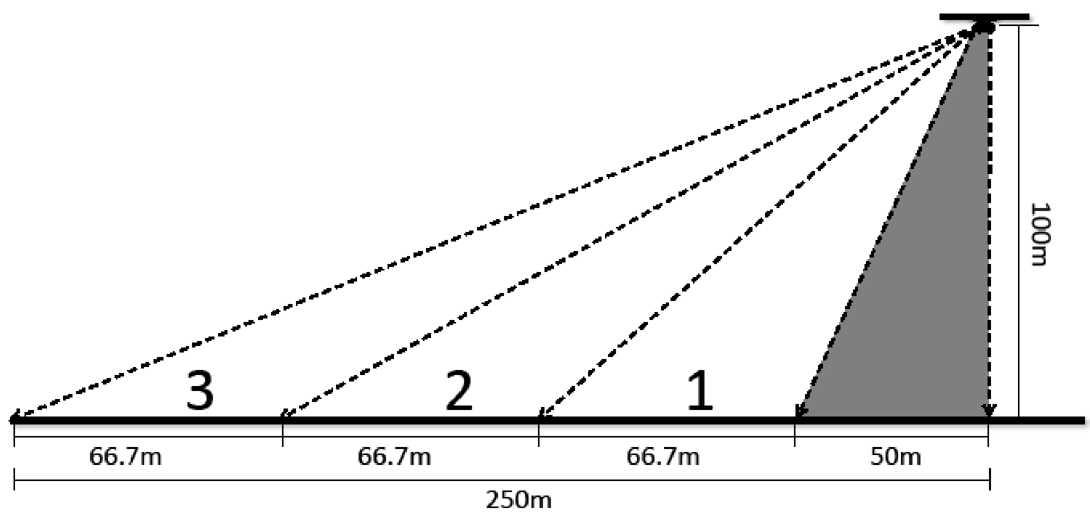
Alaska Refuges Report 2-2012

Use of Distance Sampling to Estimate Sitka Black-tailed Deer Abundances in Non-forested Habitats of Kodiak Island, Alaska

McCrea Cobb, Ph.D.



Kodiak National Wildlife Refuge
November, 2012

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Citation:

Cobb, M.A. 2012. Use of distance sampling to estimate Sitka black-tailed deer abundances in non-forested habitats of Kodiak Island, Alaska. Kodiak National Wildlife Refuge. Alaska Refuges Report Series no. 2-2012.

Keywords:

aerial survey, distance sampling, Kodiak Island, line-transect, *Odocoileus hemionus sitkensis*, population estimation, Sitka black-tailed deer

Use of Distance Sampling to Estimate Sitka Black-tailed Deer Abundances in Non-forested Habitats of Kodiak Island, Alaska

McCrea Cobb

Abstract

Maximizing Sitka black-tailed deer (*Odocoileus hemionus sitkensis*) harvest opportunities on Kodiak Island, and minimizing deer impacts on native flora and fauna, are the primary goals of the Kodiak National Wildlife Refuge, but these goals require statistically-robust estimates of trends in deer abundance. We evaluated the feasibility of using distance sampling, applied to traditional line-transect aerial counts, to estimate, with statistical confidence, abundances of Sitka black-tailed deer in non-forested habitats of Kodiak Island. We completed 3 aerial survey replicates on the Aliulik Peninsula of Kodiak Island, between 16 May and 22 May, 2012. We observed an average of 64 deer in 39 groups per survey. After correcting for estimated deer detection using Program Distance 6.0, which took into account distance to the observer and habitat type, we estimated that there were 115 deer (SE=15.82) on the Aliulik Peninsula. Moreover, we demonstrated that distance sampling can be used to produce statistically robust estimates of trends in deer abundance, in non-forested regions of Kodiak Island. We provide recommendations for adapting the distance sampling method to survey deer across a wider region of Kodiak Island.

Introduction

Sitka black-tailed deer (*Odocoileus hemionus sitkensis*) were introduced to Kodiak Island between 1924 and 1934 (Burris and McKnight 1973), and the population subsequently increased in size and range. By the mid-1980s, the population peaked at over 100,000 deer (Smith 1989). Deer currently play a central economic and ecological role on Kodiak. Deer meat is the most important source of subsistence protein for rural residents of Kodiak Island. In addition to their economic importance, Kodiak's deer likely play a keystone ecological role by affecting plant biodiversity and structure (Danell et al. 1994), nitrogen processing (Olofsson et al. 2001), and soil composition (Hobbs 1996). Non-native ungulates can have profound, undesirable, and often irreversible effects on native flora and fauna (Savidge 1987, Courchamp et al. 2003), and these impacts can be particularly magnified in island and northern latitude systems that have comparably low levels of resiliency to change (Pojar et al. 1980, Gaston et al. 2006). The impacts of deer on Kodiak's ecosystem are unknown. For all these reasons, effective management of Kodiak's deer is critical.

Our ability to effectively manage the deer population to maximize hunter harvest opportunity and minimize undesirable ecological impacts has been constrained in the absence of an empirical population estimate with statistical confidence. Without a quantitative estimate of abundance, objectives established by the Alaska Board of Game (a population of 70,000-75,000 and an annual harvest of 8,000-8,500) are difficult to justify to the public and have limited management utility. Between 2005 and 2010, estimated annual deer harvest levels fluctuated between from 3,948 deer (2007-2008) to 7,885 deer (2005-2006) (Van Daele and Crye 2009), but it was unclear whether these variations were linked to changes in population abundance or other factors.

In addition to improving harvest management, an estimate of deer abundances will allow managers to address more in-depth questions related to the impacts of environmental and anthropogenic factors on Kodiak's deer population dynamics. It is likely that the deer population has been regulated primarily by winter severity. Results of ground-based surveys of deer carcasses conducted in early spring, an indirect method of winter-mortality estimation, suggested that deer mortality is greater during colder winters (Cobb 2011). However, a quantitative estimate of population abundance is needed to determine how winter weather affects rates of mortality, changes in population abundance, and harvest opportunities. Other factors might be affecting deer population growth rates, such as hunting, disease, predation, habitat conditions, and endocrine disrupting environmental contaminants causing testis dysgenesis (Veeramachaneni et al. 2006). The relative role of these factors on deer population dynamics is currently unclear because annual changes in deer abundance are unknown.

Surveying deer abundances across Kodiak Island using a single method is not likely feasible because of substantial regional differences in terrain and cover of deciduous shrub and tree vegetation. Aerial transect surveys are commonly used to count ungulates in non-forested habitats (White et al. 1989, Hone 2008), and may be an effective method to innumerate deer in the non-forested habitats of central and southern Kodiak where cover of tall deciduous shrub and tree vegetation is limited (Fleming and Spencer 2007). Distance sampling is a commonly used technique to estimate the size of a population (Buckland et al. 2007), and has been successful been applied to aerial surveys to determine ungulate abundances and densities in open habitat type (Quang and Lanctot 1991, Cassey and McArdle 1999, Schmidt et al. 2012). For this method, observers record distances to target animal groups and use these measurements to estimate a detection function, which is applied to the population estimate to provide an unbiased result (Buckland et al. 2001). Recent advances to the distance sampling method allow for inclusion of environmental covariates, such as habitat type, in estimating the detection function (Buckland et al. 2007). If used in conjunction with a survey method robust in forested habitats, the aerial distance sampling may offer a promising avenue for assessing annual changes in deer abundances across Kodiak.

Our goal was to evaluate the feasibility of estimating, with statistical confidence, the annual abundances of Sitka black-tailed deer in non-forested habitats of Kodiak Island. Specific objectives included: 1) quantify deer abundances using fixed-wing aerial line-transect surveys on the Aliulik Peninsula of southern Kodiak Island, 2) quantify the effects of habitat type, and distance between deer and observers, on deer sightability during fixed-wing aerial line-transect surveys, 3) apply sightability corrections to survey results to produce an unbiased estimate of deer abundance, and 4) determine the spatial extent that aerial line-transect survey methods can be applied to Kodiak Island.

STUDY AREA

Kodiak Island (8,975km^2) is located in the western Gulf of Alaska (Fig. 1). Separated from mainland Alaska by the Shelikof Strait, the island is approximately 160km long, and varies in width from 15 to 130km. Topography is mainly mountainous, with elevations ranging from sea-level to 1,362m. The climate is sub-arctic maritime and characterized by long, wet winters and wet summers. Precipitation annually averages 195cm (Kodiak City), and temperatures annually average 4.8^{o}C, including a mean monthly low of -1.2^{o}C (January) and a mean monthly high of 12.9^{o}C (August). The winter of 2011-12 was unusually snowy (365.25cm) and cold according to records derived from the National Weather Service station based at the State Airport in Kodiak.

Deer were widely distributed and inhabited most areas of Kodiak. Habitats in northeastern Kodiak generally were dominated by Sitka spruce forest, alder and willow-dominant shrub habitats in lower elevations, and forb-graminoid meadows in the high country (Fleming and Spencer 2007). Dominant habitats in southwestern Kodiak consisted of sub-arctic heath and large wetlands, similar to the Aleutian Islands and Alaska Peninsula. Central Kodiak was composed deciduous forests along river valleys; alder and forb meadows along the hillsides; and alpine meadow, heath, and bare rock habitats at higher elevations.

The study site was the southern region of the Aliulik Peninsula (215km^2) of Kodiak Island, Alaska (Fig. 2), which is 30km long and 12km wide at its widest point. We selected this area as the study site because detection of deer is relatively unrestricted by concealing terrain and tall deciduous shrub and tree vegetation. Habitats consisted of a mixture of rolling and hummocky tundra (primarily composed of *Empetrum nigrum*), herbaceous grassland habitats, and patchily-distributed deciduous shrub habitats (Barnes and Smith 1997, Fleming and Spencer 2007). Willow and alder-dominated shrub habitats bordered streams, lowlands, and small lakes. Patches of salmonberry (*Rubus spectabilis*) and elderberry (*Sambucus racemosa*) mixed with open grass and forb-dominated habitats at mid-elevations. Grass and forb-dominated alpine tundra meadows encompassed higher elevations (>750m).

Figure 1. Location of the Aliulik Peninsula study site on Kodiak Island, Alaska.

METHODS

We quantified deer abundances in the study area using a distance sampling approach applied to aerial line transect survey data (Buckland et al. 2001). We flew a systematic sample of line transects that encompassed the study site, and totaled 587km in length (Fig. 2). The distance between adjacent transects (strip width) was 500m. The passenger (McCrea Cobb) served as the primary observer from a fixed-wing airplane (Aviat Husky). The pilot (Jim Traub) attempted to maintain an above-ground level (AGL) of 100m and a ground speed of 110km/h. The passenger scanned for deer on alternate sides of the aircraft between successive transects, resulting in a survey window that always extended north from the transect line (Figure 3). When a deer group was observed, the passenger recorded a waypoint fix with a handheld GPS unit (Garmin 76CSX) as soon as the deer group was perpendicular to the transect line (directly off the wing of the plane). Marks on the aircraft's wing struts delineated boundaries between 3 distance classes on the ground (Fig. 3). The passenger aligned his vision by lining up a mark on the side window of the airplane with the closest strut boundary markers to insure consistent measurements. For each deer group, the passenger recorded a distance class that encompassed the centroid of the group, and a habitat class based on habitat classes (forb/graminoid meadow, heath/tundra, shrub, water, or beach) identified in the Kodiak Archipelago Land Cover Classification GIS layer (Fleming and Spencer 2007). We conducted 3 replicate surveys.

We analyzed survey data in Program Distance 6.0, Release 2 (Thomas et al. 2010). An assumption of distance sampling is that animals in the minimum distance class are detected with certainty. In our case, we assumed that the probability of detecting deer in the closest distance class was 100%. The second assumption of distance sampling is that animals do not move before being detected and that none are counted more than once (i.e. animal movement is random relative to the survey line). Deer generally did not respond to airplane, and when they did, it was not until the airplane was almost directly overhead. The most substantial reaction that deer made to our aircraft was to stand and walk. No deer ran from the plane for more than 100m, and therefore, it was not likely that any deer could have moved far enough to be double counted over adjacent transect lines. In accordance with protocol, random animal movements within the study site relative to the progression of the survey are acceptable and will not bias results. The third assumption of distance sampling is that measurements are exact. Since untrained observers tend to be poor at estimating distances by eye, we decided to use 3 distance classes instead of the exact distance to avoid biases associated with inexact measurements. We assumed that the detection probability for deer within 50m of the transect line (below the aircraft and out of view of the passenger) was zero (Fig. 4). Therefore, we excluded deer that were closer to the path of the aircraft than the inner boundary of the closest distance class (Thomas et al. 2010).

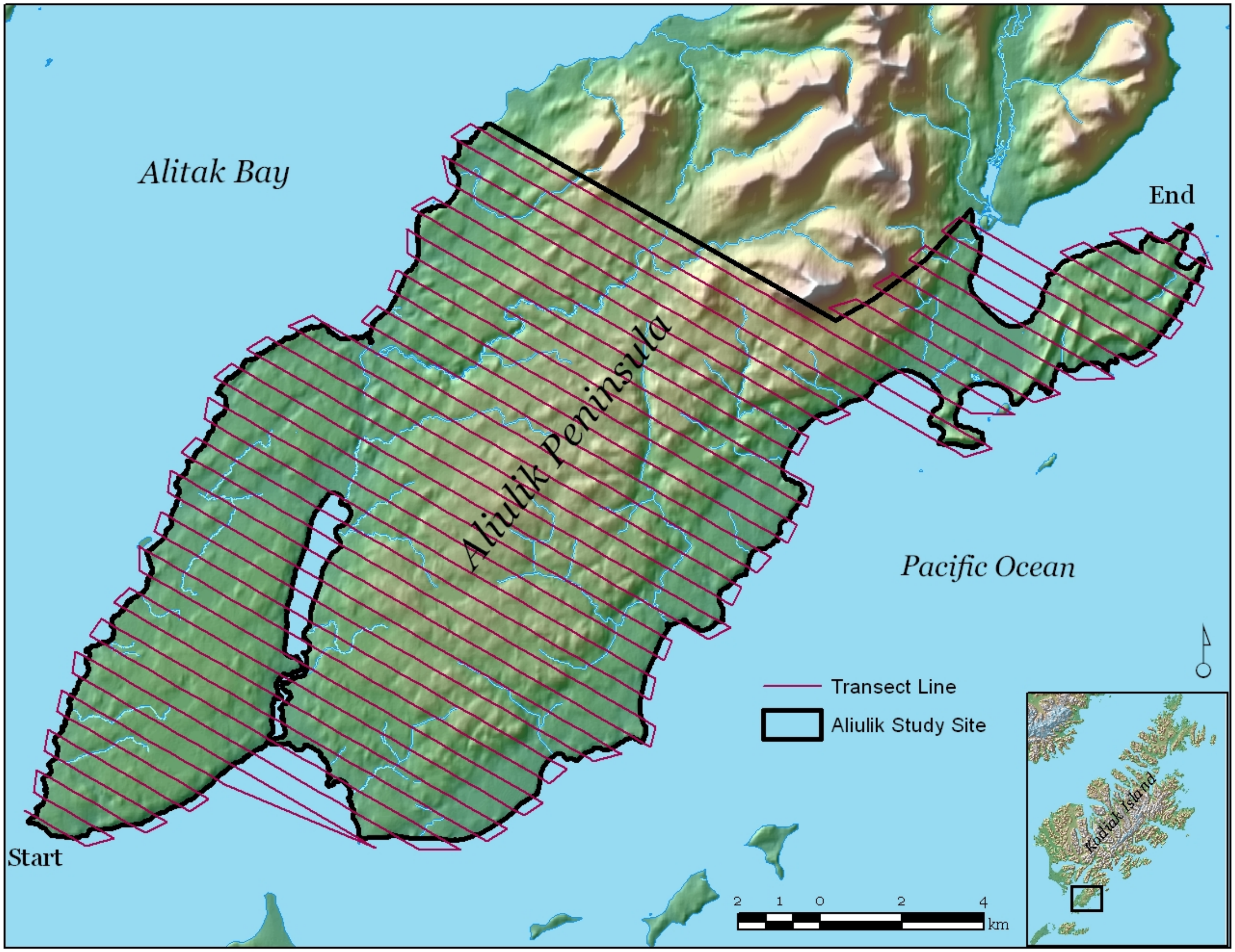


Figure 2. Aliulik Peninsula study site and planned Sitka black-tailed deer survey line transects, Kodiak Island, Alaska.

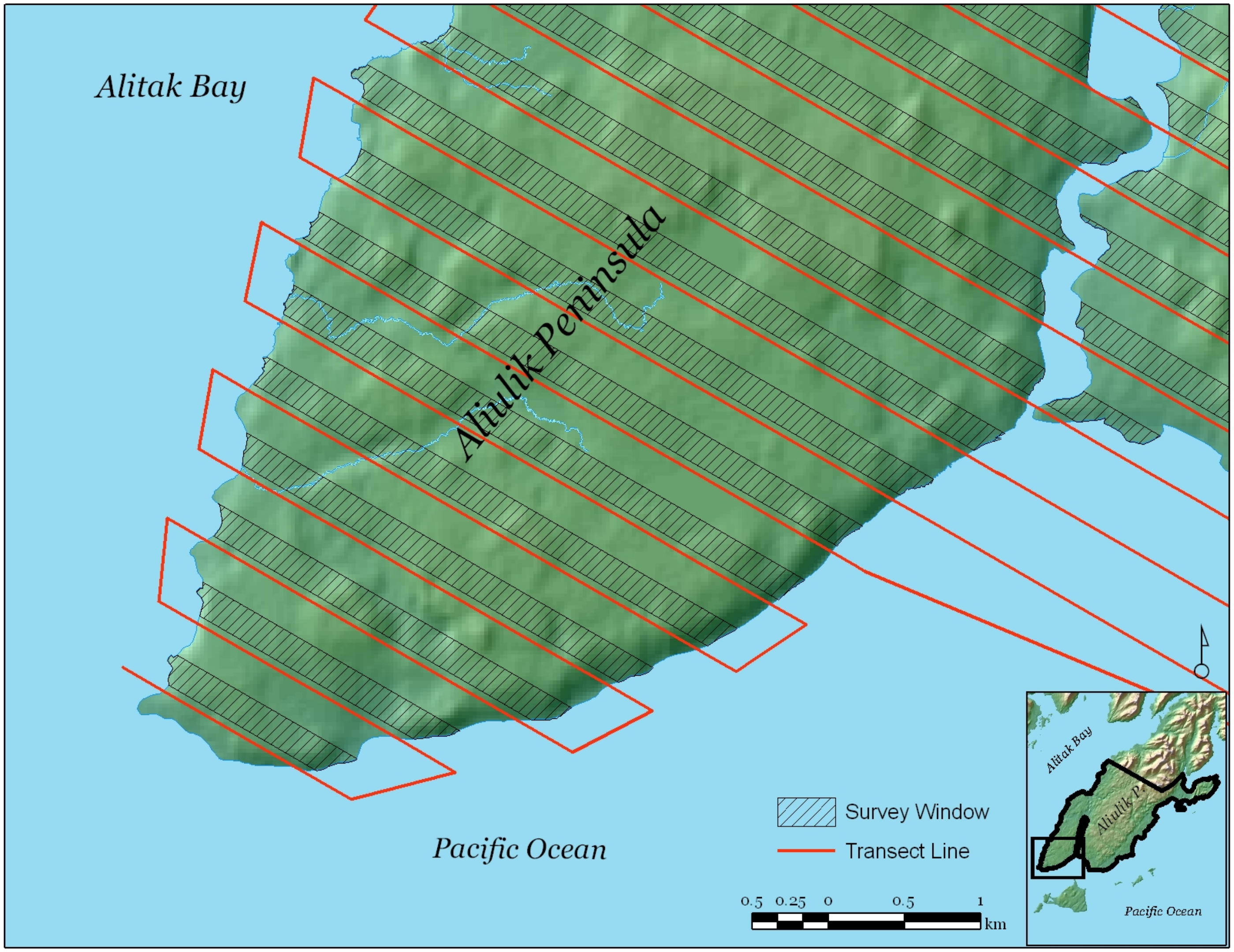


Figure 3. Map depicting areas scanned for Sitka black-tailed (survey window) during aerial line-transect surveys, Aliulik Peninsula, Kodiak, Alaska, May 2012. The survey window extended from 50m to 250m from the side of the airplane. The observer scanned on alternating sides of the airplane to maintain a north-facing survey window relative to the transect line.

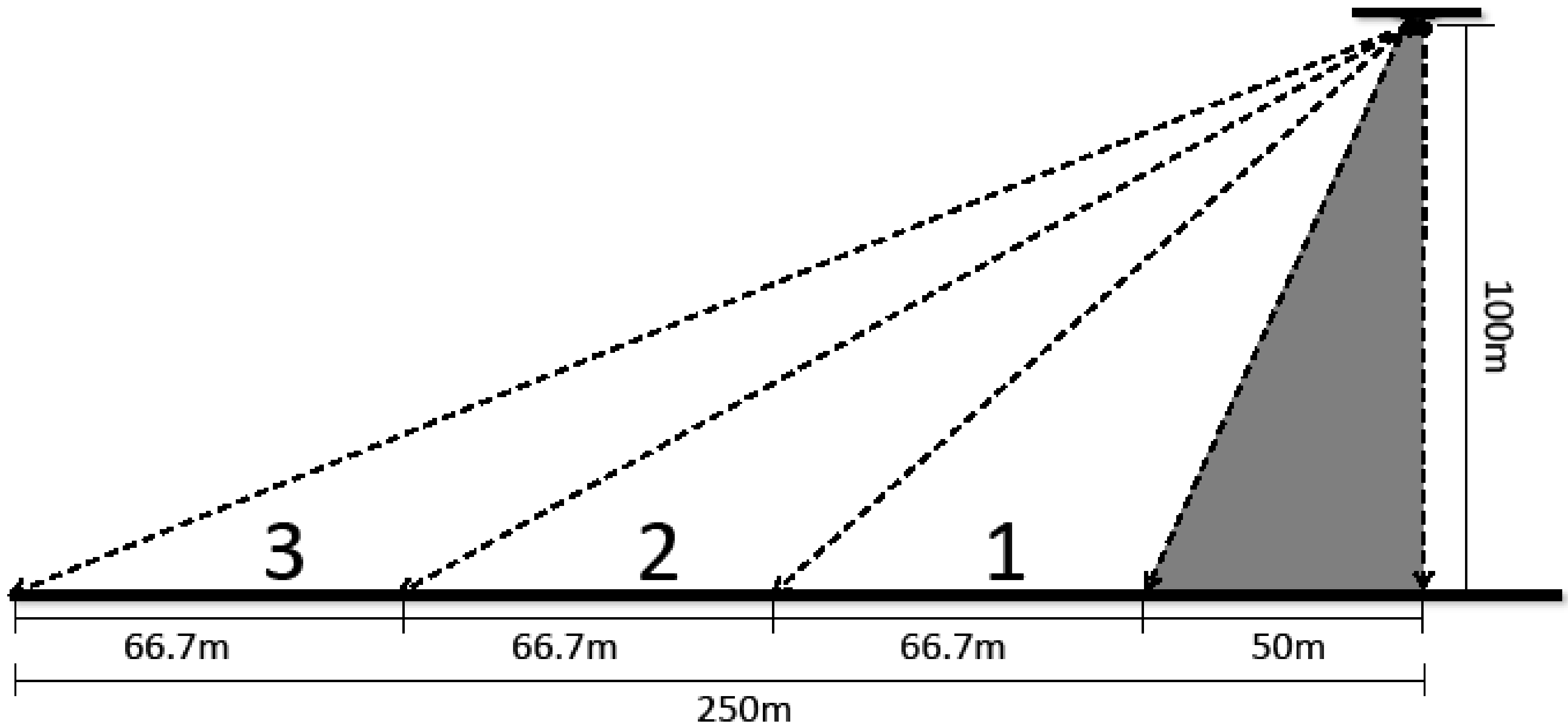


Figure 4. Depiction of distance classes (1-3) for Sitka black-tailed deer surveys, Kodiak Island, Alaska. The shaded area (0-50m on the ground, from the airplane) was not visible, because the airplane floats obstructed the observer's view during surveys.

We used the multiple covariates distance sampling analysis (MCDS) engine within Program Distance to facilitate estimation of detection probabilities. We selected the half-normal key function as the detection function. We conducted exploratory data analyses, model selection, and final analyses using this statistical approach (Marques et al. 2007). We incorporated potentially significant covariates into the model that we believed would affect the probability of detecting deer: whether deer were observed grass (versus tundra and shrub), deer group size, and whether deer were standing (versus bedded). We also tested whether population estimation results differed among survey replicates, by using the replicate number as a covariate.

Because deer occur in clustered groups, we estimated deer abundance within the study area ($\widehat{N}$) as:

$$\widehat{N} = \sum_{i=1}^{n} \frac{S_i}{\widehat{P}_i}$$

where $\widehat{P}_i$ was the estimated inclusion probability for animal *i* and *n* was the number of observations. $\widehat{P}_i$ included 2 components: the probability that deer *i* fell within the sampled transect (coverage probability) and the an estimate of its probability of detection, given that it was on the transect. S_i was the size of the deer group *i, i* = 1, … , *n* (Thomas et al. 2010).

We selected an *a priori* candidate model set, fit the models, and used an information-theoretic approach to rank competing models. Our limited sample size (deer groups) prevented us from comparing models that included multiple covariates, so we compared models with single covariates to assess the relative influence of each covariate on detection.

RESULTS

We completed 3 replicates of aerial line-transect surveys for deer at the Aliulik Peninsula study site (16, 20 and 22 May, 2012) (Fig. 5). We surveyed for a total of 15.3hrs (5.6hrs on 16 May, 4.5hrs on 20 May, and 5.2hrs on 22 May). Surveys were conducted between 09:30 and 17:00hrs. Weather conditions were overcast with very light rain changing to partly cloudy on 16 May, overcast changing to partly cloudy on 20 May, and partly cloudy to sunny conditions on 22 May. Winds were calm (<5km/h), and turbulence was absent to light during all surveys.

The 54 line-transects in the study area totaled 428km in length, and ranged from 0.07km to 13.21km each (mean = 7.92km). The total area surveyed was 107.8km^2, and individual line-transect strips ranged from 0.01km^2 to 3.25km^2 (mean = 2.00km^2).

Summed among the three surveys, we observed a total of 192 deer in 116 groups (Fig. 6, Table 1). We observed an average of 64 deer in 39 groups/survey (1.7 deer/group). The most commonly observed behavior was bedded (59), and the least common behavior was walking (5) (Table 2). Most deer groups were observed in the closest distance class (51) and fewest deer were observed in the furthest distance class (28)

The model containing grass habitat as predictor of deer detectability was the best approximating model in the *a priori* candidate model set, based on Delta AICc values. Based on results derived from this model, 115 deer (SE=15.82) inhabited Aliulik Peninsula, at a density of 0.53 deer/km^2 (SE=0.07) or 0.36 deer groups/km^2 (SE= 0.05) (Table 3). Our estimated average detection probability declined with distance to the airplane, from 0.95 at 50m to at 0.35 at 250m (Fig. 7). The model predicted that our ability to detect deer was higher for grass habitat and lower for shrub and tundra habitats (Fig. 8A and B).

Table 1. Number of Sitka black-tailed deer and groups observed during aerial line-transects, Aliulik Peninsula, Kodiak, Alaska, May 2012.

Survey	Date	Deer	Groups	Deer/Group
1	5/16/12	51	32	1.6
2	5/20/12	77	44	1.8
3	5/22/12	64	40	1.6
Average	--	64	39	1.7

Table 2. Summary of the behavior of Sitka black-tailed groups observed during aerial line-transect surveys, Aliulik Peninsula, Kodiak Island, Alaska, May 2012.

Survey	Date	Bedded	Standing	Walking	Running
1	5/16/12	18 (56.3%)	9 (28.1%)	3 (9.4%)	2 (6.3%)
2	5/20/12	27 (61.4%)	12 (27.3%)	1 (2.3%)	4 (9.1%)
3	5/22/12	14 (35%)	24 (60%)	1 (2.5%)	1 (2.5%)
Average	--	19.7 (50.9%)	15 (38.8%)	1.7 (4.3%)	2.3 (6%)

Table 3. Summary of the rankings of competing distance sampling models, and the associated deer density (#/km^2) and population estimates for the Aliulik study area, for each model.

Rank	Predictor	AIC	ΔAIC	Density (95% CI)	Pop. Est. (95% CI)
1	Grass	246.33	0.00	0.53 (0.41-0.70)	115 (88-150)
2	Bedded	249.95	3.62	0.58 (0.45-0.76)	125 (96-164)
2	None	250.17	3.84	0.53 (0.37-0.74)	113 (80-160)
3	Cluster Size	252.00	5.67	0.53 (0.43-0.72)	138 (85-285)
3	Replicates	252.41	6.08	0.053 (0.40-0.69)	113 (87-148)

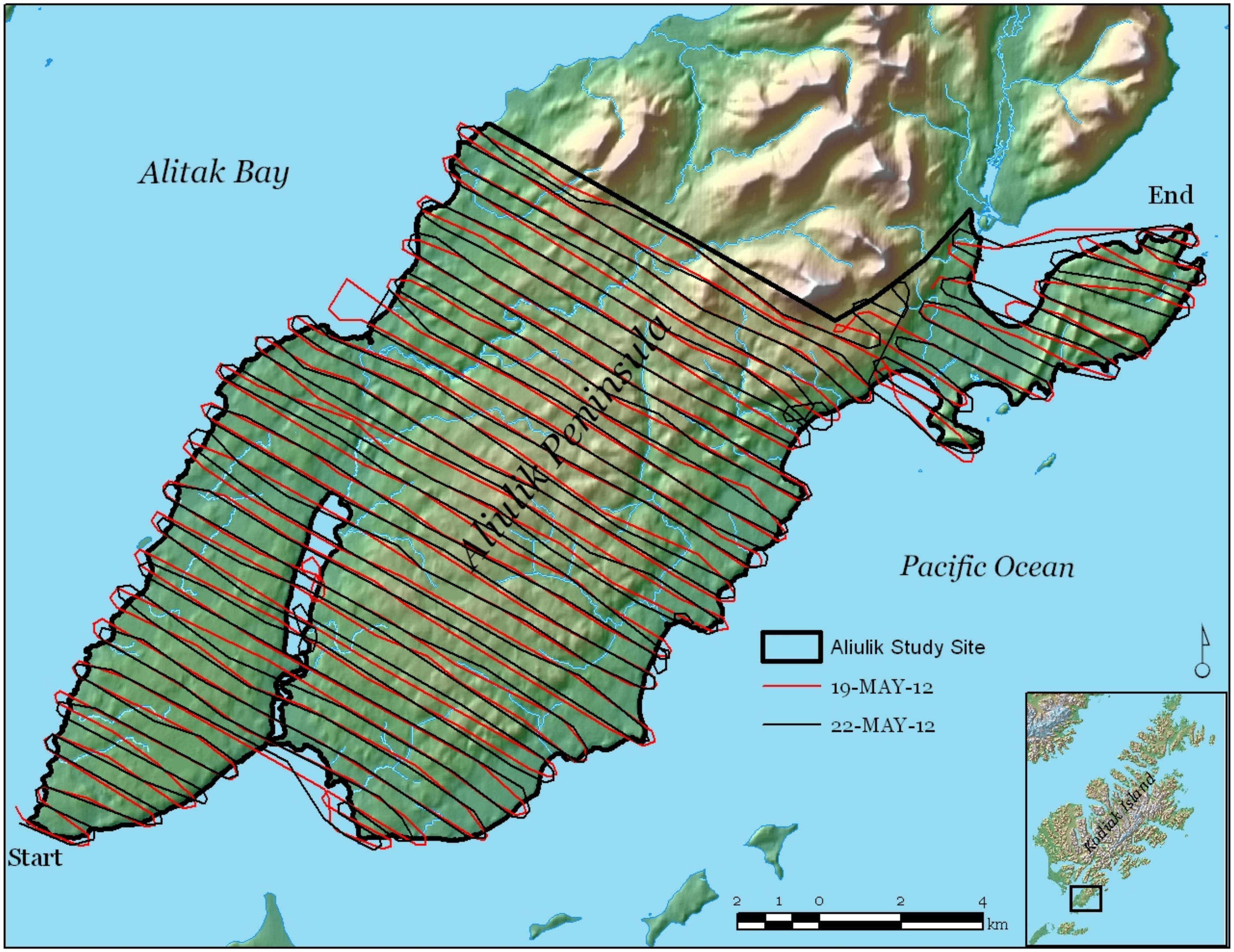


Figure 5. Track lines recorded by GPS during Sitka black-tailed deer aerial line-transect surveys, Aliulik Peninsula, Kodiak Island, 20 and 22 May, 2012. We did not record a GPS track line during the 16 May survey.

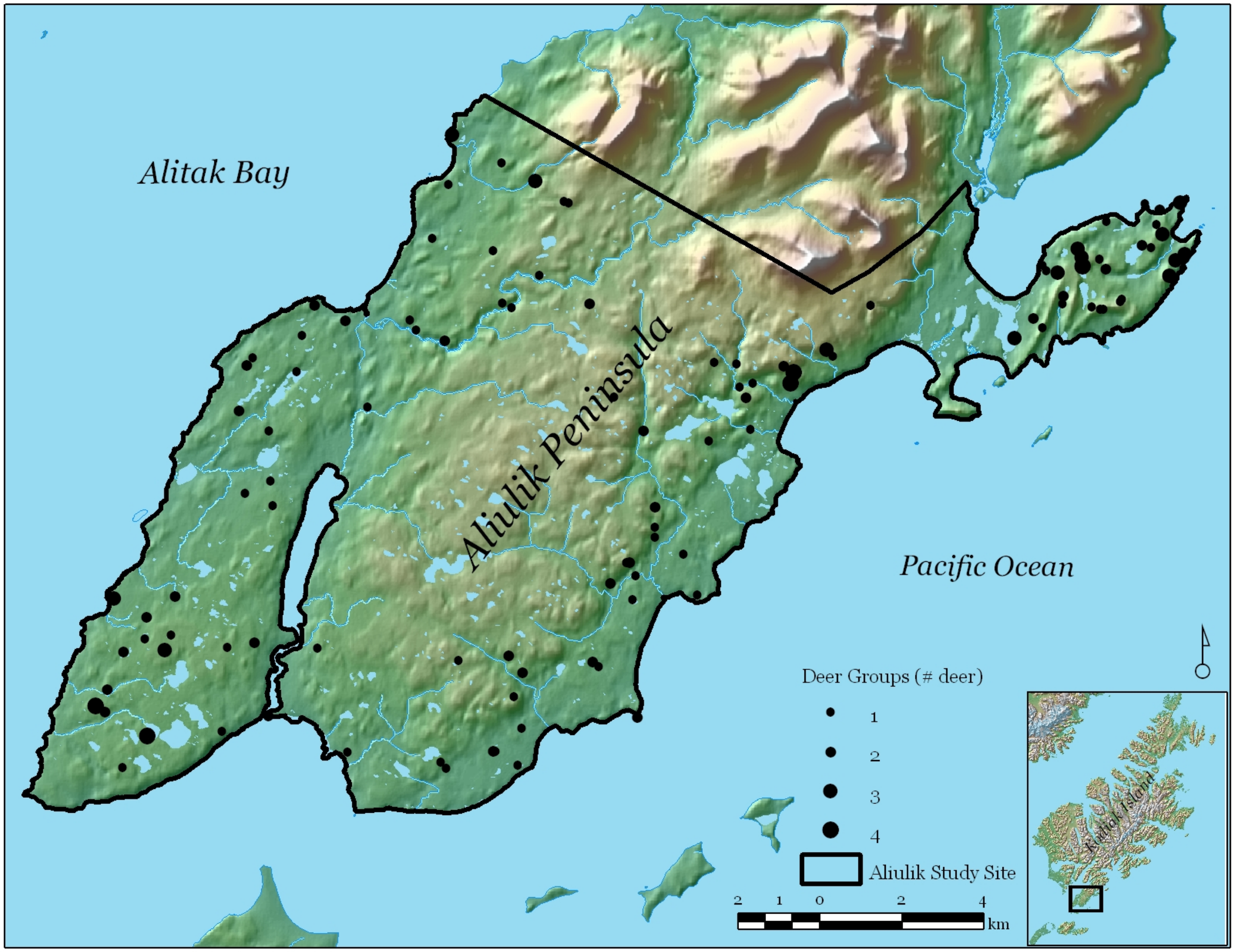


Figure 6. Approximate location of deer groups observed during aerial surveys, Aliulik Peninsula, Kodiak Island, 20 and 22 May, 2012. Points have not been offset from transect lines. The size of the points are scaled relative to group size.

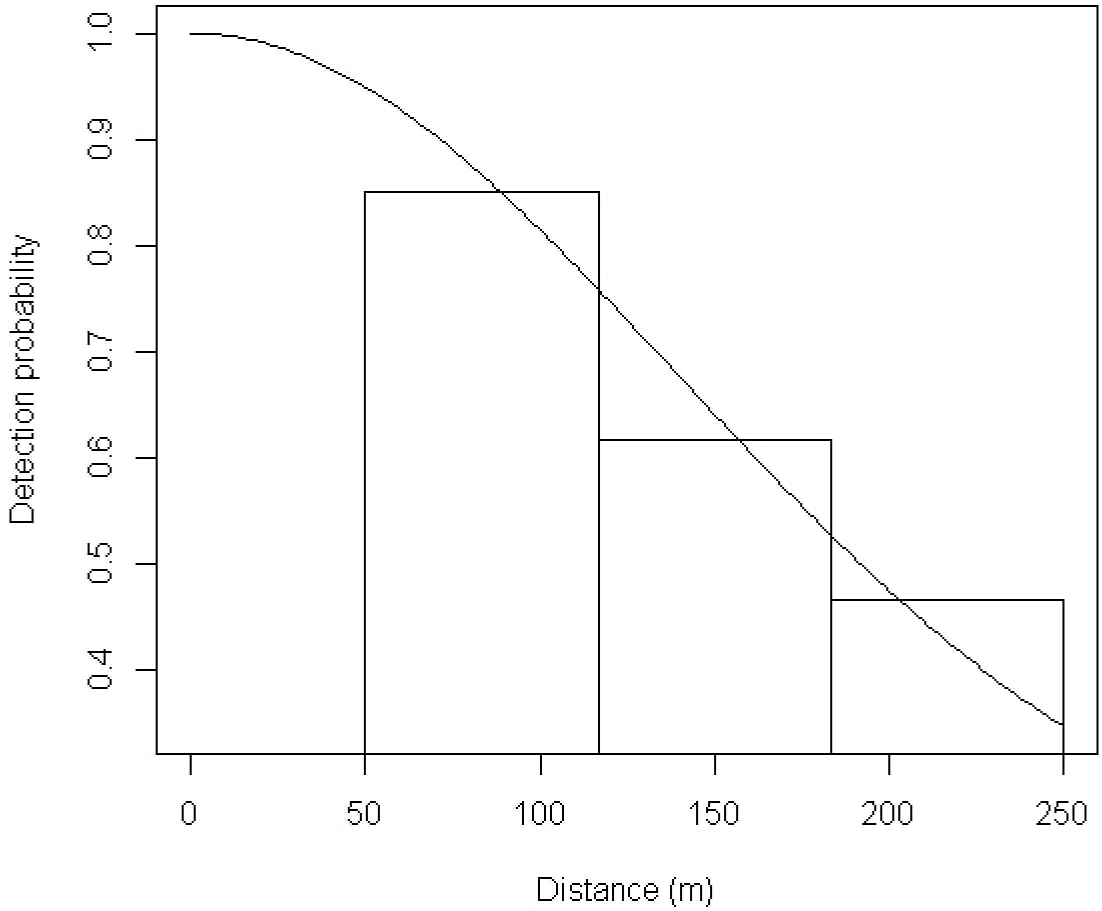
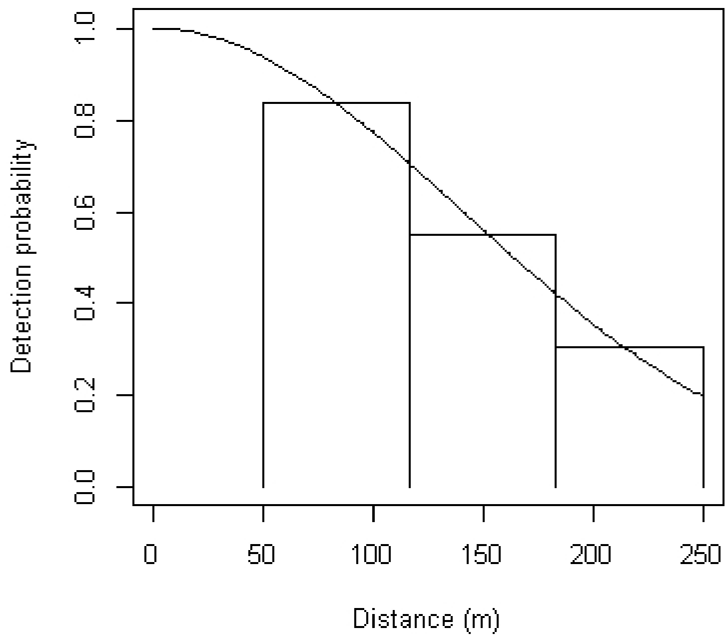


Figure 7. Plot of estimated detection probabilities for Sitka deer by distance (m), superimposed on a histogram showing the observed frequencies at a given distance, Aliulik Peninsula, Kodiak Island, Alaska, 2012.

A) Grass



B) Tundra and Shrub

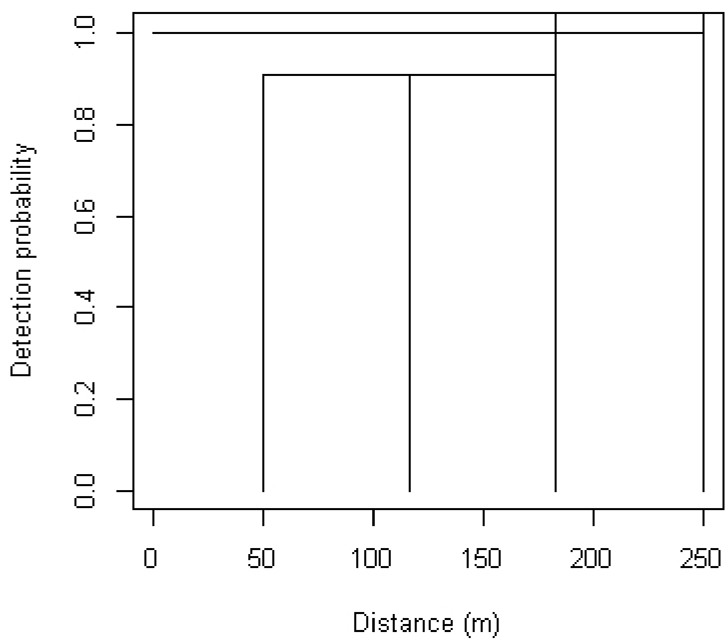
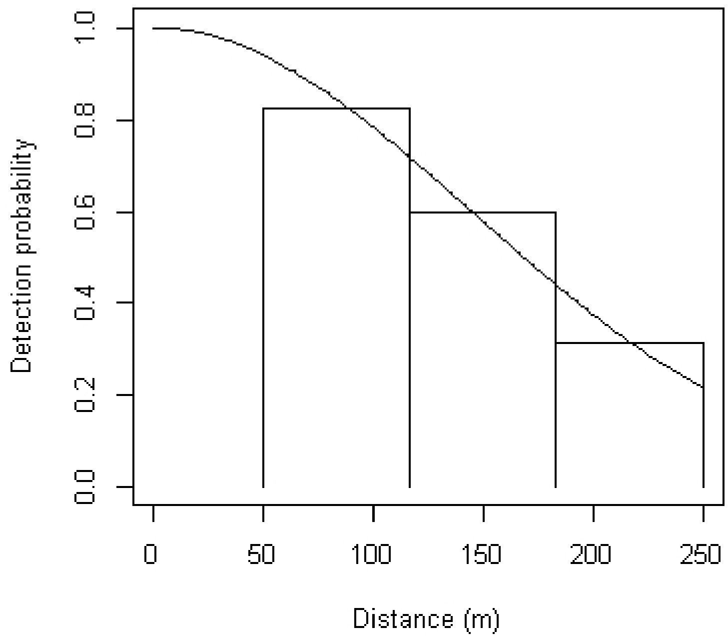


Figure 8. Plot of estimated detection probabilities for Sitka deer by distance (m) observed on A) grass habitat, or B) tundra and shrub habitats, during aerial surveys on the Aliulik Peninsula, Kodiak Island, Alaska, 2012. Detection functions are superimposed on histograms showing the observed frequencies at a given distance.

A). Bedded



B). Not Bedded

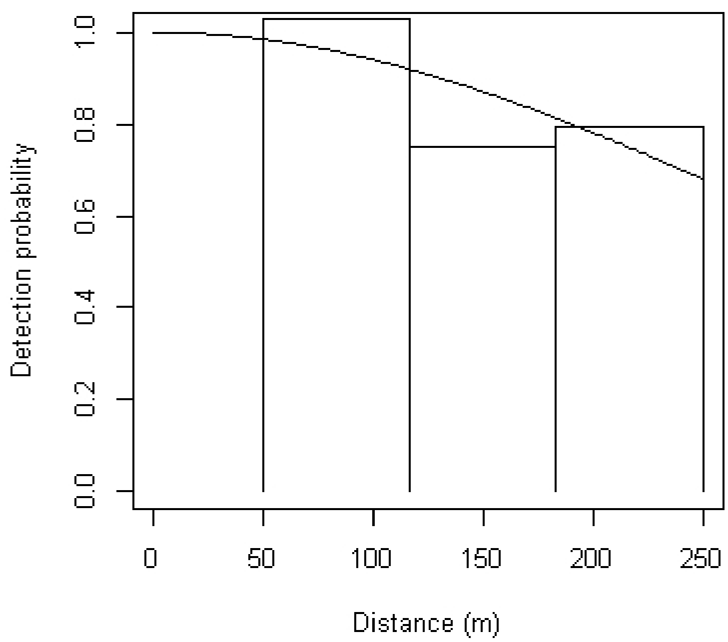


Figure 9. Plot of estimated detection probabilities for Sitka deer by distance (m) observed when the majority of the deer group was A) bedded, or when the majority of the deer group was B) not bedded (standing, walking, running, and feeding), Aliulik Peninsula, Kodiak Island, Alaska, 2012. Detection functions are superimposed on histograms showing the observed frequencies at a given distance.

The model containing deer behavior as a predictor (bedded vs. all other behaviors), and the model without predictor covariates (null model), was the second best approximating models among the candidate model set, based on AIC values. Results from the model containing deer behavior indicated that deer that we detected were bedded at a lower proportion than deer that were standing, walking, or running. The difference in detection rates between bedded deer and other deer amplified when deer were further from the transect line (Fig. 9A and B). Specifically, our detection probability at 50m was 0.94 for bedded deer, and 0.98 for deer exhibiting other behaviors. At 250m from the transect line, the model predicted that we were over 3-times less likely to detect a bedded deer (0.22 detection probability), than a deer exhibiting another behavior (0.68 detection probability).

The models containing deer group size and survey replicate as predictors both ranked lower (Delta AIC > 2) than the null model, indicating that these predictors had no measurable effect on our ability to detection deer.

DISCUSSION

We produced the first quantitative estimate of deer abundance on Kodiak using a distance-based method applied to aerial surveys. Overall, our effort showed that the distance sampling method can be successfully used to estimate deer abundances in non-forested areas of Kodiak with statistical confidence. Future efforts should include stratification of survey transects by habitat type (or complex of habitat types) for more precise estimates of detection probabilities. When combined with a complementary method that is robust for surveying deer in forested habitats, such as a pellet survey (Kirchhoff 2003, Jenkins and Manly 2008, Brinkman 2009), this approach could allow wildlife managers estimate the deer population size on Kodiak.

Our estimate of deer density (0.53 deer/km^2) at the Aliulik Peninsula study site was almost 10-times lower than a Kodiak Archipelago-wide deer density estimate (5 deer/km^2, at deer population of 70,000 deer). There are a number of possible explanations for this difference. First, in the absence of a statistically robust method to quantify deer abundances, wildlife managers have estimated Kodiak Archipelago deer abundances using results from annual hunter questionnaires and subjective accounts from the public (Van Daele and Crye 2011). While these data provide information on deer population trends, they are not an impartial method of ascertaining deer numbers or density. Another explanation for the apparent low densities of deer is the probable high rate of mortality associated with adverse conditions of the 2011-12 winter. Kodiak received almost record snowfall (365.25cm) during 2011-12, and January 2012 was the snowiest month on record (135.65cm) (National Weather Service). In combination with below-average winter temperatures, these conditions resulted in large deer die-offs, estimated in the range of 20-30% of the population. Rates of mortality likely varied across the Archipelago, and could have been higher on the Aliulik Peninsula (see discussion of carcass surveys below).

Our model results showed that deer detection probabilities were strongly influenced by habitat types: deer observed in grass were more difficult to spot than those observed in tundra and shrub. While this was true for our surveys, it should be noted, however, that these results may vary across other areas of Kodiak Island because of variations in extent of these habitats and their apparent substantial influence on detection rates. In addition, annual changes in factors that impact annual changes in vegetative phenology, such as snowfall and temperatures, would also impact deer detection probabilities. The winter prior to this study was unusually cold and snowy. During our survey period (May), grass habitats were still brown, making it difficult to spot deer. Surveys conducted later in the year would likely allow for a higher detection probability in grass habitats, but deer in shrub habitats would be very difficult to see because of concealing leaves. Because of this tradeoff, we recommend that future deer surveys on Kodiak Island occur during April-May timeframe when most snow cover has dissipated and before deciduous shrub and tree vegetation have leafed. An ancillary benefit of conducting deer surveys during spring is that deer carcasses are clearly visible during this time, so a concurrent carcass count could serve to index rate of winter mortality. If funding allows, a complimentary fall deer survey would provide additional data on fawn production and initial survival.

Deer behavior also influenced our ability to spot them during surveys: bedded deer had a lower detection probability than deer that were standing, walking, and running. This result was supported by comments made by the pilot and observer during the surveys, and has been reported elsewhere during distance sampling of ungulate populations (Focardi et al. 2002, Ward et al. 2004). Moving deer were spotted more easily, and during sunny conditions, the shadows cast by standing and moving deer made them stand out from the background. We concluded that bedded deer were especially difficult to spot on grass habitats because of the aforementioned reasons, but we were unable to test for interactions among predictors because we only had three distance classes.

The study provided a first opportunity to examine distance sampling methods as applied to aerial surveys on Kodiak. Based on our efforts, we have suggestions to refine future surveys using this method. First, we tested the practicality of using a laser rangefinder (Laser Technology Impulse XL) to quantify distance between the observer and deer. The laser rangefinder was able to determine distances through the aircraft's Plexiglas windows, but accurately determining distance to deer groups was very challenging because of the flight speed. Additionally, recording distances using the laser rangefinder required the observer to accurately target the deer group with the rangefinder and manually record the distance values, which was not practical when combined with the other data collection needs. This problem could be overcome by using a automated recording system (Southwell et al. 2002), or one that is voice-activated and coupled with a GPS, such as VoiceGPS (Neilson 2006). Using such software could also allow observers to survey for multiple species during a single survey. A second challenge was maintaining a consistent above ground level (AGL) during surveys. The rolling terrain of the Aliulik Peninsula required the pilot to change elevations, but maintaining a consistent AGL over topography would have required a helicopter, which was cost-prohibitive. To address this constraint, we recommend arrangement of survey transects parallel to elevation gradients, such as waterways and slopes.

We anecdotally noted that weather conditions appeared to influence our ability to detect deer, although we did not quantify this finding. Deer, especially while standing, cast shadows during sunny conditions that make it easier to spot them. However, during sunny conditions, glare in the pilot's eyes made staying on course during east-bound transects more difficult. Given this finding, we recommend that observers on future surveys note weather conditions (sunny versus cloudy) for each survey transect, which will allow for inclusion of a weather predictor in future distance sampling candidate models.

Because this was a pilot project to assess the feasibility of distance sampling, we limited the number of distance classes to three, which is the minimum acceptable number of classes for distance sampling. Although we were able to get robust estimates for detection probabilities and associated deer density and population estimates using only three classes, by limiting our analysis to three classes, we were unable to fit more than one covariate to each model. As a general guideline, Buckland et al. (2001) recommended using at least four distance classes, and preferably five. Based on our experience from this pilot study, we believe that accurately classifying deer groups in the correct distance class would be challenging if more than five classes were used, and the potential for bias would outweigh any advantages associated with a more precise measurement. Based on these findings, we recommend that future surveys have five distance classes.

Future surveys aimed at estimating deer abundances across a wider region of Kodiak Island will be at lower survey intensities than this area-restricted pilot study because of budget and logistic constraints. With this in mind, we offer suggestions for survey design across a larger area of Kodiak Island. We surveyed four to five hours per days, and observers were notably fatigued by the end of each day. In addition to the potential for lower quality data, long survey days present a greater risk of changes in weather that could prevent the survey from being completed. Therefore, we recommend limiting daily survey durations to a maximum of four hours, and ideally three hours. Additionally, we recommend hourly survey breaks between transects. Secondly, we recommend that surveys continue to be conducted at 100m above ground level (AGL), and no higher than 150m AGL. Using this AGL, we recommend that the strip width remains at or below 500m (250m per side of the aircraft), because our detection probabilities were reduced even at that distance (0.35). As for distributing the survey transects, we recommend using a stratified random sampling approach, and stratifying by habitat type (grass, shrub, and tundra) and slope. We recommend weighting the number of transects per strata based on their relative areas within the landscape and estimated deer densities. Placement of individual transect lines with stratums could be achieved using the Kodiak Landcover Classification habitat GIS layer and a DEM within a GIS. As mentioned earlier, efforts should be made to orient lines parallel to the elevational gradient, to help maintain a consistent AGL during surveys. Program Distance 6.0 includes an element for survey design, with a simple GIS, that may be useful.

Deer carcass remnants, demarked by hair piles, were readily observed, and generally were within one km from the coastline. Following the transect-based surveys, we surveyed and enumerated 39 deer carcasses along the coastline of the Aliulik Peninsula study site. This number represents a minimum count because we missed an unknown number of carcasses during this additional survey effort. When compared to our mean daily deer count (64), and assuming that detection probabilities were similar between deer and deer carcasses and that there was no deer immigration or emigration from the study area, this result suggests that upwards of 60% of the deer at the Aliulik study site died during the 2012 winter. We suggest that future surveys include enumeration of deer carcasses by distance class along transects so that an estimate of deer carcasses corrected for detection probability can be obtained. However, collection of these data without compromise to other data would require use of an automated recording device, such as VoiceGPS.

Acknowledgements

A special thanks to National Park Service pilot, Jim Traub, for safely and effectively flying the surveys. His good sense of humor and positive attitude made long survey days enjoyable.

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