Aerial Surveys Vs Hunting Statistics To Monitor Deer Density: The Example Of Anticosti Island, Québec, Canada

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Source: Wildlife Biology, 13(3) : 321-327

Published By: Nordic Board for Wildlife Research

URL: https://doi.org/10.2981/0909-6396(2007)13[321:ASVHST]2.0.CO;2

Aerial surveys vs hunting statistics to monitor deer density: the example of Anticosti Island, Québec, Canada

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Pettorelli, N., Côté, S.D., Gingras, A., Potvin, F. & Huot, J. 2007: Aerial surveys vs hunting statistics to monitor deer density: the example of Anticosti Island, Québec, Canada. - Wildl. Biol. 13: 321-327.

Cervid densities have recently increased in many parts of North America and Europe. To design sustainable harvesting strategies, a good understanding of deer population dynamics and reliable estimates of population densities are required. This is especially true on Anticosti Island, Québec, Canada, where sport hunting is the main source of income, and where long-lasting impacts of white-tailed deer *Odocoileus virginianus* on the forest ecosystem have been reported due to high deer densities. We compared white-tailed deer densities estimated in 2001 on the basis of an extensive aerial survey of 512 plots, each 3.5 km long by 60 m wide, with indices based on hunting statistics in 24 hunting zones on the island. We found a positive correlation between the number of deer seen per hunter day and the density of deer estimated by the aerial survey, but this correlation was highly influenced by the four locations with the highest densities of deer. We detected no significant correlation between deer density estimated by the aerial survey within each hunting zone and the number of deer harvested per hunter day. Our results underline the need for comparative studies addressing the validity of density indices based on hunting statistics to monitor variations in cervid population numbers.

Key words: aerial survey, hunting, Odocoileus virginianus, white-tailed deer

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Received 20 January 2006, accepted 15 May 2006

Associate Editor: Göran Ericsson

A major goal for successful management of hunted populations is to define harvesting strategies that are accepted by everyone, sustainable, not leading to instabilities or extinctions, and that optimize annual yield, with as little variation among years as possible (Lande et al. 1995, Sutherland 2001). Requirements for such successful strategies include a good understanding of deer population dynamics and a need for reliable estimates of population densities.

Estimating density of cervids is a hard task, and several methods have been developed to cope with it (Caughley 1977, Seber 1982, 1992). A distinction is generally made between methods aiming at monitoring trends in population sizes and methods designed to provide absolute values of population sizes (Seber 1992), although the distinction is not always clear (see e.g. Marques et al. 2001). There is no consensus on the use of one particular approach, and the choice of method is generally a function of area considered, questions asked, species under study, structure of the landscape, budget and number of people that could be involved in the monitoring (Rabe et al. 2002).

To provide accurate estimates of the population sizes of large animals ranging over extensive areas (such as deer), aerial surveys are often the only practical way (Caughley & Sinclair 1994). They have been extensively used in Australia to monitor red kangaroo *Macropus rufus* (Cairns & Grigg 1993), in North America for elk *Cervus elaphus*, moose *Alces alces* and caribou *Rangifer tarandus* (Courtois et al. 1994, Couturier et al. 1996, Eberhardt et al. 1998), and in Africa to monitor ungulates such as wildebeest *Connochaetes taurinus*, zebra *Equus burchelli*, elephant *Loxondonta africana* or antelopes (e.g. Harrington et al. 1999, Mduma et al. 1999, Ogutu & Owen-Smith 2003).

There are, however, shortcomings associated with aerial surveys. First, one of the main challenges has been to improve accuracy, which is a measure of how close a population estimate is to the true population size. Underestimates are indeed the rule in aerial surveys (Caughley 1974). Some of the factors contributing to a negative bias in aerial surveys are vegetation cover, species surveyed, survey specifications (e.g. height above ground, speed and strip width), weather conditions, the number of observers and the observers' experience (e.g. Baylis & Giles 1985, Caughley & Sinclair 1994). The progress made to account for such biases has, however, largely contributed in making aerial surveys an efficient method to estimate population sizes over large areas (e.g. Potvin & Breton 2005).

Another challenge with aerial surveys is that they are expensive and, therefore, cannot generally be used for long-term monitoring. To monitor deer densities over large areas on a yearly time scale, typical alternatives include observation methods (e.g. Ericsson & Wallin 1999, Sylvén 2000) and use of hunting statistics. Many authors have indeed used hunting-based indices to estimate changes in population sizes (e.g. Grøtan et al. 2005, Pettorelli et al. 2005). Although it has been proposed that indices designed to monitor trends, such as hunting-based statistics, need to be calibrated before use (Seber 1992), few studies have confronted trend indices with more accurate estimates such as those obtained with capture-mark-recapture (CMR) methods or aerial surveys (but see Fuller 1991, Gaillard et al. 1996).

In this paper, we aim at comparing white-tailed deer *Odocoileus virginianus* densities estimated in 2001 by aerial surveys with hunting statistics in 24 hunting zones on Anticosti Island, Québec, Canada, to determine the potential of hunting statistics as a surrogate estimate of deer densities. The white-tailed deer population on Anticosti stems from the introduction of about 220 deer at the end of the 19th century. In the absence of predation, the population grew rapidly, and today deer density exceeds 20 deer/km^2 locally (Potvin & Breton 2005). The high costs of aerial surveys urge wildlife managers to find reliable and less expensive alternatives.

Material and methods

Study area

Our study was conducted on Anticosti Island in Québec, Canada (49°28'N, 63°00'W), which covers an area of 7,943 km^2. Forests are naturally dominated by balsam fir *Abies balsamea*, white spruce *Picea glauca* and black spruce *P. mariana*. White birch *Betula papyrifera* and trembling aspen *Populus tremoloides* are irregularly found on the island. The climate is maritime and is characterized by long, mild winters. Mean temperatures are -11°C in January and 15°C in July, snow precipitation averages 327 cm annually and rainfall 610 mm (Environment Canada 1982).

Data

Hunting statistics

White-tailed deer hunting on Anticosti Island takes place during 1 August-24 December; during August, only antlered individuals can be hunted, whereas all sex and age classes can be harvested from 1 September onwards. The average area of the 24 hunting zones is 287 km^2, ranging from 77 to 956 km^2. The number of hunter days (Ericsson & Wallin 1999, Sylvén 2000) varied from 209 to 2,073 among the hunting zones, and this measure of effort positively correlated with the size of the hunting zone ($N = 24$, $r = 0.94$, $P < 0.001$). The numbers of deer harvested per hunter day and deer seen per hunter day were available for 24 hunting zones on the Island in 2001 (covering a total area of 6,899 km^2).

Aerial survey

The Anticosti Island was surveyed using the double-count technique during 13-24 August 2001 (Rochette et al. 2003, Potvin et al. 2004). Two observers took place on the left side of a helicopter, one in front and one in the rear, and a navigator sat in the back-right seat. The observers counted white-tailed deer between 0 (vertical) and a maximum angle of 45°, delimited by aligning a mark on the window and one on an outside rod attached to the front of the helicopter (see Fig. 2 in Potvin et al. 2004). The altitude was checked using a radar altimeter and was maintained at 60 m above ground level, and the speed was kept from 70 to 100 km/hour. A Global positioning satellite system (GPS) was used to follow a north-south or south-north direction on flight lines spaced at 2.5' of longitude (about 3,125 m). Survey plots, each 3.5 km long, were systematically distributed along survey lines, with 1.5-km spacing between two consecutive plots. Two different communication systems were used between the observers and the navigator to ensure independent counts. The navigator tallied information (number of deer seen and their activity) separately for each observer on a 1:20,000 map at the location where the group was reported. A total of 607 plots (of which 512 were considered for this study), each 3.5 km long and 60 m wide, were surveyed over the whole island, and 1,772 deer were seen. The average accuracy of this aerial survey technique was recently evaluated on Anticosti Island to be 65% (Potvin & Breton 2005). Densities per plot were estimated using the CERF Software (Rochette et al. 2003), and we averaged density per hunting zone. There were on average 20 ± 14 aerial survey plots per hunting zone.

Analyses

We linked our data at the minimal common spatial unit, i.e. at the hunting zone scale ($N = 24$). We used Linear Models (LM) to analyse correlations between the density estimated by the aerial survey and indices derived from the hunting statistics (i.e. the number of deer seen and the number of deer harvested per hunter day). All statistical analyses were performed using the statistical package R (Crawley 2005).

Results

Aerial survey and number of deer seen

The number of deer seen per hunter day ranged from 3 to 24 individuals (mean = 11.7 ± 5.0) in

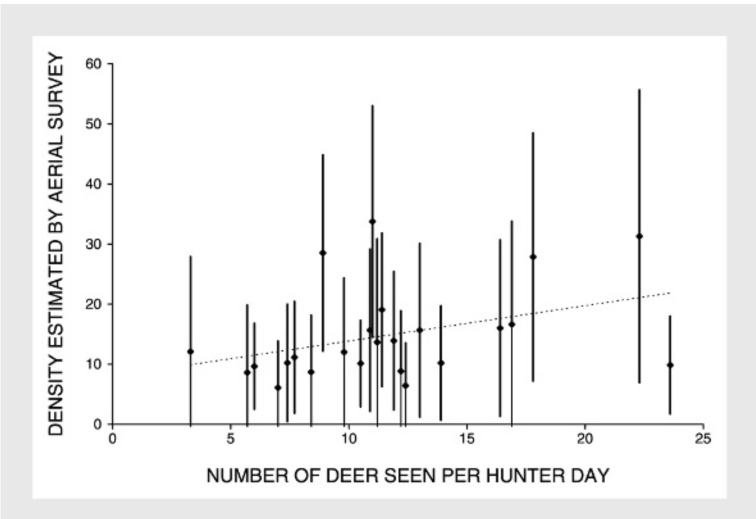

Figure 1. Relationship between white-tailed deer density (deer/km^2) estimated by helicopter surveys and number of deer seen per hunter day on Anticosti Island, Québec, Canada, with standard deviations associated with the aerial survey estimates provided.

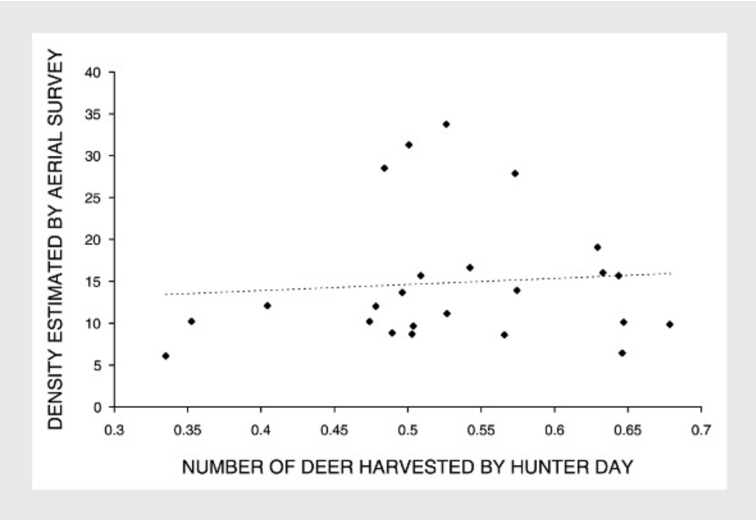

Figure 2. Relationship between white-tailed deer density (deer/km^2) estimated by helicopter surveys and the number of deer harvested per hunter day on Anticosti Island, Québec, Canada.

the different hunting zones. We found a nearly-significant and positive correlation between the number of deer seen and the density of deer estimated by the aerial survey (N = 24, r = 0.37, P = 0.07; Fig. 1). The correlation was mainly due to the four locations with the highest densities of deer. If the four points are removed, the correlation remains positive but not significant (N = 20, r = 0.29, P = 0.21).

Aerial survey and number of deer harvested

In 2001, the number of deer harvested per hunting zone ranged from 136 to 1,263 individuals, and the number of deer harvested per hunter day was 0.3-0.7. The density estimated by the aerial survey ranged from 6.1 to 33.8 individuals/km^2. We found no significant correlation between the deer density estimated by the aerial survey and the number of deer harvested per hunter day (N = 24, r = 0.08, P = 0.70; Fig. 2).

Discussion

Wildlife managers and scientists often assume that indices derived from hunting statistics can provide useful information to monitor variations in ungulate population sizes (e.g. Swihart et al. 1998, Solberg et al. 2004). Our study, however, demonstrates that this assumption is not always valid and seems to be dependent on deer density. The number of deer seen per hunter day appeared to be more informative in our area than the number of deer harvested. At $<$ 20 deer/km^2, however, the correlation became weak (see Fig. 1), which indicates that hunting-based statistics capture large spatial variations in density, but are imprecise at average and low deer densities.

Although we only had one year of data, we used a large area representing 24 hunting zones covering around 7,000 km^2, with estimated densities ranging from 6 to 33 deer/km^2. But, can we trust our approach and the assumption that aerial survey estimates are of higher quality than indices derived from hunting statistics? Aerial surveys can be affected by problems such as observer bias and experience, double counting, limited sightability and sex differences in sightability (Caughley 1974, Routledge 1981, Samuel & Pollock 1981, Pollock & Kendall 1987, Samuel et al. 1992, McCorquodale 2001). Biases in helicopter surveys can also result from extraneous sources of variability, such as speed and altitude effects, and sampling intensity (DeYoung 1985, Beasom et al. 1986, Shupe & Beasom 1987). However, most of these effects have been accounted for in our survey which had an accuracy of 65% (Rochette et al. 2003, Potvin & Breton 2005).

The Anticosti Island may represent a particular case. Quotas are fixed at two deer per permit and two permits per hunter visit. However, most hunters only buy one either-sex permit, which may influence the relationship between number of animals harvested and density estimates obtained from the aerial survey. Infrastructures of outfitters are the main factor limiting the number of hunters per zone, but the occurrence of infrastructures is not expected to be linked to deer densities, although we found a good correlation between the number of hunter days and the size of the hunting zones. Another point is that some hunters benefit from professional local guides, who generally highly improve hunter success. The experience of a guide operating in a specific hunting zone may therefore be a source of bias. Finally, standard errors in aerial survey estimates are high at the hunting-zone scale (see Fig. 1). All these factors could presumably affect the strength of the relationship between the number of deer estimated by the aerial survey and hunting statistics.

Catch (or observations) per unit (CPU) effort indices, such as the number of deer seen per hunter day, are sensitive to a number of factors, including hunting effort or scale of hunting zones (Sylvén 2000). The number of observations made from a few days of hunting might indeed provide a less precise and stable index than if made during a higher number of hunter days. Moreover, the correlation between the actual density and CPU effort indices is expected to increase with the size of the sampling area; a minimum size of 500 km^2 has been previously suggested (Sylvén 2000). Only three out of the 24 hunting zones on Anticosti Island exceeded 500 km^2. Our measure of effort (number of hunter days) highly correlated with the size of the hunting zone, although both parameters varied greatly. This high variability, associated with the variability in habitat characteristics, might also influence the strength of the relationship between the number of deer seen per hunter day and density estimated by the aerial survey.

Our findings have implications at multiple scales. At the scale of the island, our results suggest that, as for now, there seems to be no real alternative to expensive aerial surveys to provide reliable estimates of deer densities. We have data of only one aerial survey for the whole island, and there are no other indices at the scale of the island against which the estimates from the aerial surveys could be compared. Body masses of harvested individuals, for example, have not been monitored regularly and are difficult to obtain at the scale of the island. The only time series existing at the scale of the island are the hunting based indices, which prove here to provide limited information on deer densities. Our results obtained with the number of deer seen per hunter day, however, are encouraging and in accordance with results from Scandinavia (Ericsson & Wallin 1999). Wildlife managers for Anticosti Island are, nevertheless, left without any precise and confirmed reliable annual monitoring tool, even though deer-density variations affect the outcome of most residents and outfitters of the island, and the high deer density reached nowadays affects the biodiversity and ecosystem functioning of the island (Côté 2005, Tremblay et al. 2005, Pellerin et al. 2006).

At the international scale, our results strongly encourage comparative studies to assess the validity of hunting-based statistics to estimate cervid density. We need to know whether the situation on Anticosti Island is common or an exception. Clearly, scientists and wildlife managers cannot use hunting statistics as a surrogate of density and assume that they are reliable without first testing this assumption. This is particularly important considering the growing use of hunting statistics to estimate ungulate density in ecological studies (e.g. Swihart et al. 1998, Solberg et al. 2004, Grøtan et al. 2005, Pettorelli et al. 2005). In many locations experiencing ecological problems associated with deer overabundance (Côté et al. 2004), there is still no effective monitoring program launched or available monitoring tool to obtain reliable estimates of ungulate densities.

Acknowledgements - we thank the outfitters on Anticosti Island for help with recording hunting statistics and J-P. Tremblay for ideas, comments and suggestions on previous drafts of this work. Funding for the aerial survey was provided by the Ministère des Ressources naturelles et de la Faune du Québec and Nathalie Pettorelli was supported by the Chaire de recherche industrielle CRSNG-Produits forestiers Anticosti.

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