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EVALUATION AND TESTING OF TECHNIQUES FOR MOOSE MANAGEMENT

By

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ANNUAL REPORT (RESEARCH)

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Period Covered: 1 January 1987-30 June 1987
(with additional data from 1 July 1986-31 December 1986)

SUMMARY

Several jobs were active during this report period. A manuscript was prepared summarizing the use of carfentanil/xylazine and naloxone/yohimbine for anesthesia and antagonist during surgical vasectomy of moose. Data collection continued on the evaluation of an activity monitoring system for moose. Results will be published in a Master of Science thesis in December 1987. A literature review dealing with assessment of body condition was completed and a manuscript prepared. Testing of chinball markers for detection of estrus in moose was partially successful. Direct observations indicated that the length of estrus in moose was around 12-36 hours, and the modal interval between estrous cycles was 25 days for adult cows and 22 days for 2-year-olds. Females entered their 1st estrus in relation to their social dominance within the breeding group. A one-way gate was installed and tested, and modifications were suggested. The gate will be used along the Glenn Highway near Anchorage. Recommendations for continuation of studies are presented.

Key Words: activity, *Alces alces*, body condition, breeding, estrous cycle, moose, one-way gate.

CONTENTS

BACKGROUND

The Moose Research Center (MRC), with known numbers of confined animals and facilities to handle them, provides unique conditions for developing and testing techniques applicable to moose management. This study has been continuously active since 1969 when the MRC became functional. Three Federal Aid Final Reports covering the period from 1968 through 30 June 1986 have been published (Franzmann et al. 1974, Franzmann and Schwartz 1982, Franzmann et al. 1987). In addition, over 30 publications have emanated from the technique studies (LeResche and Lynch 1973; LeResche and Rausch 1974; Franzmann and Arneson 1974, Arneson and Franzmann 1975; Franzmann et al. 1974, 1976a, 1976b, 1982, 1984a, 1984b; Franzmann and Flynn 1977; Gasaway et al 1978; Franzmann 1978, 1980, 1981, 1982a, 1982b, 1982c, 1986; Ballard et al 1979; Regelin et al. 1979, 1980, 1981; Schwartz et al. 1980, 1985; Oldemeyer and Franzmann 1981; Franzmann and Schwartz 1982; White et al. 1984; Hubbert 1987). These publications covered evaluation and testing of drugs, trapping methods, aerial census, pellet-count census, telemetry, biotelemetry, rumen sampling, marking and collaring, weighing, fertilization of browse, electronic tissue measuring, raising moose calves, developing a moose ration, developing feeding trial and digestion crates, and developing a respiratory chamber, radioisotope digestion markers, and a carrying capacity model.

This report contains information collected since the 1987 final report. New jobs include: (1) activity monitoring, (2) total body fat estimation, (3) estrus monitoring, and (4) testing a one-way gate. We retained the old job of drug testing and evaluation.

The activity study was added because monitoring of diurnal moose activity is an essential part of the inputs needed to budget the energy requirements of both nutritionally stressed and unstressed moose. A study was designed to address this problem (Bevins 1985). It was necessary to first develop the techniques required to monitor moose 24 hours a day using an automated telemetry system. The MRC provided the facilities and animals necessary to test this system.

Body condition was identified as a critical variable within the moose carrying capacity model (Hubbert 1987, Schwartz et al. 1987a, 1987b) and body fat is a major driver of the moose submodel. This critical parameter (total body fat) must be accurately measured in moose. This job was developed to test known techniques and determine if they are useful and applicable to moose.

The need to obtain information for better assessment of "optimum" bull:cow ratios in Alaska moose populations hinges on a thorough understanding of the estrous cycle. This entails the length of estrus, the receptive period during estrus, the time periods between estruses, and the number of estrus periods during the breeding season. Markgren (1969) identified the time between estruses at 25-30 days, but the other needed data have been speculative. At the MRC we conducted late-breeding experiments and were able to demonstrate that calves are subsequently born late (Schwartz et al. 1986). The consequences of altered or nonoptimum breeding during the rut has been attributed to low bull:cow ratios, but with no clear supporting evidence. Nevertheless, the issue remains and is in need of systematic research to help resolve the matter. A basic requirement needed to begin this type of study is for a technique to identify the timing of copulation. In domestic animal science, a device for marking animals during mounting was developed for this purpose. This job was designed to test various devices available for their application to moose.

The Alaska Department of Fish and Game has been working with the Alaska Department of Transportation to develop a one-way gate for moose; the gate would be installed along a fence constructed to keep moose from crossing a major highway. A gate was constructed and placed between enclosures at the MRC to test the device's effectiveness. This job provides the assessment of the gate.

OBJECTIVES

To test and evaluate techniques that are potentially useful for management of moose. (STUDY OBJECTIVE)

To test and evaluate immobilizing, tranquilizing, adjunct, and reversing drugs. (Job 2).

To test and evaluate a telemetry activity-monitoring system. (Job 3).

To investigate physiological parameters that may provide an index to total body fat in moose. (Job 4).

To test and evaluate marking devices for detecting copulation (mounting) in moose. (Job 5).

To test a design of a one-way gate for moose. (Job 6).

To test miscellaneous techniques. (Job 7).

METHODS

Job 2. Drug Testing

We tested carfentanil/xylazine and naloxone/yohimbine mixtures for anesthesia during vasectomy in bull moose. The technique was summarized in a manuscript (Appendix A).

Job 3. Activity Monitoring

This job will be summarized in a Master of Science thesis that will be completed by December 1987.

Job 4. Total Body Fat Estimation

A literature review was conducted under this job to determine which techniques are currently utilized for body composition estimation (Appendix B).

Job 5. Estrus Monitoring

Eight female, and 2 male moose (ages >1.5 years) were used in studies to determine the length of estrus (the period of sexual receptivity), the length of the estrous cycle (number of days between estrous cycles), and the number of estrous cycles (number of cycles during the breeding season) in female moose. All animals were semi-tame and maintained at the MRC. Animals were held in a 10-acre enclosure during the study and fed a pelleted ration (Schwartz et al. 1985).

We tested 2 marking devices to indirectly determine if it was possible to detect breeding in moose by observing marks on the females. The 2 devices (Chin Ball Mating Device, Westquard Insd., Eric, Col; Bull Point Marker, Ag-tronics, Hastings, Neb.) were standard chinball markers designed for domestic bulls. To monitor the estrous cycle and to confirm that females were marked only during the receptive period, we observed the animals each day. To ensure that the females would not conceive, we vasectomized both males. Details of the surgical procedure were prepared for publication; the manuscript is presented in Appendix A. The bulls were vasectomized on 5 and 11 September 1986. We began daily observations on 9 September and continued through 2 March 1987.

Job 6. Test One-way Gate

A one-way moose gate similar to the design used for mule deer (*Odocoileus hemionus*) (Reed et al. 1974) was installed at the MRC on 11 August 1986. To help evaluate use by moose, we removed all vegetation within 1 m of the gate, and loosened the soil to aid in track observations. The gate was placed in a fenceline between Pen 2 and a small holding pen used for the tame animals. The gate was tested to determine if moose would use the gate and pass through it only in the correct direction. Usage was confirmed by visual observation, and indirectly, by tracks. The tame moose were released into Pen 2 prior to installation of the gate. Passage was confirmed when they were sighted in the small pen, or observed entering the gate and successfully going through it. We also determined unsuccessful attempts visually, and indirectly, by observing tracks in the loose soil at the gate.

RESULTS AND DISCUSSION

Job 2. Drug Testing

Results of this job were published; the manuscript is included as Appendix A.

Job 3. Activity Monitoring

The field work and testing of the activity system was completed during this field season. The results are currently being analyzed and will be reported in a Master of Science thesis which will be completed by December 1987.

Job 4. Total Body Fat Estimation

A literature review was completed during this report period by Al Franzmann and is presented in Appendix B.

Job 5. Estrus Monitoring

Numerous factors have combined to stimulate research on the estrous cycle and the factors influencing it in the cow moose. The biological significance of successful reproduction and the potential problems incurred as a result of low fertility and late breeding have been major factors in this development.

Evaluation of the 2 chinball markers demonstrated that they may have limited potential for indirectly determining breeding in moose. We placed the Bull Point Marker on Joker (11 September), and the Chin Ball Mating Device on Hugo (5 September) while they were immobilized for vasectomies. During most of the breeding season, Joker was the dominant bull. Unfortunately, his chinball marker did not work because the spring keeping the marking ball in position was too strong and prevented the ball from moving, with the consequence that no ink could pass out of the device. The marker placed on Hugo worked quite well, and we observed marking on several cows. However, because Hugo was the subdominant male, he had very little opportunity to participate in breeding, and most marking occurred after a cow was no longer in estrus or marking was not related to breeding. We observed Hugo "marking" cows at the feeder when they were not receptive. Animals ate from a large "self-feed bunk" (approximately 2 m wide) and when there were several moose eating from the bunk at 1 time, they often displaced each other by pushing on one another's rump and back with their heads. Hugo likewise did this, and subsequently marked the females. Most of this marking occurred later in the study after both males began consuming food. The cows in our study were in contact with only 2 vasectomized bulls and their continual estrous cycling made it possible to observe the late marking. Under "normal" conditions, most females go through 1 estrus cycle and are successfully inseminated. Intake studies (Schwartz et al. 1984) demonstrate that bulls during the rut fast for as long as 18 days; consequently, marking of this nature would not likely occur. Most of the problems we experienced could be overcome by using only the Chin Ball Mating Device and keeping only 1 bull with each group of females, thus eliminating post-estrus marking by a subdominant animal. Visual observations of breeding moose showed that the bull commonly rubbed his chin across the rump of the estrous female prior to mounting. Females tolerated this rubbing when they were in estrus, but were intolerant at other times and usually ran away from any approaches made by the male.

We were able to observe breeding in 7 of the 8 females during 33 estrous periods. Not all females were observed breeding during each estrus, but we were able to obtain sufficient data to quantify the length of the estrous cycle in the cow moose. The model length based on the number of days between observations of breeding was 25, with a range from 22 to 28 days (n = 23); the mean time was 24.4 ± SD 1.3 days (Table 1, Fig. 1). Our data suggest that the estrous cycle in moose is longer than that previously presented (20-22 days, see review of Lent 1975), and shorter than the 30-day period suggested by Edwards and Ritcey (1958). The estrous cycle of moose is slightly longer than that reported for domestic cattle (model length 20 and 21-22 days for heifer and cow, respectively) (Cole and Cupps 1959:225).

Two of the 8 females were yearlings (Betsy and Zumu); we compared estrous cycles of heifers and adult cows. Unfortunately, we were only able to obtain 3 data points for Betsy and none for Zumu. This limited data did suggest that the mean length of the estrous cycle for heifer moose (23 ± SD 0.8 days) was slightly shorter than that for adult cows (25 ± SD 1.1 days). This is in agreement with data presented for the domestic cow (Cole and Cupps 1959:225) where the length of estrus is 1-2 days shorter in the heifer.

We missed observing the 1st estrus in our moose. On 2 October 1986 we weighed both bulls. At that time it was noted that Joker's testicles were enlarged and swollen, probably from the surgery of 11 September. Also during that time, Joker was dominant over Hugo and would not allow Hugo near the cows. Angel was thought to be in estrus on 2 October. She did have marking ink on her rump that morning from Hugo's marker. He possibly mounted her that day, but we did not observe it. The timing of Angel's estrus was correct if we back-date from her next observed estrus on 26 October (24-day cycle length). She was observed to have a vaginal discharge on 6 October and records from other cows observed in estrus indicated that this discharge was normally observed a few days before to a few days after estrus (Table 1). Deneki and Janie were observed with vaginal discharges during this time period (Table 1) and were probably in estrus at this time. Since we did not directly observe breeding early in the rutting period (prior to 11 October) we only used data from observed breeding to calculate the length of the estrous cycle, estrous length, and timing of vaginal discharge. We did summarize observations made during this period and they are listed in Appendix C.

The length of estrus, or the interval during which a cow will stand when mounted by the bull, was estimated. These observations represented the shortest period of receptivity since we could have missed some breeding activity either early or at the end of estrus. Our observations indicated that duration of estrus was less than 2 days and probably less than 24 hours in most females (Table 1 and Appendix D).

Reproduction in the moose varies with area and habitat, but is generally divided into 2 distinct forms: those of the tundra- and taiga moose (Bubenick in press). Dominant females in rutting groups of the tundra type (Alaska moose are in this category) are believed to enter estrus first, followed by subdominant animals. A comparison of the dominance order of our females with the dates of their 1st estrus substantiated this theory. Dominance order was listed as Deneki, Trixie, Janie, Angel, Molly, Oly, Betsy, and Zumu. Observations of estrus in October indicated 2 distinct periods. One group of cows cycled mid-month (11-14 Oct) and the 2nd group cycled late in the month (24-27 Oct). Of the early group, Deneki cycled prior to Trixie, Trixie prior to Molly, and Molly prior to Betsy, and for the 2nd group, Janie cycled prior to Angel, and Angel prior to Oly. In all instances, the dominant cow entered estrus prior to the subdominant individuals. We have no explanation as to why the cows cycled in 2 distinct groups.

Our observations of breeding in moose suggest that copulation lasts only a few seconds. Prior to mounting, the male sometimes rubbed his chin on the rump of the female and spent up to a minute or more aligning his body parallel to that of the female and directly behind her. This was sometimes done while the chin was on the female's rump. Mounting and intromission were brief and the entire act lasted only 3-4 seconds. This information is in agreement with the summary presented by Lent (1975:313). Bulls attempted copulation several times before successful intromission, and it was not uncommon to observe up to 9 mounts prior to a successful copulation. We observed 5 successful copulations by 1 bull in a single day over a period of 7 hrs 49 min (0910, 1017, 1222, 1456, and 1659 hours, [Janie, 18 Nov, see Appendix D] and 4 successful copulations over a period of 7 hr and 39 min (0849, 0928, 1000, and 0418 hours, [Deneki 1 Dec, see Appendix D]). The shortest time period between successful copulations observed was 32 minutes.

Behavioral activity during the study varied with time. Early in the rutting period (Sep and Oct) we observed the more classical displays associated with moose rutting (flehmen, vocalizing in both males and females, wallowing and thrashing). Later in the study (Dec through Feb) the intensity of mating diminished, and there was considerably less vocalizing by the bulls, and fewer rutting pits. The bulls continued flehmen, and cows vocalized, but mainly when they were no longer receptive but still pursued by the bull. A major surge in rut activity was observed when Hugo established dominance over Joker for a short period. During his reign, he actively established pits and courted females with a grunt vocalization. That quickly ended when Joker reestablished his dominance.

We discontinued our observations in early March, even though the females were still cycling. We do not know how long they would have continued to cycle, but we decided that for practical purposes additional information was not useful.

It was apparent from these studies that female moose continue to cycle and come into estrus until successfully bred. In the wild, this probably occurs in the 1st or 2nd estrus. This information is useful because it demonstrates that pregnancy rates in adult cows probably will always be extremely high. After the rut, nonpregnant females likely did not cycle, were incapable of pregnancy, or lost their fetus; all these factors have biological implications.

Job 6. Test One-way Gate

During testing of the one-way gate, we observed several moose pass through. Initially, antlered bulls could not pass through. We modified the gate by removing the upper bars; bulls with antlers up to 50 inches could then successfully pass. One wild female also passed through the gate into the small holding pen. She was later found dead. Loss of hair from her carcass, and hair found on the gate suggested that she had possibly tried to pass the wrong way back through the gate. If this was the case, she possibly punctured her body with the sharp points of the gate. This possibility was noted and corrective action was taken in the design. Details will be reported (McDonald unpubl. data).

RECOMMENDATIONS

We plan to continue to evaluate new drugs and related products as they become available for use. A new tranquilizer product (R 51163) will be tested in the winter of 1988. Recommendations for the activity study will be included in the Master's thesis. Several techniques to estimate body composition of moose need to be evaluated and we plan to begin this winter. The one-way gate test is complete.

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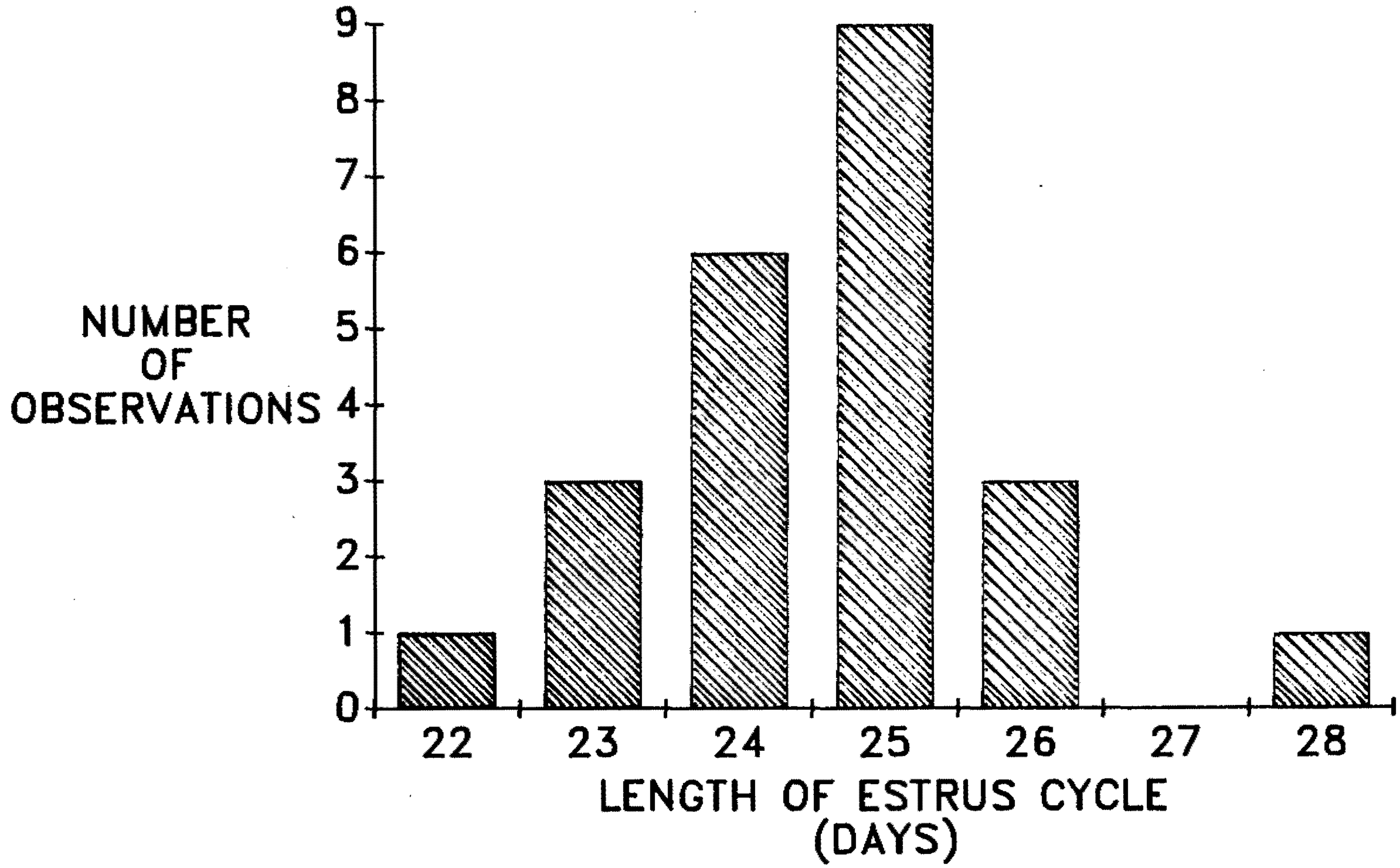

Fig 1. Distribution in days of the length between estrus in cow moose, from the Moose Research Center, Soldotna, Alaska, September 1986-March 1987.

Table 1. Summary of observations of estrus in 8 captive female moose at the Moose Research Center, Soldotna, Alaska from September 9, 1986 to March 2, 1987.

Moose	Date of estrus	Type of data[a]	Period between estruses (days)[b]	Date of vaginal discharge	Length of estrus (hours)[c]
Deneki				25 Sep	?
Deneki	11 Oct	O		10, 14-16 Oct	18-?
Deneki	5 Nov	O	25	6, 10-11 Nov	24-?
Deneki	1 Dec	O	26		8-?
Deneki	26 Dec	O	25	25, 27, 30-31 Dec	24-?
Deneki	20 Jan	O	25	26 Jan	24-?
Deneki	15 Feb	S	26[d]	16, 20 Feb	?
Trixie				25-26 Sep	
Trixie	12 Oct	O		14-17 Oct	?
Trixie	4 Nov	O	23	28-29 Oct, 6 Nov	25-36
Trixie	28 Nov	O	24	2 Dec	23-36
Trixie	23 Dec	S	25[d]	25-27 Dec	?
Trixie	17 Jan	O	25[d]		?
Trixie	9 Feb	O	23		15-?
Molly	13 Oct	O		15-17 Oct	2-8
Molly	6 Nov	O	24		4-?
Molly	30 Nov	O	24		6-?
Molly	25 Dec	O	25	25-27 Dec	?
Betsy	14 Oct	O		17-19 Oct	1-4
Betsy	7 Nov	O	24		?
Betsy	29 Nov	O	22	1 Dec	4-?
Betsy				24-25 Dec	
Betsy	14 Jan	O	46/2 = 23[d]		?
Betsy	6 Feb	O	23	6 Feb	15-24
Janie			1 Oct		
Janie	24 Oct	O	25, 27 Oct		18-?
Janie	18 Nov	O	25		24-36
Janie	12 Dec	O	24		?
Janie	9 Jan	O	28		?
Janie	3 Feb	O	25		9-?
Janie	27 Feb	O	24	28 Feb	8-?

Table 1. Continued.

Moose	Date of estrus	Type of data[a]	Period between estrus (days)[b]	Date of vaginal discharge	Length of estrus (hours)[c]
Angel	2 Oct	S		6 Oct	
Angel	26 Oct	0	24[d]	29, 31 Oct	24-?
Angel	21 Nov	0	26	20, 25 Nov	4-?
Angel	16 Dec	0	25	11, 21 Dec	?
Angel	10 Jan	0	25		25-36
Angel	5 Feb	0	26	6, 8 Feb	32-?
Angel	2 Mar	0	25		?
Oly	27 Oct	0	29 Oct		?
Oly			23-24 Nov		?
Oly	25 Feb	0	121/5 = 24[d]		?
Zumu	No observations				

[a] 0 = observed breeding, S = suspected estrus, based on indirect evidence. For details see Appendix D.

[b] Time between first observed mounting of each estrus.

[c] Length of receptive period was difficult to determine because of incomplete observations. The lower number represents the shortest known period of receptivity, while the upper number indicates that observations were continuous enough to bracket nonreceptive periods prior to and/or after the receptive period. If we only observed mating once during an estrus, then a question mark appears.

[d] Data were not used to calculate length of estrus cycle.

Appendix A.

ANESTHESIA OF MOOSE FOR VASECTOMY USING CARFENTANIL/XYLAZINE AND REVERSAL WITH NALOXONE/YOHIMBINE

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Abstract: We report on the use of a mixture of carfentanil hydrochloride and xylazine hydrochloride to anesthetize 2 adult male moose (Alces alces) for surgical vasectomy and the subsequent reversal of these drugs with a mixture of naloxone hydrochloride and yohimbine hydrochloride. Induction, relaxation, reversal, and recovery were considered ideal. With minor downward dosage adjustment, we recommend the outlined methodology for surgical procedures in moose.

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For surgical anesthesia on moose (Alces alces), we have previously relied on the drug xylazine hydrochloride (Rompun, Bayvet Div., Miles Laboratories, Shawnee, KS) which was not reversible, or etorphine hydrochloride (M-99, Lemmon Co., Sellersville, PA) which lacked good muscle-relaxing qualities and required large volumes of drug for adult moose (Franzmann 1982). Combining these 2 drugs lowered the volume of etorphine hydrochloride needed and provided muscle relaxation, but required lengthly recovery from the effects of xylazine hydrochloride (Franzmann et al. 1982). Carfentanil hydrochloride (Wildnil, Wildlife Laboratories, Fort Collins, CO) was recently introduced and became the immobilizing drug of choice for moose, primarily because of its low-volume dosage (Meuleman et al. 1984), Franzmann et al. 1984, Seal et al. 1985). Carfentanil hydrochloride is reversible with naloxone hydrochloride (Naloxone, Wildlife Laboratories, Fort Collins, CO). Yohimbine hydrochloride (Antagonil, Wildlife Laboratories, Fort Collins, CO) was also recently introduced as an effective reversing agent for xylazine hydrochloride in cervids (Hsu and Shulaw 1984, Seal et al. 1985). This report outlines our experiences using these drugs to anesthetize and reverse 2 male moose at the Moose Research Center (MRC), Alaska.

MATERIALS AND METHODS

Two adult male moose (Hugo, Joker) that were hand-reared as calves (Regelin et al. 1979), and maintained as experimental animals on a pelleted ration (Schwartz et al. 1985) at the MRC were selected as marker bulls (vasectomy procedure) for a reproduction study. On 5 September 1986 Hugo was weighed on a platform scale (514 kg) and injected IM with 5.5 mg carfentanil hydrochloride (0.011 mg/kg) and immediately turned into a 25 X 25 m outside pen. Induction time was 3 minutes. Four minutes after induction, 300 mg xylazine hydrochloride (0.58 mg/kg) was injected IV. We deantlered the bull, trimmed his feet, prepared for surgery, performed a vasectomy, and prepared for reversal of the drugs 46 minutes following induction. We injected 500 mg naloxone hydrochloride IM and 100 mg IV (1.2 mg/kg, 109 mg/each mg carfentanil hydrochloride) followed by 200 mg yohimbine hydrochloride IV and 200 mg IM (0.78 mg/kg). The animal became alert in 4 minutes and was easily pushed to sternal recumbency from lateral recumbency. He was up and mobile in 15 minutes following the last injection of antagonist drug.

On 11 September 1986 the same procedure was followed for Joker who weighed 490 kg. He was given 5 mg carfentanil hydrochloride (0.01 mg/kg) IM and induction time was also 3 minutes. We decided to decrease the xylazine hydrochloride dosage to 200 mg IV, but after 5 minutes it became apparent that more was indicated and we gave an additional 100 mg IV (0.61 mg/kg total). Excellent relaxation followed and we completed the processing and surgery in 32 minutes. We then injected 500 mg naloxone hydrochloride IM and 100 mg IV (1.2 mg/kg, 120 mg/each mg carfentanil) followed by 150 mg IV and 50 mg IM (0.41 mg/kg) Of yohimbine hydrochloride. The bull was alert in 5 minutes and up and mobile in 17 minutes.

RESULTS AND DISCUSSION

Dosage for induction (0.011 and 0.010 mg/kg carfentanil hydrochloride), response time to induction dosage (3 minutes), relaxation dosage (0.58 and 0.61 mg/kg xylazine), and the antagonist dosage for carfentanil hydrochloride (1.2 mg/kg naloxone hydrochloride) were similar for both animals. We decreased the antagonist dosage for xylazine hydrochloride for Joker to 0.41 mg/kg of yohimbine hydrochloride from 0.78 mg/kg on Hugo. We detected no difference in response to the lower dosage of yohimbine hydrochloride.

The rapid 3 minute induction times indicate that a slightly lesser dosage of carfentanil hydrochloride may be considered. The dosage of 0.6 mg/kg of xylazine hydrochloride provided better muscle relaxation than did 0.4 mg/kg.

The naloxone hydrochloride dosage for Hugo was 109 mg/each mg carfentanil hydrochloride, and 120 for joker. Both dosages were higher than the 100 mg we have used when antagonizing moose that have received only carfentanil (MRC records). We could have used a lesser dosage of naloxone hydrochloride for these moose, and suggest that as a future possibility.

Induction, relaxation, reversal, and recovery were considered ideal, and other than some minor downward dosage adjustments, we recommend the outlined methodology for surgical procedures in moose.

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Appendix B.

ASSESSMENT OF CONDITION STATUS AS A MANAGEMENT TOOL FOR BIG GAME SPECIES

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Abstract: Condition (health, nutrition) status of wildlife populations has long been pursued using the indicator animal concept by applying a variety of techniques measuring form (morphology), function (physiology), and activity (behavior) of animals. At the Moose Research Center (MRC), Alaska, we have in the past focused on measuring blood parameters. However, after an 8-year study on developing a carrying capacity model for moose (*Alces alces*), it became evident that a major driving force in the model was total body fat. Our direction now is toward assessing procedures that can, with a minimum of effort and expense, estimate total body fat in wild animals.

PAST AND PRESENT

When we assess the status of tools available for effective big game management (economic and political considerations aside), we must focus on biological necessities and ask "What are the most important questions to be answered?" Depending on type of animal, location and our special interest, we may expect a variety of questions. We went through this exercise at the Moose Research Center (MRC), Alaska, in the late 1970's, and in the process we had essentially 2 points of view. One was to continue developing applications of the indicator animal concept (Franzmann 1985); the other was to address carrying capacity.

Application of the indicator animal concept was ongoing and we had concentrated on finding physiologic and morphometric parameters that would indicate the condition of moose (*Alces alces*) in a population (Franzmann and LeResche 1978, Franzmann et al. 1987). However, we had reached a point where we could no longer progress without controlled studies (Franzmann 1985). We could detect extremes in condition using selected blood parameters, but we could not define the in-between areas we called "relative goodness." Controlled studies required maintaining captive animals that could be serially sampled while being maintained on known nutritional intakes.

Our concerns for answering the questions regarding carrying capacity were addressed using the concept advocated by several authors (Moen 1973, Robbins 1973, Wallmo et al. 1977) that carrying capacity for wild ungulates should be determined on a nutritional basis. This concept required integrating the animals' nutrient requirements with those available in the habitat. Maintaining captive animals for feeding and metabolism trials was also required.

The need for captive animals, if we were to pursue either of our priority needs, presented a problem because moose could only be maintained in captivity by daily cutting and hauling of browse for feed. Attempts to feed moose on rations that were fed to other cervids were unsuccessful (Thorne 1979); therefore, our first need was to develop a ration to maintain healthy moose. The ration we developed was based on the natural nutritional intake of moose which dictated that we substitute lignin for fibrous cellulose. We selected aspen sawdust because of its availability and lignin content (Schwartz et al. 1985). With a suitable ration, we began hand-rearing calves (Regelin et al. 1979) to provide a population of experimental moose and began constructing facilities for feeding and metabolism trials (Franzmann and Schwartz 1982).

Soon after initiating our studies, it became evident that collecting blood from moose during feeding trials was not possible because the animals became excited and stressed. Immobilizing the animals to collect blood was attempted, but this caused the animals to go off feed and invalidated the trial (Schwartz et al. 1987b). Therefore, we discontinued efforts to bleed moose, and our controlled studies of physiologic parameters as indicators of condition were placed on hold.

The carrying capacity study consisted of 2 parts: one dealt with the animal, the other part concerned the vegetation, but each was guided by a working model to assimilate accumulated inputs. The vegetation model was tested at the MRC (Regelin et al. 1986) using the nutritional requirements provided by the animal studies (Hubbert 1986, Regelin et al. 1985, Schwartz et al. 1987a, 1987b, 1987c, 1987d, 1987e). Regelin et al. (1986) concluded that the concept of nutritional carrying capacity was valid and that it is possible to predict utilization levels based on intake rates from simulation models and from accurate food habits data. These authors also acknowledge that vegetation measurements are time-consuming and expensive.

Hubbert and Schwartz (1987) presented the MRC animal model that estimates food intake based on seasonal body condition and growth requirements. They noted that moose voluntarily go through an annual cycle of high and low metabolic rates (Regelin et al. 1985), feed intakes (Schwartz et al. 1984) and fat reserves (Hubbert 1986) which occur independently of changes in diet quality or availability. Their model provides the opportunity to evaluate habitat in relation to animal response and allows estimates of carrying capacity from animals rather than from forage availability. This model essentially combined the 2 approaches we sought at the MRC; nutritional carrying capacity and the indicator animal concept.

The importance of the Hubbert-Schwartz model is that it soundly supports a population assessment approach, which many researchers have sought. It will refocus our energies to areas of research that will potentially be more productive. The many sources of variation associated with estimating forage production and utilization and relating it to animal performance, which we assumed to be necessary for development of a nutritional carrying capacity model, are bypassed.

Application of the Hubbert-Schwartz model requires field estimates of total body fat which are at present limited to controlled experiments with captive animals. This should not deter us from progressing with the application. We must simply accelerate efforts toward finding procedures to estimate total body fat in animals from free-ranging populations.

FUTURE

The Hubbert-Schwartz model is based on estimates of total body fat but presently we have no practical method for obtaining these data in the field. Procedures that have been applied to big game are measurements of total body fat by extraction (Huot 1982) and measurement of total body water using tritiated water as an index of total body fat (Torbit 1981, Torbit et al. 1985). Various fat indices have been applied, but are difficult to correlate with total body fat (Franzmann 1985).

Research in human medicine, and more recently in the field of sports medicine, has long been concerned with estimates of total body fat (Durnin 1958, Keys and Brozek 1953, Grande and Keys 1980). The methods used have included: hydrostatic weighing (Behnke et al. 1942, Brozek et al. 1963), total body potassium determination (Barter and Forbes 1963, Forbes and Reina 1970), deuterium oxide dilution (Pace and Rathbun 1945, Sheng and Higgins 1979), skinfold measurements (Durnin and Womersley 1974, Durnin and Rahaman 1967), ultrasound measurements (Sloan 1967, Volz and Ostrove 1984), total body electrical conductivity (Harrison and Van Itallie 1982, Presta et al. 1983*a*, 1983*b*), total body impedance (Hoffer at al. 1970, Spence et al. 1979, and infrared interactance (Conway et al. 1984). Researchers in domestic animal science have utilized tritium oxide, deuterium oxide, and urea dilution techniques for *in vivo* prediction of body composition. The urea dilution technique is favored because of cost and ease of analysis (Rule et al. 1986).

Now is the time to devote efforts toward determining methods to estimate total body fat in free-ranging animals. We may benefit by association with sports medicine and domestic animal researchers who have the same goal, but different objectives. Wildlife managers have long understood the value of fat reserves to animals, but have had difficulty in applying the concept to carrying capacity estimates. The Hubbert-Schwartz model provides a method for this application.

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Appendix C.

BREEDING ACTIVITY FOR 8 FEMALE MOOSE FROM 9 SEPTEMBER TO 5 OCTOBER 1986 AT THE MOOSE RESEARCH CENTER, SOLDOTNA, ALASKA.

Date	Observation
17, 18 Sep	Joker moving and vocalizing (grunting), Trixie walking.
21 Sep	Joker vocalizing and running through trees. Trixie vocalizing and running as if trying to escape from Joker.
	Betsy smelling at rutting pit, then lying down in it.
	Molly at feeder beside Hugo. She had marking ink on her rump.
	Hugo made mew-like vocalization and left area when Joker approached.
	Joker smelled and licked Trixie's genital area, lip curled, then chased Trixie away. Also chased Deneki and Janie.
	Joker also chased Betsy and when 4 cows gathered in or near trap at NW corner of Pen 2A, Joker pawed a rutting pit nearby. He repeatedly squatted over it, but seemed unable to urinate.
22 Sep	Joker still seems to be "herding" cows. Joker was near Molly and Trixie when Deneki vocalized and ran along fenceline. Joker stayed out in spruce trees running parallel to Deneki. Soon, Janie joined Trixie and Deneki at south corner and little Molly and her calf also joined the group. The cows grouping together seems to be partly voluntary and partly due to Joker. He was standing out in spruce trees away from the fenceline.
	Hugo laid his head on Betsy's back while they were at a feeder in a small pen. He marked Betsy's hump with his marking ink.
	Cows have been running and vocalizing; bulls are chasing cows and making rutting pits. Molly lay down in one of Hugo's pits in afternoon.
23 Sep	Angel ran and made a loud bellow. She also did this yesterday. Hugo was with several cows but left when Joker showed up.

Date	Observation
	In evening, Trixie ran toward Joker as she vocalized; then she ran back away. Betsy and Joker nosed each other; Joker checked her genital area and lip-curled, Betsy left. Another moose (not identified) vocalized and approached Joker. He laid back his ears and chased the moose, then also chased Zumu.
24 Sep	Joker vocalizing, thrashing brush, antagonizing Chief and Bando (morning).
	Later, Trixie was lying in Joker's rutting pit with Joker standing beside it. She got up, stamped in pit, then ran off vocalizing. Joker lay down in the pit. Trixie ran only a short way, then began rubbing her head and/or neck on a spruce tree. Joker and Trixie seemed to be exchanging vocalizations occasionally.
	In the evening, Deneki was lying in the same rutting pit.
	Hugo was in trap 2N. Trixie approached trap vocalizing. Hugo came out, smelled Trixie's genital area as she stood still. However, she then ran away with Hugo running after until Joker appeared. Then Hugo ran away.
25 Sep	(Morning) Joker was antagonizing Bando and Chief. After Joker and some cows moved away from feeder area, Hugo showed up. He smelled and licked Trixie's genital area. She vocalized and moved away.
	(Early afternoon) Janie was lying in Joker's rutting pit. Trixie and Deneki have been lying in same pit on previous days. Joker was nearby. Soon Janie got up and began vocalizing. Joker approached, Janie vocalized and ran, and Joker chased her.
	(Evening) Joker was chasing Deneki and Janie back and forth through the timber below the feeder. The cows were vocalizing loudly.
26 Sep	(Morning) Joker was chasing Janie who was running and vocalizing. He made a rutting pit near the fence of the small pens. Trixie approached Joker, then ran away vocalizing. Deneki also ran and vocalized, but neither went far. First Betsy, then Zumu went over to Joker and were smelling him and being smelled in return.

Date	Observation
	(Afternoon) Joker spent most of afternoon lying down near small pens. Deneki, Janie, Zumu were all lying near Joker's rutting pit, and Betsy was lying in the pit.
27 Sep	(Morning) Some moose up at pens. Joker, Janie, Zumu were near each other at north side of marsh.
	(Afternoon) Joker, Betsy, Janie, and Trixie lying down, downhill from feeder. Janie got up, vocalized, ran. Then Joker got up and ran a short way.
	Hugo was standing near Angel who was lying down on west side of the pen.
	Moose have been relatively quiet last couple of days.
28 Sep	(Late afternoon) Most of moose were in area near feeder or along north fence. No interactions were noted.
29 Sep	(Morning) Betsy, Deneki, Zumu, Janie all nuzzled Joker, first frontally and then to rear. Betsy nuzzled Joker's scrotal area. Then the moose stood together for some time. Betsy moved toward Joker; Janie ran her off. Then Janie chased the others. Then they all stood for about 15 minutes without interacting. Then they followed observer as he walked toward small pens.
	(Evening) Deneki, Trixie, Zumu were all chased by Joker when they tried to approach the feeder.
30 Sep	(Morning) All cows (except Angel) and Joker were in general area of feeder and small pens. Angel was lying down in SW part of pen with Hugo standing nearby.
	Soon Janie and Joker came to south area of pen. Janie was vocalizing. Janie lay down in a rutting pit. When Molly and her calf came near, Janie got up and chased Molly away, then again lay down in the pit. Molly's calf lay down in pit next to Janie. When Janie got up to chase Molly again, Molly's calf sniffed around at the pit, then lay in middle of it.
	The calf seemed to be affected by the rutting pit's smell much the same as the adult cows. Janie finally moved to another pit nearby and lay down. Molly joined her calf lying in the first pit. Joker approached Janie. She came to him. After interaction (observer's view blocked by trees), Janie moved away, vocalizing, then lay down again.

Date	Observation
	(Afternoon) Joker was following Deneki and Janie and grunting as they moved and vocalized.
	(Evening) Joker was standing behind Janie near the feeder. I thought he might mount her. I left for a few minutes to quiet a barking dog. When I returned, Joker, Trixie, Janie, and Zumu were further west. Janie soon approached Joker. I believe she was rubbing her head on his neck or shoulder. Then a cow ran through the trees vocalizing and Joker followed her. After that, Janie moved away.
1 Oct 86	(Morning) As I walked through spruce trees, Joker came running toward me. As soon as he saw me (or heard my voice), he stopped and returned to area near Betsy, Trixie, Janie, Deneki, and Zumu.
	(Afternoon) All of the cows and Joker were in the SW part of the pen. When Joker got up, Janie went to him. He nosed her rear end, but didn't try to mount. Then he disappeared in trees after just standing for a while. I was near most of the cows when they began running everywhere and Joker came running my direction. With all those moose running around, I got uncomfortable and left the area. Joker may have been chasing Hugo who had been nearby before all of the running.
	(Evening) Joker heard me as I was looking for all the moose and he came grunting over which spooked me even though he wasn't aggressive. When I returned to small pens, Joker and all of the cows (except Deneki who was at south side) were there. Joker just seems to be keeping tabs on the cows.
2 Oct	(Morning) Joker, who had been near the feeder with some cows, went walking and grunting up to meet Angel along the north fence. Angel soon ran around Joker, ran up into the small pens, ran back out and down the hill. Joker went to chase someone through the woods and Angel came back to the feeder. She had marking ink (from Hugo) on her rump. She stood still when I rubbed her rump instead of acting spooky. I believe she is in estrus. Later, when Hugo was at small pens and I weighed him, I noticed that his testicles were considerably smaller than Joker's testicles.

Date	Observation
3 Oct	(Morning) Joker and some cows were near feeder. Later, Joker and Deneki were near each other in south part of pen and other moose were more scattered around the pen than they had been recently. Hugo came up to small pens and lay down.
	(Evening) All moose were in area of small pens. When Hugo began following Trixie, Joker went out of small pens and began stalking Hugo. Hugo ran a short distance, then walked away with Joker following. They disappeared in trees.
4 Oct	(Morning) Joker seen eating at feeder for first time in a long while.
	(Late afternoon) Hugo was eating at feeder. All others were lying or standing in SW part of pen.
	Only activity this day seemed to be Joker chasing Hugo a couple of times. Otherwise, things seem to have quieted down. Maybe all or most of cows have been through their first estrus.

Appendix D.

FREQUENCY OF BREEDING AND LENGTH OF RECEPTIVE PERIOD IN 8 FEMALE MOOSE FROM 9 SEPTEMBER 1986 TO 2 MARCH 1987 AT THE MOOSE RESEARCH CENTER, SOLDOTNA, ALASKA.

Moose	Date	Observation
Deneki	11 Oct	Early morning, one mount, successful; 11:00 a.m., one mount, successful.
Trixie	12 Oct	Afternoon, several mounts, one successful.
Molly	13 Oct	4:15-4:35 p.m., 6 mounts, last successful. Molly vocalizing and moving away in morning and again in evening. Only receptive for a short time.
Betsy	14 Oct	2:30 p.m., Betsy moving and vocalizing 4:00 p.m. Joker got Betsy up; she vocalized a little, then became quiet. 4:28-4:55 p.m., Joker mounted Betsy 9 times, none successful. Joker left to chase Hugo. When he came back, Betsy was again moving and vocalizing. I believe this was her only receptive period, but Joker and Hugo harassed her for 2 more days.
Janie	24 Oct	Mid-afternoon, Joker attempted to mount twice, then did mount 3 times in 30-minute period.
	25 Oct	Mid-morning, Joker mounted Janie twice, once successfully.
Angel	26 Oct	Joker mounted Angel 3 times at about 9:00 a.m. Later in morning, he mounted Angel 8 more times.
Angel	27 Oct	Morning, Joker attempted to mount several times and did mount once, but Angel kept moving and he was not successful.
Oly	27 Oct	11:15 a.m., Hugo attempted to mount Oly once, then mounted her successfully once.
Trixie	4 Nov	8:45 a.m., Joker mounted once, unsuccessfully.

Moose	Date	Observation
		9:25 a.m., Joker mounted once, successfully.
		11:28 a.m., Joker mounted once, successfully.
Trixie	5 Nov	9:40 a.m., Joker mounted twice, 2nd successful.
		1:30 p.m., Trixie lying down, vocalizing when Joker approaches. Probably no longer receptive.
Deneki	5 Nov	4:30 p.m., Hugo mounted 3 times, 3rd successful.
		4:50-5:15 p.m., Joker mounted 4 times, probably successful on 4th mount.
Deneki	6 Nov	8:30 a.m., Hugo mounted, then escaped with Joker chasing.
		10:10 a.m., Hugo mounted Deneki, Joker came running and Deneki ran with Hugo riding for 15-20 yards. Hugo then departed hastily. Joker then mounted 4 times, successful on 4th.
Molly	6 Nov	11:44 a.m.-12:08 p.m., Joker mounted Molly 5-1/2 times (once not fully mounted), successful on last. On 2nd mount, Molly fell completely down and rolled sideways, but was apparently unhurt.
		2:45 p.m., Joker got Molly up, mounted but probably not successfully; he was still interested, but observer left.
Betsy	7 Nov	9:00-9:45 a.m., Joker mounted 7 times, but Betsy could not support his weight.
Janie	18 Nov	9:05-9:10 a.m., Joker mounted 3 times, 3rd successful.
		10:17 a.m., Joker mounted once successfully (after a half-mount).

Moose	Date	Observation
		12:22 p.m., Joker mounted twice, 2nd successful.
		2:56-3:02 p.m., Joker mounted 3 times, 3rd successful.
		4:59 p.m., Joker mounted once successfully.
Janie	19 Nov	Morning, Joker approached Janie. She vocalized while still lying down, then soon got up.
		8:44-8:55 a.m., Joker mounted twice, 2nd successful.
		1:40 p.m., Joker pursuing, but Janie vocalizing and moving away. Probably no longer receptive.
Angel	20 Nov	May have been bred late on this date. Observed in mid-afternoon.
	21 Nov	Morning, Angel's rump hair messed and marked with ink.
		11:00 a.m., Hugo mounted Angel. He bred her again later in morning. Not observed in afternoon.
Trixie	28 Nov	5:15 p.m., Joker mounted Trixie, probably successful.
	29 Nov	8:37 a.m., Hugo came out of trees, quickly mounted. Joker ran toward them; Hugo, trying to dismount, fell down on his side. Joker almost got him, but Hugo managed to jump up and escape.
		8:42 a.m., Hugo again sneaked up and mounted Trixie.
		She began moving up fenceline toward Joker with Hugo still aboard. He was forced to escape again. Hugo should be an entertainer.
		9:22-9:32 a.m., Joker mounted Trixie twice, successful on 2nd mount.

Moose	Date	Observation
		2:10-2:12 p.m., Joker mounted Trixie twice, 2nd successful.
		4:10-4:12 p.m., Hugo quickly mounted Trixie 3 times. The 2nd time Trixie ran a long way with Hugo riding. After 3rd mount, Joker appeared and chased Hugo away.
Betsy	29 Nov	9:30 a.m., Betsy probably in estrus. Staying close to Joker (even sparring with him) as Joker was breeding Trixie.
		2:30 p.m., Joker got Betsy up.
		2:35-3:05 p.m., Joker mounted 8 times, 8th successful.
Molly	30 Nov	8:45-10:40 a.m., Molly doing everything except back under Joker who seems about worn out. He did finally mount at 10:28 a.m. and partially mounted twice more about 10:40 a.m.
		Earlier, Janie tried to mount Molly twice.
		3:00-4:45 p.m., Joker staying with Molly, but not trying to mount. She seems to still be in estrus. Joker may be too pooped.
Deneki	1 Dec	8:49 a.m., Joker mounted once successfully.
		9:28 a.m., Joker mounted once successfully.
		9:55-10:00 a.m., Joker mounted twice, 2nd successful.
		10:00a.m.-3:45 p.m., Not observed.
		4:14-4:18 p.m., Joker mounted twice, 2nd successful.
Janie	12 Dec	10:21 a.m., Joker mounted once successfully.

Moose	Date	Observation
Angel	16 Dec	Mid-afternoon, Joker bred Angel. Her hair coat indicated earlier mounting also.
Trixie	23 Dec	9:30 a.m., All cows except Trixie had frosty rumps. Her rump hair all mussed up. However, was not actually observed being mounted. Hugo dominant at this time.
Molly	25 Dec	3:30 p.m., Hugo mounted twice.
Deneki	26 Dec	10:00 a.m., Hugo mounted once.
		9:30 a.m., Hugo mounted once.
Janie	9 Jan	4:42-5:00 p.m., Joker mounted 5 times, 5th time successful.
Angel	10 Jan	10:00-11:30 a.m., Joker mounted many times, probably successful more than once.
	11 Jan	10:25 a.m., Joker mounted Angel.
		11:05 a.m., Joker mounted Angel.
Betsy	14 Jan	10:00 a.m., Joker mounted 3 times in 5 minutes.
Trixie	17 Jan	Morning; Joker mounted Trixie twice.
Deneki	20 Jan	9:24 a.m., Joker mounted Deneki once.
		9:49 a.m., Joker mounted Deneki once.
		10:19 a.m., Joker mounted Deneki once.
	21 Jan	9:15 a.m., Joker mounted Deneki.
Janie	3 Feb	8:50-9:00 a.m., Joker mounted or attempted to mount 4 times. Successful once.
		5:03-5:45 p.m., Joker mounted many times, but didn't always get fully mounted; Janie's hind legs buckled sometimes.

Moose	Date	Observation
Angel	5 Feb	9:06-9:12 a.m., Joker half mounted, then mounted twice. Afternoon, Angel lying down (vocalizing when Joker or I come near).
	6 Feb	Morning, Angel vocalized when I got her up and when Joker first approached her; then became silent.
		9:15-9:30 a.m., Joker mounted (or tried to mount) 6 times, 6th successful.
		5:20-5:25 p.m., Tried to mount 3 times and did mount on 3rd try, but may not have ejaculated.
Betsy	6 Feb	6:00 p.m., Hugo mounted Betsy on the move; Joker was heading toward them so Hugo dismounted and ran.
	7 Feb	Morning, Betsy standing quietly while Joker went through his elaborate premounting ritual; then, when Joker tried to mount, Betsy would move. This happened many times, but Joker made several half mounts and once or twice actually got mounted, but didn't succeed with intromission.
Trixie	9 Feb	3:55-4:00 p.m., Joker mounted 4 or 5 times, last successful.
	10 Feb	Morning, Trixie still seemed receptive and Joker was staying with her, but didn't try to mount. He was busy threatening Chief through the fence.
		Afternoon, Joker still staying with Trixie, but made no attempt to mount during one hour of observation.
Deneki	15 & 16 Feb	Deneki has had mussed rump both days. No mounting activity observed, but based on hair condition she probably was mounted.
Oly	25 Feb	Morning, Oly in estrus. Hugo butting Oly as she stands passively.

Moose	Date	Observation
		9:30-9:40 a.m., Hugo mounted at least 4 times.
		Zumu mounted Oly once, then fell off as Oly ran.
Janie	27 Feb	8:30-8:40 a.m., Hugo mounted (or tried to mount) 6 or 7 times. Between attempts, he was very rough, butting and pushing Janie constantly.
		Late afternoon, Joker mounted or attempted to mount Janie 5 times within a few minutes. When he did mount, Janie's hind legs seemed to buckle. Joker is a "gentlemoose" compared to bully boy Hugo.
Angel	2 Mar	Hugo mounted Angel. (All cows in Pen 2 now).