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AERIAL MOOSE SURVEY TECHNIQUES WORKSHOP

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The last formal review of moose census techniques was presented by Tim Timmermann at the 1974 Moose Workshop and Conference in Quebec at which time he left us with the challenge to improve census methods to optimize moose management (Timmermann H. R. 1974, Moose inventory methods: a review. Naturaliste Can. 615-629). Accordingly, the 1982 Moose Workshop Steering Committee decided that it was time to review moose census procedures. To summarize census activities during the past 10 years a questionnaire was designed and distributed to all political jurisdictions within the moose range of North America. Response was 100%.

The demands on the moose resource have increased manyfold over the past decade, and along with these demands, a need to establish accurate and precise estimates of moose populations under a wide variety of habitat situations across the continent. This need has been brought about by many factors, including increasing demands for harvesting moose by native and non-native peoples, demands on habitat through accelerated development, measuring the effects of predation, habitat evaluation and resource planning needs, to mention but a few. Hunting regulations are increasing in complexity in attempts to manage moose populations, requiring accurate and precise measurement of the population. (Accuracy is defined as the closeness of the estimates to the true values and precision refers to the measure of dispersion, whether or not the mean value around which the dispersion is measured approximates to the "true" value).

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Considerable effort has gone into developing moose census techniques and in conducting censuses and it is the purpose of this workshop to assimilate and discuss the current state of the art.

A survey was conducted of all jurisdictions on the North American continent with native moose populations to obtain background information regarding moose census techniques as they are currently applied (Table 1). Parks Canada provided similar information from individual parks where moose censuses are conducted (Table 2). From the surveys reported in Table 1 it can be seen that all jurisdictions except one are using some sort of aerial census and three (Nova Scotia, Ontario and Minnesota) report the use of ground census, which for the most part are pellet counts done in conjunction with white-tailed deer (Odocoileus virginianus) surveys, or some type of observational survey (Wyoming and Montana). Most report using the census to estimate and manage moose populations, obtain data on sex ratios and recruitment. Although these are stated goals, the level of precision regularly obtained in these surveys leaves something to be desired. Only 5 of the 17 respondents reported their technique provided accurate population estimates, while 7 were satisfied with the precision. Those generally satisfied with precision were working at 90 or 95% confidence level with a 10-20% confidence interval. Eleven of 16 replied that their technique provided representative sex and age data, and 8 of 17 felt it provided a rapid indicator of population trends. Ten of the 17 were actively engaged in attempting to improve the census technique, while 1 was investigating pellet counts. About half take the time to train moose census crews prior to the actual census.

The bottom line to this whole effort is whether or not moose management would be changed with better population estimates, to which 12 answered "yes", one "hopefully" and 4 "no".

The following is an edited version of the census workshop discussion after presentation of the survey information.

BILL GASAWAY (Alaska)

The answers to the question on survey accuracy were a real eye opener. People were asked to rate the quality of the census data, i.e., whether it was good, moderate, marginal, no good, or they did not know. A little less than half of the people said they had good accuracy, and less than half of the people said they were in the marginal category, and then almost a third were in the do not know. Accuracy and precision are clearly our major population estimation problems.

Several people will give a brief resume of the major techniques they use. Michel Crete will talk about methods used in Quebec; Pat Karns has already told about block surveys in Minnesota; Bob McFetridge, Alberta, will give information on block surveys using the Cook-Jacobsen correction factor; I will provide information on block surveys in Alaska, and last Craig Greenwood will talk about transects and contrast them to blocks as used in Ontario.

MICHEL CRETE (Quebec)

Moose range in Quebec is characterized by deep snow and thick cover. The best time to see moose from the air is early winter (January). Snow depth is generally between 20-90 cm.

In the beginning, we were using both fixed wing and helicopter. The fixed wing flew transects 400 m apart to locate moose tracks. Then the helicopter was used to count animals and to sex them. After 3 years, we found a very good correlation between the number of moose that people in the aircraft saw and the number we found with the choppers. Now we are only using fixed wing. We have a model with multiple regression equation that allows us to predict how many moose would be found if we were using a helicopter.

Three years ago, we started a province-wide program to estimate the total population. We surveyed more than 100 blocks each winter. Five to 7 crews conduct surveys. Our province-wide survey has been described in the proceedings of last year's moose conference. The method has been published in French so that Yankees cannot understand them.

We still have some problems to solve. We feel quite confident because our estimates are similar from year to year. We found an average density of 0.12, 0.14, and 0.14 moose/km^2 for southern Quebec. But we still have to deal with missed moose. We are estimating this value with radio-equipped animals to determine the size of the bias. We probably miss 15-20% of the moose using a chopper. The other problem that we all face is incorrectly computing confidence intervals. We gave a contract to a statistician to solve this problem. Now we have to build a program and put our data in the computer to calculate confidence intervals. Maybe I am more confident than other people, but I think the precision will not be too bad.

When we know the bias and can calculate confidence intervals, I think we will not need any more aerial surveys. We found a very good correlation between moose density and hunting effort as given by mail questionnaire. We plan to use the mail questionnaire to estimate moose density, which is much cheaper. We will work on this next fall. We will still use aerial surveys when we are interested in sex and age ratio and for the research project.

BILL GASAWAY

If you use moose harvest questionnaires to estimate moose density, how large a land tract do you need?

MICHEL CRETE

You need an area where at least 200 moose are killed. In Quebec, it would be 2,000-3,000 km^2.

BILL GASAWAY

As we are going through the methods today, bear in mind what your needs are for estimating population. If it is province-wide, one method might work; if you require estimates for 500 or 1,000 km^2, then other methods will be better.

FROM THE FLOOR

Michel, can you give us weather criteria for your surveys?

MICHEL CRETE

We look only at snow depth and snow freshness. You work a maximum of 5 days after a snow fall of more than 5 cm so that you can recognize fresh tracks. Snow depth must be 20-90 cm.

BILL GASAWAY

His method has very strict snow requirements because he is looking for tracks, which is contrary to what most of us do, i.e., looking for moose first and tracks secondarily.

Rob McFetridge, from Alberta, will discuss their experience using the Cook-Jacobsen method to correct for sightability bias.

BOB MCFETRIDGE (Alberta)

Cook and Jacobsen designed a method for estimating visibility bias in aerial surveys; it was published in Biometrics, 1979. It was largely based on the work they did for us in Alberta. I will go over the major points in their paper. I have not been directly involved with the method; therefore, I do not really feel that comfortable speaking about it. I have talked with people who have used it, and I have gone over the papers to some extent, but I am still unfamiliar with the statistical procedures and some of the probability theory behind it.

The survey design requires 2 observers to assume different roles during the survey, a primary observer and a secondary observer. In the detection of groups, the primary observer behaves as if he was the only observer present. The secondary observer confirms all sightings by the primary observer and records only those groups that he detected that were missed by the primary observer. Once a group has been sighted, both observers may assist in the enumeration of animals in order to meet the assumptions. The secondary observer must not aid the primary observer in the detection of groups. Essentially, the second observer's record is conditional on the records of the primary observer. This procedure is followed until approximately half the survey has been completed, at which time the two observers switch roles, i.e., the second observer becomes the primary observer. For obvious reasons, the observers must be situated on the same side of the aircraft. This makes the design more costly than the ones in which the observers are situated on opposite sides.

I will discuss its use in Alberta. I do not want you to get the impression that this is the major system that we use in Alberta. We are still using fairly standard survey techniques in Alberta, but we have tested this sytem for a number of consecutive years on deer transects. The people on this project are fairly confident that they are gaining a useful correction factor for visibility bias. The type of habitat that they are using it in is fairly uniform topography, and that is an advantage when you are using this particular system. We have used it once for moose, and that was in this past survey season. The biologist was pleased that he got a correction factor for visibility bias, which is something that we have not been getting from other surveys. That is the extent of use in Alberta. British Columbia has tried it on one occasion near Fort St. John, and in talking to Don Eastman, he was impressed with the correction factor obtained from the technique. But he was not prepared to suggest that they use the technique more widely.

I think what would be appropriate would be to run some controlled tests to determine what increase in observability you get by using a second observer and if the correction for bias is accurate.

FROM THE FLOOR

During moose surveys, it is not uncommon in a two-place airplane for one person to say "there's a moose", while the second individual has a lot of trouble seeing that moose. If that happened very often in your situation, you're applying a sightability correction factor based on one of the two observers spotting the moose, but what I question is, how often do moose get by that you do not know about. That is an additional correction that may not be taken into account.

BILL GASAWAY

The Cook-Jacobsen method may hold some real promise, and in time we will know. Hopefully, some of the western provinces that are now investigating the method will determine if we whould be using it. We will be looking forward to hearing from biologists from British Columbia, Alberta, and Manitoba. We are looking for something inexpensive, and it is an inexpensive correction factor under some conditions, because it does not involve expensive re-survey work.

BRIAN CHURCHILL (British Columbia)

Having played with it a bit, it does appear to be a cheap correction factor in one sense, but the whole problem with transects is the fact that you do not know the area searched because of problems keeping an aircraft at a fixed height above the ground. I think the

method has a high probability of providing precise estimates, but accuracy involves an estimate of area covered. Area is a problem.

BILL GASAWAY

Do you restrict its use to transects? It can be used with block counts, can't it?

BRIAN CHURCHILL

Yes, it could be used with block counts, but again we are making the basic same assumption that you and Michel are, i.e., if blocks are done with helicopters, you get close to a total count.

BILL GASAWAY

Yes, you are getting close to a total count, but you are not getting a total count, and that is the additional component we are looking to estimate. Michel is going to use radio-collared moose to get that additional number between what he can see from a helicopter and what is truly there. It is the same with the Cook method, if you are using a helicopter presumably there is still some missed moose that could be estimated.

BRIAN CHURCHILL

We have another problem: variation in sightability among habitats. We may be looking at areas as small as 10 ha that are very open habitat, interspersed with areas of the same size that are totally closed canopy. We are trying to come to grips with that problem.

BILL GASAWAY

Cook and Jacobsen state their method is best applied in uniform habitat. You are looking for uniform sightability of individuals and groups, and as soon as you change habitat types, you have a new stratum. Habitat heterogeneity is a problem we will not readily overcome. Another thing that they said was the level of precision was generally less than that obtained by block surveys. Their level of precision was measured in uniform habitat. If you have to go to variable habitat within plots or along transects, you are going to decrease the precision even more. This may then make your final estimate of precision unacceptable, and, as a result, the method may not have application where you require a specified level of precision, say ± 20% of an estimated true number of moose.

MIKE WOLFE (Utah)

In the late 60's and early 70's we were encouraged by the use of infrared photography. We could go back to Tim Timmermann's paper from 1973 and find that at that time the thing seemed to be a bust. However, I would like to bring your attention to recent work that Dave Anderson has been doing at Utah State University in conjunction with the Utah Division of Wildlife Resources. They have been working with remote censusing, but the system is a bit different. Previously, if I understand it, infrared detection devices were used to either take pictures and go back home and try to interpret what went on, or infrared scanners were used on board. Human interpretation was involved there. Anderson, with some electrical engineers, has put computers in planes, so that the signals that come through are interpreted by the computer. What they end up getting are behavioral signatures. I believe the kind of stuff Anderson is doing is multi-spectral scanning; they are not only looking at infrared but at a whole range of things and then putting it together. I think the signature concept is what is really important, and that is interpreted

in a little computer. You do not have to make the mental gyrations yourself and say whether it is a porcupine, a moose, or a hot rock. They have looked at hot rocks, and all the things that we had problems with in the past. They have been working primarily on deer in juniper stands where the cover is fairly heavy. Dave is quite excited about what this thing has in store, and while I am sure it is too early to say anything about how it might work, it is something one might look to in the future. You cannot use this thing on a large scale for your entire block or the 25,000 km^2 that you have to census, but on a limited scale it might be something where you want to tie in and build a correction factor. I would look to see some of that material coming out within the next 2 or 3 years.

FRAN HAZELWOOD (British Columbia)

This past winter I was working with the B.C. Forest Service in the Rocky Mountain trench, and they were telling me about their scanner for infrared for use in detecting hot spots in some of the areas where they burn slash. He said quite often they'd detect animals with this camera. They would circle with the helicopter until it was found; they identified porcupines and things like that. I think there is good potential here.

RICK PAGE (British Columbia)

The problem with all those sensing units is that they cannot see through the vegetation. If they can see it, you can too. If you are flying in a survey airplane and you have observers, the chance of the observers seeing animals in the open is probably as good as the equipment is. The only advantage is you do not have observer fatigue or other search problems. In areas where we survey moose and have vegetation problems, none of these techniques are going to work. We cannot make them work for caribou, where we do not have to worry about vegetation. So I don't think there is much hope there for moose within the next decade anyway.

BILL GASAWAY

What was the problem with caribou when they would not show up on IR?

RICK PAGE

There are enough anomalies in terms of bushes that absorb infrared in the same way. Diseased bushes, for instance, will absorb infrared. There are a lot of things that can go wrong. In the case of caribou, you cannot separate cow/calf pairs, or two animals standing together often appear as one. It basically did not work well enough.

The U. S. military flew Isle Royale with surveillance equipment. We heard about it in a round about way. They did it because they had a moose population estimate to work from. This was the best technology available, which we would not get for a long time. They came up with 200-2,000 moose on Isle Royale, depending on the signature used, and there was no proper signature. They determined it was not very valuable for censusing animals.

BILL GASAWAY

We use a stratified, random block survey method like that of Siniff and Skoog (1964) and Evans et al. (1966). We have modified their methods to improve accuracy (an unbiased estimate) and to provide an estimate of precision that incorporates sampling error among sample units and sampling error associated with estimating sightability of

moose. Our sightability correction factor corrects for moose not seen and is obtained by re-surveying areas with very intensive searches.

The most suitable method in Alaska is a stratified random sampling procedure using blocks. With this method, search effort could be prescribed, i.e., in difficult areas we can increase search effort. Search effort on transects is harder to alter; you move forward at a constant rate, so transect width is the only variable. Also, we want to be able to re-survey an area to correct for sightability bias, which can be done easily using blocks. In the hilly mountain country that dominates Alaska, transects are not really suitable. Our blocks have natural boundaries because we did not want to be tied to any special technology such as aerial photographs or special maps of high resolution. We need to use the maps that are available for the entire state.

The basic approach is as follows: The area is stratified based upon moose density. Stratification is done by flying in a fast aircraft such as a Cessna 185. Generally you fly over each sample unit (block) very quickly, give it a category of high, medium, or low, and move on. The sample units are irregular in shape, 10-15 mi^2, formed by creeks, rivers, ridges, and occasionally straight lines between very identifiable points. Sample units are selected at random from each strata. We search about 4 min/mi^2, which is equivalent to flying quarter mile wide transects. We circle over each aggregation seen in an effort to locate additional moose. We maximize the precision of the estimate by optimizing our sampling effort. Optimization is getting the most precision for your dollar. The difference between what we are doing and what is commonly done is we optimize during the survey on a daily basis, whereas, most methods optimize prior to sampling. At the end of each day we estimate population size and variance for each stratum. Tomorrow's effort is directed toward the stratum with the poorest estimate, i.e., greatest variance. We find that day-by-day optimization is beneficial, because what we would predict in the beginning to be the optimum sampling scheme is not necessarily the optimum one in the end. Optimum allocation ahead of time depends upon assumed variances, which are often incorrect.

Accurate estimates are ensured by correcting for moose not seen. We estimate the moose missed in randomly selected portions of sample units by re-surveying at a high intensity. Moose seen on the second search divided by moose seen on the first search gives you a multiplier that is used to estimate the number of moose. You cannot find every moose during aerial searches. So, we used radio-collared moose to estimate the percentage of moose missed on the second search. In the fall, we missed a radio-collared moose with second search effort 2% of the time. This miss rate was also corrected for. By using brute force, i.e., putting in a high search effot, we see the majority of the moose. Thus, we have small correction factors for moose that cannot be found from a Super Cub.

In late winter, moose are much harder to see. Therefore, we have restricted our survey work primarily to early winter when moose have a high sightability. With the same search effort, 90% were seen in early winter, whereas only 63% were seen in late winter.

Now, let's look at the estimate of precision. Our first dealings with precision were during optimum allocation where we adjusted our

sampling scheme to get the best precision. That was one sampling error in the total error component. The second one enters through our estimated sightability correction factor. The two errors are combined to produce a final variance and confidence interval which centers on an unbiased estimate of moose numbers. Normally people calculate confidence intervals only with the first error component. This is our attempt to come up with a more realistic confidence. In the past, using one error, we obtained 90% confidence intervals that were 10-20% of the estimate. Now we are looking at 15-30%. Our precision is not as good as we would like, but we have come closer to the realistic precision estimates. We are, hopefully, not going to fool ourselves as often thinking our estimates are better than they are.

The last thing I want to say about what we are doing in Alaska is that we have a manual written up that is very detailed. The intent was a step-by-step procedure manual that can be used as a training aid in workshops, and by people in the field. We are trying to standardize what we do.

Craig Greenwood will discuss transect survey methods used in Ontario.

CRAIG GREENWOOD (Ontario)

Ian Thompson, my predecessor in Ontario, has written up a method for correcting population and sex/age estimates from aerial transect surveys. We are using transect surveys to estimate population size and as a means of stratifying areas when existing information is inadequate. We also use transects to sample in areas where only presence or absence of moose is desired, e.g., in my habitat research, I am looking at the association of moose relative to morphometric measurements of habitat. We are using presence/absence and 100% coverage with transect surveys.

There are a number of transect survey types outlined in Caughley's book "Analysis of vertebrate populations", and for those who are interested, he also gives the calculation for calculating variability and confidence intervals. I do not think I will go through that now. There is basically systematic sampling and random sampling. Within those two types, there are variable and fixed width transects. Variable width tends to give you better precision but it is logistically more difficult. That is where Thompson's paper comes in very handy in terms of using a quadratic equation to correct.

In my region of Ontario, we have 3 major units that are flown by transects, and for differing reasons. The techniques follow very strict guidelines that we have developed for our plot surveys. We fly within 72 hours of a snowfall and at least 12 hours after a storm so that animals can move and make tracks. We fly between 1000 and 1400 hours and when there is a minimum of 30 cm of snow. Our guidelines say hazy to clear skies, based largely on Hepburn and Passmore's work years ago, but actually most people find it better to fly when it is overcast and using yellow glasses. We fly 100-200 m above ground level at air speed of 90 mph when winds are less than 20 km/hour. Our transect widths were variable depending on habitat. We also fly transects for caribou. The sightability there is obviously increased over that of moose. We fly from 0.5-0.8 km total transect widths, with either one or two observers on each side, plus the navigator, with the exception of one unit which I will mention in a minute. In one of our units,

we use photo mosaics. The photos greatly enhance the accuracy of the count, because you can count animals only within your transect width. This technique gives us a precision of ± 20% with a 90% confidence level, and that is fairly consistent. We break transects into 10 km segments even though your transect line may be 11,000 km long, or what have you. In this area, we have a 9.8% coverage of the area, which in sampling terms is not great according to the literature.

Why do we use transects in Ontario? Largely because of logistics. We have tremendous chunks of land that are inaccessible. You may be talking 2 hours of air time just to get to the site where sampling begins. Transects are much more efficient use of flying time than blocks. Some areas totally lack physiographic features; you cannot find the plot. If anyone has worked in the Hudson Bay lowlands, they will know exactly what I mean. Compasses are not of much value either because there is a lot of magnetism.

We use transects to get a trend through time. If we are statistically correct, we should be able to stratify an area and each year pick new plots in that strata and end up with an estimate that has some degree of precision and accuracy as the surveys before it. But many people, and most of our biologists, are very apprehensive that they have lost trend-through-time data, and that is extremely important. Therefore, we use a systematic approach to transect sampling to get annual population trends. Transect surveys are easier to navigate than blocks, particularly if you are using photo mosaics. With transects, we feel there is less chance of missing coverage than with plots. In plots, we fly a minimum of 4 lines in a 25 km^2. However, because of physiography, there is a tendency to miss coverage. With transect surveys the area follows the flight path; therefore, you have 100% confidence you have seen all of your area. In this case, transect surveys may provide a greater degree of accuracy.

There are both parametric and non-parametric methods for estimating correction for number of moose seen on transects. Methods by Eberhardt and Gates are parametric; methods of Kelker, Anderson, and Burnham are non-parametric. Ian has found, and he has got good statistical evidence, that Eberhardt's method of using a quadratic equation was the best correction. Eberhardt's uses right angle frequency of sightability from your flight line. It basically says, I will see 100% of the animals that are in a strip 10-20 m from the flight path. And, I will see fewer and fewer animals the farther away I get from that area of 100% sightability. The right angle of frequency is the most commonly used correction. The quadratic equation does correct for aggregations, loners, and cow/calves. Ian shows there is a definite behavioral difference of cow/calves in terms of their distribution, or in their habitat selection, which affects the sightability. In terms of systematic versus random type of approach, navigation is much easier on a systematic transect survey. Movement of animals, between plots or transects, and double counting is no problem with systematic sampling. Systematic transects also give the greatest degree of coverage of a sampled area per unit time flown, which is important from a cost point of view.

In sampling, we get hung up--have we got independence, is it random, and what have you. I borrowed a term from Graham Caughley, as he points out, the most important thing is the statistic robust, i.e., does it, within the limitations that you know, give you a reliable

estimate of what you have got. I think really that is the important thing and I think transect sampling is robust.

MIKE WOLFE

If you are dealing with the non-parametric type of things like the Kelker and Burnham et al. methods, one of the most important assumptions is that you see all the animals on your line. Obviously if you are looking down from an aircraft, you are violating that particular assumption. I may be wrong, but that is the most important one. The method itself is realtively robust as you pointed out, but that is the same kind of problem people have with censusing aquatic mammals or subterranean mammals.

CRAIG GREENWOOD

I think it is a valid point, and as far as my knowledge serves me, you might be right. That not only applies to non-parametric but to parametric methods. You are striving to see 100% of the animals there. That is why some of the quadratic equations were formed to try and correct for what you would miss. I suppose in that sense we do violate the 100% sightability, but that is the assumption that we do make.

MICHEL CRETE

I am not very familiar with line transect methods, but I know many estimates can come from the angle at which you see the animal flushing. With an aircraft, of course, you don't look in front, but you look on the sides. I think there is a correction there.

CRAIG GREENWOOD

Yes, that is the right angle frequency correction; it is applied because we do not use flushing distance. The correction in the quadratic equation is based on right angle freqency, as if you were looking at right angles from the aircraft body, which, of course, most observers are because they are stuck because of the strut.

BILL GASAWAY

One of Craig's points is that there are places where transects are ideal, and one of the places is where you cannot find where you are. In this case, plots really break down. So there are places for transects, and places for plots, e.g., in the mountains and hills.

FROM THE FLOOR

How do you use line transects where compasses do not function well?

CRAIG GREENWOOD

We use a compass where we do not have magnetic interference. Where we have magnetic interference, there are navigational aids that you can use. They are fairly pinpointed. The thing with accuracy of the flight line, you really do not have to stay on your selected line. As long as you are measuring the same width, you could actually go all over the place. It would not really matter as long as you do not double count, or as long as you do not subjectively select areas.

MIKE WOLFE

If you have a fixed width transect, then that works. You can wander pretty well. If you are using the non-parametric methods, you have to stay pretty well on transect. You can zig and zag, but you have to know the distance from the transect. It is particularly important near the transect, because what you are looking at when you crank it through the computer program of Burnham et al. is a

Fourier series (a decay) of how your observations fall off from the transect line. So those distances that are very close to the line are very important; those that are farther out are not so important. I think if you are going to use it for the thing you are talking about, the fixed transect width would be the better way to go.

CRAIG GREENWOOD

Statistically, that is really the only way you can--well, you can do it the other way, but in terms of variables it is extremely difficult.

BILL GASAWAY

Today, people have been introduced to the primary methods that are used across North America. We have seen the perfect census method is yet to be developed, but progress has been made in the last decade. I hope you have benefited from hearing how various organizations tackle their census problems, and hope their methods may help you improve your population estimates.

RESPONDENTS TO 1982 MOOSE CENSUS SURVEY
1982 North American Moose Conference & Workshop
Whitehorse, Y.T.

Jurisdiction	Respondent
Newfoundland	Gene Mercer
Nova Scotia	Art Patton
New Brunswick	John C. Baird
Maine	Karen Morris
Quebec	Michele Crete
Ontario	Ray Stefanski
Minnesota	Pat Karns
Manitoba	Vince Crichton, Brian Knutson
Saskatchewan	H. J. Hunt, E. R. Wiltse
Wyoming	Dale Strickland
Montanna	Graham Taylor
Idaho	Jerry Thiessen, Michael W. Schlegel
Utah	John S. Kimball, Jr.
Alberta	Gerry Lynch
British Columbia	Don Eastman
Northwest Territories	Vernon Hawley
Yukon	Doug Larson
Alaska	Bill Gasaway

Table 1. Summary of moose census techniques used on the North American continent in 1982.

Jurisdiction	Type of census	Area censused (km²)	Frequency of census			
			>1/yr	Annual	Every few years	≥ 5 yr interval
Newfoundland	Aerial	20700		x	x	x
Nova Scotia	Aerial & ground				x	
New Brunswick	None					
Maine	Aerial	33000			x	
Quebec	Aerial			x		
Ontario	Aerial & ground	200000		x	x	x
Minnesota	Aerial & ground	26000		x		
Manitoba	Aerial	3000		x	x	
Saskatchewan	Aerial	3200		x		
Wyoming	Aerial & ground	varies			x	
Montana	Aerial & ground 1)	650		x	x	
Idaho	Aerial	varies		x		
Utah	Aerial	2600		x	x	
Alberta	Aerial	65000-200000	x	x	x	
British Columbia	Aerial			x	x	
Northwest Territories	Aerial	10000		x	x	
Yukon	Aerial	14200			x	
Alaska	Aerial	12900			x	x

1) Incidental to elk or deer work

Table 1. Cont.

Jurisdiction	Census made for: Management of specific populations	Geographic areas	Research	Total population estimate
Newfoundland	X		X	X
Nova Scotia	X			X
New Brunswick				
Maine				X
Quebec			X	X
Ontario		X	X	X
Minnesota	X	X		X
Manitoba	X	X		
Saskatchewan	X	X		X
Wyoming	X			
Montana	X	X		
Idaho	X	X	X	
Utah	X		X	X
Alberta	X		X	X
British Columbia	X	X		
Northwest Territories	X	X		
Yukon	X			
Alaska	X	X	X	

Table 1. Cont.

Jurisdiction	Other reasons for census: Sex ratio	Recruitment	Population trend	Seasonal distribution	Other
Newfoundland	X	X	X		
Nova Scotia			X		
New Brunswick					
Maine			X		
Quebec	X	X			
Ontario	X	X	X		
Minnesota	X	X	X		
Manitoba	X	X	X		
Saskatchewan	X	X	X		
Wyoming	X	X	X	X	
Montana	X	X	X		
Idaho	X	X	X	X	
Utah	X	X	X		
Alberta	X	X	X	X	X
British Columbia	X	X			
Northwest Territories	X	X	X	X	
Yukon	X	X	X	X	
Alaska	X	X	X	X	

Table 1. Cont.

Jurisdiction	Level of precision desired: Confidence interval ± number of moose	Sampling methods used: Random transects	Systematic transects	Stratified systematic transects	Systematic plots	Random plots	Stratified random plots	Total counts
Newfoundland	80±10-20%				X		X	
Nova Scotia	?		X					
N. Brunswick								
Maine	90±20-30%		X					
Quebec	90±10-20%						X	
Ontario	90±10-20%		X	X		X	X	
Minnesota	80±0-20%						X	
Manitoba	80±10-20%			X				
Saskatchewan	80±10-20%		X				X	
Wyoming	90±variable			X				
Montana	Unspecified	X						X
Idaho	90±Unspecified				X			
Utah	Unspecified	X						X
Alberta	95±20-30%	X	X			X	X	
Br. Columbia	80±10-30%		X			X		
NWT	80±Unspecified		X				X	
Yukon	90±10-20%						X	
Alaska	90±10-20%						X	

Table 1. Cont.

Jurisdiction	Correction factor estimated?	Level of precision regularly obtained	Type of aircraft used: Place 2	4	6	Helicopter
Newfoundland	No	90±20-30%		X		X
Nova Scotia	Yes			X		X
New Brunswick						
Maine		80±30-40%				X
Quebec	Researching	90±10%		X	X	X
Ontario	Yes	90±20-40%		X	X	X
Minnesota	No	95±20%		X	X	
Manitoba	Yes	95±10-20%	X	X		
Saskatchewan	No	Unknown		X		X
Wyoming	No		X			X
Montana	No		X			X
Idaho	No					X
Utah	No			X		X
Alberta	Researching	95±20-40%		X		X
British Columbia	No					X
Northwest Territories	Yes	90± (unspecified)		X		
Yukon	Yes	95±10-20%	X			X
Alaska	Yes	90±10-30%	X	X		

Table 1. Cont.

Jurisdiction	Does your census technique provide: Accurate population estimates	Satisfactory precision	Representative age and sex data	Rapid trend identification
Newfoundland	Yes	Yes	Yes	Yes
Nova Scotia	Yes-marginal	No	No	Yes-marginal
New Brunswick				
Maine	Don't know	No	No	No
Quebec	Yes	Yes	Yes	Yes
Ontario	Yes	Yes	No	Yes
Minnesota	Yes	Yes	Yes	No
Manitoba	Marginal	Marginal	Yes	No
Saskatchewan	Marginal	No	Yes[1)]	Marginal
Wyoming	No	No	Yes	Yes
Montana	No	No	Yes	Yes
Idaho	Don't know	Don't Know	Yes	Marginal
Utah	Don't know	No	Yes	Yes
Alberta	Marginal	Researching	Yes	Yes
British Columbia	Marginal	Yes	Marginal	No
Northwest Territories	Marginal-?	Marginal-?	?	No
Yukon	Yes	Yes	Yes	Yes
Alaska	Yes	Yes	Yes	Marginal

1) On specific sex-age surveys

Table 1. Cont.

Jurisdiction	Are you working to improve the census?	Staff devoted to moose census?	Do you conduct training sessions?	Would management change with better estimates?
Newfoundland	Yes	Yes	No	No
Nova Scotia	Pellet counts	No	No	Hopefully
New Brunswick				
Maine	No	No	No	Yes
Quebec	Yes	No	Sometimes	No
Ontario	Yes	No	Yes	No
Minnesota	Yes	Yes	No	Yes
Manitoba	Yes	Yes	No	Yes
Saskatchewan	Yes	Yes	No	Yes
Wyoming	Yes	No	No	Yes
Montana	No	No	No	Yes
Idaho	Yes	No	No	Yes
Utah	No	Yes	Yes	Yes
Alberta	Yes	Yes	No	Yes
British Columbia	Yes	No	No	Yes
Northwest Territories	No	No	No	Yes
Yukon	No	Yes	Yes	Yes
Alaska	Yes	Yes	Yes	Yes

Table 2. Summary of moose census techniques employed by Parks Canada in 1982.

Jurisdiction National Park/ Province	Type of census	Area censused (km²)	Frequency of census			
			>1/yr	Annual	Every few years	> 5 yr Interval
Terra Nova NP/ Newfoundland	Aerial	396		X		
Cape Breton Highlands/ Nova Scotia	Aerial & ground	950		X	X	
Fundy/New Brunswick	Aerial	207		X		
Riding Mountain/ Manitoba	Aerial	2849		X		
Prince Albert/ Saskatchewan	Aerial	3874			X	
Elk Island/Alberta	Aerial & ground	194		X		
Banff/Alberta	Aerial & ground	6000		X		
Wood Buffalo/ Alberta-NWT	Aerial	2849		X		
Nahanni/NWT	Aerial	4662 1)		X		
Yoho/British Columbia	Aerial & ground	1813	X			
Mt. Revelstoke & Glacier/ British Columbia	Aerial & ground	518	X			
Kluane/Yukon	Aerial	5180		X		

1) only about 30% is moose range

Table 2. Cont.

Jurisdiction	Census made for:			
	Management of specific populations	Geographic areas	Research	Total population estimate
Terra Nova NP/ Newfoundland				X
Cape Breton Highlands/ Nova Scotia	X			
Fundy/New Brunswick				X
Riding Mountain/ Manitoba		X	X	
Prince Albert/ Saskatchewan		X		
Elk Island/Alberta	X			X
Banff/Alberta				X
Wood Buffalo/ Alberta-NWT	X	X		
Nahanni/NWT		X		
Yoho/British Columbia	X			
Mt. Revelstoke & Glacier/ British Columbia	X			
Kluane/Yukon		X		

Table 2. Cont.

Jurisdiction	Other reasons for census: Sex ratio	Recruitment	Population trend	Seasonal distribution	Other
Terra Nova NP/ Newfoundland			X	X	
Cape Breton Highlands/ Nova Scotia			X		
Fundy/New Brunswick			X		
Riding Mountain/ Manitoba			X	X	
Prince Albert/ Saskatchewan			X		
Elk Island/Alberta	X	X	X		
Banff/Alberta	X	X	X	X	
Wood Buffalo/ Alberta-NWT	X	X	X	X	Habitat selection
Nahanni/NWT				X	
Yoho/British Columbia					Hwy/railroad mort. problems
Mt. Revelstoke & Glacier/ British Columbia	X	X	X	X	
Kluane/Yukon				X	

Table 2. Cont.

Jurisdiction	Level of precision desired: Confidence interval ± number of moose	Sampling methods used: Random transects	Systematic transects	Stratified systematic transects	Systematic plots	Random plots	Stratified random plots	Total counts
Terra Nova NP/Nfld.	80±30-40%			X				
Cape Breton Highlands/ Nova Scotia	90±30-40%	X						
Fundy/N. Bruns.	90±30-40%		X					
Riding Mount./ Manitoba	95±10-20%		X					
Prince Albert/ Saskatchewan	95±10-20%		X					
Elk Island/ Alberta	80± 0-10%		X					X
Banff/Alberta	80±(unspec.)				X			
Wood Buffalo/ Alberta/NWT	90±10-20%		X				X	
Nahanni/NWT	Unspecified							X
Yoho/B.C.	90±10-20%							X
Mt. Evelstoke & Glacier/B.C.	Unspecified	X						X
Kluane/Yukon	Unspecified							X

Table 2. Cont.

Jurisdiction	Correction factor estimated?	Level of precision regularly obtained	Type of aircraft used: Place 2	4	6	Helicopter
Terra Nova NP/ Newfoundland	Yes	80±20%				X
Cape Breton Highlands/ Nova Scotia	No					X
Fundy/New Brunswick	No	90±30-40%				X
Riding Mountain/ Manitoba	No	95± 0-20%		X		
Prince Albert/ Saskatchewan	No			X		
Elk Island/Alberta	No					X
Banff/Alberta	No					X
Wood Buffalo/ Alberta-NWT	No	90±30-40%		X		X
Nahanni/NWT	No					X
Yoho/British Columbia	No	80±10-20%				X
Mt. Revelstoke & Glacier/ British Columbia	Yes					X
Kluane/Yukon	No					X

Table 2. Cont.

Jurisdiction	Does your census technique provide: Accurate population estimates	Satisfactory precision	Representative age and sex data	Rapid trend identification
Terra Nova NP/ Newfoundland	No	Marginal	No	Marginal
Cape Breton Highlands/ Nova Scotia	No	No	Marginal	Yes
Fundy/New Brunswick	Yes	No	No	Yes
Riding Mountain/ Manitoba	Don't know	Yes	N/A	Yes
Prince Albert/ Saskatchewan	Don't know	Don't know	N/A	Marginal
Elk Island/Alberta	Yes	Don't know	No	Yes
Banff/Alberta	No	No	No	Marginal
Wood Buffalo/ Alberta-NWT	Don't know	Marginal		Marginal
Nahanni/NWT	No	No	No	No
Yoho/British Columbia	Yes	Yes	No	No
Mt. Revelstoke & Glacier/ British Columbia	Marginal	Marginal	No	Marginal
Kluane/Yukon	No	No	Don't know	Don't know

Table 2. Cont.

Jurisdiction	Are you working to improve the census?	Staff devoted to moose census?	Do you conduct training sessions?	Would management change with better estimates?
Terra Nova NP/ Newfoundland	No	No	No	No
Cape Breton Highlands/ Nova Scotia	Yes	No	Yes	Possibly
Fundy/New Brunswick	Yes	No	Yes	No
Riding Mountain/ Manitoba	No	No	No	No
Prince Albert/ Saskatchewan	Yes	No	No	Yes
Elk Island/Alberta	Yes	Yes	No	No
Banff/Alberta	Yes	Yes	Yes	No
Wood Buffalo/ Alberta-NWT	Yes	No	Yes	Yes
Nahanni/NWT	No	No	No	No
Yoho/British Columbia	Yes	Yes	No	Yes
Mt. Revelstoke & Glacier/ British Columbia	Yes	No	No	No
Kluane/Yukon	No	No	No	No