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CENSUSING MOOSE

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INTRODUCTION

Because much of the range of moose is remote from population centers, and because large moose populations have developed relatively recently, little effort has been expended in finding practical ways to census moose. The methods presently in use are aerial surveys and sex and age ratios. Other techniques for censusing big game, however, have been developed, and these could probably be adapted for use in censusing moose.

Aerial surveys and sex ratios, however, are not particularly suited to censusing moose in the parts of its range where the coniferous forest type prevails. Therefore, a new technique for censusing moose will be proposed in this paper. It is hoped that this method will be useful in sensusing moose, particularly in the eastern portion of its range.

DISCUSSION

CENSUS Methods Presently Being Used

Aerial surveys - Schrader (1944) and Morse (1946) have reported on some of the earlier attempts to census big game from the air. In all of the early attempts both terrain and weather severely limited the accuracy of the survey. More recently, however, aerial censusing has become a very important tool for inventorying big game herds. For example, in many parts of the northern reaches of the range of moose, (Alces americana) aerial surveys are the only practical means for determining the size of moose populations (Banfield et al., 1955).

Most aerial surveys are flown along predetermined flight lines. The flight lines are laid out on a map, and the pilot flies each one as if it were a separate azimith. The distance between flight lines depends on the species of game surveyed. For moose, the flight lines usually are one-half mile apart (Aldous and Krefting, 1946; and Ledin and Karns, 1963).

It is necessary to be as accurate as possible in determining the width of the strip flown. In some cases, the observer plots each individual moose sighted on a map, and calculates the strip width by scaling the distance off the map (Ledin and Karns, 1963). This method, however, requires a considerable amount of time. An easier method is to estimate the angle of sight to each moose and record the planes altitude; then calculate the strip width trigonometically (Edwards, 1954; and Banfield et al., 1955). A draw back to this method is its dependence on the altimeter of the plane. Most altimeters are accurate to no more than plus or minus 100 feet. This error is magnified at the low altitude at which the aerial surveys are usually flown.

The proper altitude for a survey varies with the terrain and forest cover. Banfield et al. (1955) reported that moose surveys had to be flown lower than aerial surveys of other big game because it was difficult to see moose from the air. Consequently, most moose surveys are flown 300 to 700 feet above ground elevation (Aldous and Krefting, 1946; and Ledin and Karns, 1963).

The plane used should have a low stalling speed and be highly maneuverable. Edwards (1952) used a DeHaviland Beaver. Another suitable aircraft would be a Piper Super Cub. For the sake of visibility a high-winged plane would be better than a low-winged plane. Aldous and Krefting (1946) censused Isle Royale from a low-winged plane and allowed a 20 per cent error to account for the obstruction of the lower wing.

To obtain a random sample of a large area, flight lines are systematically drawn on a map of the area, and the survey is carried out by flying these lines. Many times, however, serious error results from using this method. Robinson (1962) reported that results obtained from systematic flight lines were so variable as to be useless. He calculated that the intensity of air coverage with this method had to be increased seven-fold in order to get confidence limits of plus or minus 10 per cent. Watson and Scott (1956) found that all their aerial surveys between 1948 and 1954 varied among each other by as much as 50 per cent. In 1955 they changed their metnod to a stratified aerial census. Basically in this type of a census, the area is sectioned into blocks of known or expected concentrations of animals. THE Aerial survey is then concentrated on those blocks THAT have the high population concentrations. The object of stratifying an area is to divide the range into homogenous units so that accurate estimates of the population of the total area can be determined from intensibely surveying individual homogenous units (Siniff and Skoag, 1964).

Stratification has not yet been applied to censusing moose, although Bowman (1955) used a modification of a stratified census when counting moose in the summer. He concentrated his flight lines along streams and ponds where moose tended to congregate. Caribou (Rangifer arcticus), however, have been surveyed by stratified aerial censuses (Bergerud, 1963; and Siniff and Skoag, 1964). Sumner (1948) used a modification of the stratified aerial census when censusing Dall Sheep (Ovis canadensis) in Mount McKinley National Park. It seems probable that stratified aerial censuses hold promise for improving the accuracy of future aerial surveys of moose.

Another coming change in aerial surveys might be the replacement of fixed-wing planes by helicopters. Owens (1959) used a helicopter to census elk (Cervus canadensis); Aldous (1956) censused deer (Odocoileus spp.) with a helicopter in Oklahoma. Some of the advantages of using a helicopter are its stability at low altitudes, its ability to fly in bad weather, and the ability to land and take off from small areas. Helicopters have not yet been used to census moose; but with improved helicopters and an increased demand for more knowledge avout the moose, it is certain that the helicopter will soon become an effective tool for surveying moose popülations.

The major advantages of aerial surveys are the ease in which they can be accomplished and their speed. There are, however, as we might expect from the above discussion, many sources of error. The following is a list of some of these sources of effor.

1. errors due to improper sampling techniques
2. errors of observation
3. errors due to the position of the observers (The observer sitting next to the pilot always has higher counts than the observer sitting in the rear.)
4. mechanical errors involved in conducting the census
5. errors caused by misjudging the altitude of the aircraft
6. errors due to eye fatigue

7. errors caused by sloping ground which affects the accuracy of estimated angle widths
8. errors caused by the blind spot beneath the plane

This list was compiled from work done by Edwards (1952; 1954) and Watson and Scott (1956).

In spite of the many chances for error, with proper care and improved techniques, aerial can give fairly consistent results. Gilbert and Grieb (1957) compared air counts with ground counts and concluded that the air counts gave consistent results.

Sex and age ratios - Recently. sex and age ratios have come to play a more important role in determining moose populations. It is the only method besides aerial surveys that is being seriously considered at the PRESENT TIME.

There are many ways in which sex and age ratios can be obtained. The system most often used is aerial survey. Chatelain (1950) reported using an aerial survey to get cow-calf ratios on the Kenai peninsula. British Columbia (Robinson, 1962) used an aerial survey to determine the post-season sex ratios of moose. Minnesota recorded sex and age ratios ALONG WITH ITS REGULAR census of moose (Ledin and Karns, 1963). To be effective in obtaining sex and age ratios from the air, the survey should be conducted at a time when moose are easily seen and the bulls still have their antlers.

Dasmann (1952) reported that sex and age ratios should be as accurate as possible. He cautioned that the sex and age ratios used should be representative of the herd in question and the the herd boundaries should be well defined.

Once the data have been abtained, the problem of calculating the population is a matter of simple algegra. For esample, Rasmussen and Doman (1943) have outlined the following metHod for calculating a deer population from kill data and age ratios.

Fall age counts give - A fawns : B adults

After the kill counts give - A_1 fawns : B_2 adults

Dead deer age ratios give - A_2 fawns : B_2 adults

$$X = \text{adults in fall} \qquad (1)$$

$$\frac{A}{100} X = \text{fawns in fall} \qquad (2)$$

$$\frac{A}{100} X - A_2 = \text{fawns after loss} \qquad (3)$$

$$\frac{A_1}{100} (X-B) = \text{fawns after loss} \qquad (4)$$

$$\frac{AX}{100} - A_2 = \frac{A_1}{100} (X - B) \qquad (5)$$

1) Solve number 5 for X to get adults in the fall.
2) Using X, calculate the number of fawns in the fall by equation number 2.
3) Add the fall adult and fall fawn populations together and then subtract the total number of deer killed in the hunting season to get the post-season population.

A slightly more sophisticated method is that proposed by Petrides (1949). He based his work on the following assumptions:

1. The animal censused is not sexually mature until the end of the first year.
2. Sexes are born in a 50 : 50 ratio.
3. There is a differential mortality in the sexes later on.

Petrides developed, algebraically, two basic formulas. The first formula determines the pre-season populations (P_1) using sex ratios and kill data.

$$P_1 = \frac{f_2 K - K_f}{f_2 - f_1} \qquad (6)$$

f_2 = post-season proportion of females

f_1 = pre-season proportion of females

K_f = number of killed females

K = total kill

The second formula uses kill data in conjunction with age ratios.

$$P_1 = \frac{f_2 K - K_J}{J_2 - J_1} \qquad (7)$$

J_2 = post-season proportion of young juveniles

J_1 = pre-season proportion of young juveniles

K_J = number of young killed

The population after the hunting season is simply determined by subtracting the total kill from the pre-season population. Although Petrides worked with deer, with appropriate hunting controls, the method is admirably suited for moose.

British Columbia has been attempting to do this very thing with moose for the last few years (Mitchell, 1964). Difficulties have been encountered, however, in collecting sufficient data to give meaningful results. The trouble lies in trying to determine the post-season sex and age ratios and the composition of the kill. Once effective techniques have been developed for determining sex and age ratios of moose, it is certain that they will become a useful tool in moose management.

<u>Other Big Game Census Techniques and Their Applicability to Moose</u>

Because of the remoteness of much of the range of moose, and because only recently has moose management been given serious consideration, not all the big game census techniques have been applied to moose. The more important of these techniques are explained below and evaluated for their future usefulness in censusing moose.

<u>Drives</u>. - The drive is a technique developed in the depression era when man power was plentiful. It was primarily devised to be used for censusing deer. A large group of men called counters surrounded

an area on three sides. A line of men called drivers moves down the open end of the area forcing the deer ahead of them. The counter keeps track of each deer that goes by him (Hosley, 1936). The area driven depends on the man power available, the topography of the area, the type of cover present, and the presence or absence of cleared lines (McCain, 1939). Sometimes the number of men required can be reduced by combining a drive with a track count. To do this, it is necessary that the area driven is surrounded by cleared spots where tracks can be easily seen (Morse, 1943).

The big advantage of game driven is that they are accurate and dependable (McCain, 1934). The disadvantages are their limited applicability in rough terrain and their very high cost, particularly in man power (Ruff, 1939).

There have been few, if any, recorded instances where drives have been used to census moose. Actually, the method seems to be quite applicable to moose in many parts of its range. The restrictions imposed by the man power requirement, however, have probably eliminated this method from serious consideration.

Pellet-Group Counts. - Pellet-group counts have been primarily used to estimate deer populations. In general, if the defecation rate of an animal is known, a relationship exists between the number of pellet-groups found on an area and the population of deer on that area.

Although Bennett et al. (1940) originally attempted to census deer by pellet-group counts, it wasn't until Eberhardt and Van Etten (1956) developed their method that pellet-group counts became a practical way to census deer. Eberhardt and Van Etten based their method on the following assumptions:

1. The average rate of deposition of pellet groups is 13 groups per day per deer.[1]
2. April and May pellet group counts will include only those groups deposited since last fall, and the pellet groups will persist from October to April.
3. All pellet groups are correctly identified and none are missed.
4. The sampling technique used is adequate.

[1] White-tailed deer (Odocoileus virginianus) deposits 13 pellet groups per day per day; however, the mule deer (Odocoileus hemionus hemionus) has a defecation rate of 15 pellet groups per deer per day (Rogers et al., 1958).

If a 0.02 acre sample plot is used, they proposed the following formula to calculate the deer per square mile:

deer per square mile =

$$\frac{\text{average number of pellet groups per plot} \times 50 \times 640}{\text{days since leaf fall} \times 13}$$

Eberhardt and Van Etten went on to suggest that the following precautions be taken when making a pellet group census.

1) Conduct the survey as early in the spring as possible.
2) Properly train the personnel used to make the census.
3) Develop a system for random rechecking of sample plots.

The defecation rate, so vital a part of this census method, is influenced by several variables. The first is sampling errors. The second is lack of precise stocking figures. The third is differences in stocking rates per pasture. The fourth is individual variation of deer and the fifth is the length of time deer have fed on green herbaceous matter (Rogers *et al.*, 1958).

The major reason for using pellet-group counts is that they provide a persisting record of deer populations, uninfluenced by the presence of an observer. Eberhardt and Van Elten (1956) felt, however, that the method was subject to serious errors, particularly the ability of individual observers to accurately record the number of pellet groups on a sample area. In addition, a question has been raised by Wallmo <u>et al</u>. (1962) concerning the persistency of pellet-groups in semi-arid areas.

Hotter and Martin (1960) used a pellet group census metnod to determine moose density. They felt a serious drawback to the adequacy of this method for moose is the large sample required to effectively estimate the density of such a mobile animal as moose. Cameron (1949), however, reported that moose are relatively sedentary. Therefore, this may not be as important a condition as Hatter and Martin (1960) claim. A factor that is limiting the usefulness of this method to moose is that the average defecation rate for moose is poorly known. It seems reasonable that once moose defecation rates are determined, pellet-group counts will be a suitable means for censusing moose.

<u>Strip Census</u>. - One of the earliest methods used to census wildlife of any kind was a strip census. Basically, it is an adaptation of a forestry strip cruise to censusing wildlife populations.

The original work on a strip censuses was done by King (Leopold, 1933). King was basically concerned with ruffed growse (*Bonasa umbellus umbellus*), but his formula was so fundamental that it has been used for a variety of other animals. The formula is as follows:

$$P = \frac{A\ Z}{X\ Y} \qquad (8)$$

P = total population

A = total area sampled

Z = total number of animals observed

X = total distance walked

Y = twice the average distance from the observer to the animal when flushed

Webb (1942) and Hayne (1949) have both proposed modifications of the above formula; however, their modifications apply to highly specialized situations and add very little to the general applicability of the original formula proposed by King.

Basically, the cruiser walks a compass line and notes the number of desired animals he flushes. He then estimates the perpendicular distance from the line he is walking to the point where the animal flushed. With this information and the total length of line walked, the population can be estimated using the formula proposed by King. The mobility of the specie being censused determines the distance between cruise lines. Other things that may effect the accuracy of the method are the density of the vegetative cover, the sex and age of the animal, the time of year and the weather conditions (Erickson, 1940; and Krefting and Fletcher, 1941).

Strip counts have received only limited use in censusing moose. Edwards (1954) was one of the few to use a strip cruise to census moose. The observer walked a straight line counting only those moose seen within 200 feet of either side of the strip. The total population of moose was calculated using the King formula.

Edwards and Ritcey (1956) used a form of the strip census while studying moose migrations. A straight line was walked and the number of moose tracks crossing this line was recorded. This gave an index to the relative movement of the moose herds but said little about their total population.

The strip census will probably not see intensive use for determining moose populations, because not all the moose on a strip will flush or be seen, and consequently, a substantial error will be introduced.

Strip counts can be made from a car. Roadside counts were used to census ungulate populations in Africa (Dasmann and Mossman, 1962). The counts always underestimated the actual population, but the degree of accuracy was directly proportional to the size ofthhe animal.

It is probable that roadside counts would work with moose on some areas of its western range that are readily accessible by roads. In other parts of the range of moose, inaccessiblity and dense cover would make this method impractical.

Tagging Big Game

Although tagging big game is not a census technique, it is a cornerstone of a new metnod for censusing moose that will be proposed in this paper. Therefore, it is appropriate that an appreciation of the methods and problems involved in tagging big game be acquired.

Manual Tagging. - Almost all manual techniques for tagging big game require that the animal be captured or immobilized in some way. Ritcey and Edwards (1956) and Grasse (1950) used a large corral to capture and hold moose. The moose were baited into the corral which automatically tripped shut behind them. They were then herded into a chute where they were tagged. The cost of this type of an operation is often prohibitive due to the amount of labor and material needed.

In Yellowstone National Park, elk were trapped by means of large corrals. A unique feature of this was the use of helicopters to herd the elk into the corral (Howe, 1963). Individual traps have been used for deer, particularly the "clover" trap (Pickens, 1964) but the "clover" trap has yet to be used with any degree of effectiveness with moose.

Recently, in an attempt to side step the high cost of building corrals and traps, game biologists have turned to using various types of tranquilizing agents, usually administered by means of a CO_2 gun. Bergerud <u>et</u> <u>al</u>. (1964) used succinylcholine chloride in CO_2 propelled darts to immobilize caribou and moose. Succinylcholine chloride is a neuromuscular blocking drug that causes a temporary paralysis in large animals. The dosage for a wild moose varied BETWEEN 0.020 mg. per pound and 0.030 mg. per pound. Bergerud immobilized and tagged a total of 31 moose by this method. Rausch and Ritcey (1961), on the other hand, using a nicotine compound, found difficulty in finding a dosage that would immobilize a moose but not kill him. Harper (1964) working with elk in Oregon and Buechner _et al_. (1960) working with African big game, felt that using drugs to immobilize big game holds promise for the future. Refinements are needed in the delivery system and more knowledge is needed concerning dosages for various big game species.

One of the most unique methods devised to date for the purpose of tagging moose is the use of a float equipped helicopter. The work is done in early summer when the moose are feeding along lake shores. The helicopter herds the moose out to deep water and attempts to maneuver the moose between the floats of the helicopter. A man then climbs out onto one of the floats and places a metal tag in the ear of the moose. As difficult as the maneuver sounds, the whole process only takes about five minutes (Simkin, 1963).

Automatic Tagging. - All of the above methods that involve capturing or immobilizing big game are expensive or slow, or both. Because of this, some workers have attempted to develop an automatic tagging or marking device.

Early attempts with moose along this line involved the use of paint or dye. One method was a paint filled balloon that was broken by a razor blade attached to a rat trap. The rat trap was sprung when the moose stepped on a trip wire. The other method was simply an arm on a pivot with a cup of paint on one end. The moose stepped on a string which caused the arm to fly up and deposit a cupful of paint on the moose. Neither idea worked very well because bears (Ursis spp.), raccoons (Procyon lotor), and other animals tripped the marking devices as frequently as the moose did (deVos, 1956; and Taber et al., 1956). Clover (1954) recommended using a shotgun shell fitted with dye to mark deer. The shell was fired by a rat trap that was set off when a deer stepped on the trip wire. He also proposed an automatic sprayer that worked on a pneumatic pressure tank. Deer and other animals were liberally sprayed with dye whenever they stepped on the treddle that acted as the firing mechanism. The disadvantages of these methods are that a number of different animals could set the divice off; and dye did not remain on an animal for any length of time.

If an effective bu inexpensive census program for moose is to be based on tagging individual animals, none of the above methods is going to be satisfactory. The following proposal, however, seems to offer a minimum in cost and effort, yet a maximum in efficiency and control. This method was developed by a Russian, Romanov, in 1956 (Verme, 1962). It is basically a modified snare that instead of choking an animal, places a polyethylene collar around its neck. Verme tested this idea on white tailed deer, but there is no reason why it would not be applicable to tagging moose. This method was chosen as the best tagging method to use with the census technique proposed in this paper.

Lincoln-Romanov Method of Censusing Moose

The census method proposed in this paper was named the Lincoln-Romanov method of censusing moose because it has as its basis the Lincoln Index and the Romanov automatic tagging device. The salient features of the Lincoln-Romanov method are:

1. Automatically tag moose with a polyethylene collar.
2. Carry out a strip census after the moose have been tagged.

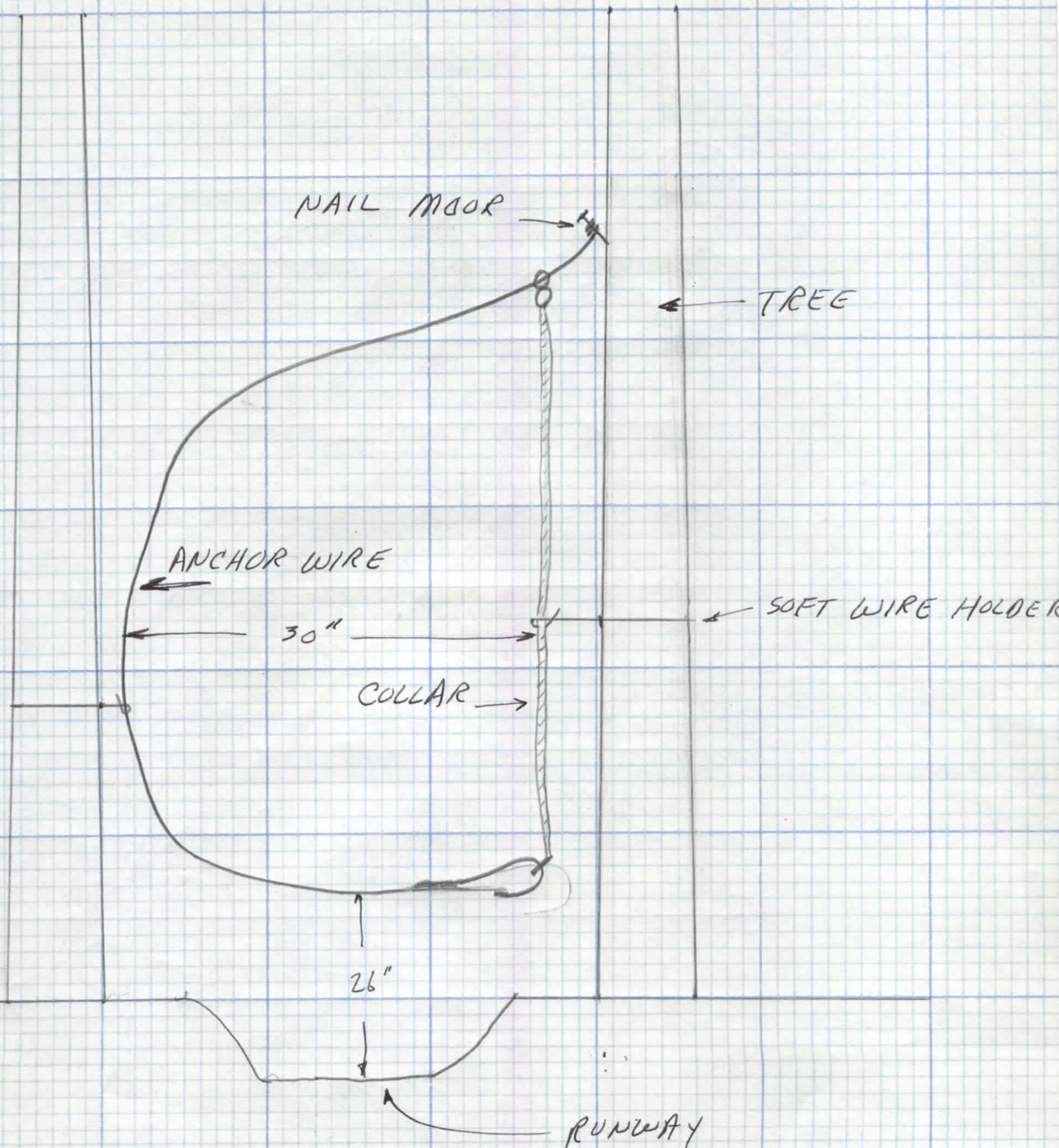
3. Record the total number of moose seen and the moose seen with collars.

4. Use a modification of the Lincoln Index to calculate the total moose population.

Mechanics of the Romanov Tagging Device.- Figure one shows the Romanov tagging mechanism set. As the deer enters the snare, the soft wire holders disengage from the anchor wire and polyethylene collar. As the deer pulls through, end "B" of the polyethylene collar runs freely along the anchor wire. It will eventually lock itself on the sheet steel snap (Figure two). A notch cut in the anchor wire allows it to snap free, leaving the collar around the neck of the moose. Care must be taken not to allow the diameter of the set snare to be too large, because it may settle around the shoulders of the animal and prevent the collar from locking. Verme (1962) also reported that the collar fails to lock sometimes when the ring at end "B" gets caught on the notch in the anchor wire. To prevent this, he suggested greasing the anchor wire. In all of the above cases where the collar fails to lock, it usually is found in the vicinity of the trap.

Setting. - Figure one serves as a good example of how the snare should be set. It can be attached

FIG. 1



SETTING THE ROMANOV SNARE

FIG – 2

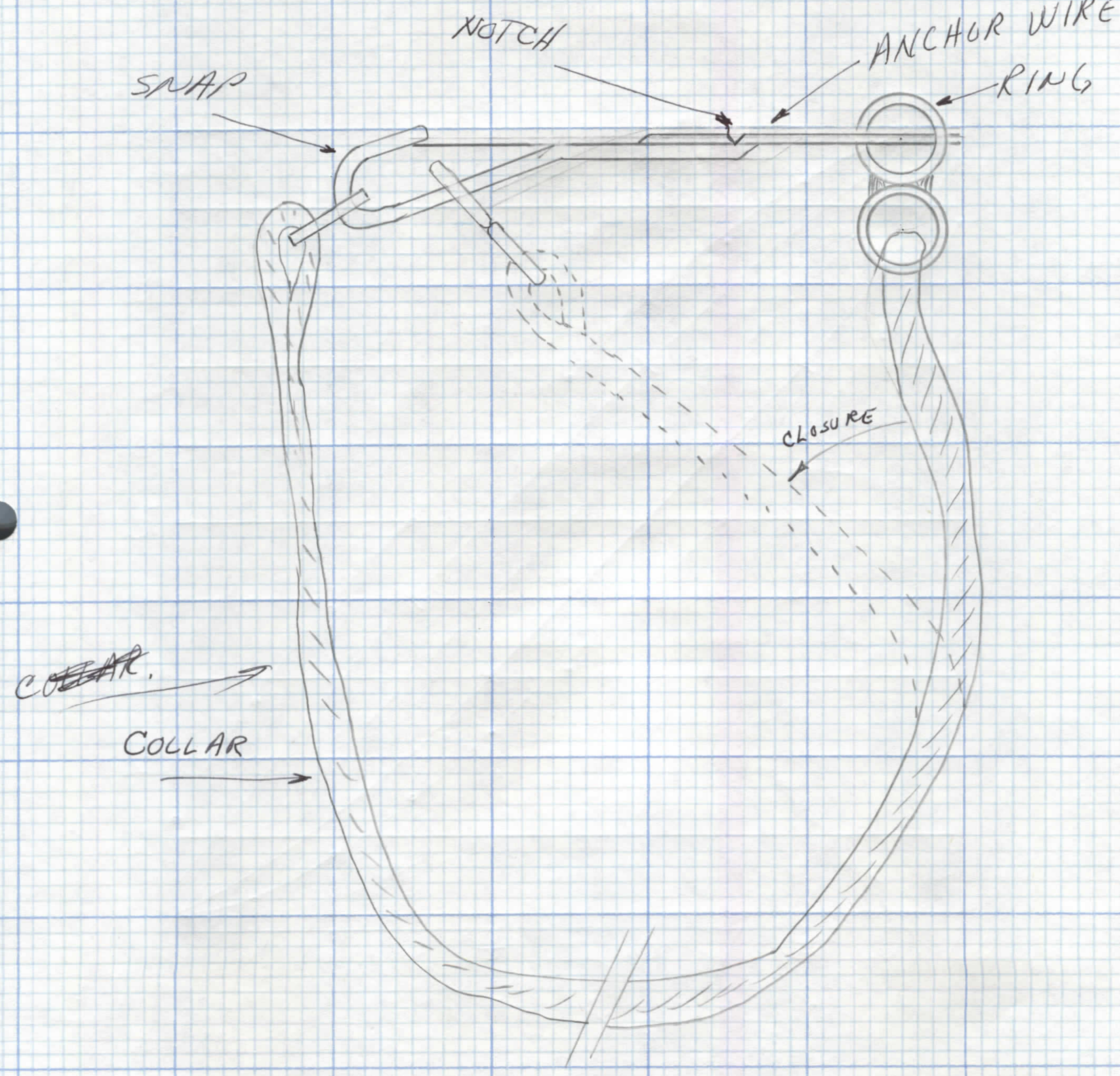


DIAGRAM of ROMANOV TAGGING DEVICE

to a heavy drag as well as between two trees. Using a drag is a safety factor in case the anchor wire fails to break immediately. Verme suggested setting the trap in runways which deer frequently use. The snare could be deployed in the same manner for moose, since they also frequently use runways (deVos, 1956). The snare should be well camouflaged since deer were extremely wary and seemed to be able to sense the presence of the device. In this way, one would have an advantage working with moose. Although moose are by no means reckless or dull, their reaction to intrusion or to a new circumstance is calmer and more controlled than deer (McMillan, 1953; and McMillan, 1954a). Therefore they may not be as frightened by the snare as deer are.

The difference in size between the moose and the deer is a consideration when collar length and measurements for setting the snare are concerned. According to Palmer (1949), the moose stands about seven feet at the shoulders while the white tailed deer stands four feet. Since the principle concern in setting the trap is the height of the animal, the 75 per cent difference in the two heights can be used as a correction factor. Although the figures obtained in the way are only rough estimates, they will have to suffice until actual field work has been done for moose. Verme (1962) recommended setting the snare 15 inches off a deer runway. Correcting this figure to be applicable to moose, we get roughly 26 inches. Verme used 15 inches as the diameter of the loop; but the neck of a moose is disproportionately larger than that of a deer, therefore, 30 inches is arbitrarily chosen as the diameter of the set snare. The length of the collar for deer is given at 22 inches. Applying the correction factor brings this length to 38.5 inches. Making an arbitrary allowance FOR THE SIZE of the neck of a moose, the final length of the collar is put at 42 inches.

Since the only evidence of having tagged a moose is the absence of a collar, a serious error can be introduced if all the missing collars are not on moose. Two things can happen. First, a moose might be tagged twice. There is little that can be done about this; but the chances of this happening are slight, consequently the resulting error is probably slight also. The second source of error is more serious; that is, the probability that some other animal besides moose will be tagged. There are only two animals in the East that pose a serious threat to the accuracy of the census in this manner. They are the black bear (<u>Ursus americanus</u>) and the white-tailed deer. Although it is possible ~~for a black bear to become tagged, and~~

for a black bear to become tagged, it is not probable. The black bear stands only 36 inches at the shoulder while the snare is set 26 inches off the ground. This leaves a fairly narrow margin in which the bear can become tagged. In addition, if the census were carried out in late winter, the activities of the black bear would be much curtailed. The white-tailed deer, however, is frequently abundant on many parts of the range of the moose, and it has a very good chance of being tagged. A correction factor will be introduced later on to allow for the tagging of deer. Due to the construction and size of the snare, IT is unlikely that other animals will be tagged.

Animals like the raccoon or porcupine (Erethizon dorsatum) might accidentALLY trip the snare or destroy its setting, but in these cases, the collar will probably be found in the vicinity of the snare.

Time. - For the Lincoln - Romanov method a stable population is essential; therefore, if one chose late winter or early spring, roughly the month of March, he would avoid the complicating feature of births increasing a population, since calves are usually born in May or June. In addition, mortality would be low. Losses to hunting would have occurred in the fall: and winter losses, if any, would largely be over. Another advantage of choosing March is THAT most of the bulls have lost their antlers; therefore, there will be no bias resulting from antlered bulls not being tagged. Actually, the bulls lose their antlers over a period extending from November to late March (deVos, 1956); but March can be considered the month when the largest percentage of bulls are antlerless. A final advantage of choosing March is that the moose are still on their wintering areas.

Habitat. - Although the herd instinct is weak in moose, they do tend to concentrate during the winter. Altmann (1956) reported that moose group together in winter-time in the West. Peterson (1955) stated that moose in the East concentrate into "voluntary" yards. During this "voluntary" yarding, the moose gather in favorable feeding spots and interlace the area with a network of trails.

Cameron (1949) reported that moose concentrate on southern exposures of mixed conifer-deciduous ridges. Pimlott (1953) confirms this and adds that in some cases moose winter on large barrens or muskegs that have an interspersed tree cover.

To obtain the greatest efficiency with the

Romanov tagging device, Verme (1962) suggested it be set up in places where deer tend to concentrate in the winter. The same is probably true of moose, and therefore setting the Romanov device on conifer-deciduous ridges where the moose gather would probably result in an effective tagging program.

Censusing. - The area to be censused should be broken up into zones of expected or known moose concentrations. There is a good deal of precedent for stratifying the sample area in this way. Krefting and Fletcher (1941) stratified deer ranges to simplify strip cruising deer in Oklahoma. Whitlock and Eberhardt (1956), when censusing winter lost deer, laid out their census lines according to where they expected to find large concentrations of dead deer. As mentioned earlier, aerial surveys, which are really glorified strip counts, are frequently stratified.

The tagging devices are placed in areas where moose are likely to get tagged, and are left there for an equal period of time on all areas. This time length could vary. Probably three days to a week would be most realistic. After all the snares have been removed, a period of time should elapse before the strip census is taken. In absence of any figures to the contrary, a week has been arbitrarily chosen as being a sufficient time.

The distance between census strips usually depends on how far an animal will run after it is flushed. In deer, this distance is about one quarter of a mile; consequently, census strips are placed one half mile apart (Krefting and Fletcher, 1941). The running distance for moose is unknown; but, due to the nature of the animal, it is likely that this distance is less than one quarter of a mile. Therefore, if census lines were placed one half mile apart, they would be sufficiently separated to prevent a moose flushed on one cruise line from appearing on another cruise line. The cruise lines should extend one quarter of a mile beyond the sample area to give any moose that hapens to be flushed off the sample area a chance to be counted.

Men walking the cruise lines should record the total number of moose seen and the number of tagged moose seen. It is not necessary to estimate the width of the strip walked, nor is it necessary that all the moose on the strip be seen. It is important that the segment of the moose population seen is representative of the total population on the area.

Lincoln Index. - Once the data has been gathered by means of the strip cruise, the population can be readily calculated by use of the Lincoln Index (LEOPOLD 1933). This index was originally proposed for use with waterfowl banding returns. It is basically a ratio between two equal fractions. In the original form used by Lincoln it appeared as follows:

$$\frac{\text{number of ducks banded}}{\text{total population}} = \frac{\text{number of banded kills}}{\text{total kill}}$$

It is a simple matter to change the above formula into the following formula more appropriate to moose.

$$\frac{\text{total population}}{\text{total moose seen}} = \frac{\text{number of moose tagged}}{\text{number of tagged moose seen}}$$

If the Lincoln Index is to be valid, the following assumptions must hold (Adams, 1951).

1. The marked animals must suffer the same natural mortality as the unmarked ones.
2. The marked animals must not lose their marks.
3. The marked animals must be as subject to sampling as the unmarked animals.
4. The marked animals must become randomly mixed with the unmarked animals.

5. All marked animals must be recognized and reported when seen.

6. Recruitment in the population must be negligible.

Progulske (1957) made collars for deer out of belt leather. He reported no known cases of mortality to deer as a result of being tagged with a collar. Straley (1960) reported no casualties with elk that had been tagged with plastic collars. Although moose have not been tested, it seems probable that the presence of a collar would not seriously increase their mortality.

In almost all cases where collars were attached to big game, retention of the collars ran as long as a year and one half. Fashingbauer (1962) and Lightfoot and Maw (1963) reported that deer retained a high percentage of their collars. Progulski (1957) reported that some deer kept their collars as long as 16 months. Therefore, in view of work done on other big game, it is probable that moose will retain their collars for a sufficiently long period of time.

There are no reasons why assumptions three and four would be untrue. The first of these two assumptions was originally designed to account for bias resulting from a trap - retrap census. There was always debate whether an animal that was trapped and tagged once would enter a trap as freely as an animal that had never been trapped. Since it is not necessary to retrap moose with the Lincoln-Romanov method, this assumption is not really pertinent. Assumption number four can best be met by adequately placing the tagging devices so that the animals' normal movement will result in a random mixing.

Recognition of the collarsin most cases studied has been good. Straley (1960) reported that the collars he placed on elk could be seen from the air. Although polyethylene collars placed on the moose will probably be easily seen, it should be pointed out that the collars Straley used were considerably wider than the collars used in the Romanov tagging device.

March was deliberately chosen as a time when recruitment would be at a minimum. Cameron (1949) reported that moose calves in the East are born in May. He also stated that the animal is somewhat sedentary reducing the chance that moose form another part of the range would wander onto the sample area.

From the works cited above and from general knowledge of moose behavior, the six assumptions on which the Lincoln Index is based probably are true for moose. It should be noted, however, that if the Lincoln-Romanov method is ever going to be used to census moose, all six assumptions must undergo extensive field testings.

There are many instances in the literature where the Lincoln Index has been used to census big game. McMillan (1954b) used a crude approximation of the Lincoln Index when estimating moose populations summer ranges. He was able to identify by various physical features certain individual moose. A week after he had determined the number of identifiable moose on the area, he censused the same area and noted the number of identifiable moose seen. He estimated the total population of moose on the summer range in the following way:

$$\frac{\text{number of identified moose in the first week}}{\text{number of identified moose in the second week}} = \frac{\text{total population}}{\text{total number seen in second week}}$$

Modifications of the Lincoln Index HAVE been used to census deer. As early as 1938 fawns were tagged on the Superior National Forest in Minnesota.

The total population was calculated from data gathered by means of hunter returns (Olson, 1938).

Dasmann and Taber (1955) compared total counts, Lincoln Index, sample area counts, and pellet group counts to determine which method gave the best results for Columbian black-tailed deer (Odocoileus hemionus columbianus). They concluded that the Lincoln Index gave as good results as did the total count and sample area count. The pellet group count was not effective.

Schofield (1960) developed a unique method for censusing winter lost deer. As many dead deer as possible were located by means of hunter interviews. These carcasses were found and tagged. Later, different workers searched the area for dead deer by following fox (Vulpes spp.) trails which led from one carcass to another. The number of deer located in this manner was recorded along with the number of tagged deer found. The total number of dead deer was then calculated USING a modified Lincoln Index formula. Robinette et al. (1954) tested five ways to census lost deer. These methods included the Kelker belt transect method, the Lincoln Index, the King grouse census, the Webb snow-shoe hare census, and the Hayne modification of the King census.

Of these, only the Lincoln Index, the Kelker census and the King Census gave reliable results. Robinette et al. (1956) repeated the test after refining some of their techniques. They concluded from these tests that only the Lincoln Index and the Kelker method were suitable.

It is apparent that the Lincoln Index has HAD a considerable history of use in censusing big game. The greatest problem involved with its use has been THE effort involved in tagging big game. With the advent of the Romanov tagging device this problem has been overcome.

Correcting for Deer. - Now to return to a problem mentioned earlier - how to handle the probability that deer will be tagged as well as moose. The correction methods for deer are subject to the six basic assumptions of the Lincoln Index. In the case of deer, however, there is some question whether they will retain the collars since the collars designed for moose are considerably larger than those designed for deer. Since the time between tagging and censusing is only a week, the number of tags lost by deer will probably be small. In addition, it is important that for both correction methods to be accurate, the proportion of the deer herd tagged is the same as the proportion of the moose herd tagged.

We also must assume that all missing tags are on either moose or deer. Considering the number of animals likely to be tagged by the snare, this is a reasonable assumption.

The first method proposed can be used in an area where the deer herd is intensively managed and good population estimates for the herd exist. In this case, when the area is censused for the marked individual, the total number of marked and unmarked deer are recorded as well as the total number of marked and unmarked moose. The number of deer originally tagged is calculated in the following way:

A_D = total population of deer on the area - known

B_D = total number of deer seen - from survey

C_D = total number of tagged deer seen - from survey

X = number of deer originally tagged

$\frac{A_D}{B_D} = \frac{X}{C_D}$ — from the Lincoln Index

$$X = \frac{A_D C_D}{B_D} \qquad (9)$$

L = total number of tags missing

L - X = number of tags on moose

B_m = total number of moose seen - from survey

C_m = total number of tagged moose seen - from survey

A_m = total population of moose

$$A_m = B_m \frac{(L - X)}{C_m} \qquad (10)$$

A hypothetical example will make this clearer.

A_D = 180 - total population of deer

B_D = 60 - total deer seen on the survey

C_D = 15 - total number of tagged deer seen

$$\frac{180}{60} = \frac{X}{15}$$

$$X = 45$$

L = 150 - number of tags missing

L - K = 105 - number of moose tagged

B_m = 60 - total number of moose seen on survey

C_m = 15 - total number of tagged moose seen

Total population of moose (A_m) = $\frac{60 \times 105}{15}$ = 420

Using this method, it is well to remember that the figure for the total moose population is no more accurate than the figure for the total deer population.

In many situations, however, the size of the deer population is unknown. In this case, the correction method described above will not work. Therefore, a second method is proposed. This method is subject to the same conditions as the first one was. The second correction method is as follows:

L = number of tags missing

X = number of moose tagged

$L - X$ = number of deer tagged

B_D = total number of deer seen on the survey

C_D = number of tagged deer seen

B_m = total number of moose seen on the survey

C_m = number of tagged moose seen

The total population of deer, and the total population of moose is, in both cases, a function of X; and therefore, if is designated f(x).

$$\frac{f(X)}{B_D} = \frac{L - X}{C_D}$$

$$f(X) = \frac{B_D\ (L - X)}{C_D} \qquad (11)$$

$$\frac{f(X)}{B_m} = \frac{X}{C_m}$$

$$f(X) = \frac{B_m\ X}{C_m} \qquad (12)$$

Solve for X by setting equation number 11 equal to equation number 12.

$$\frac{B_D\ (L - X)}{C_D} = \frac{B_m\ X}{C_m}$$

$$X = \frac{L\ C_m\ B_D}{(B_m\ C_D + C_m\ B_D)} \qquad (13)$$

The number of moose tagged (X) can now be substituted in the basic Lincoln Index formula, and the total population of moose calculated.

The following hypothetical example illustrates this.

$L = 150$ - number of tags missing

$B_D = 50$ - total number of deer seen on survey

$C_D = 5$ - number of tagged deer seen

$B_m = 100$ - total number of moose seen on survey

$C_m = 50$ - number of tagged moose seen

X = number of moose originally tagged

$$X = \frac{L\ C_m\ B_D}{(B_m\ C_D + C_m\ B_D}$$

$$X = \frac{150 \times 50 \times 50}{100 \times 5 + 50 \times 50}$$

$$X = 125$$

$$\frac{f(X)}{100} = \frac{125}{50}$$

$f(X) = 250 \equiv$ corrected total population of moose on the area

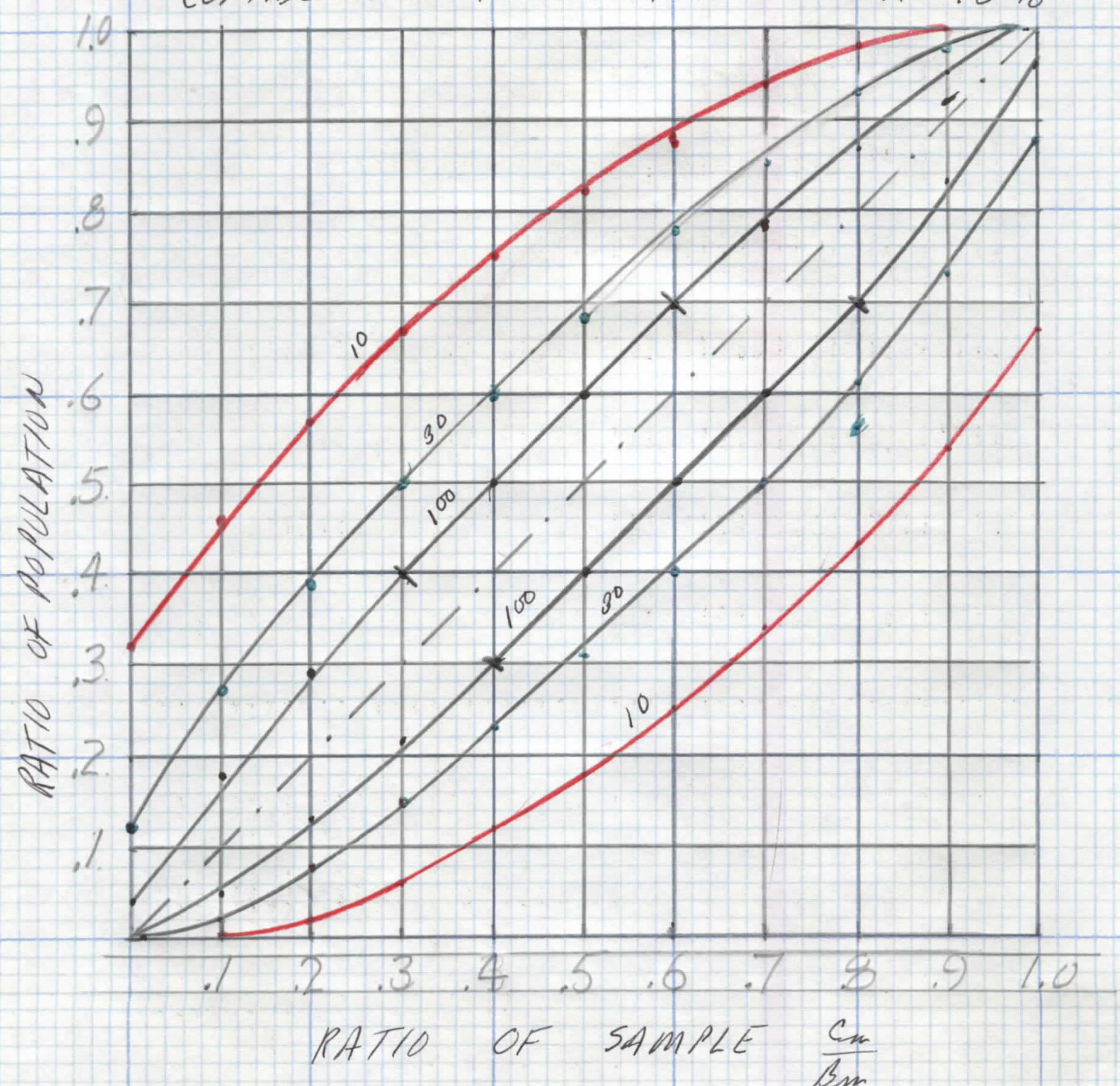
If circumstances should arise where another animal besides deer and moose were being tagged, for example elk, this last correction method could still be used. Instead of having two unknowns and two equations, it would have three unknowns and three equations. In addition, cruisers would have to keep track of three species of animals rather than just two.

Confidence Limits. - The establishment of confidence limits is vital for all sampling procedures. The following description for determining confidence limits for the Lincoln Index survey was taken from work done by Adams (1951).

According to the laws of chance, the ratio of unmarked animals to marked animals in a population will not always be the same as it is in the sample. The ratio could range from one to one to all marked animals to no unmarked animals. The ratio most likely to occur, however, is the true ratio of the population. The larger the sample, the greater will be the chance that the sample ratio will be the same as the population ratio. Therefore, confidence limits can be calculated for a particular sample. The computations are quite complicated and have been reduced by Adams to graphic form (figure 3). Although this graph is for the 95 per cent confidence level, other confidence levels could be calculated and presented in a similar manner. It is also possible to calculate curves for population sizes other than those given in figure three.

FIG 3

CONFIDENCE LIMITS FOR LINCOLN INDEX 95%



To use figure three, the ratio of marked animals to the total number of animals seen in the sample is calculated and entered along the horizontal scale of the graph. Read up the vertical line until it intersects the first curve representiNG the total size of the sample. Then, read across to the vertical scale to get the lower limit of the ratio. Continue along the original vertical line until it intersects the second curve representing the total sample size. Once again, read across to the vertical scale and find the upper limit of the ratio.

For example, if 100 moose were seen, and 50 of these were marked, the value of the ratio C_m (marked moose) to B_m (total moose seen) would be 0.5. Entering this in the horizontal scale of figure three and reading up to the lower 100 curve and then over to the vertical scale, a lower limit of 0.4 is found for the original ratio. Doing the same thing for the upper 100 curve, an upper limit of 0.6 is obtained. Now, if 125 moose had originally been tagged, the total population of moose is:

$$\frac{X}{100} = \frac{125}{50} = 250 \text{ moose}$$

Using the upper and lower limits found in figure three, the chances are 19 to 1 that the true population of moose lies somewhere between 312 and 208 moose. This is because the total population is calculated by dividing the ratio of marked animals to total animals seen in the survey into the total number tagged. If A_m equals the total population of moose, and C_m and B_m are as before, then:

$$\frac{A_m}{B_m} = \frac{X}{C_m}$$

$$A_m = \frac{B_m\, X}{C_m} = \frac{X}{\frac{C_m}{B_m}} \qquad (14)$$

Since the graph gives the upper and lower limits of the ratio $\left(\frac{C_m}{B_m}\right)$, to obtain the upper and lower population estimates, the total number of moose tagged is divided by the upper and lower ratios.

Points for Further Study. - As can be expected, an untried method has many questions that meed answering. The following is a list of the more important areas for further study.

1. What size should the collar be to properly fit moose?
2. Where should the smares be located to have the greatest efficiency?
3. What are the proper measurements for setting the snare for moose?
4. What proportion of the moose are tagged twice?
5. How long should the tagging period last?
6. What is the propertime length between the tagging period and the census period?
7. How far will moose run after they are flushed?
8. How far apart shodd census strips be placed?
9. Are tagged moose more subject to mortality than untagged moose?
10. How long will the collars stay on the moose?
11. How readily are tagged moose spotted in the field?
12. Is the proportion of deer tagged the same as the proportion of moose tagged?

CONCLUSIONS

With appropriate modifications, the aerial survey is an effective way to estimate moose populations if the forest cover type does not limit visibility. Sex and age ratios hold promise for the future. Their usefulness is impaired at the moment by their dependence on aerial surveys for post-season or pre-season sex ratios. With the development of better ways of determining sex and age ratios, this method will receive increased use.

Of the existing big game census methods not yet applied to moose, pellet counts are probably the most applicable. The drive method would be effective, but the large number of men required makes the cost prohibitive. The strip census, when used by itself, will only give a roung estimate of the moose population. This is because of difficulty in estimating strip width, and the fact that not all the moose on the strip will be seen.

The Lincoln-Romanov method for censusing moose is untried. It is not possible to draw any concrete conclusions about the applicability of this method until it has been properly tested in the field.

SUMMARY

Aerial censuses are the most common way to census moose at the present time. The results from aerial surveys can be variable, but with improved techniques a certain amount of consistency can be achieved. Sex and age ratios are also in use at the present time, but sufficient data has yer to be gathered to make population estimates from sex and age ratios meaningful.

Deer drives have never been applied to moose, and it is doubtful whether they will have an important role to play in censusing moose in the future. Pellet-group counts are used on many forms of big game; and as soon as more is known about moose physiology, they will be a useful tool for censusing moose. Strip counts have been used with a variety of animals ranging from ruffed grouse to deer. For most big game species, the results from strip counts are not very accurate.

The Lincoln - Romanov method for censusing moose is based on tagging moose with the Romanov automatic tagging device and calculating the total population of moose using the Lincoln Index formula. The operation and placement of the device are explained. Two methods for correcting for tagged deer are proposed, and a technique for calculating the confidence limits is given.

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