard transect and the starting point of a second one. The 2007 survey is the only time where the field work been has performed at different time of the day i.e. morning, day and evening. All remaining years (2008 – 2012) has each transect been monitored in the evening only and between 18:57-19:37 hrs.

Out in the field has binoculars (Leica, Geovid 8x56), range-finder (Leica Rangemaster 1200), compass (Silva), GPS (GPSmap 60CSx, Garmin), paper forms (Appendix 3) and pencils been used to document an object observed along transects. Most transects are headed towards North ↔ South but a few are headed West ↔ East. To ensure that all transect was walked with headwind were the wind direction measured in advance.

This year was the survey performed by three fieldworkers walking separate transects each evening. However, frightened animals might run and traverse another observers transect and would thus be counted twice in one day as a result of the survey itself. To ensure that the observers did not affect the animals so that they would interfere with other transects, the transects were thoroughly selected each day. They were also surveyed every other day in the northern and southern area to further ensure that no interference occurred and to minimize the temporal difference in mean monitoring date between areas. To reduce the interference from the car began no lines within a 50m radius from where the observer left the car, and the observer stood silently and waited five minutes before starting the survey. All transects should as far as possible be walked without any deviations. If a transect for some reason could not be completed, because the end point was in a lake or the transect was crossed by wide streams without any bridges, the new end point location was noted. The transects should be surveyed with caution to minimize the risk of frightening the animals and once an animal was detected there were three main measurements to be taken.

First, once an object, in this study a cluster (which also can be a single animal, but they are still treated as a cluster), was observed the number of individuals, the distance and the angle to the animal/s was taken. If the animal were scared, a particular emphasis was considered to identify the original spot where the animal/s was originally situated, if this was not the same location as were they were first sighted. Secondly, the coordinates from where the observer was standing when observing the object was recorded using the GPS. If the objects were still visible after all the measures were taken the group composition (sex and age class) was noted. Adults were categorized as female in one age class and males in three classes based on antler size. Finally, the sight in all four cardinal directions (North, South, East, and West) was measured and divided by four to calculate the mean surrounding "openness" or possibility to do observations.

Distance 6.0

Most distance sampling surveys are designed and analyzed using the software Distance. To analyze the collected data from Koberg the software Distance 6.0 was used. All data was organized into four nested layers: global (used for data regarding the whole area e.g. detection function), stratum (data relating to each individual survey strata in this study e.g. northern or southern area, and different years), sample (data relating to individual lines or points e.g. species) and observation (data related to single observations of animals e.g. sex) (Thomas *et. al.* 2010). Analysis in Distance involves combining three factors: (1) a survey that specifies which data layer to use and which method that have been used, (2) a data filter, which makes it possible to choose e.g. subsets of data and truncation distance, (3) a model definition, which specifies how the data should be analyzed. These are then run using the analysis engines "Multiple covariates distance sampling" (MCDS) which allows inclusion of covariates other then the distance from the line in the detection function, g (y), (Thomas *et. al.* 2010). A covariate may relate to different things such as, cluster size, animal behavior, habitat, weather and year.

When MCDS engines is used only two key functions are allowed, half-normal or hazard-rate, which are two different mathematical models to calculate how much and how quick the perpendicular slope will decline. These can further be combined with three different series expansion: cosine, simple polynomial and termite polynomial function. Depending on how well the mathematical models fit to the collected data the "Akaike's Information Criterion" AIC, value will differs and the model with the lowest AICc (corrected for small sample size) number was chosen.

To analyze the data from Koberg I was following the defaults settings in Distance 6.0 for both fallow deer and roe deer; MCDS was used as the analysis engine and the analysis of the detection function was estimated at the global level, assuming that the detection of animals did not differ between areas or years 2007-2012

Truncation
Data analyzed in Distance can be truncated beyond some distance to delete outliers that make the modeling of the detection function g (y) difficult (Buckland *et al* 2001). There are two ways to chose truncation either by choosing a determined length, based on the number of observations that are made at a specific distance, and exclude all data that show too low values to be relevant, beyond that distance, or by saying that 5-10 % of the detected at the largest distance (Buckland *et al* 2001). In this study, the first way was used for both species

Encounter rate
The encounter rate n/L (were n = number of observed animals and L= total length of transect lines) is the number of objects detected per unit effort (Fewster *et. al.* 2009)

Density
The ecological significance means, a term indicating the number of individuals per unit of area as in this study: animals/km^2, population density.

The Density – Encounter rate relationship
The relationship between the density and the encounter rate visualize the robustness in the estimated density as the encounter rate is the empirically collected data divided by effort (Fig. 6 and Fig. 8). A standard linear regression model was fitted to the relationship using Excel (version 2003). However, the probability that these relationships have statistical support has not been possible to include in this study. The estimated density of animals in a region is calculated as the encounter rate (n/L) divided by the estimated detection probability (P_a) (Fewster *et. al.* 2009).

Results

Primary results

In total, a survey distance of 1504km has been covered, 12795 fallow deer and 507 roe deer been observed throughout the six years (Tab. 1). In general has more fallow deer been observed in the southern area than in the northern (mean S = 1887 vs. mean N = 246 animals/ km^2) and less roe deer in the south than in the north (mean S = 44 vs. mean N = 40 animals/ km^2).

Table 1. The number of standard transects, transects length and new lines where the total traveling length each year have been calculated (Ltot). New lines are the lines surveyed while walking between the actual lines. N stands for the estimated number of animals.

Area (ha)	Year	Number of transects (k)	$L_{transect}$ (m)	New lines (k_n)	L_{tot} (km)	N (Fallow deer)	N (Roe deer)
North	2007	40	1000	-	108	269	59
	2008	40	1000	-	157	135	56
	2009	40	1000	-	195	150	45
	2010	40	1000	53	120	286	29
	2011	40	1000	54	115	147	26
	2012	40	1000	45	63	488	27
South	2007	40	1000	-	81	2697	57
	2008	45	1000	-	154	1588	34
	2009	45	1000	-	82	1418	47
	2010	45	1000	73	123	1796	34
	2011	45	1000	77	131	1846	36
	2012	45	1000	91	175	1975	57

Detection function

Fallow deer

The slope of the detection function, g (*y*) indicates that the probability to detect a fallow deer decreases with increasing distance (Fig. 3). The figures in appendix 14-15 indicate how the detection function vary for both species and all years separated. There are good probabilities to detect a cluster in the range of 0 - 40 meters from the transect line (Tab. 2.) As the slope indicate it is slightly more difficult to detect a cluster at distance of 40 m and further away from the transect (Fig. 3).

Table. 2. Number of true (Observed) and expected observations of fallow deer for each 40m cut point. The expected values are derived from the estimated detection function and the Chi-square (χ^2)-value indicates the probability that the two values do not match. In this case they all fit very well as P > 0.05 in all cases.

Interval	Cut Points	Observed value	Expected value	Chi-square (χ^2) Values
1	0-40	269	266.29	0.028
2	40-80	149	154.24	0.178
3	80-120	109	101.24	0.595
4	120-160	66	74.19	0.904
5	160-200	61	58.05	0.150

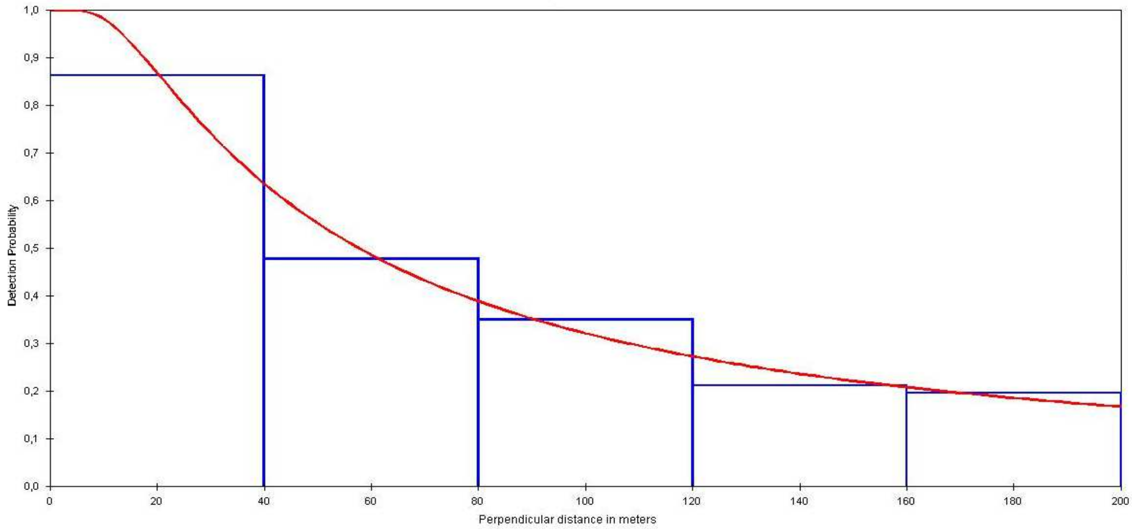


Figure 3. Global detection function for fallow deer, all years and both areas merged. The horizontal axis shows the perpendicular distance (*y*) in meter and the vertical axis shows the detection probability g (*y*). The slope indicates how the detection function g (*y*) decreases in relation to the distance. At the interval 0 – 40meter are the g(y) ≠ 1 when the expected value are lower then the observed value. The second interval is the opposite, the observed value is higher then the expected value and therefore g (y) >1.

Roe deer

The slope of the detection function, g (*y*) indicates how the probability to detect roe deer decreases with increasing distance (Fig. 4). The slope indicate that at the first interval (0 – 56 m) the detection probability g (*y*) =1, at the fist few meters but decreases after ~ 10 meters. Which means that all roe deer directly on the transect line or ~ 10 meter away was detected to 100 %. After 10 meter are the number of observed roe deer generally higher than the expected values and the detection function is higher than one.

Table. 3. Number of true (Observed) and expected observations of roe deer for each 56m cut point. The expected values are derived from the estimated detection function and the Chi-square (χ^2) value indicates the probability that the two values do not match. In this case they all fit very well as P > 0.05 in all cases. Table. 3
The Chi-square (χ^2)-value

Interval	Cut Points	Observed values	Expected values	Chi-square (χ^2) Values
1	0-56	103	95.75	0.549
2	56-112	55	61.23	0.634
3	112-168	25	26.53	0.088
4	168-224	7	8.43	0.243
5	224-280	4	2.06	1.814

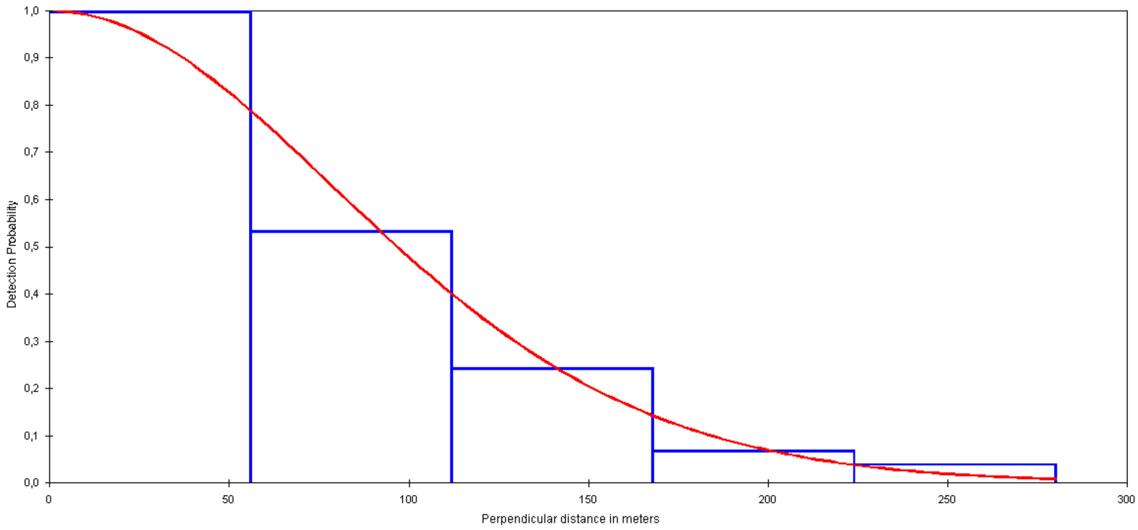


Figure 4. Global detection function for roe deer, all years and both areas merged. The horizontal axis shows the perpendicular distance (*y*) in meter and the vertical axis shows the detection probability g (*y*).

Encounter rate

Fallow deer

The encounter rate (n/L were n stand for number of observed animals and L for the transect length), shows how far one must travel along a transect to detect a fallow deer each year. In 2008, only 0.25 fallow deer was observed per km and consequently one had to walk around 4 km (1.00/ 0.25 fallow deer per km = 4.0 km) to make a fallow deer observation in the northern area that year (Fig. 5). In the southern area, with an expected high density, (Tab. 4) the number of observations per km is also higher than in the north and one does not have to walk as far distance to do an observation. Still, 2007 and 2012 were the only years when it was enough to travel around 1 km (1.00/ 1.00 fallow deer per km = 1.0 km) to actually detect one cluster per km.

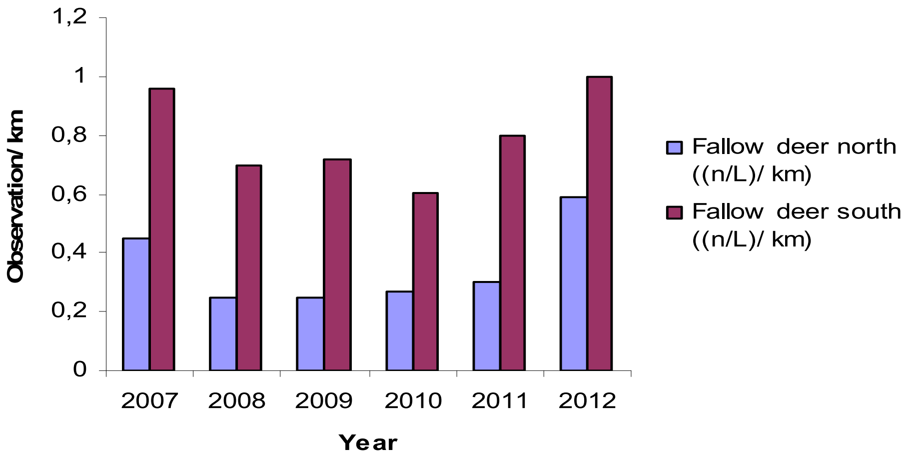


Figure 5. Encounter rate, n/L, fallow deer, both areas and all years separated. 2007 and 2012 are the only year where 1 kilometer was enough to travel to have a detection probability as close to 1.00 as possible.

When combining the encounter rate for fallow deer for all years and both areas in relation to the estimated fallow deer density a regression analysis gives a coefficient of determination at $R^2 = 0.87$ (N = 12) and thus indicate a strong relationship between the empirically collected field data and the estimated density. However, the intercept (i.e. were the line intersect the y-axis) can be interpreted as that at a density of zero animals per km^2 one can still observe ~ 0.2 fallow deer/km. This indicates that the density estimates most likely are under estimating the true population size.

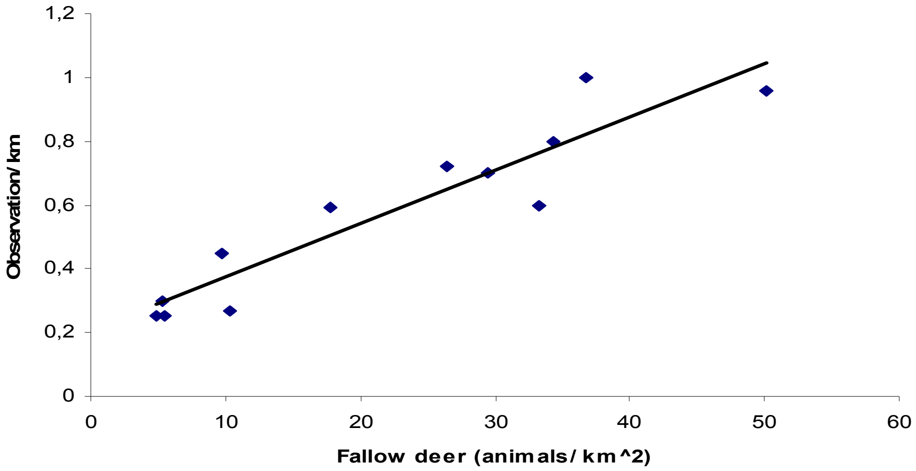


Figure 6. Encounter rate for fallow deer all years and both areas combined in relation to the estimated fallow deer density with a coefficient of determination at $R^2 = 0.87$. The linear line does not cut through zero and at none density can still ~0.2 animals be detected in the whole area (the linear regression model is $y = 0.0168x + 0.2046$).

Roe deer

As expected, all values was much lower in both areas compared to fallow deer since the roe deer density were very much lower than the fallow deer density, One had to walk a significantly longer distance to observe a roe deer (Fig. 7). In 2008 for example, the encounter rate in the southern area was 0.03 roe deer/km and consequently one had to travel ≥ 33 km (1.00/ 0.03 roe deer per km^2 = 33.33 km) to surely detect an animal. In the best case, not even 2 km traveling length was enough to detect a roe deer in the north.

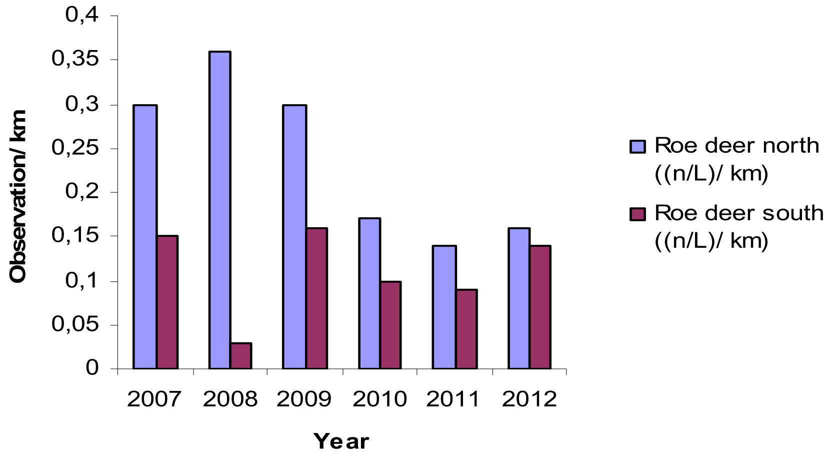


Figure 7. Encounter rate, n/L, roe deer, both areas and all years separated. At none of the years was not even 2 kilometer enough to travel to detect an animal.

Contrary to fallow deer was the relationship between the encounter rate and the estimated density for roe deer, all years and both areas combined, indicating an over estimation of the true density (Fig. 8). The regression analysis indicate a coefficient of determination value of R^2 = 0.90 (N = 12) and thus an even a stronger relationship, than for fallow deer. However, the intercept is negative and indicating that when the density is zero, the encounter rate is a negative number of animals detected.

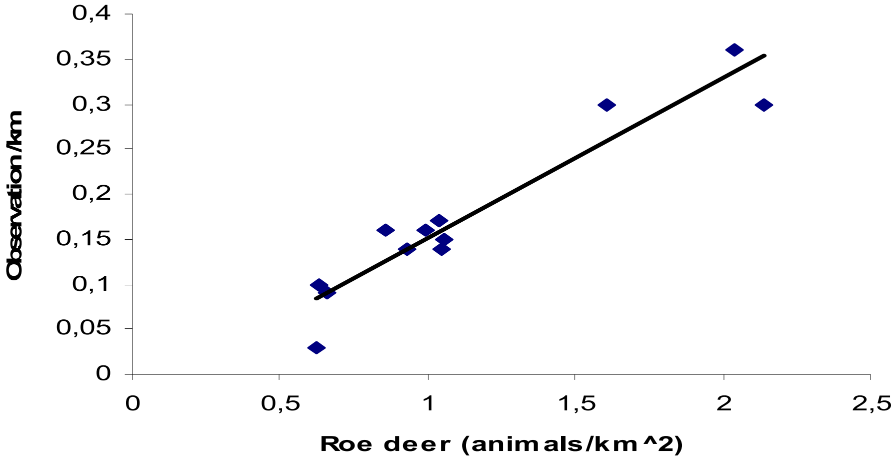


Figure 8. Roe deer encounter rate. The linear line cuts the y-axis at a negative value and at no density are a negative number of roe deer detected in the area. The linear regression model is y = 0.177x – 0.0261.

Density and abundance

Fallow deer

The estimated fallow deer population density (*D)* in 2007 in the northern area was estimated to 9.75 animals/km^2, and the estimate of density of cluster (*DS*) was 2.72 animals/km^2. The coefficient of variance (*CV*) value for 2007 is the same for both *D* and *N* (22.23%), but differs in the density of clusters *DS* (17.33 %). The same *CV*- trend goes through all the years (Fig. 9). Year 2012 was found to have the highest *N*, *D* and *DS*, values in the northern area. Lowest values were found at year 2008 (Tab. 4). An almost a halved N value is detected in the northern area between 2007 and 2008/2009 (Fig. 9).

The southern area has much higher estimated density then the northern (Fig. 9). The (*N*) and (*D*) peaks in year 2007 (*D* = 50.15 animals/km^2) and the lowest density can be found at year 2009 (*D* = 26.36 animals/km^2) but a clear decrease can be observed in 2008 (Tab. 4). These changes follows the same trend in the northern area.

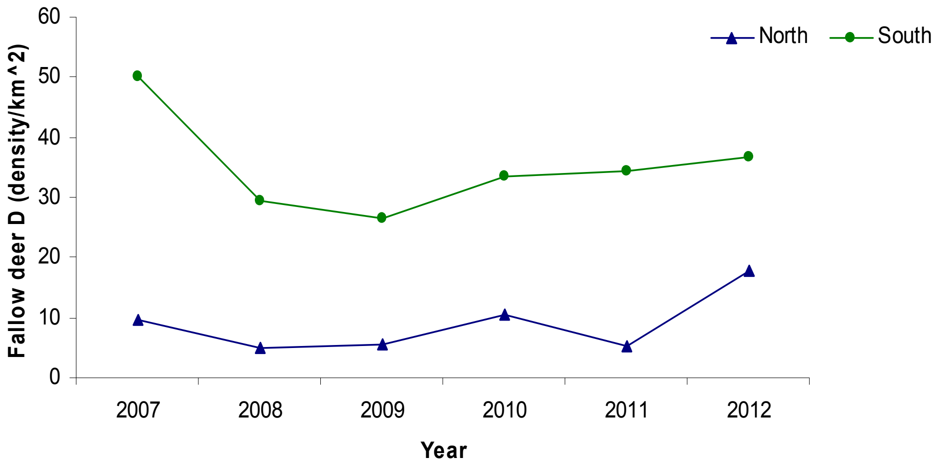


Figure 9. Estimated density of fallow deer in the northern and southern area at Koberg in spring, 2007-2012. Both areas follow approximately the same trend through the first four years but after 2010 the density decreases in the northern area to 5.3animals/km^2, and then increase with an irrational speed to 17.7 animals/km^2. But the density in the southern area continued to increase.

Roe deer

The density and abundance for roe deer is interpreted in same way as for fallow deer (Tab. 4 and Fig. 10). In the northern area, were the highest *(N)* and *(D)* values found in year 2007 and the lowest in 2011. Both *(N)* and, *D)* decreases from 2007 - 2011 and increases slightly again in 2012. The estimate of density in cluster *(DS)* has however changed considerably between 0.08 – 1.73 in the different years (Tab. 4).

In the south area, the estimated number of animals *(N)* is equal for 2007 and 2012, which also was the highest value (Fig.12). They have however not the same *(D)* value but they do not differ so much from each other. Same goes for the lowest value of, $N = 34.0$, it is the same for both 2008 and 2010 but the *(D)* and *(DS)* value still differ between the years (Tab. 4).

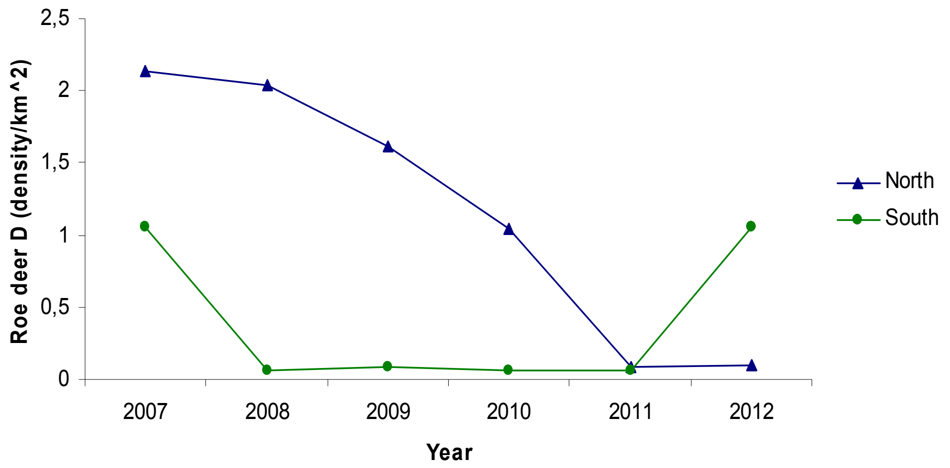


Fig. 10 Estimated density of roe deer in the northern and southern area at Koberg in spring, 2007-2012. The population trend in the northern area are rapidly decreasing to 2011, to level off and remain at a steady level around 0.1 animals/ km^2. The southern area has even a more rapidly decreasing at 2007 and remains at a value around 0.06 animals/ km^2 the following years, to then increase to a value of 1.05 animals/ km^2 year 2012.

Table 4. Estimated population size (N), density (D), cluster density (DS) and the coefficient of variance (%) for D in April, for both fallow deer and roe deer in two areas (north and south) at Koberg 2007-2012. Italic text shows the CV for the density of clusters.

Area (ha)	Year	Fallow deer/ km^2		Roe deer/ km^2		Fallow deer	Roe deer	Fallow deer	Roe deer
		D	N	D	N	DS		CV *(CV (DS))*	
North	2007	9.75	269	2.14	59	2.72	1.14	22.23 *(17.33)*	22.76 *(21.16)*
	2008	4.89	135	2.04	56	1.53	1.73	38.79 *(31.09)*	19.74 *(18.50)*
	2009	5.43	150	1.61	45	1.53	1.45	27.86 *(23.91)*	23.93 *(23.03)*
	2010	10.37	286	1.04	29	1.63	0.08	37.65 *(22.59)*	24.71 *(23.67)*
	2011	5.34	147	0.09	26	1.82	0.06	26.01 *(20.53)*	28.80 *(25.18)*
	2012	17.7	488	0.1	27	3.54	0.08	29.20 *(21.53)*	37.65 *(35.14)*

South	2007	50.15	2697	1.06	57	5.74	0.07	24.78 (19.34)	29.01 *(25.35)*
	2008	29.53	1588	0.06	34	4.17	0.01	27.76 *(19.90)*	111.33 *(73.88)*
	2009	26.36	1418	0.08	47	4.32	0.07	23.62 *(17.27)*	33.16 *(31.85)*
	2010	33.4	1796	0.06	34	3.57	0.04	24.80 *(16.07)*	33.90 *(31.15)*
	2011	34.33	1846	0.06	36	4.87	0.04	21.04 *(15.19)*	36.19 *(33.90)*
	2012	36.73	1975	1.05	57	6.54	0.06	22.33 *(15.03)*	43.93 *(39.27)*

Bag statistics

In the hunting season of 2007/2008, the highest number of killed fallow deer was reported (164 - north; 832 - south) in line with managers attempt to decrease the fallow deer population in those years (Fig. 11). Roe deer mortality has peaked at approximately 20 animals in the 2006/2007 season and gradually declined until the harsh winters in 2009/2010 and 2010/2011 when mortality increased in both areas (Fig.12).

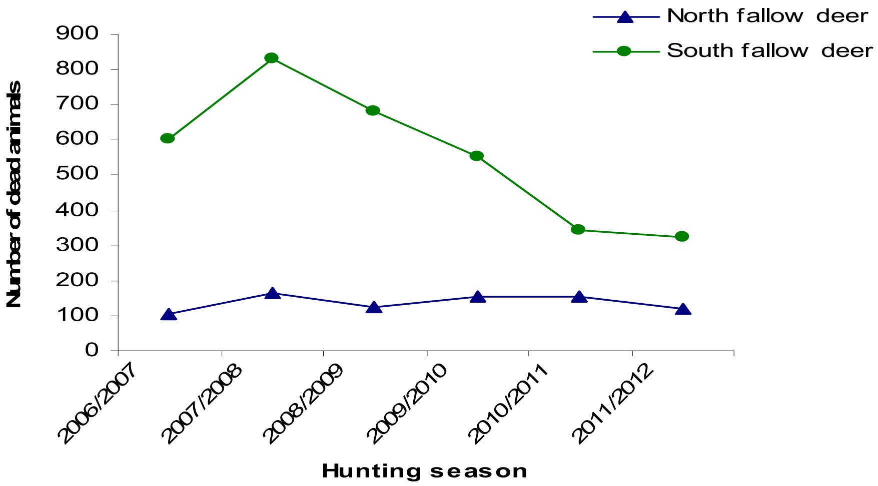


Figure 11. Number of killed or found dead fallow deer in six consecutive hunting seasons at the Koberg estate in south western Sweden, 2006 -2012.

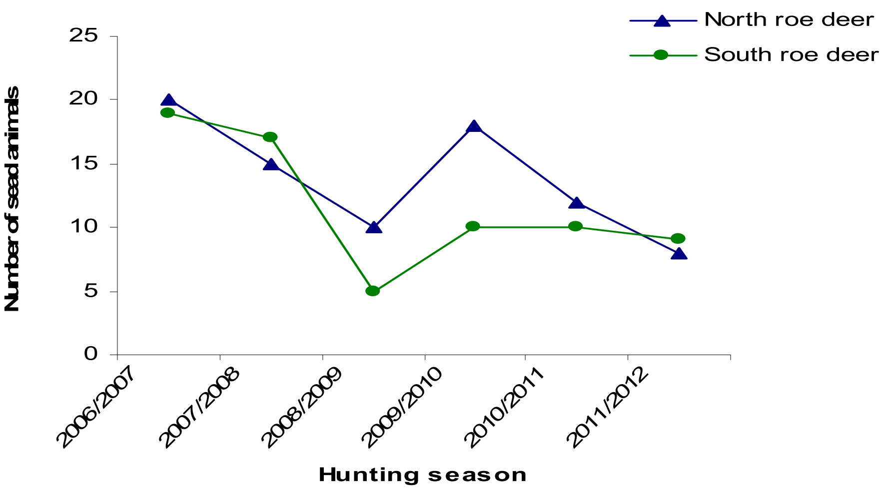


Figure 12. Number of killed or found dead roe deer in six consecutive hunting seasons at the Koberg estate in south western Sweden, 2006 -2012.

Discussion

The aim of this study was to determine if the fallow deer and roe deer population has changed over this six year. Furthermore, I aimed to calculate the encounter rate and based on these results investigate the quality and credibility of this study. Hence, determine whether the distance sampling method, line transect sampling, is the most suitable inventory at the Koberg estate. I found that both the fallow deer and the roe deer density has changed substantially over these six years and particularly contrasting densities have been found between the northern and southern areas. In both the southern and northern areas there is a distinct higher fallow deer density then roe deer density.

How well suited are used method for fallow deer and roe deer estimations at Koberg estate compared to other surveys? As mention in the introduction, the distance sampling method line transect sampling was chosen based on the other methods limitations. Pellet counts are conducted in the spring and the plots are cleaned from dung during autumn to ensure that only dung from the following winter is counted. When plots have not been cleaned, something that is common due to limited resources, it is necessary to determine the age of the dung, which can be difficult even for experienced field workers (Pehrson 2004). Because of the multi species community including several ungulates such as red deer, fallow deer, roe deer, mouflon and moose at the Koberg estate was pellet count a less appropriate method for this study area since it is difficult to distinguish the species dung. It is well known that it is particularly difficult to differentiate fallow deer and roe deer pellet (Carlström & Nyman 2005), and since both species lives in both areas are pellet inventory no alternative. Another disadvantage is that a pellet count does not give any information about the gender and age distribution in an area. Estimations about how much dung each individual and species are producing each day must also be taken into account and can be difficult to estimate.

There is particular one limitation that makes strip transect sampling less suitable to use as an inventory method in this study. In strip transect sampling is there a fixed width and all observed objects within that width are recorded. Thus this method may not be the most effective way to estimate the density since objects beyond the width might be detected but has to bee ignored (Buckland *et. al.* 2001).

A third possible option to estimate the fallow deer and roe deer density at Koberg estate could be aerial counts. As all other methods has also aerial counting advantages and disadvantages, and the main disadvantages are that it is an expensive method since fieldworkers, a pilot, fuel and the helicopter rent becomes expensive. Other aspects that make aerial counts less suitable are that aerial count can only be performed during winter and only gives an occasional picture of the population size and if emigration or immigration occurs in the area it can provide an over-or under-estimated result. To perform an aerial count, the snow depth must be deep enough to cover any dark areas to not confuse the observer. But it must not be too much snow either because crown snow-load complicates the detection of animals (Bergström & Sand 2004). Aerial count is therefore a less suitable method to use at inventories of small deer species as fallow deer and roe deer. Two other reasons for not using aerial count at the survey at Koberg estate is that aircrafts might frighten the animals and in a running group of fallow deer is it difficult to count the number of individuals. Secondly, the survey area is too small is to be worthwhile monitor with aircraft. According to Cederlund & Wallin (2004), the smallest recommended area for aerial surveys is 50 000 ha and the survey area at the Koberg estate is approximately 8 000 ha.

The coefficient of variance (*CV*) is a well-established measure of the quality of an estimate that also can be compared between studies. A comparison between the *CV* for an aerial count performed in Africa and the CV in this study further confirms that line transects probably are a better alternative for surveys at the Koberg estate. The *CV* from the aerial count of different species in the African study shows a mean *CV* value of 65.65 % ranging between 36.10 % - 111.43 % (Jachmann 2002). This compared to a mean value in this study of 27.18 % (21.04 % - 38.79 %) for fallow deer and 37.09 % (19.74 % - 111.33 %) for roe deer density (*D*). This shows that this survey carried out by line transects gives a lower *CV* value and has a greater reliability than the aerial count in the African study (Jachmann 2002). In the same African study was a line transect survey performed (very similar to my study), at the same time and place as the aerial count (described above) was done. The generated *CV* values from the distance sampling survey (mean value 35.07 % (20. 89 % - 76.88 %)) confirm that line transect counts can give a greater reliability than aerial counts (Jachmann 2002).

Finally, the distance sampling method line transecting sampling was used because data about more species than fallow deer and roe deer was collected during the survey and many of those species would have been impossible to detect with helicopters.

After looking at the disadvantages with pellet count, strip transect sampling and aerial count was line transect sampling considered to be the most appropriate approach for this study and area. However, even this method and analysis in Distance 6.0 has some limitations that might have affected the results which I will discuss further. There was a generally underestimated density value for both species all years and for the whole study area (Tab. 4). A reason for why nearly all results are so low could be that the three essential assumptions are not fulfilled. Measurements are probably fairly exact – even if the human factor might have influenced the results through rounding errors in measuring distances and angles during field work. Even if it is less likely, another source could have been data errors in the analysis in Distance 6.0

Objects do not move – this assumption is probably the easiest to fulfill in theory but it could still be a measure that have been measured incorrectly. Objects (animals) on the line are detected with certainty – the detection function (Fig. 3 and 4) is the result that best can shows that this assumption might be incorrect in this study. The number of detected fallow deer in the first interval (0 - 40 meter) gives generally a lower expected value then the observed value, which may explain why, $g(0) \neq 1$. Whereas at the second interval (40 – 80 m) it is a higher expected value then the observed value, which can explain why $g(y) > 1$ (Tab. 2). A qualified guess is that it may depend on the different behavior and morphology in the two species. Fallow deer are herd animals and have well developed senses to avoid predators. When a fallow deer are watching for predators are all senses involved but, along with the sense of smell, are probably hearing the sense which are primarily used by fallow deer in order to detect danger (Svenska Jägareförbundet, Swedish Association for Hunting) Their herding behavior in combination with their high developed senses make them very observant of their surroundings and are difficult to get close to without being detected. Roe deer on the other hand, are solitary or in smaller groups and exhibit a different behavior and is to a higher extent a hiding animal compared to fallow deer and therefore shows a different result (Tab. 3 and Fig. 4). When the observer are approaching a roe deer on or close to the transect, it instincts is to hide remain as motionless as possible to avoid being detected. But when the observer gets too close the flight behavior sets in and it jumps up a few meters from the observer which results in a higher number of observed animals then expected on or close to the transect. To explain why the expected value is higher than the observed in the second interval my hypotheses is, that the observer never get so close to the animal so instead it remains motionless and are consequently not detected.

To get more credibility in my assumption that most of the results are incorrect, I chose to compare them with the number of dead animals reported since 2006-2012 (Fig. 15 and 16). The roe deer density shows most inaccuracies but the same assumptions can be taken as for the fallow deer. With knowledge of what the results showed it can be concluded that there some things in this survey that can be improved to obtain more reliable results. The main thing to change, and probably the change that makes the most difference for the result, are the length of the transects. The encounter rate clearly show that all transects in both areas are to short relative to the density. According to the overall values for the northern area would a transect length of minimum 4 kilometer give an encounter rate closer to 1.00 fallow deer/ transect. In the southern area is a transect length of approximate 2-3 kilometer enough to ensure to detect a fallow deer, almost twice as much length is needed in the northern area. To increase the detection function for roe deer in the northern area is an average value of 6 kilometer needed to detect an animal and in the south is a optimum transects length estimated to be 6-10 km (note that in 2008 was 33 km needed to detect one roe deer in the south).

According to (Cassey 1999) is it concluded that, if observers understand the principles of distance sampling and are experienced with the species and its environment the estimation of distance will not provide any difficulties. And the program Distance 6.0 will produce reliable estimates of density. If one take Cassey's assumption about experience and understanding the principles in regard, can the observers experience be a small factor to why the results were unreliable.

Even if some of the values did not show reliable results is this study not to discard. The results still gives an index of a population increase or decrease over a six years period. It also gives an index of the total number of individuals, sex ratio and age ratio of both species, in both areas which is of great importance for the hunters before planning the following years hunting quotas and maintain populations of a vital sex distribution.

Acknowledgment

First of all, this has been a really interesting project and I am very grateful that I got the opportunity to implement it. It has been hard work and late nights but it has been worth it and I would gladly do it again. But I had to admit that would not been possible to fulfill this project without some important people. First I want to thank my assistant supervisor Petter Kjellander for all support and help during my time at Grimsö Wildlife Research Station. Secondly I would like to thank my supervisor Ulrika Alm Bergvall for reading my report and for giving me some comments to make it easier to understand distance sampling in case the reader would not be familiar with the subject. I also want to thank two field workers that helped me collect data at the Koberg estate during the month there, Ramona Paulsson and particularly Madeleine Christensson for teaching me how the method distance sampling is carried out in the field. Finally I would like to thank the other students at Grimsö Wildlife Research Station for wonderful dining evenings and for teaching me how to play Innebandy. An extra thanks goes to Andrew "Andy" Allen, without his help, I would probably still struggle with the program Distance.

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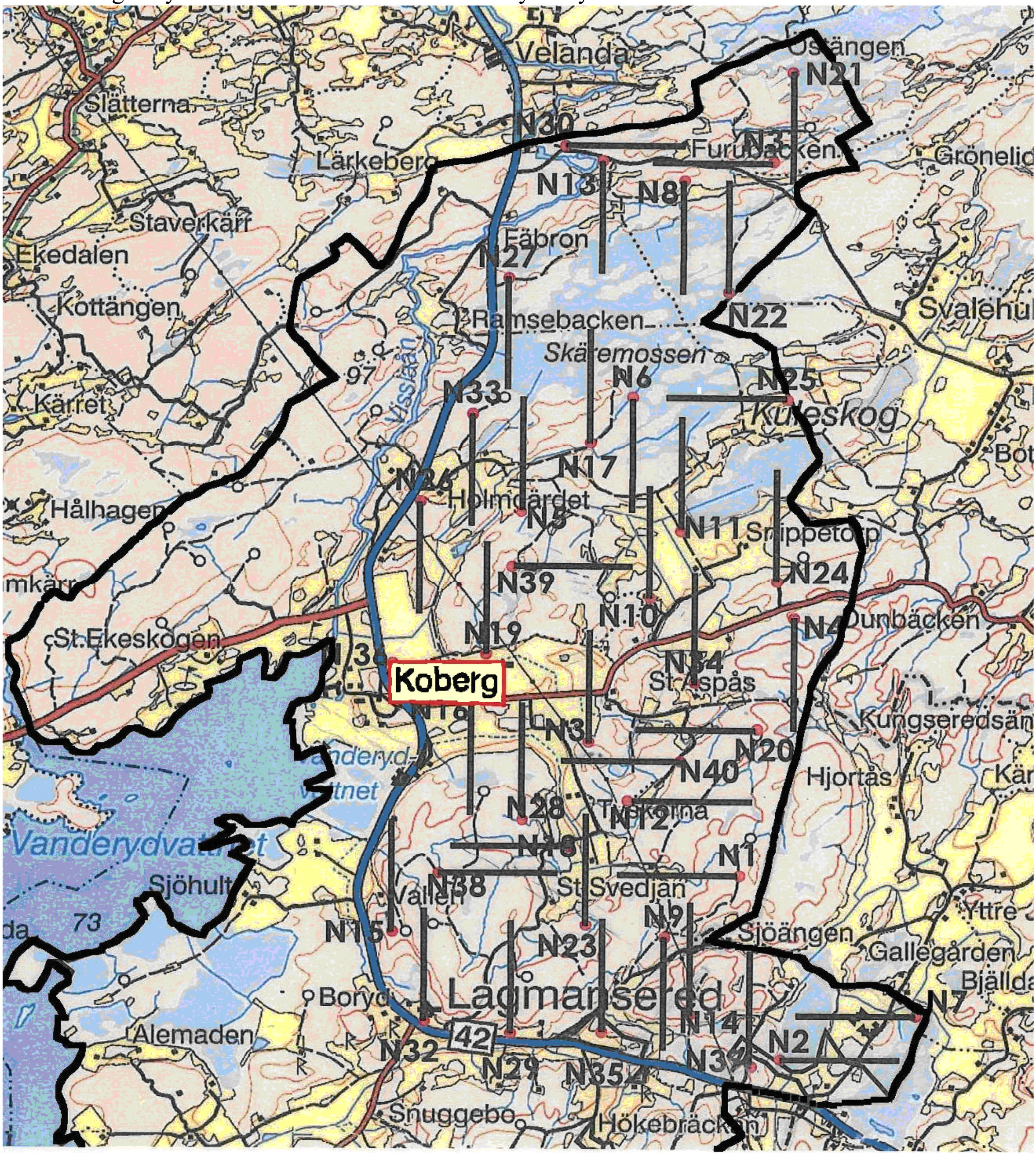
Appendix

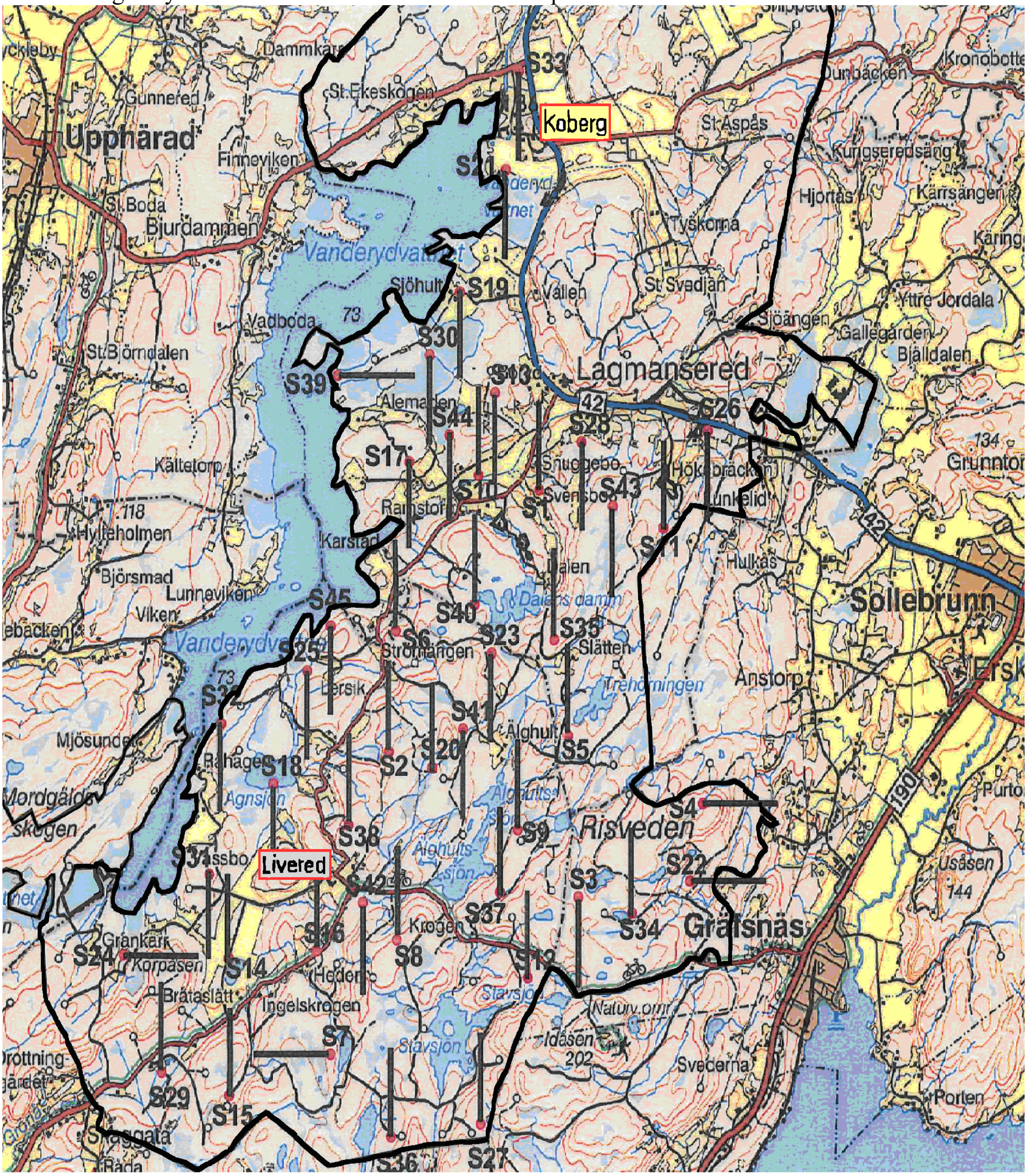
Appendix 1

Map over the northern study area. 40 transects are randomly placed to cover the whole area. National highway 42 divide the area in to the actually study area.



Appendix 2

Map over the southern study area. 45 transects are randomly placed to cover the whole area. National highway 42 divides the area from the northern part.



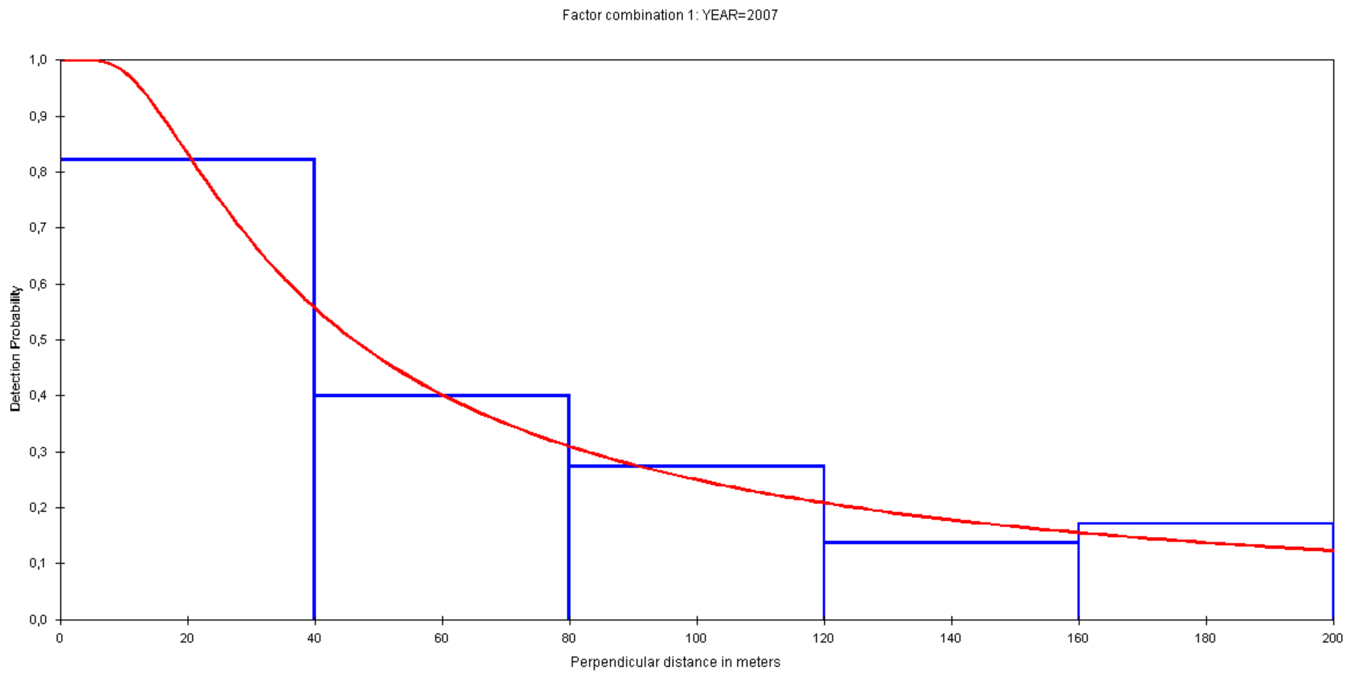
Appendix 3

Paper form used at field work to note down the observed objects.

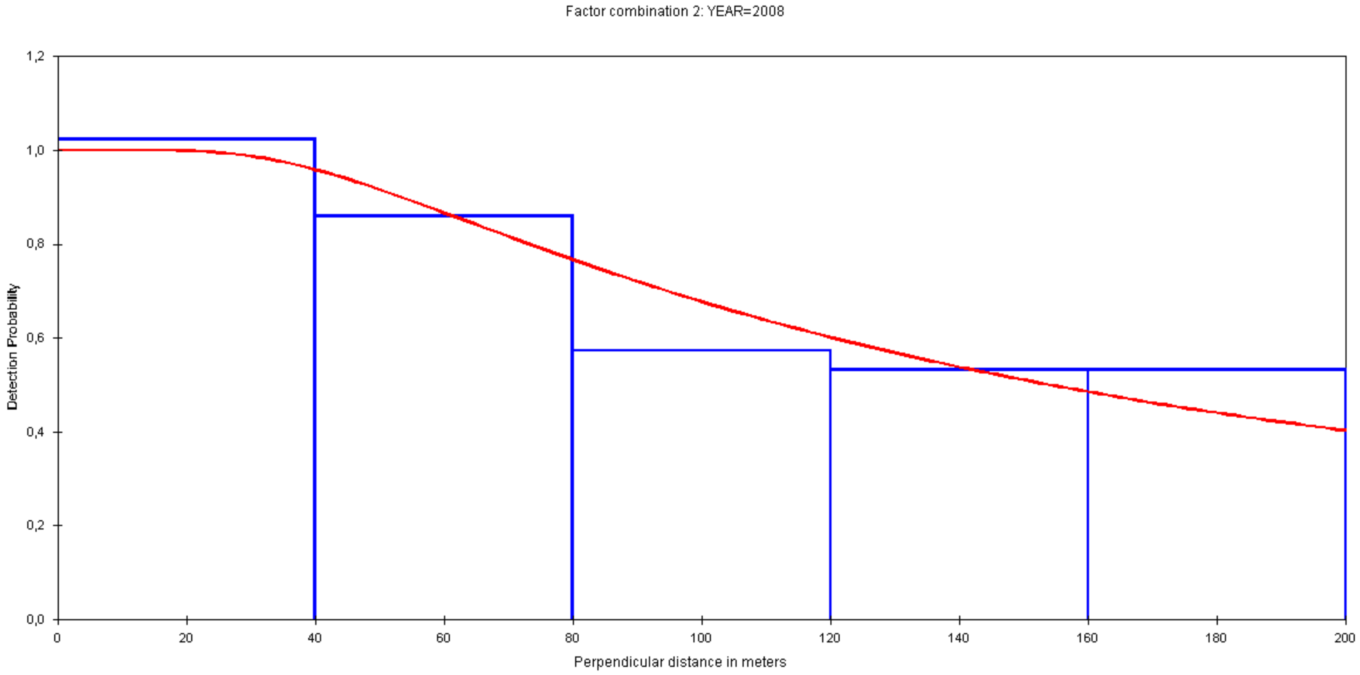
Transect	Date			Start time					Weather						Wind direction			
Observer		Heading →		Stop time											Wind strength			
										Males				Females		Unknown		
Time	Heading	Waypoint	X-coord	Y-coord	Sight (m)	Dist (m)	Angle	Spec.	Wind.	Calf	Spike	Adult	Trophy	Calf	Ad	Calf	Adult	Unknown
Sight:	Average of 360°								Wind strength:	NO= No wind		WK= Weak		M= Intermediate		ST= Strong		

Appendix 4 - 9
Appendix 4 - 9shows the detection function for fallow deer year by year. The horizontal axis shows the perpendicular distance (y) in meter and the vertical axis shows the detection probability g (y). The slope indicates how the detection function g (y) decreases in relation to the distance.

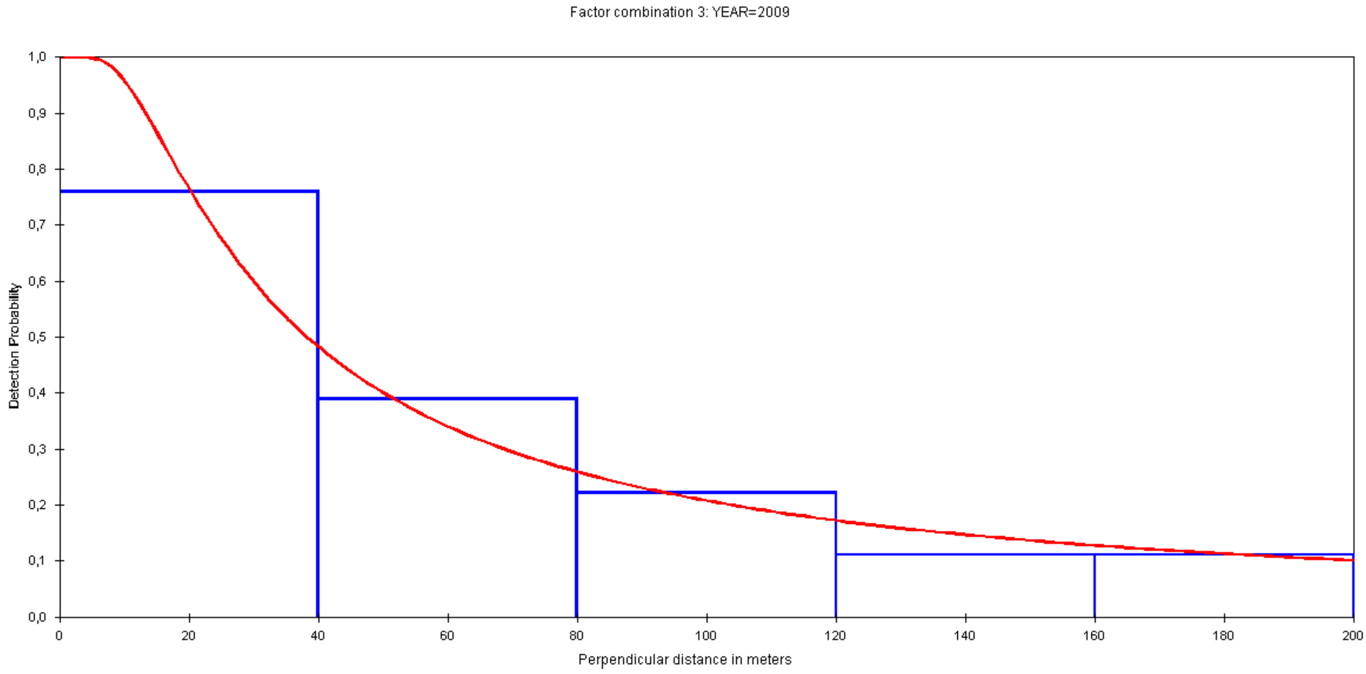
Appendix 4. Detection function for fallow deer. 2007.



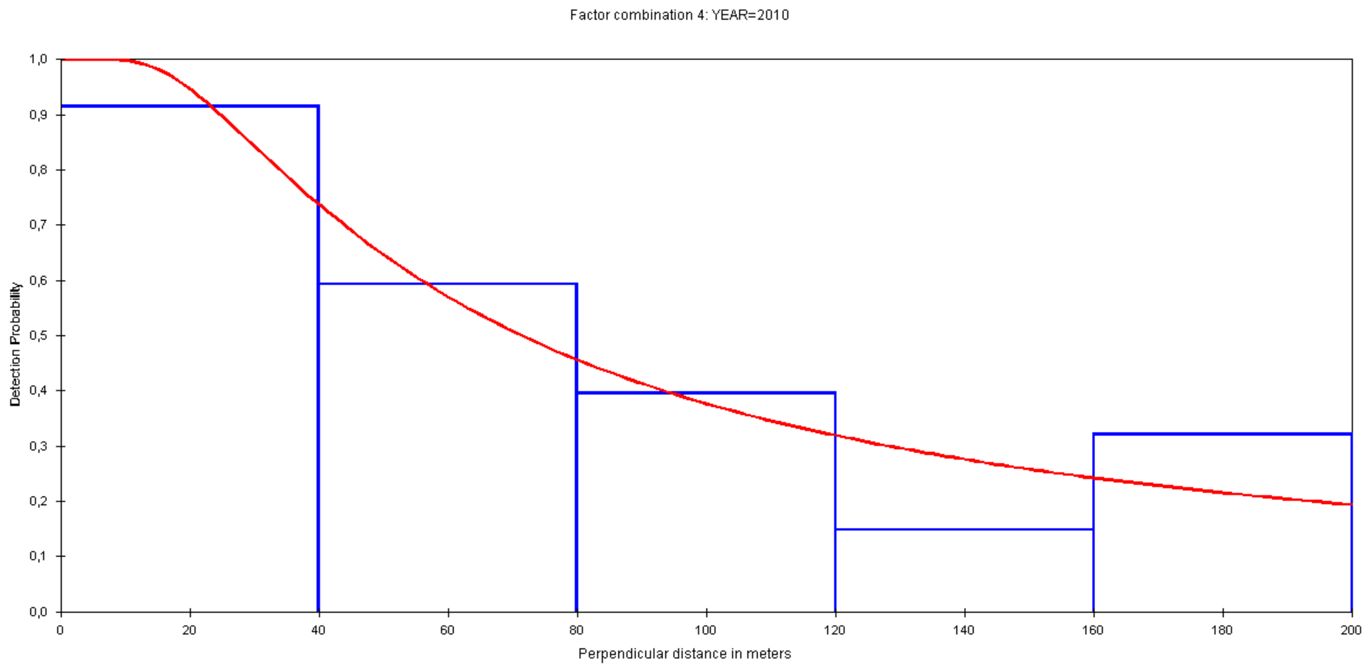
Appendix 5. Detection function for fallow deer. 2008.



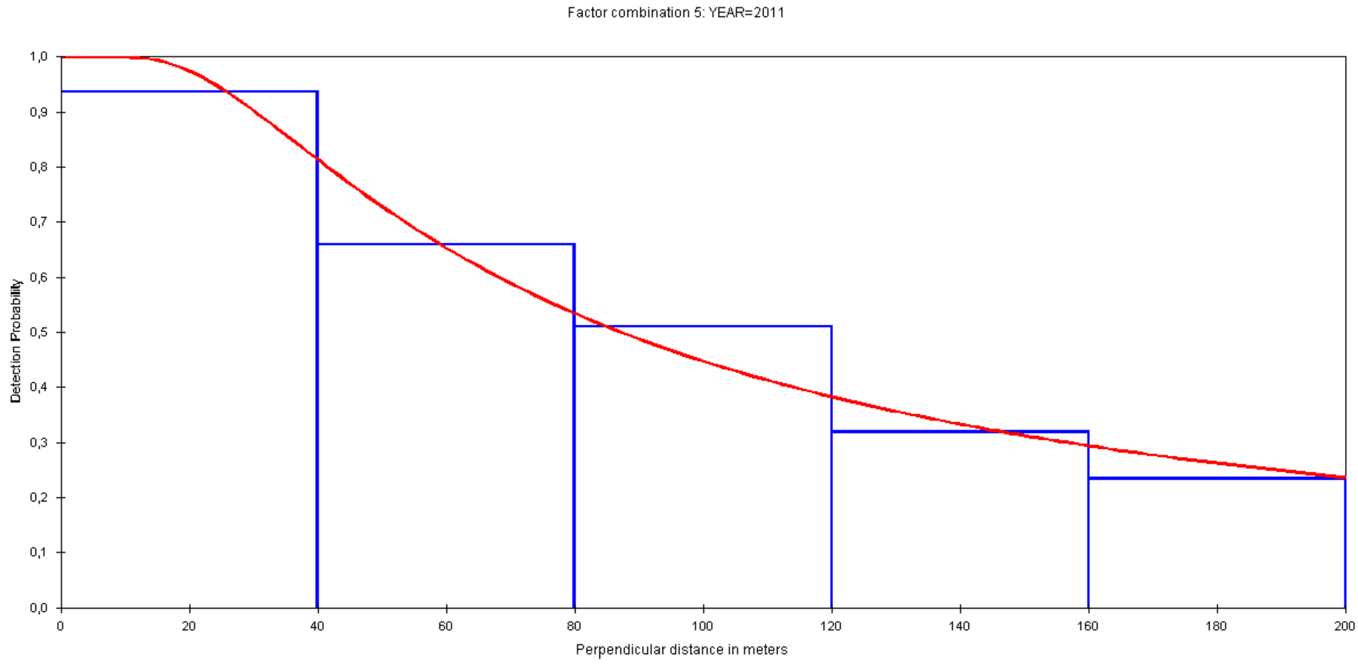
Appendix 6. Detection function for fallow deer. 2009



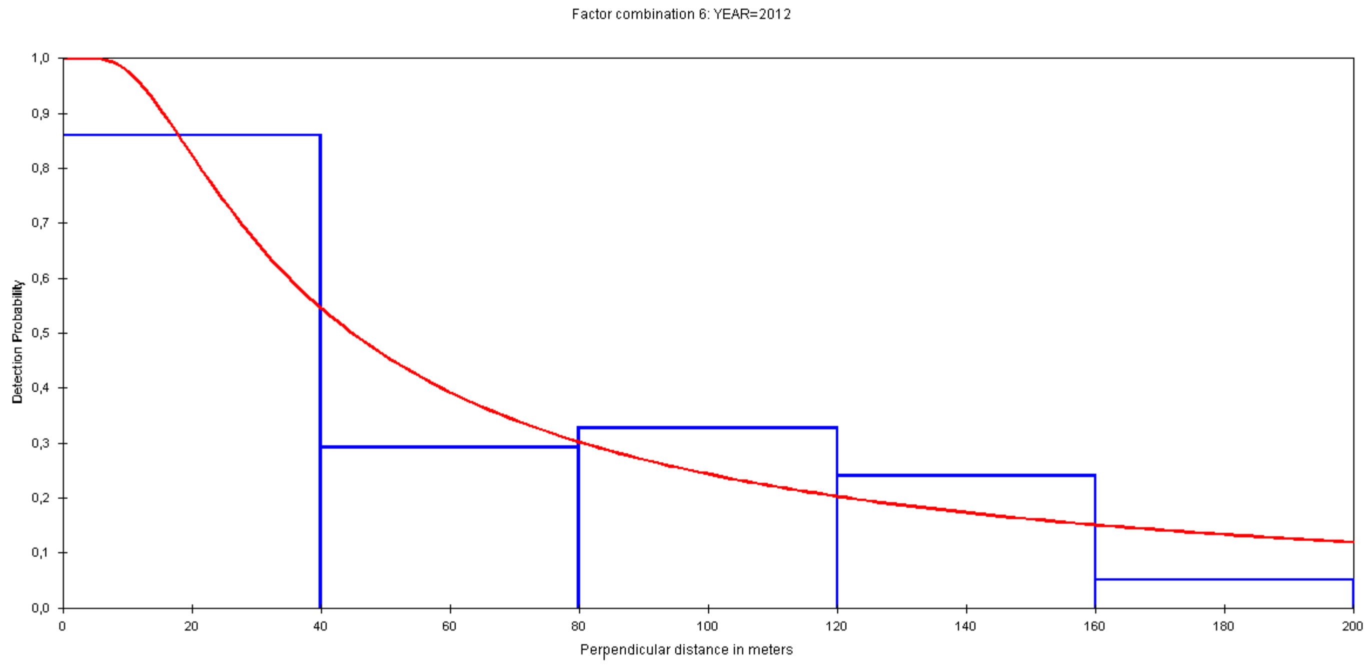
Appendix 7. Detection function for fallow deer 2010



Appendix 8. Detection function for fallow deer. 2011



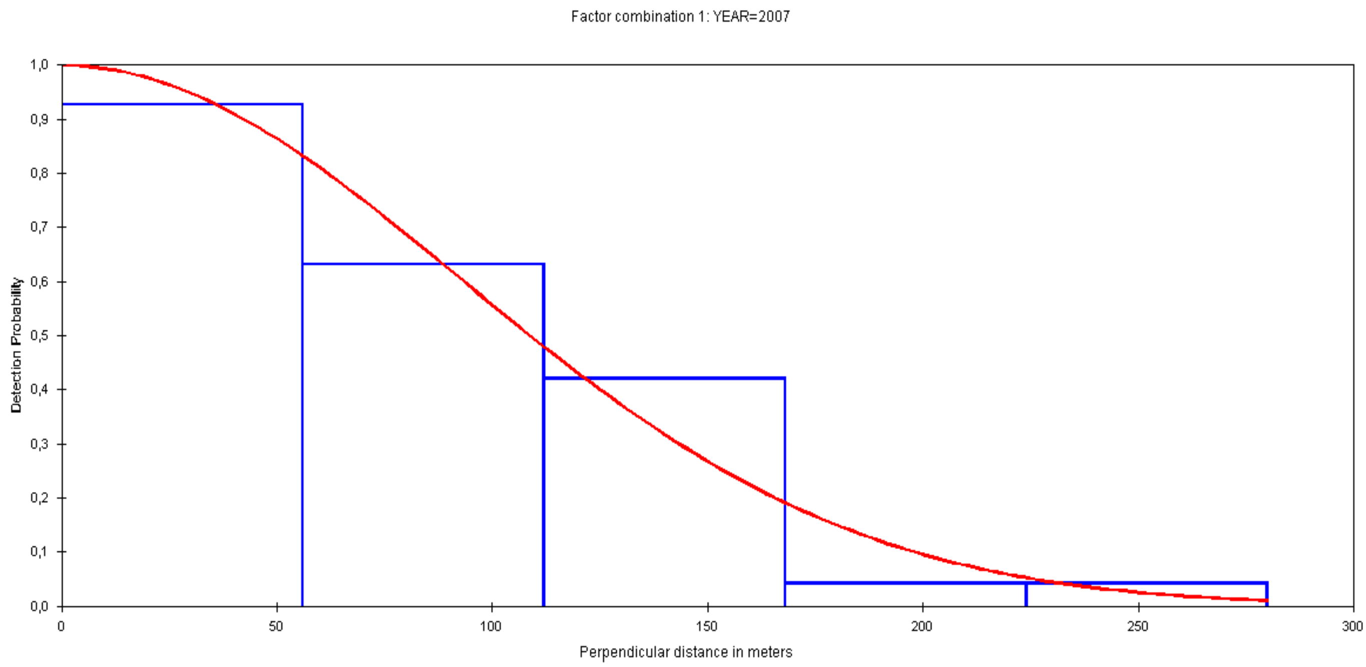
Appendix 9. Detection function for fallow deer. 2012



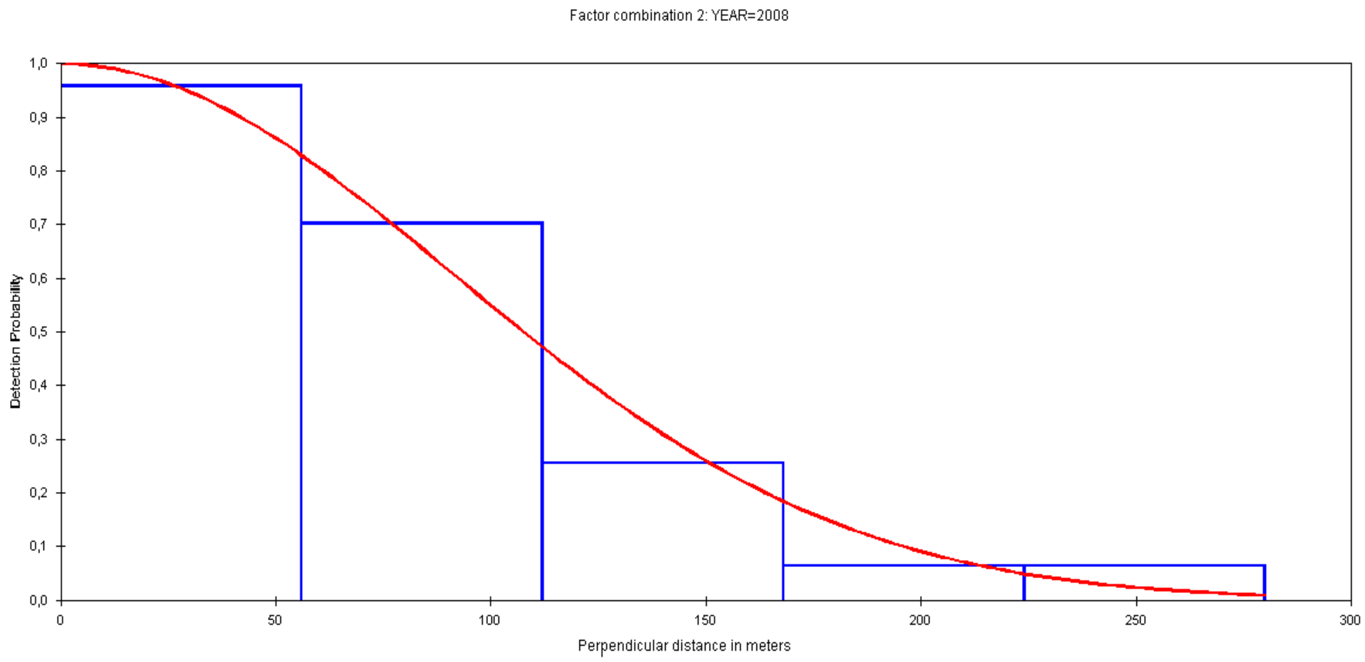
Appendix 10 - 15

Appendix 10 - 15shows the detection function for fallow deer year by year. The horizontal axis shows the perpendicular distance (y) in meter and the vertical axis shows the detection probability g (y). The slope indicates how the detection function g (y) decreases in relation to the distance.

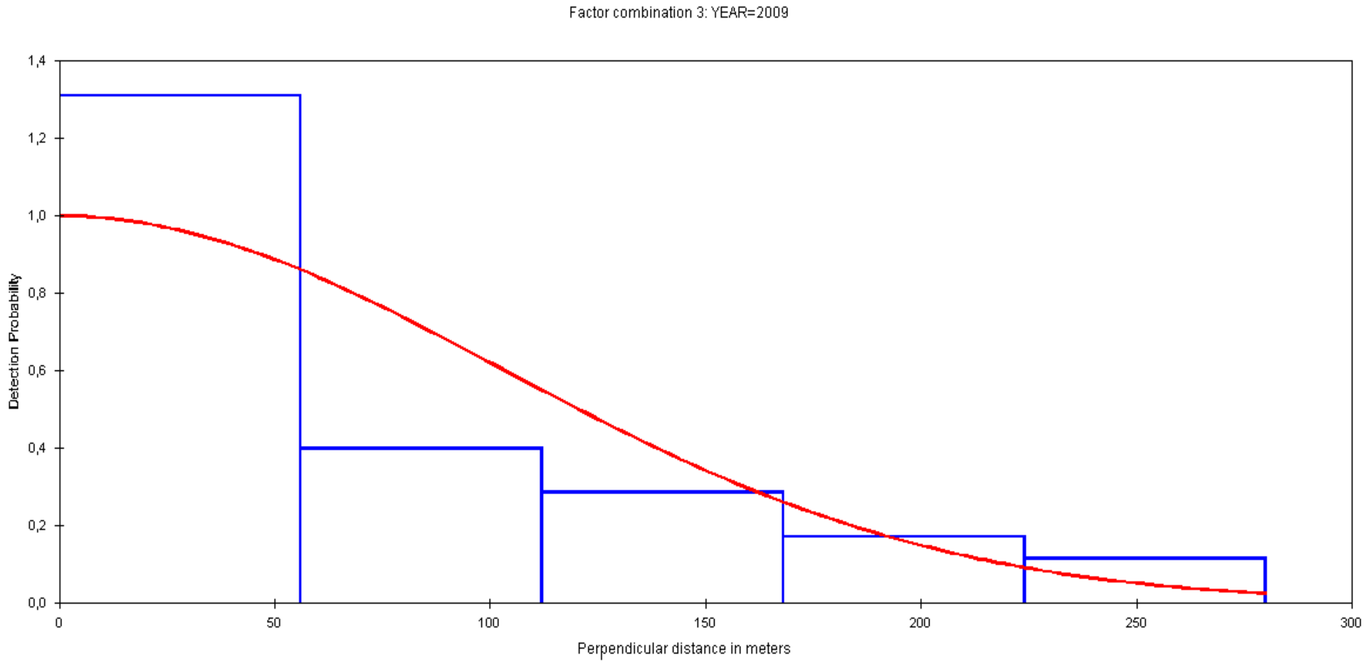
Appendix 10. Detection function roe deer. 2007



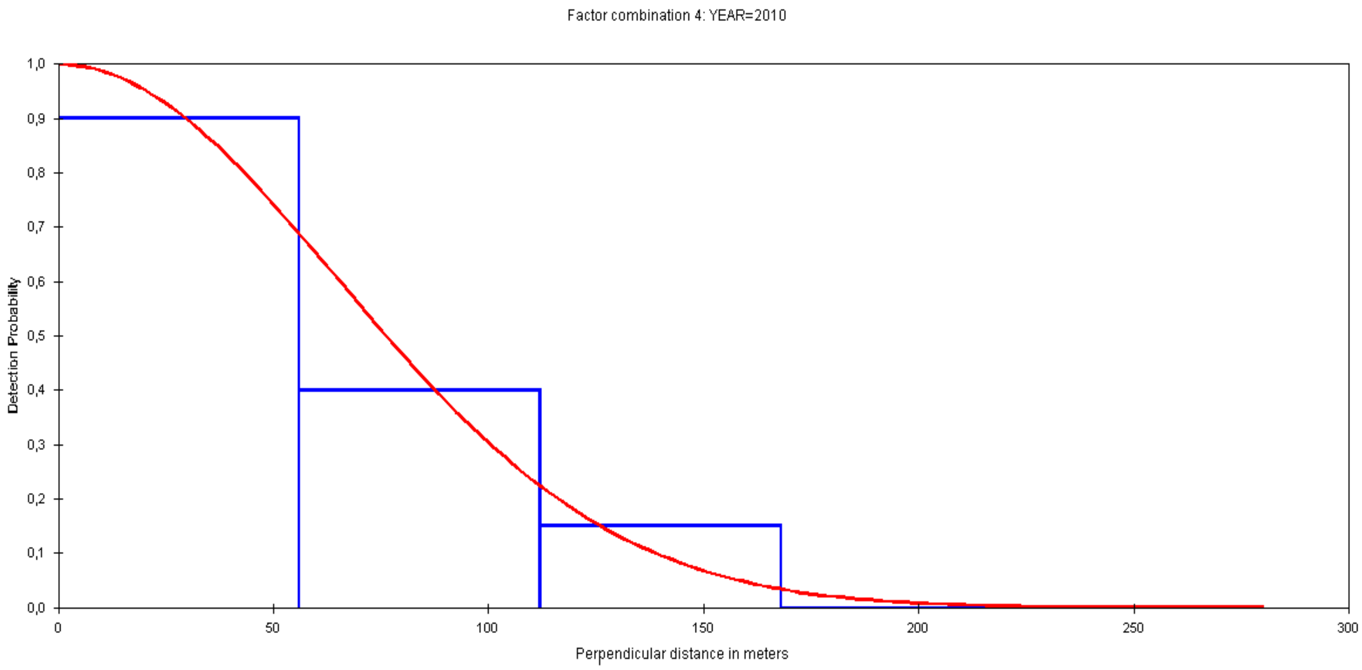
Appendix 11. Detection function. 2008



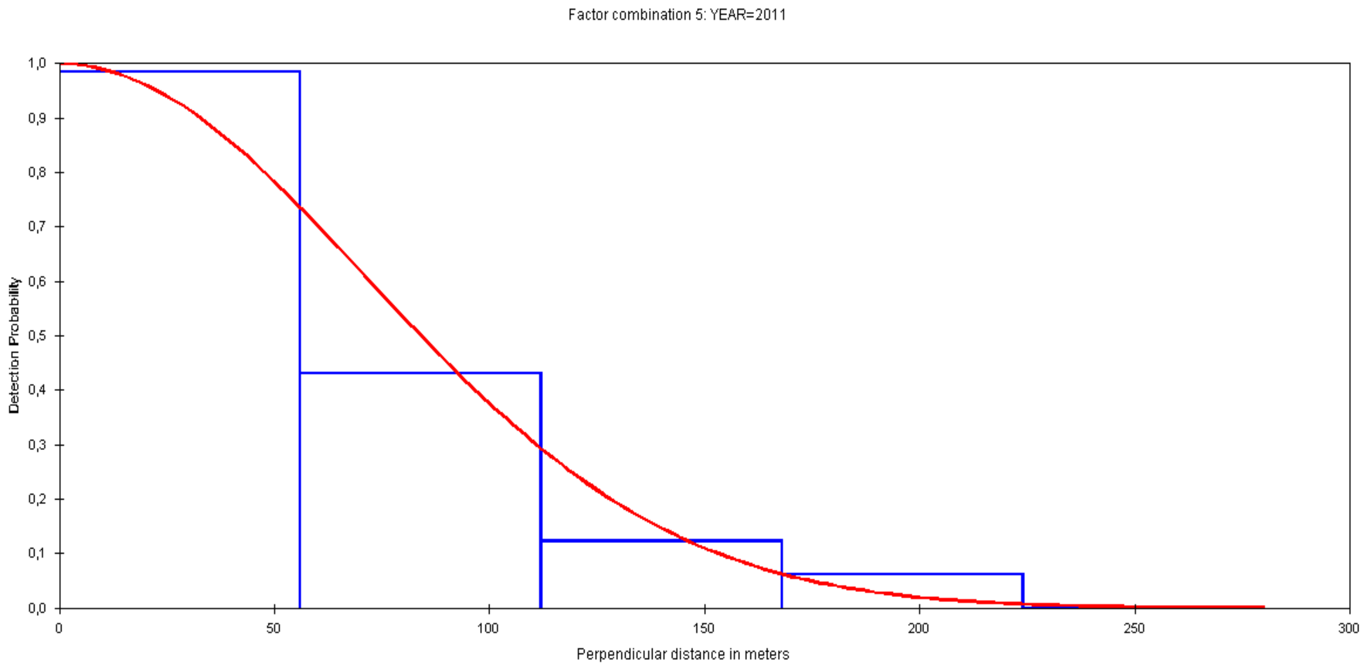
Appendix 12. Detection function for roe deer. 2009

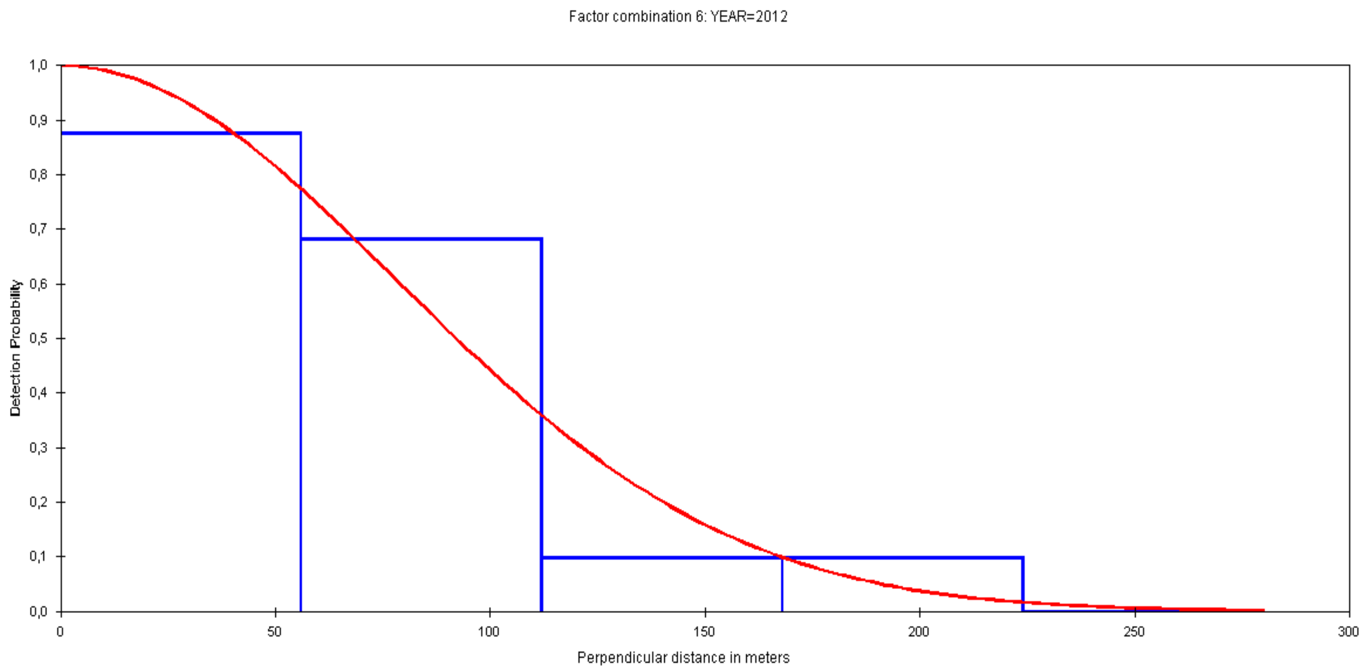


Appendix 13. Detection function for roe deer. 2010



Appendix 14. Detection function for roe deer. 2011





Appendix 15. Detection function for roe deer. 2012