A Survey of the Feral Horse Population in the Victorian Eastern Alps, December 2021

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Abstract

1. An aerial survey of the feral horse population in the Victorian Eastern Alps conducted in December, 2021.
2. This survey was designed using the automated survey design engine of DISTANCE 7.3, and was conducted using helicopter line transect sampling. The results were analysed using DISTANCE 7.3.
3. A total of 1,071 km of transect was surveyed using helicopters flown at a ground speed of 93 km^{-1} (50 kts) at a height of 61 m (200 ft). Two observers were seated in the rear seats on either side of the aircraft. Sightings of clusters of horses were recorded into five distance classes in a 150-m wide survey strip on either side of the aircraft. A total of 78 clusters of horses were sighted.
4. A single global detection function model was fitted to the data and was used to estimate horse population densities and abundances in the survey region.
5. The population density of horses in the survey strata was estimated to be 1.32 km^{-2} (0.58-2.25), with the population density for the whole of the survey region being estimated to be 0.81 km^{-2} (0.36-1.38)
6. The estimated total number of horses in the 3,037 km^2 of the Victorian Eastern Alps at the time of the survey was 2,456 (1,088-4,186).
7. Two other species of large herbivores, wild deer and cattle, domestic and feral, were counted during the survey. It was estimated that there were 602 (344-1,035) deer and 2,496 (467-5,120) cattle in the Victorian Eastern Alps at the time of the survey.

1. Introduction

The Australian Alps National Parks (AANP) extends through the alpine regions of south-eastern New South Wales (NSW) through into the alpine regions of north-eastern Victoria. Found within the general region covered by these parks are a number of populations of feral horses (*Equus caballus*). As part of the development and execution of evolving plans to manage these horse populations, a number of population surveys have been undertaken; most under the auspices of the Australian Alps Liaison Committee (AALC).

The feral horse populations of the Australian Alps National Parks have earlier been surveyed using helicopter line transect sampling in 2001, 2003 and 2009 (Walter 2002, 2003; Dawson 2009). Also, an adjacent area of State forest in NSW was surveyed in 2004 (Montague-Drake 2004). A reasonably recent survey, conducted over an expanded survey area to encompass both national parks and adjacent areas of State forest, was designed and carried out in April-May 2014 (Cairns 2014, 2019). The timing of this survey and the decision to expand the survey area was in response to recommendations with regard to future surveys made by Dawson (2009). This survey was repeated five years later in April-May 2019 (Cairns 2019). An outcome of the second of these two surveys was that the overall size of the feral horse population in the Australian Alps was found to have reached its highest recorded level (Cairns 2019).

In response the outcome of the 2019 survey (Cairns 2019), in 2020 the NSW National Parks and Wildlife Service (NPWS) undertook a follow-up survey of parts of the Kosciuszko National Park within that part of the AANP estate north of the NSW-Victoria border (Cairns 2020). In 2021, Parks Victoria decided to undertake a follow-up survey of the Victorian Eastern Alps region, within that part of the AANP estate south of the NSW-Victoria border. Both these surveys were undertaken, in part, in response to the severe drought that extended from April 2017 through until October 2019 (http://www.bom.gov.au/climate/drought/knowledge-centre/previous-droughts.shtml), and the severe bushfires that occurred in parts of the AANP during the summer of 2019-2020 (https://www.vic.gov.au/2019-20-eastern-victorian-bushfires).

Reported on here is the conduct and outcome of the survey of the feral horse population in the Victorian Eastern Alps that was conducted in December 2021. The development of the design of this survey is outlined in Cairns (2021). This current report covers the survey method and data analysis procedures, and the results obtained from the conduct of the survey, along with some discussion of these results and the methods used to obtain them.

2. Study Area and Survey Design

For the purpose of surveying the feral horse population in the Victorian Eastern Alps, the survey region was divided into three strata, two of which were to be surveyed using helicopter line transect sampling (Cairns 2021). The two strata to be surveyed were one constituting those parts of the region comprising medium terrain (relief <20º) alpine habitat and the other comprising that portion of the Snowy River Valley that made up part of the survey region. These strata were identified as the Medium Alpine stratum and the Snowy River Valley (SRV) stratum. The third stratum which was not surveyed comprised steep country with relief >20º. This stratum was not included in the survey for the reasons of safety of the helicopter crew and the likelihood that this steep country was not being utilised by horses.

The total area of the Victorian Eastern Alps survey region was 3,036.6 km^2. The areas of the two strata that were surveyed are given in Table 1. The area of the third, steep terrain stratum was 1,172.6 km^2. This stratum comprised 39% of the total area.

Table 1. The areas of the two survey strata in the Victorian Eastern Alps survey region, the target level of precision of the survey as indicated by the coefficient of variation (%), the constituent number of samplers (transects) and the total survey effort of the of the survey design require to meet the target level of precision.

Survey block	Survey area (km^2)	Precision (%)	No. of samplers	Survey effort (km)
Medium Alpine	1,814.6	17.5	45	1,030.7
Snowy River Valley	49.4	–	19	40.6

The surveys for these two designated strata were designed using the survey design algorithm of DISTANCE 7.3 (Thomas *et al.* 2010). For the Medium Alpine stratum, the survey comprised a systematic random sampling design. The precision of this design was 17.5%; the details of its derivation are given in Cairns (2021). Transects in this design were placed to be flown in an east-west direction and were 1.76 km apart. The number of transects and the total survey effort they comprised is given in Table 1. The layout of this design is shown in Figure 1.

For the Snowy River Valley stratum, the survey comprised an equal-spaced zigzag design. Because the area to be surveyed was particularly small, this design was not developed in relation to a specific level of precision. Rather it was developed in relation to a previous survey designed for a larger section of the Snowy River Valley (Cairns 2019). The process involved is explained in Cairns (2021). The number of transects and the total survey effort they comprised is given in Table 1. The layout of this design is shown in Figure 1.

3. Survey and Data Analysis Methods

Two previous aerial surveys have been conducted on the feral horse populations in the Victorian Eastern Alps part of the Australian Alps national park estate. These surveys were conducted in 2014 and 2019 as helicopter line transect surveys (Cairns 2019). For the conduct of both these surveys, a standard aircraft configuration was used. It includes a pilot seated in the front right-hand seat of the aircraft and who is responsible for flying the aircraft, maintaining a constant height and speed along the survey transect; an Air Safety Observer seated in the front left-hand seat of the aircraft who is responsible for assisting with navigation and maintaining situational awareness for the aircraft; and two Aerial Survey Specialists Observers (counters) seated on either side in the rear of the aircraft who are responsible for using a calibrated sighting boom and recording animal sightings during a survey. A configuration similar to this has also been used for the present survey.

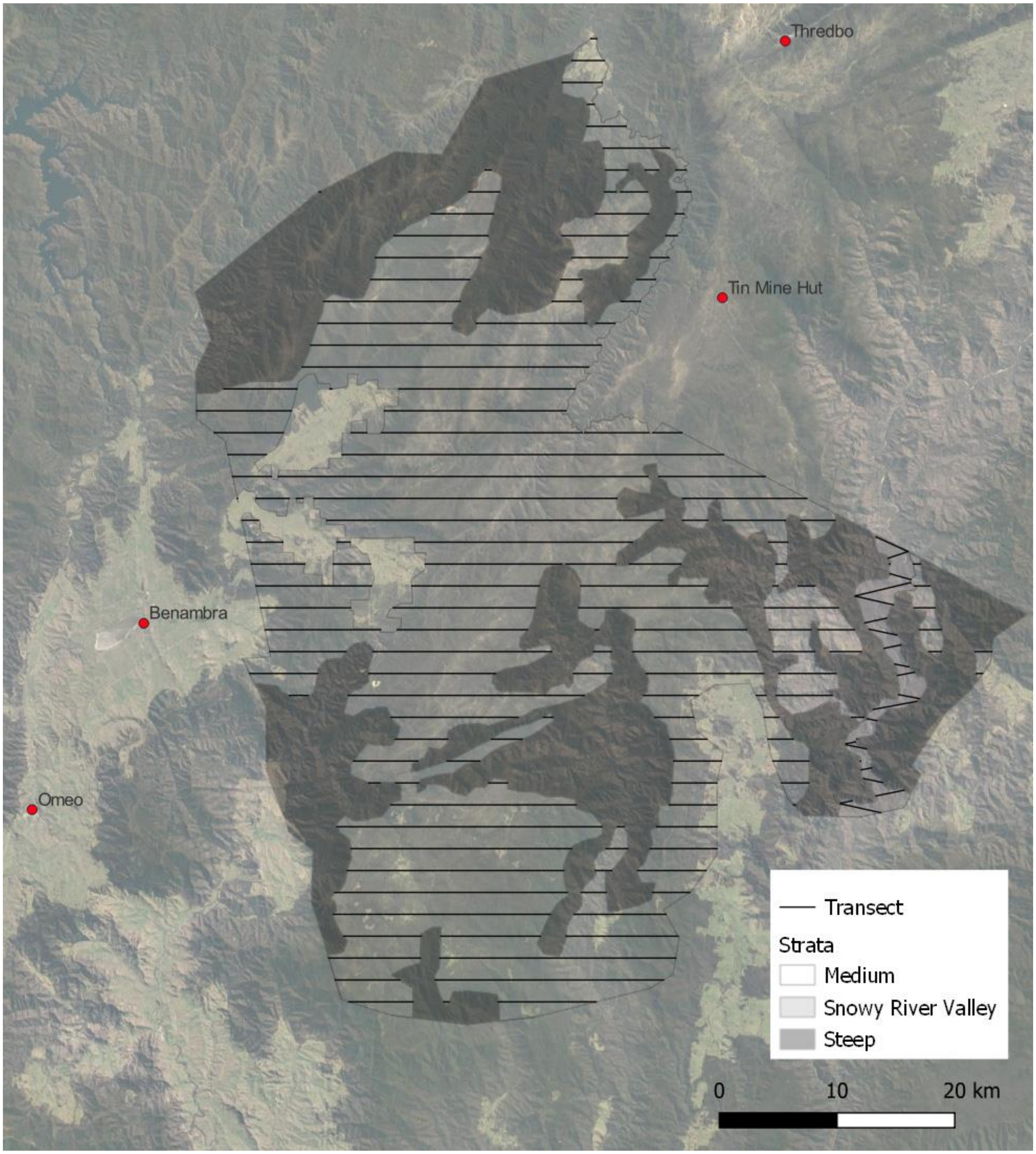

Fig. 1. The Eastern Victoria Alps survey region. Shown are the three survey strata, the population centres (towns) and landmarks, and the placement of the survey transects within the medium terrain (Medium Alpine) stratum and also the Snowy River Valley stratum on the right-hand side of the image. Note that no survey transects were placed into the steep terrain stratum.

The aircraft used was a Bell 206 Long Ranger single-engine light helicopter. The aircraft was crewed by a pilot and a flight observer occupying the front left-hand seat. Two observers were used, operating in rotation between seating positions in the rear of the aircraft. The seating of the observers in relation to the left-hand and right-hand side of the aircraft was allocated randomly for each survey session.

3.1 Helicopter Line Transect Surveys

The surveys were carried out during daylight hours, with sessions flown in the morning after sunrise and in the later part of the afternoon. The conduct of the survey was such that the designated transects were flown sequentially during survey sessions. With the parallel transect lines in the Medium Alpine stratum being 1.76 km apart, the survey could be undertaken this way with a reasonable degree of confidence that there would be no double counting of horses on adjacent transects during a survey session.

In conducting the surveys of the two strata, the helicopter, with the two rear doors open, was flown along each straight transect line at a ground speed of 93 km h^{-1} (50 kts) and a height of 61 m (200 ft) above ground level. Navigation was by a global positioning system (GPS) receiver. The two observers occupied the rear seats of the helicopter and counted horses seen on either side of the aircraft, recording the sizes of the clusters observed within specified perpendicular distance classes from the transect line. Sightings of clusters of horses were recorded into the 0-20 m, 20-40 m, 40-70 m, 70-100 m and 100-150 m distance classes, perpendicular to the transect centreline. These distance classes were delineated on metal booms extending from either side of the helicopter.

Data in the form of the sizes of clusters of horses sighted within the different delineated distance classes from the transect centreline were recorded using electronic keypads linked to a GPS, an Inertial Measurement Unit and LiDAR so the aircraft position, roll, pitch, yaw and height AGL were recorded at time of observation. Similar counts of other large mammal species, namely deer, cattle (feral or domestic) and feral pigs were also recorded this way. Ancillary information required for the analyses of the survey results was also recorded. Along with observer identification, sun direction, survey aspect, this information also included the type of vegetation occupied by animals at the point-of-detection and the proportion of cloud cover during a survey session to be used as an index of general visibility. Recorded survey data were downloaded at the end of each survey session.

No rest breaks were taken by the observers on any transect during the survey sessions. Hence, for the purpose of data analysis, the exact sampler lengths were equal to the allocated lengths in the survey designs.

3.2 Data Analysis

The analysis of distance sampling data such as those collected here first involves the estimation of the detection probability of animals within the covered area (usually a designated survey strip), then the estimation of the density of animals within the covered area given this detection probability and, finally, the estimation of the number of animals in the survey region given the density of animals in the covered area (Borchers & Burnham 2004). With a properly designed survey, inferences can be safely made about the survey region using information obtained from sample units (Thompson 2002). Density ($\widehat{D}$) in the covered area is estimated from:

$$\widehat{D} = \frac{n_a \hat{E}(c)}{2wLP_a} \qquad \text{eqn. 1}$$

where, n_a is the number of clusters observed, $\hat{E}(c)$ is the expected cluster size (see later), L is the survey effort (total transect length) and P_a is the probability of detecting a cluster of the animals within w, the half-width of the designated survey strip (Buckland *et al.* 2001).

In order to estimate the probability (P_a) of detecting a cluster of the animals within w, the detection function $g(x)$, the probability that a cluster of animals at perpendicular distance x from the survey transect centreline is detected (where, $0 \leq x \leq w$ and $g(0) = 1$) needs to be modelled and evaluated at $x = 0$ (Thomas *et al.* 2002). To do this, the sampling data, the counts of clusters of animals (horses) within each of the five distance bins dividing the half-width of the survey transect, were analysed using the line transect analysis routines in DISTANCE 7.3 (Thomas *et al.* 2010). Basing the analysis on the sightings of clusters in preference to the sightings of individual animals has been found to ensure against overestimation of the true variances (Southwell & Weaver 1993).

In analysing the results of surveys such as those undertaken here, it is important that the recommended minimum sample sizes of both transect lines and observations are at least attained. According to Buckland *et al.* (2001), the recommended minimum number of samplers (replicate transect lines) should be 10-20 in order to ensure reasonably reliable estimation of the variance of the encounter rate, and the recommended number of observations, clusters of horses in this instance, should be 60-80 for reliable modelling of the detection function. The number of replicate transects flown across the survey block exceeded the necessary minimum with 45 transects being flown in the main survey stratum and 19 being flown in the Snowy River Valley. The total number of clusters of horses sighted exceeded the recommended minimum (see Table 4).

The analysis program DISTANCE 7.3 has three different analysis engines that can be used to model the detection function (Thomas *et al.* 2010). Two of these, the conventional distance sampling (CDS) analysis engine and the multiple-covariate distance sampling (MCDS) analysis engine, were used here. In analysing survey results using the CDS analysis engine, there is no capacity to include any covariates other than the perpendicular distance of a cluster of horses from the transect centreline in the modelling process. Hence, an assumption is made of pooling robustness, i.e. it is assumed that the models used yield unbiased (or nearly unbiased) estimates when distance data collected under variable conditions are pooled (Burnham *et al.* 1980). If the MCDS analysis engine is used, then additional covariates can be included in the analysis. This can help to relax to some extent (but not entirely) reliance on the assumption of pooling robustness (Burnham *et. al.* 2004).

The analysis protocol followed was such that the results of the analyses conducted using detection function model options available within both the CDS and

MCDS analysis engines were compared serially in order to determine which was the most parsimonious model and, hence, which were the most likely and accurate estimates of population density and abundance. The model with the lowest value for a penalised log-likelihood in the form of Akaike's Information Criterion (*AIC= -2 x log-likelihood + 2[p +1]*; where *p* is the number of parameters in the model) was, as is generally the case, selected as the most likely detection function (Burnham & Anderson 2002; Thomas *et al.* 2010). In selecting the most parsimonious model, along with comparing AIC values, some secondary consideration was given to goodness-of-fit and the shape criterion of the competing detection functions; with any model with an unrealistic spike at zero distance, rather than a distinct 'shoulder' near the transect line, being likely to be rejected. Although it can be used as an option to improve goodness-of-fit, no manipulation of the grouping intervals was undertaken.

Four detection function models were considered in the analyses using the CDS analysis engine. Each model comprised a key function that, if required, can be adjusted by a cosine or polynomial series expansion containing one or more parameters. The different models considered were a Half-normal key function with an optional Cosine or Hermite Polynomial series expansion, and a Hazard-rate key function with an optional Cosine or Simple Polynomial series expansion. The number of adjustment terms incorporated into a model was determined through the sequential addition of up to three terms.

Because the sighting of horses was recorded as clusters of one or more individuals, estimation of expected cluster size for use in the determination of density and abundance can be problematic. The obvious estimator, the mean size of detected clusters, may be subject to group-size bias. If larger clusters are more detectable at greater distances from the survey transect than are small clusters, then mean size of detected clusters will be a positively biased (rather than an unbiased) estimator of expected cluster size (Buckland *et al.* 2001). There are a number of optional remedial measures that can be used to address this possible problem (Buckland *et al.* 2001). The one used here was a regression method, whereby the expected cluster size ($\hat{E}(c)$) is determined using the regression of the logarithm of observed cluster size ($ln(c)$)

against the estimated probability of detection ($g(x)$) at the perpendicular distance (x) from the transect centreline. Significance of this relationship is determined in relation to $\alpha = 0.15$ rather than the conventional value of $\alpha = 0.05$. By doing this, the likelihood of Type I error in relation to testing the null hypothesis of no association between $ln(c)$ and $g(x)$ is increased, and the likelihood of Type II error decreased. Here, increasing the likelihood of accepting an association between $ln(c)$ and $g(x)$ may represent a "false positive" in outcome (Type I error), but it has a precautionary advantage in case this association really exists.

If required, this method is able to correct for size-biased detection and the underestimation of the size of detected clusters, provided that neither of these effects occur at the transect centreline (Buckland *et al.* 2001). If the observed sizes of detected clusters are independent of the perpendicular distance from the transect centreline (i.e. if $g(x)$ does not depend upon c), then the sample mean cluster size ($\bar{c}$) is taken as an unbiased estimator of the mean size of the n clusters in the covered area. If, however, the observed sizes of detected clusters are found to be dependent upon the perpendicular distance from the transect centreline, then, $\bar{c}$ is replaced by an expected value determined from the above-described regression of this relationship (Buckland *et al.* 2001).

The MCDS analysis engine allows for the inclusion in the detection function model of covariates other than the perpendicular distance from the transect centreline (Thomas *et al.* 2010). The key functions available in this analysis engine are the Half-normal and the Hazard-rate functions. The covariates can be either factor (i.e. qualitative or categorical) or non-factor (i.e. continuous) in form. Incorporating covariates into a model has the effect of altering the scale but not the shape of the detection function. That is, they can affect the rate at which detectability decreases with increasing perpendicular distance from the transect line, but do not alter the overall shape of the detection curve (Marques & Buckland 2004; Thomas *et al.* 2010). A number of covariates related to individual detections of clusters of horses were used in these analyses. These were identified as observer, vegetation type (cover) at point of detection, sun direction, survey aspect and cloud cover score. All five covariates were categorical. There were two observers (A and B), two types of vegetation cover (open and timbered), two sun direction classes (sun ahead of aircraft or sun behind aircraft), two survey aspects (northerly and southerly) and three grades of cloud cover (1 = clear to light, 2 = medium, 3 = overcast to dull). In order to avoid model over-parameterisation, these covariates were included in the analyses singly. Cluster size could have been included in the analysis as a non-factor covariate. However, if this had been done, it would preclude the use of stratification in the analyses; stratification being required with the use of a single detection function model with the two survey strata. Possible bias associated with cluster size was therefore dealt with in the same manner as it was in relation to the use of the CDS analysis engine.

The methods of determination of the density estimates of clusters of horses, the density estimates of individual horses and the estimates of population abundance in relation to the most parsimonious detection function model using the CDS analysis engine are described in Buckland *et al.* (2001). The methods of determination of these statistics in relation to the most parsimonious detection function model using the MCDS analysis engine are described in Marques & Buckland (2004). The outcomes of analyses using either of these analysis engines can be compared using AIC, so long as the dataset analysed remains unchanged.

While densities and abundances, and their associated statistics of variation were, in most instances, determined empirically, confidence limits (LCL and UCL) and coefficients of variation (CV %) were also determined by bootstrapping the data. If confidence intervals are calculated using the conventional, empirical method of estimation, then it is assumed that the data being analysed have been drawn from a population of values that is log-normally distributed (Buckland *et al.* 2001). This may be the case, but quite often, it is not. If it is not, then the calculation of confidence intervals using the conventional method of estimation fails to truly represent the uncertainty associated with the point estimate in question. Bootstrapping the data can circumvent this problem.

Once the most likely detection function model had been determined, in order to determine the bootstrap confidence intervals, the data were bootstrapped 999 times in relation to all model options in the analysis engine and not just the model selected to determine the empirical estimates. The 95% confidence limits were presented as the 2.5% and 97.5% quantiles of all respective bootstrap estimates. Confidence intervals determined using this method have some advantages. One of these is that, with bootstrap-resampling of the data, the variance and associated interval estimates will include a component due to model selection uncertainty (Thomas *et al.* 2002). This is expected to improve the robustness of the interval estimation of density and abundance (Buckland *et al.* 2001). Bootstrap confidence intervals are essentially distribution-free and because their calculation is based only on the data in the sample, if the data were drawn from a population with a skewed distribution, this asymmetry will be represented in the confidence interval.

4. Results and Discussion

4.1 Feral Horses

The aerial survey of the Victorian Eastern Alps was completed over a period of five days from 30 November to 4 December, 2021. Two survey sessions were flown on each of these days. A total of 1,064.6 km of transects were flown across the two survey strata which had a total area of 1,864.0 km^2. The number of transects flown across each survey block are given in Table 1. Seventy-eight clusters of horses were sighted during the survey. All sightings occurred in the large Medium Alpine stratum (see Table 4). Although no horses were sighted in the Snowy River Valley stratum, the survey effort for this stratum is still integral to the analyses.

The method of analysis used to estimate the population densities and abundances of the feral horses conformed to a general and well-understood framework for analysing distance sampling data, as presented in Buckland *et al.* (2001). Key to the analysis is the modelling of the detection of clusters of horses in relation to at least one covariate, the perpendicular distance from the transect centreline. The analysis involved the use of both the CDS and the MCDS analysis engines of DISTANCE 7.3 (Thomas *et al.* 2010); with a number of different detection function models being compared (see Section 3.2).

With the analysis, the most parsimonious (specific) detection function model, global or stratified, was selected principally on the basis of it being the one that yielded the smallest value of the AIC statistic (see Section 3.2). In relation to this process, it should be noted that an individual AIC value is, by itself, not interpretable due to the unknown interval scale to which it is related (Burnham & Anderson 2002). Hence, for a given model, the value of the AIC is only comparative, relative to other AIC values in the set of models tested. It is the AIC differences (ΔAIC) that are important. In comparing any two models, when ΔAIC >2.00, the interpretation is that there is mounting evidence that it is increasingly less plausible that the fitted model with the larger AIC could be considered the better of the two models, given the data. The converse to this is that when ΔAIC ≤2.00, it can then be thought that, in this instance, there is some level of empirical support for the model with the larger AIC as well as for the model associated with the smaller AIC, given the data. For further information on the use of AIC in model selection, see Burnham & Anderson (2002).

Table 2. Comparison of the top eight detection function models generated using the conventional distance sampling (CDS) and multiple-covariates distance sampling (MCDS) analysis engines in DISTANCE 7.3. Model selection was based upon comparison of the AIC statistics for the models. For details of the models and the selection process, see text.

Analysis engine	Model	Covariates	AIC	ΔAIC
CDS	Half-normal	–	252.14	0.25
	Hazard-rate	–	252.17	0.28
MCDS	Half-normal	Observer	251.88	**0.00**
	Half-normal	Cover	252.49	0.61
	Half-normal	Aspect	254.13	2.25
	Hazard-rate	Observer	252.12	0.24
	Hazard-rate	Cover	254.02	2.14
	Hazard-rate	Aspect	254.13	2.25

The outcome of the comparative model selection process is given in Table 2. The most parsimonious global detection function model was found to be a multiple-covariate model that had a Half-normal key function with no series adjustment, but included, along with the perpendicular distance of a cluster from the transect centreline, the added covariate of observer. On the basis of the test criteria, there is strong general support for this model. However, based on the principal model selection criterion a number of the other models tested could also be considered to be plausible detection function model (ΔAIC <2.00; Table 2). Giving consideration to the goodness-of-fit and shape criterion of the two models, confirmed the primacy of the Half-normal model. The form of the detection function in relation to the observer covariate is shown in Fig. 2. The inclusion of a covariate in a model has the effect of altering the scale of the detection function, but not its general form (Marques & Buckland 2004).

Associated with the survey outcome and detection function modelling are a small number of informative, ancillary statistics. These are the encounter rate (n/L), the probability (P_a) that a randomly selected cluster of horses in the nominal survey strip (150 m) will be detected and the associated effective strip (half-) width (µ). The encounter rate is a useful statistic from a comparative point-of-view. It is perhaps a more informative statistic than is the number of clusters detected (Buckland *et al*. 2001). Encounter rate variance is usually the dominant component of the overall variance of object (horse) density. The encounter rate for the whole survey was 0.073 clusters of horses per km of survey effort. It was slightly higher (0.076) for the Medium Alpine stratum, where all sighting were made. The probability (P_a) that a randomly selected cluster of horses in the nominal survey strip will be detected was 0.630 and the associated effective strip (half-) width was 94.5 m.

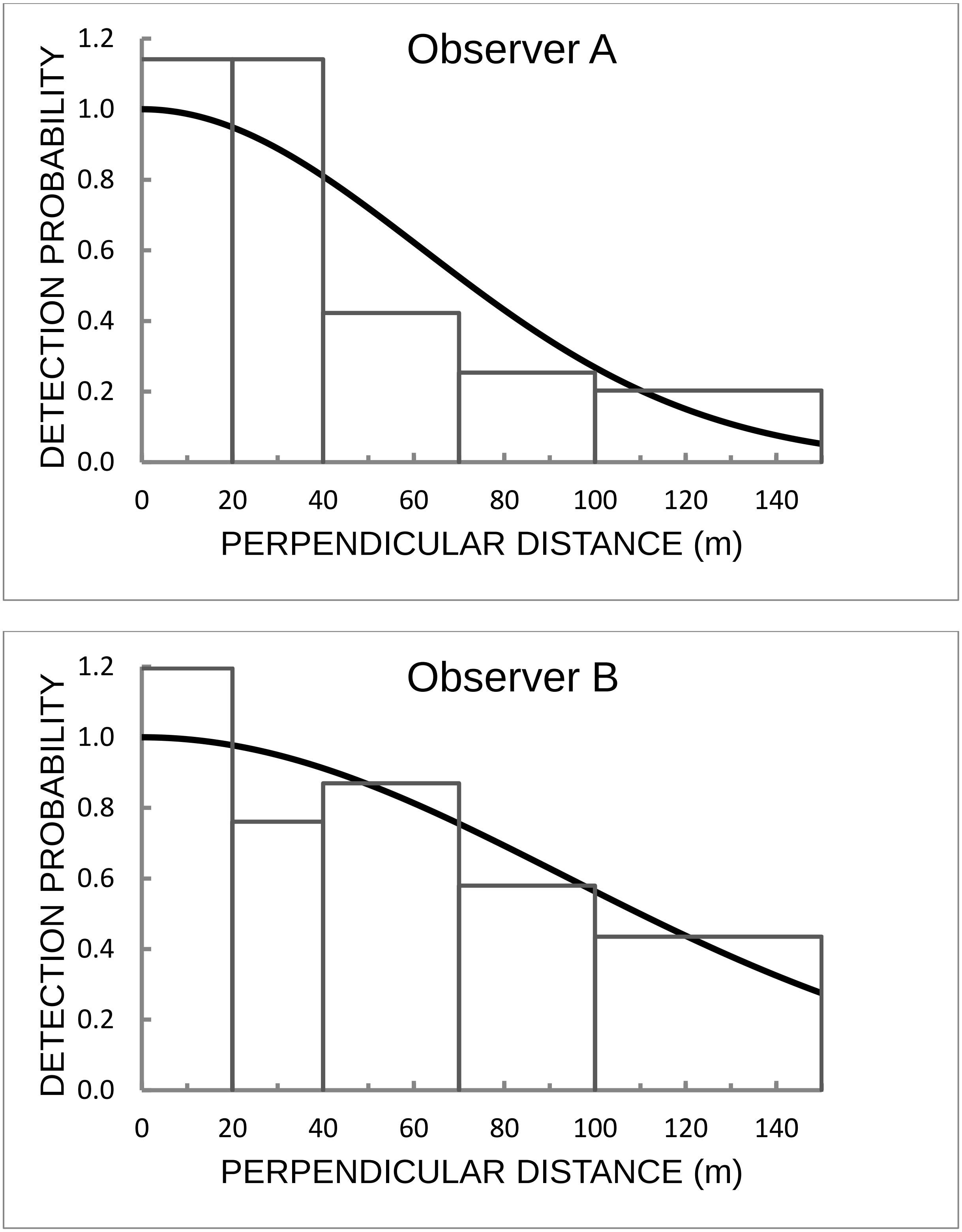

Fig 2. The Half-normal detection functions for feral horses in the Victorian Eastern Alps, 2021. These two functions represent the form of detectability in relation to the two observers used in conduct of the survey.

While P_a is required as part of the estimation process (see eqn. 1), both it and the associated effective strip width can be viewed as indicators of the interaction between the subjects of the survey, the landscape they occupy and the observers and conditions on the survey platform. Like the encounter rate, this parameter has some comparative value. The associated statistic, the effective strip width (μ), is interpreted as the perpendicular distance from the transect centreline (i.e. the half-strip width) for which as many animals (horses) are detected beyond that distance as remain undetected within it (Buckland *et al.* 2001). Hence, a line transect survey can be thought of as effectively covering a survey strip of a total area of $2L\mu$, for some value of $\mu \leq W$ (the nominal width of the survey strip) and length L (Borchers & Burnham 2004). Another way of interpreting this is: if all the animals on the survey strip were to be detected, this could only be possible if the half-width of the survey strip (W) was equivalent to the effective strip width (μ) on either side of the transect centreline. By virtue of the way μ is determined ($\mu = W x P_a$), the higher the value of P_a, the wider will be the effective strip width. The effective strip widths determined in relation to the results of this survey was just less than two-thirds of the nominal strip width of 150 m. The effective strip widths for the Byado-Victoria survey block that was part of the Australian Alps Liaison Committee (AALC) “Feral Horses in the Australian Alps” surveys conducted in 2014 and 2019 were markedly different at 66.9 m and 37.7 m, respectively (Cairns 2019). The Victorian Eastern Alps survey region overlap with the southern part of the Byado-Victoria block.

As well as P_a, another parameter determined from the survey data that is required for density estimation is an estimate of the expected (mean) cluster size ($\hat{E}(c)$). Details regarding the determination of this parameter are given in Table 3. The overall size range of the clusters counted was 1-13. No size bias was detected in the estimation of cluster size. Hence, the sample mean of the observed cluster sizes was used as the expected cluster size (Table 3). In relation to this, it needs to be noted here that clusters are defined by the distance bins used in the survey process. They do not represent social groupings.

Table 3. The expected size ($E(c) \pm SE$) of the clusters of horses counted on the survey transects. Given along with the estimates of $E(c)$ are the size ranges of the clusters sighted, the correlation coefficient (r) and the P-values for the assessment of the significance of the linear relationship between $ln(c)$ and estimated $g(x)$. For further details, see text.

Survey stratum	$E(c)$	Range	r	P-value
Medium Alpine	3.36 ± 0.28	1 – 13	-0.091	0.214
Snowy River Valley	–	–	–	–

The densities of clusters of horses and the corresponding population densities are given in Table 4, and the horse population abundance estimates are given in Table 5. To add another perspective to this result, a whole survey region density can be calculated from the abundance estimate. This value of a whole-region horse density was 0.81 km^{-2} (0.36-1.38). It should be noted that in determining this density, it is assumed that there were no horses in the steep terrain stratum, which was not surveyed.

Table 4. Results of the helicopter line transect surveys of feral horses conducted in the Victorian Eastern Alps survey region in December, 2021. Given are the is the number of clusters of horses detected (n), the estimated density of clusters of horses (D_c) and the horse population density (D) along with their 95% bootstrap confidence intervals and coefficients of variation (CV%).

Survey stratum	n	Cluster density (km^{-2})			Population density (km^{-2})		
		D_c	95% confidence interval	CV (%)	D	95% confidence interval	CV (%)
Medium Alpine	78	0.40	0.25 – 0.62	22.6	1.35	0.60 – 2.31	33.0
Snowy River Valley	–	–	–	–	–	–	–
Combined	78	0.39	0.25 – 0.61	22.6	1.32	0.58 – 2.25	33.0

In relation to the survey region of this study, the Victorian Eastern Alps there have been two previous surveys of this general area commissioned by the AALC.in 2014 and 2019 (Cairns 2019). The region surveyed in these instances was identified as the Byadbo-Victoria survey block that extended over from the Victorian Eastern Alps north across the Victoria-New South Wales (NSW) into the southern parts of the

Kosciuszko National Park. The total area of this survey block was 4,946 km^2, with 3,237 km^2 (65.5%) being deemed suitable and available to be surveyed. By way of broad comparison, the survey density of horses in the Medium Alpine and Snowy River Valley strata of the Byadbo-Victoria block in 2014 was 1.33 km^{-2} (1.00-2.26). In 2019, it was estimated to be 2.63 km^{-2} (1.95-3.85). The whole-block densities of horses obtained from these two surveys were 0.87 km^{-2} (0.60-1.45) and 1.72 km^{-2} (1.28-2.52). In 2020, NSW National Parks & Wildlife Service conducted a survey of the NSW portion of the Byadbo-Victoria block (Cairns 2020). The estimated density of horses obtained from this survey was1.25 km^{-2} (0.83-1.70).

Table 5. The population estimates (N) for each of the survey stratum. Given along with these estimates of abundance along are their 95% bootstrap confidence intervals and coefficients of variation (CV %). Given also are the areas of the strata surveyed and the total area of the Victorian Eastern Alps survey region.

Survey stratum	Area (km^2)	N	95% confidence interval	CV %
Medium Alpine	1,814.6	2,456	1,088 – 4,186	33.0
Snowy River Valley	49.4	–	–	–
Victorian Eastern Alps	3,036.6	2,456	1,088 – 4,186	33.0

The survey conducted here was designed for a relatively high target level of precision of 17.5%. Unfortunately, the level of precision represented by the bootstrap coefficient of variation fell well short of this mark (Table 4). An examination of the three components of the variance of the density estimate found that the variance of the sample size (n) was relatively large compared to the variance of the probability density function evaluated at zero perpendicular distance ($f(0)$) and the variance of cluster size (c). Although the additive effect of these three variance components contributed to the relatively large variance of the density estimate, it was the variance component associated with the distribution of horses across the survey area that contributed the most (70%) to the lower than expected precision of the density and abundance estimates. Contributing to this would have the fact that two-thirds of all samplers returned zero counts of horses. The majority of those transects on which horses were sighted were in the southern half of the survey area. Also, no sightings were made on the 19 transects in the Snowy River Valley stratum. By way of reference, the empirically-estimated coefficient of variation was also relatively high at 23.6%. Regarding this comparison, bootstrap estimates of variance and confidence limits are non-parametric and generally considered to be better representations of the true variation in the data.

4.2 Other Species

As well as horses, three other species of large herbivore were counted during the survey; two of these in sufficient numbers for the estimation of population densities and abundances. These were introduced deer and domestic and feral cattle, for which there were 26 and 63 sightings, respectively. There were only three sighting made of feral pigs and so population estimates could not be obtained for this species.

The counts of deer were analysed using the CDS analysis engine of DISTANCE 7.3. Because only 26 sighting were made of deer, the analysis process was restricted to the simple, robust estimation process of the CDS analysis engine. Four detection function models were tested; two based on the Half-normal key function and two based on the Hazard-rate key function. The possible influence of cluster size on detection was also tested as part of the modelling process. For full detail on the analyse protocol used, see Section 3.2. Of the 26 sightings of deer, two were made in the Snowy River Valley stratum. However, because of the small total number of sightings, no stratification was used in this analysis.

For the analysis of these survey results, the most parsimonious detection function model was a simple Half-normal model with no series adjustment (Fig. 3). The values for the probability of detection (P_a) and the effective strip width (μ) were 0.403 and 60.4 m, respectively. In both instances, these values are somewhat lower than those for horses; this probably being in line with deer being smaller and somewhat more cryptic in the landscape than are horses. Cluster size (c) for the deer was size-biased ($P = 0.09$), with an estimated expected value of 1.60 ± 0.19.

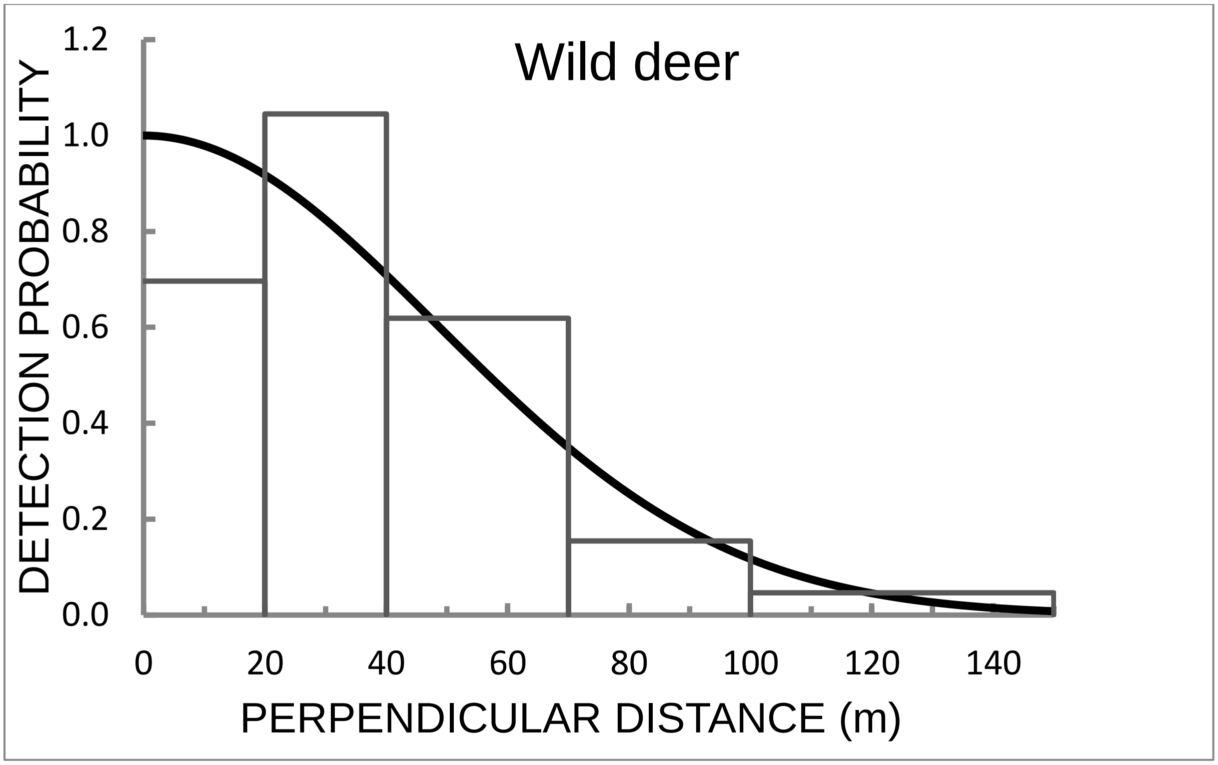

Fig. 3 The Half-normal detection function for wild deer in the Victorian Eastern Alps, 2020.

The population density and abundance estimates for deer are given in Tables 6 and 7, respectively. The density given is for the two strata surveyed. Thirty-eight percent of the survey region was not surveyed because it comprised steep terrain. As was the case with horses, it has been assumed that deer numbers in this steep terrain stratum were at negligible, trace levels, and that the estimates given for the sizes of the deer population are plausible estimates for the whole of the Victorian Eastern Alps region. In the case of this species, this is an assumption that could be open to challenge. However, if it were assumed to be true, then the density of deer for the whole region (3,036.6 km^2) was 0.20 km^{-2} (0.11-0.34). By way of comparison, the survey density of deer in the Medium Alpine and Snowy River Valley strata of the Byadbo-Victoria block in 2014 was 0.70 km^{-2} (0.54-1.21). In 2019, it was estimated to be 2.36 km^{-2} (1.65-3.52).

Table 6. Results of the helicopter line transect surveys of wild deer and domestic and feral cattle conducted in the Eastern Victorian Alps survey block in December, 2021. Given are the is the number of clusters of deer and cattle detected (n), the estimated density of clusters of deer and cattle (D_c) and the deer and cattle population density (D) along with their 95% bootstrap confidence intervals and coefficients of variation (CV%).

Species	n	Cluster density (km^{-2})			Population density (km^{-2})		
		D_c	95% confidence interval	CV (%)	D	95% confidence interval	CV (%)
Wild deer	26	0.20	0.13 – 0.30	22.0	0.32	0.18 – 0.56	28.3
Cattle	63	0.27	0.09 – 0.50	40.0	1.34	0.25 – 2.75	52.2

The counts of cattle were analysed using the CDS and MCDS analysis engines of DISTANCE 7.3. Four CDS and eight MCDS detection function models all based on either Half-normal and Hazard-rate key functions were tested. The possible influence of cluster size on detection was also tested as part of the modelling process. For full detail on the analyse protocol, see Section 3.2. Of the 63 sightings of cattle, none were made in the Snowy River Valley stratum.

Table 7. The population estimates (N) for each of the survey blocks. Given along with these estimates of abundance along are their 95% bootstrap confidence intervals and coefficients of variation ($CV\,\%$). Given also are the areas surveyed, including the total

Species	N	95% confidence interval	$CV\,\%$
Wild deer	602	344 – 1,035	28.3
Cattle	2,496	467 – 5,120	52.2

For the analysis of these survey results, the most parsimonious detection function model was a simple Half-normal model with no series adjustment (Fig. 4). The values for the probability of detection (P_a) and the effective strip width (μ) were 0.727 and 109.0 m, respectively. These values are both higher than those for horses, suggesting that from an aerial survey perspective cattle are quite visible in the landscape. Cluster size (c) for the cattle was estimated to be 4.87 ± 0.70.

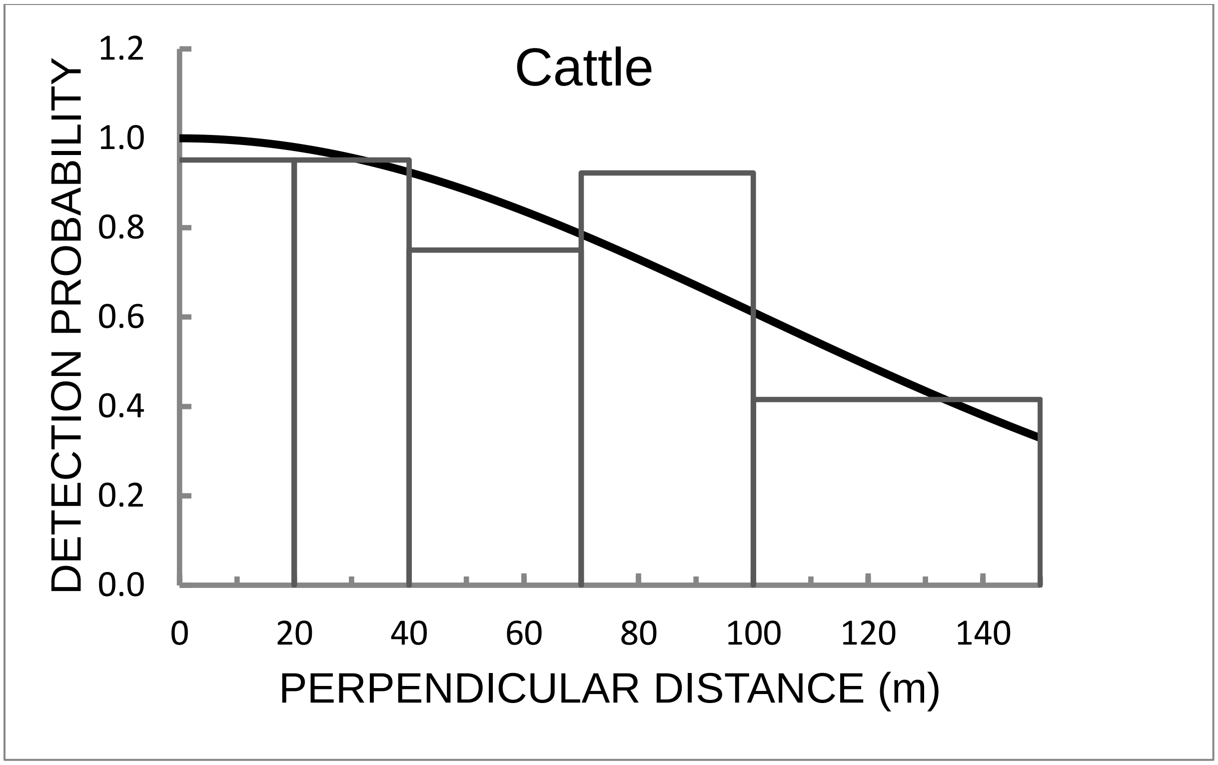

Fig. 4 The Half-normal detection function for domestic cattle in the Victorian Eastern Alps, 2021.

The population density and abundance estimates for cattle are given in Tables 6 and 7, respectively. The density given is for the two strata surveyed. Thirty-eight percent of the survey region was not surveyed because it comprised steep terrain. As was the case with horses, it has been assumed that cattle numbers in this steep terrain stratum were at trace, negligible levels, and that the estimates given for the sizes of the cattle population are plausible estimates for the whole of the Victorian Eastern Alps region. However, if it were assumed to be true, then the density of cattle for the whole region was 0.82 km^{-2} (0.15-1.69).

5. Acknowledgements

The success or failure of exercises such as these depend so much the abilities of the observers. For this reason, thanks must go to the two unnamed observers used during this survey for being able to provide a comprehensive raw dataset of exceptional quality. Regarding the flight crew, I would like to thank them for a safe execution of what turned out to be a survey flown at times over some difficult terrain. Greg Lollback provided invaluable GIS support in producing the map of the survey designs. Finally, I would like to thank John Wright for liaising with me on behalf of Parks Victoria and for his advice regarding matters associated with data analysis and production of this report.

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