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The use of point-transects distance sampling to estimate the density of alpine marmot in the Gran Paradiso National Park

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ABSTRACT

Regular counts are an important tool to study and protect animal and plant species. The method used should be practical, reliable and repeatable. In this work we apply distance sampling by point transect to estimate density of alpine marmot (*Marmota marmota*) inhabiting an area of the Gran Paradiso National Park where marmots have been marked and monitored since 2006. We compare results obtained with distance sampling with the known density of marmots in the area. Our results are good in terms of effort and density estimation, but the application of the method on this species can be improved. Future work should apply point-transect distance sampling in other areas.

Keywords: alpine marmot, *Marmota marmota*, point transect distance sampling, wildlife census, density estimate

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1. INTRODUCTION

Counts of wild animal species within and outside protected areas is of high importance to know and monitor the wildlife value of a territory (Buckland *et al.*, 2000). In fact a regular census allows to predict, apply and verify potential management and/or conservation actions for several species and their habitats (Blanco *et al.*, 1996; Buckland *et al.*, 2000). By analysing data obtained from counts it is possible, for example, to identify areas with higher or lower density, habitat of prior interest, habitat selection and temporal fluctuation in density of the species under examination (Buckland *et al.*, 2000).

Counts have always been an important tool for researchers and wildlife managers, but during these years of climate change it is even more important to regularly monitor species in their environment (Parmesan, 2006). It is crucial to collect data on the presence, density and fluctuations for any species potentially at conservation risk, such as for species which play an important role in the sensitive ecosystem. Counts are advisable also in a number of other cases such as, for example, with invasive species, hunted wildlife species or migrating species (Lewis, 1970; Parmesan, 2006; Meriggi *et al.*, 2012).

Monitoring studies and methodologies are growing and nowadays there are numerous methods of census (Lewis, 1970; Goldsmith, 1991). A good method should be applicable to the species subject of the study, easily repeatable, practical, reliable and with low or no disturbance for all the species inhabiting the area (Schemske *et al.*, 1994; Primak, 1998).

In this work we show results obtained using the point-transects distance sampling method to census the alpine marmot (*Marmota marmota*) in Valsavarenche, within the Gran Paradiso National Park. The alpine marmot is without doubt a key element of the alpine ecosystem but, despite its abundance, its density and the way to estimate it is not well know in all the Alps. Indeed all methods used in different areas of research on this species are characterized by a huge effort in terms of time and people and a scarce level of reliability. The aim of this study is to test point-transect distance sampling as a census method for the alpine marmot. In this paper we do not want to discuss the method of distance sampling itself but its application on this species. In the study area the density of marmots is well known from a long-term project started in 2006. This will allow us to compare the estimated density intervals with the known one, and thus to evaluate if this method gives reliable results for the species.

2. MATERIALS AND METHOD

2.1. Population studied

The subject of this study is the alpine marmot, a large ground-hibernating rodent. The alpine marmot is a key element in the alpine ecosystem and it is well distributed within the Gran Paradiso National Park as well as in all the Alps. It is a highly social species and populations are organized in family groups with a dominant breeding couple and a variable number of progeny of various ages

(Arnold, 1990). Each family group use a burrow system composed of multiple burrows all over its own territory, which is defended by dominant individuals against intruders (Ferrari, unpub. data). Burrows are of two type: main burrow with multiple entrances and emergence, or a simple hole in the ground where a marmot can easily hide (Durio *et al.*, 1987; Bassano and Macchi, 1991). In the Gran Paradiso National Park the main predators of marmot are red fox (*Vulpes vulpes*) and golden eagle (*Aquila chrysaetos*). The antipredator strategy of marmots relies on the burrows system to escape and on their alarm signal: a unique whistle is linked to an imminent danger, usually coming from the air, while more boos report generally terrestrial predators seen from a far (F. Pellicioli pers. observ.). Marmots, which inhabit regions surrounding the forest at 1,500 m a.s.l. up to the alpine meadows at 3,000 m a.s.l. are able to adapt their antipredator strategy in relation to characteristics of the environment (Ferrari *et al.*, 2009).

2.2. Study area

The study area is located within the Gran Paradiso National Park in Valsavarenche (North Western Italian Alps, 45°34′N / 7°11′E). In this zone a long term project on the ecology of alpine marmot is active since 2006; within the project, marmots are captured and marked, and individuals inhabiting the area are constantly monitored during the active season (Pasquaretta *et al.*, 2012). Hence the density of marmots in the area is well known by operators (Constantini *et al.*, 2012).

The census has been done in two areas characterized by a slightly different environment:

1 – Lower zone: Orvielles 2,165 m a.s.l. This area is confined within the forest and the environment is diversified with humps and shrubs all over the territory. These characteristics may complicate observations of animals. Besides, human disturbance is rather high in this area which is crossed by a walking trail used by tourists.
2 – Higher zone: Tzauplanaz 2,300 m a.s.l. This area is characterized by alpine meadow and a good visibility all over. Human disturbance is lower than in Orvielles since the trail does not cross the territory of marmots.

Orvielles and Tzauplanaz cannot be considered isolated areas between them, in fact there is contiguity between the territories with the possibility of moving for the marmots.

2.3. Distance sampling

Distance sampling refers to multiple methods that can estimate the density of populations using measurements of distances of objects located near the transect (Buckland *et al.*, 1993; Barraclough, 2000; Thomas *et al.*, 2010). A census with distance sampling can be done in two main ways: using point-transect, where the point of observation can be considered a transect of length zero, or using line-transect (Buckland *et al.*, 1993 Meriggi and Nelli, 2007). In this study we used distance sampling by point-transect to estimate density of alpine marmot, since line-transect was used in a previous census on the same species with suboptimal results (Affini, 2006).

Detection function is the main concept of the distance sampling, and it describes the probability to detect an object at a distance *y* located near the observation point of the transect (see Appendix A) (Buckland *et al.*, 1993; Thomas *et al.*, 2011). In most cases the detection function decreases with increasing distance, but it is always possible to affirm that $0 \leq g(x) \leq 1$ (Buckland *et al.*, 2001). Among the advantages of distance sampling there is the possibility to estimate the absolute density of a population with intervals of confidence and coefficient of variation without the need to detect all the animals inhabiting the area, and the possibility to use all collected observations in the analysis (Buckland *et al.*, 1993; Barraclough, 2000).

To obtain reliable results it is necessary to meet the three basic assumptions of distance sampling (Buckland *et al.*, 2001; Thomas *et al.*, 2010):

(i) Objects located on the transect are always detectable, so that $g(0) = 1$.
(ii) Objects are detected in their original position, before any movement due to the presence of the operator. Distance sampling wants to 'freeze' the position of an animal in the moment of the census. To respect this assumption we decided to wait a fixed period at the point of observation before starting the census (Barraclough, 2000).
(iii) Distances or angles have to be carefully noted.

Once data is inserted in the software DISTANCE 6.0 it is possible to run different models of g(x), and it is then possible to select between models by using AIC criteria (Akaike, 1973; Burnham *et al.*, 2011). A lower value of AIC means a better fit of the detection function to the observed data.

While with conventional distance sampling (CDS) the probability to detect an object is considered a function of the simple distance between the object and the transect (Buckland *et al.*, 2004), by running the multiple covariates distance sampling (MCDS) it is possible to take account of variables related to the current characteristics of the census (i.e. weather, time of the day etc.) as covariates in the analysis (Buckland *et al.*, 2004).

2.4. Data collection

We decided to carry out the census with distance sampling between 8:30 a.m. and 11.30 a.m. and from 14:30 p.m. to 17:30 p.m. In fact, previous studies in the same area revealed that marmots are more active in these hours (Ranghetti, 2009). The census was done during June and July 2011, excluding rainy days and weekends when the touristic disturbance was too high. We devoted two weeks before starting the census to get practised with tools and to determine the appropriate radius for the transects (Sokal and Rohlf, 1995).

Data collection was performed using different tools: a binocular (Zeiss 10×) to detect animals from distance, a telemeter (Leica) to measure the radial distance and a G.P.S. (GeoExplorer Trimble) to register the geographical coordinates of all points of observation.

To meet the assumption of distance sampling, operators have to choose in a random way point-transects within the study area (Thomas *et al.*, 2010). The radius of the circle, which is the same for all the points used in the census, is then chosen so as to include most of the territory without overlapping between different point-transects. We decided to use a radius of 110 meters for each transect: in Orvielles we had four point-transects while in Tzauplanaz three were enough to cover the entire area. Once the operator reached the point of observation (in the mid of each point-transect, see Appendix A) data collection consisted of 3 steps:

(i) 10 minutes of waiting at the point of observation to decrease the potential disturbance in the territory. During this period the operator started to observe the area but did not take any measurements. We chose 10 minutes because, based on previous experience, we knew it was a sufficient time for marmots to get used to the presence of the motionless operator and so to behave normally.
(ii) 8 minutes census. The operator was standing still then turned 360 degrees on herself. Once a marmot was detected, the operator noted the distance between the animal and the point of observation with the telemeter. After the first days of tests with the method of census we decided that 8 minutes was an adequate time to collect observations.
(iii) 2 minutes to check; at the end we changed position quietly and any marmot observed during the moving was noted.

2.5. Data analysis

To run the analysis we used the software DISTANCE 6.0 and we followed the procedure described in Buckland *et al.*, 2001 and 2004. For each model, distance sampling also creates a graph of the detection function (line) compared to observed data (histogram). This graph presents characteristic features which may help in evaluating the fit of the model: curve of detection function has a characteristic 'shoulder' form on the left (which represents the certain probability for the operator to detect an animal when the distance is equal to zero) and it decreases on the right (generally the probability of detecting an animal decreases with the increase of distance) (Buckland *et al.*, 2001). In the first explorations of our data this characteristic form was missing. In fact, despite our 10 minutes of waiting before starting the real count (see section 2.4.) our data included only a few measurements within a distance of 50 meters from the observer and this was probably the cause of the lack of the shoulder from. To avoid misleading results we thus excluded observations of measures less than of 50 m from the observer.

The software permits the use of a series of key functions and series expansion to better analyse different types of data. We divided all observations into five intervals of the same length and we ran explorative analysis with the conventional distance sampling (CDS) using AIC to select between models, in order to find the best key function and series expansion to use in the next analysis.

2.5.1. Multiple Covariate Distance Sampling (MCDS)

When collecting observations, we noted a time slot (T) in which the transect was performed, weather (W) and human disturbance (HD) to be used as covariates in the analysis. The time slot included 'morning' and 'afternoon' as categories and weather was noted as 'sunny' or 'cloudy'. To measure human disturbance we created a numerical scale: we assigned '0' when no other person except the observer was in the area during the entire observations (section 2.4.); '1' when only a few tourists (1–2) passed silently without stopping in the area; '2' when, once the transect was already started, a group of tourists (3–6) silently passed in the area or a few people remained within the confines of the transect. When human disturbance was higher than situations described above we preferred not to collect data since we considered the conditions not appropriate for a census.

3. RESULTS

All the observations were collected by the same operator (Federica Pellicioli), who was not aware of the actual density of marmots in the area. We repeated every point 10 times and finally we collected a total of 325 observations.

3.1. Conventional distance sampling analysis (CDS)

Results obtained from the conventional distance sampling analysis (CDS) with the lower AIC are shown in Table 1.

The best model uses the half-normal cosine function and has an AIC value of 658.41 with a coefficient of variation of 0.434. Comparing the shape of the detection function with collected data we observed a strong decrease of observations with an increase of distance. The analysis fulfilled the assumptions of distance sampling.

Table 1 Results of the CDS analysis according to the increase in AIC values (lower to higher). In the table are shown: type of analysis, number of parameters considered, AIC values, the effective detention radius (EDR), average density, the confidence layer: lower (LCL) and upper (UCL) and the coefficient of variation.

Analysis	N° parameters	Delta AIC	AIC	EDR	Density	LCL	UCL	CV
Half-normal cosine	1	0.00	658.41	54.31	2.467	0.950	6.410	0.434
Half-normal simple	1	0.00	658.41	54.31	2.467	0.950	6.410	0.434
Negative cosine	1	0.01	658.41	32.15	7.037	2.523	19.628	0.513
Uniform cosine	1	0.17	658.58	52.70	2.620	1.016	6.755	0.414

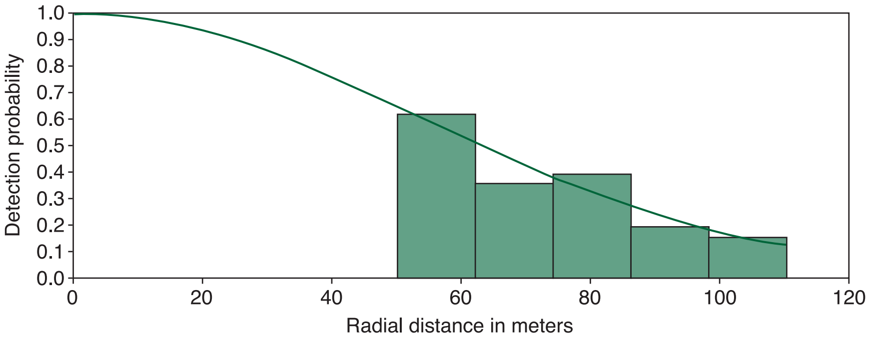

Figure 1 Graphics of the analysis with convential distance sampling and the half-normal cosine function. The green line represents the detection function while the histograms show observed data. On the right, detection function slowly decreases with the increase in distance.

3.2. Multiple covariate distance sampling analysis (MCDS)

Following explorative analyses all models were run using the half-normal cosine function. Table 2 shows models that include different combinations of covariates (time slot, weather and human disturbance). The time slot appears to influence the detection function more than all the other variables considered. All models which included time slot showed a lower AIC value compared to those run without this variable or with the conventional analysis. The best model included time slot and weather as covariates.

Variations in the shape of the detection function according to the different covariates included in the models are shown in Figures 2–5.

Table 2 Models run shown according to the increase in AIC values (lower to higher). A lower value of AIC indicates a better fit of the detection function to the data. It is possible to compare CDS analysis (without covariates) and MCDS testing. Covariates considered are: T=time slot, W=weather and HD=human disturbance

Analysis	N° parameters	Delta AIC	AIC	EDR	Density	LCL	UCL	D CV
MCDS T+W	3	0.00	654.10	49.73	2.942	1.141	7.586	0.414
MCDS T+W+HD	5	1.23	655.33	41.58	4.208	1.480	11.961	0.529
MCDS T	2	2.63	656.72	52.92	2.598	1.008	6.694	0.407
Half-normal cosine CDS	1	4.31	658.41	54.31	2.467	0.950	6.410	0.434
MCDS T+HD	4	4.47	660.57	52.40	2.649	1.028	6.827	0.408
MCDS W	2	6.21	660.31	54.30	2.468	0.958	6.359	0.407
MCDS HD+W	4	6.47	660.57	52.45	2.644	1.026	6.814	0.409
MCDS HD	3	6.54	660.64	53.65	2.528	0.981	6.513	0.407

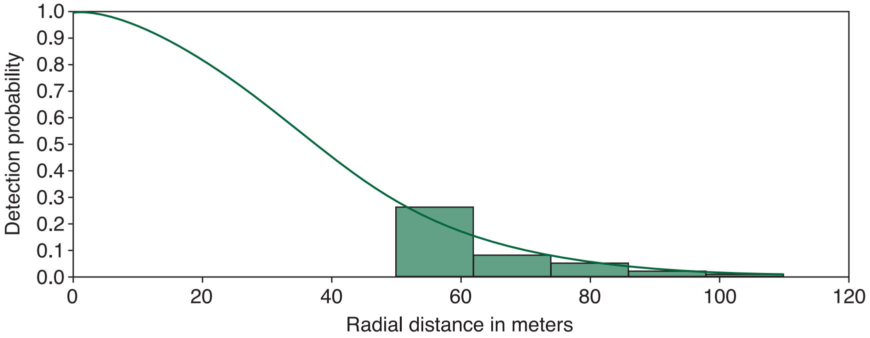

Figure 2 Graph of the MCDS model with time slot and weather as covariates. Detention function (green line) fits well with the introduction of covariates T=morning and W=cloudy compared to the observed data (histograms). The curve shows the shoulder form on the left and a clear decrease on the right. Number of observations is reduced probably due to the scarce activity of animals on a cloudy day or to scarce visibility.

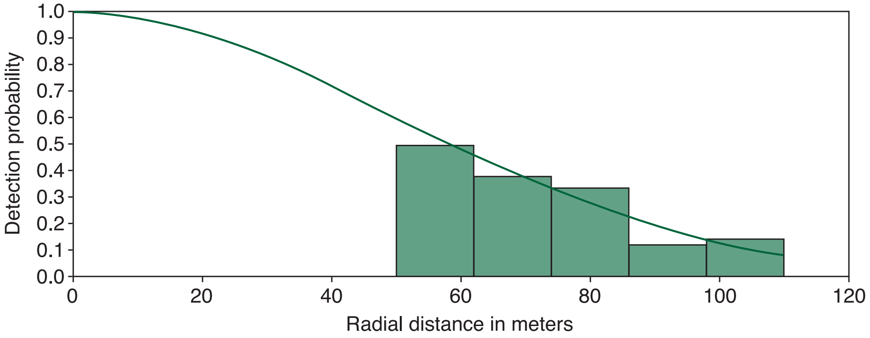

Figure 3 Graph of the MCDS with time slot and weather as covariates. Note the good fit of the detection function (green line) with the observed data (histograms). In this case covariates category are T=morning and W=sunny. Observation are more with respect to cloudy mornings (Figure 2).

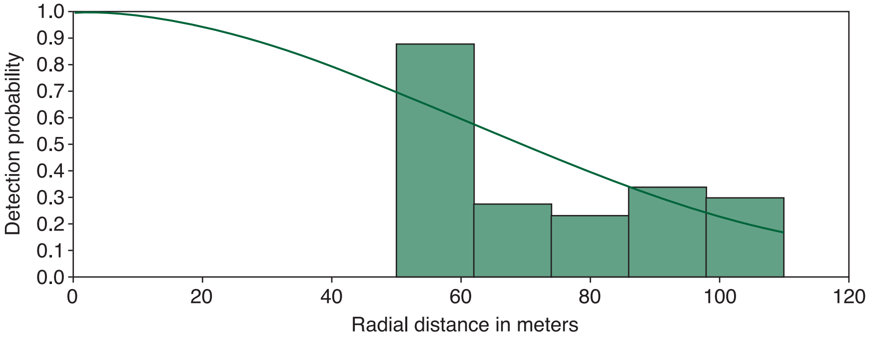

Figure 4 Detention function (green line) is represented in the graph. Its shape fits with the introduction of covariates T=afternoon and W=cloudy compared to the detected data (histograms) but the decrease on the right is not clear.

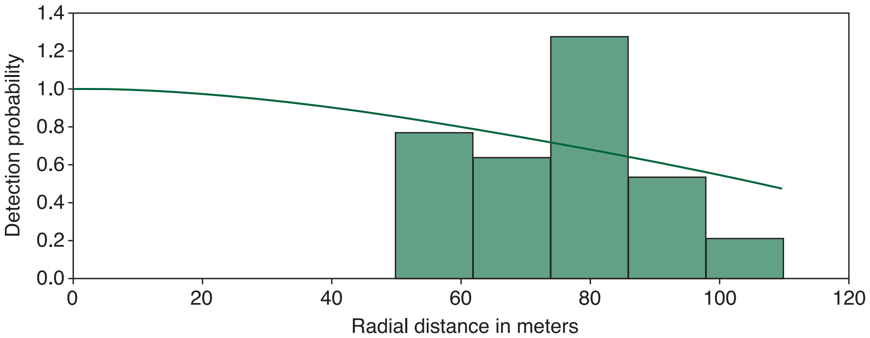

Figure 5 Detention function (green line) of the model with T=afternoon and W=sunny as covariates. The shape of the detection function shows anomalies on the left and on the right of the graph. There is a peak of observations at 80 meters of distance.

4. DISCUSSION

The use of distance sampling by point-transect to estimate density of alpine marmots gave encouraging results. The real density of alpine marmot inhabiting the study area is comprised between 3.2 and 3.9 animals / hectare. We prefer to indicate an interval and not a punctual value because territory neighbouring with the marked families included unmarked individuals that could be observed during the census.

The best model (AIC = 658, Table 1) obtained with the analysis of conventional distance sampling estimated a medium density of 2.5 animals / hectare (LCL = 0.950; UCL = 6.410, Table 1) with a coefficient of variation of 43%. This analysis did not included any covariates, while conditions of external environment are particularly important in a species which is used to hiding in burrows as soon as the situation becomes unsafe.

Analysis with multiple covariates distance sampling improved the model and provided a density estimation closer to the known one. After model selection the best was the one including time slot and weather as covariates (AIC = 654, Table 2); estimation of density was of 3.0 animals/hectare (LCL = 1.141; UCL = 7.586, Table 2) with a coefficient of variation of 41%, slightly lower that with the conventional analysis. This result is interesting since weather (thus visibility) and period of the day (thus temperature) are expected to influence the activity of alpine marmot. Surprisingly, human disturbance was not included in the best model. This result can be explained by the fact that we did not collect any observations during moments of intense disturbance and the touristic presence we recorded during census was probably comparable to the ordinary rate of encounters between marmots and humans.

In Figure 2 is shown the detection function in relation to the observed data during a cloudy morning and we note a reduced number of observations. Weather conditions, in this case cloudy, may influence both the ability of the observer to detect animals and the activity of animals, which may remain inside their burrows. In fact in Figure 3 we note an increased number of observations during the same hours (morning) but with sunny weather. Interestingly, observations are more numerous in the afternoon regardless of the weather conditions. This may be explained by the higher temperature during the second part of the day.

While in Figures 2 and 3 shapes of detection functions show the characteristic features with the shoulder form on the left and a decrease towards the right, indicating the reduced possibility to detect an animal with the increase of distance, this latter characteristic is not so clear in Figures 4 and 5, where curves show a slow decline on the right. This may be a consequence of the profile of mountains and bumps that could favour detection of animals at a distance.

In Figure 5 there is a decrease in observations between 50 to 110 m with a peak of observations at 80 m. This could be due to the high percentage of time spent by marmots close to their burrows (Labriola, 2007) and 80 meters could be the medium distances of burrows from the point of observation. Another possible explication is a minimum safe distance of 80 m between marmot and observer.

The main issue of collected data is the lack of observations within 50 meters from the point of observation. Once observed data at the extreme left (distances <50 m) and the extreme right (distances >110 m) were excluded, detection functions had good fit with observed data, but to improve the census on alpine marmot it would be advisable to solve this problem. Despite our precautions to minimize the disturbance potentially caused by the operator in the territory, only a few individuals were spotted close to the observation point.

Cases like this have been described in literature and are called 'donut effects': the movement of animals away from the point of observation is a consequence of the presence of the operator (Buckland *et al.*, 2001). Our 10 minutes of waiting time was maybe not enough for marmots, and in this case it would be interesting to see if a longer period would allow us to observe more animals. Furthermore, we may take advantage of marked individuals to see if marmots hide away or are visible but at further distances.

5. CONCLUSION

The aim of this study was to test a method to census alpine marmot that was practical, reliable and easily replicable. We used point-transect distance sampling on a marked population of alpine marmot, so as to be able to compare the known density with the estimated one.

The study of alpine marmot distribution and density within the Gran Paradiso National Park started in 1987 (Durio *et al.*, 1987; Lenti Boero, 1987; Bassano *et al.*, 1991; Peracino and Bassano, 1991). Methods were mainly based on construction of detailed maps to evaluate marmot distribution and on regular counting and monitoring of burrows located in sample area to estimate density (Peracino and Bassano, 1990; Bassano *et al.*, 1991). The main problems highlighted in these indirect surveys were the excessive effort required in terms of people and time, subjectivity and invasiveness which made difficult a regular replication of the census. Similar methods have also been used in other areas with few differences (Lòpez *et al.*, 2009; Müller, 1991; Barrio *et al.*, 2012). The study we present here had a positive outcome in terms of effort and results obtained. The entire data collection was done by a single person with an affordable workload, and census operations were minimally invasive for the species. Results were satisfying since estimated density was comparable to the known density of marmots in the area. This method can be applied in areas with different geographical characteristics (Buckland *et al.*, 2001), and the next step will be to apply point-transect distance sampling in other zones of the Gran Paradiso National Park. Point-transect distance sampling appears thus to be a valid method for census on the alpine marmot and it is therefore recommendable to use it in the studies of the species ecology.

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APPENDIX A

Here we provide definitions for some of the terms often used in the description of the point transects distance sampling

- POINT TRANSECT: it represents the circular area with radius r and the point of observation in its mid. It is placed within the study area in a random way.
- FIXED POINT OF OBSERVATION: it is placed at the centre of the point transect and it is the point from which all the observations are conducted. Number of fixed points is indicated with N.
- RADIAL DISTANCE: indicated by y is the distance in meters between the animal to the observation point
- DETECTION FUNCTION: the key function of distance sampling. It is the probability P to detect an object at a distance y from the fixed point of observation and it is expressed by the function $y=g(x)$. Generally, as the distance increase the probability to detect an object decrease. Distance refers to the radial distance for point transects and to perpendicular distance for line transect.
- ESTIMATED DENSITY: it is the number of animals for each sample area, represented by D.
- AREA: the total study area, it is calculated on $A = npr2$.