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Division of Game
Federal Aid in Wildlife Restoration
Research Progress Report

EVALUATION AND TESTING OF TECHNIQUES FOR MOOSE MANAGEMENT

by
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Project W-23-1
Study 1.39
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PROGRESS REPORT (RESEARCH)

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SUMMARY

Several jobs were active during this reporting period. A manuscript was prepared summarizing (1) the techniques used to determine activity budgets of moose using leg-mounted tip-switch transmitters and (2) a computerized data acquisition system. Preparation of results from the activity study, which will appear in a Masters of Science thesis in 1988, is in progress. Studies of moose reproduction were continued. Seven female moose were bred during either their 1st (n = 4) or 2nd (n = 3) estrous period. Mean length of gestation (n = 5), excluding a female that did not produce a calf and one that produced an underdeveloped calf, was 229.4 ± SD 4.2 days. Mean birth dates for calves conceived during the 1st and 2nd estrous periods were 24 May and 9 June, respectively. We are currently measuring growth and development in these calves.

A newly synthesized tranquilizer drug, R51163 (purina alkyl piperidine, Janssen Pharmaceutica Research Laboratory, Beerse, Belgium; supplied by Wildlife Laboratories, Fort Collins, Colorado), was tested on 6 bull moose at various dosages. When given at 0.4 mg/kg of body weight, the drug caused a significant ($P < 0.05$) reduction in the intake of dry matter in the treatment group for up to 2 weeks after the injection. The drug also appeared to affect the resting metabolisms of drugged individuals, compared with those of controls. A proposal to measure total body fat in moose was drafted during this reporting period, and preliminary testing will begin next winter. Preparations were made to install a section of special electric fence to test the feasibility of using such fencing to keep moose off the railroad tracks between Talkeetna and Willow. Chemistry of saliva collected from 2

bull moose during the rut indicated that there was 0.48 ng/ml ± 0.17 of 5a-androst-16-en-3-one (n = 15). Recommendations for continuation of studies are presented.

Key Words: activity, Alces alces, androstenones, breeding, electric fencing, estrous cycle, gestation length, moose.

CONTENTS

BACKGROUND

The Moose Research Center (MRC) 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 1986 have been published (Franzmann et al. 1974, Franzmann and Schwartz 1982, Franzmann et al. 1987); more than 30 papers in scientific journals (see Schwartz 1987) have also been published. These publications covered numerous disciplines: 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, developing a respiratory chamber, radioisotope digestion markers, and a carrying-capacity model.

This report contains information collected from 1 July 1987 through 30 June 1988. Jobs include (1) drug testing, (2) activity monitoring, (3) total body fat estimation, and (4) reproduction studies. We added a new job to evaluate the potential of electric fencing to restrict moose movements.

The activity study addressed diurnal moose activity and was 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. 1988a, 1988b); percent body fat was selected as 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 suitable techniques and determine if they are useful and applicable to moose.

Better assessment of "optimum" bull:cow ratios in Alaska moose populations required a thorough understanding of the estrus cycle. This entailed 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 as 25-30 days; however, the other necessary data have been speculative. At the MRC we conducted late-breeding experiments and, subsequently, were able to demonstrate that calves were born late (Schwartz et al. 1986). The consequences of altered or nonoptimum breeding during the rut have been attributed to low bull:cow ratios; however, we have no clear supporting evidence. Nevertheless, the issue remains, and systematic research is needed to help resolve the matter. Last year we measured the length of estrus in moose (Schwartz 1987). This year we looked at the effects of 1st and 2nd estrus breeding on growth and development of calves; we also measured gestation duration.

The Alaska Department of Fish and Game (ADF&G) has been working with the Alaska Railroad to evaluate ways of preventing moose-train collisions and thereby reducing or

eliminating the current high rate of moose mortality on the railroad right-of-way during winter. The potential of electric fencing to accomplish this objective is being evaluated at the MRC.

Moose rutting behavior involves many complex social interactions between the bull and cow (Bubenik 1987). Moose, like many other ruminants, are spontaneous ovulators. In prime animals, the annually recurrent puberty begins earlier in males than in females; generally, it occurs just before the autumn equinox. One of the attributes of cow moose is the individual timing of her estrus. This timing can be advantageous when the sex ratio is skewed and the bull moose needs a recuperation period after each mating (Bubenik and Timmermann 1982). This individual timing can cause protracted rutting and calving (Bubenik 1987). Therefore, the disposition to induce estrus may have an advantage in northern latitudes where short breeding periods are necessary for survival of the rutting bull as well as calves born late in the season.

In order to induce and synchronize the rut and thereby spare the semen reserves of the male (Bubenik 1987), many stimulating cues have evolved among northern cervids. One of these is the use of sex pheromones of the urine and saliva; the former are carried on the tarsal gland tufts on which both sexes urinate (Bubenik et al. 1979), and the latter are dropped by the salivating bull and/or smeared from the bull's chin and bell by the female.

Based on the pilot studies with red deer (Cervus elaphus), Bubenik and Claus (unpubl. data) showed that the concentration and secretion of the androstenone group sex pheromones (discovered by Claus and Gimenez [1977] in the wild boar [Sus scrofa]) correlate with age and sexual performance of the stag. Accordingly, we decided to conduct similar studies with moose.

OBJECTIVES

Study Objective

1. To test and evaluate techniques that are potentially useful for management of moose.

Job Objectives

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

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

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

5. To investigate the basic parameters of moose reproduction.

6. To design and test a one-way gate for moose.

7. To test miscellaneous techniques.

METHODS

Drug Testing (Job 2)

Many of our studies at the MRC would be enhanced if we could routinely collect blood samples in conjunction with ongoing research. In the past, we have drawn venous blood from undrugged individuals with limited success. Because immobilization with narcotics is stressful to individuals, entails a certain risk of mortality, and cannot be done when temperatures are warm, we have not routinely drugged our moose for the sole purpose of taking blood samples. Consequently, the types of physiological studies we can conduct have been limited. We are continually searching for a drug that would allow us to bleed our animals with a minimal effect on other physiological parameters. We tested the new tranquilizer drug R51163 on moose during this reporting period. We evaluated the drug's effectiveness to relax animals to the point where we could safely draw a blood sample. We also evaluated the drug's effects on dry-matter intake and resting metabolism to determine if there were latent effects on these physiological parameters.

We used 6 adult bull moose (age ≥2 years) to test this drug. Experimental design followed that recommended by Fleiss (1986:263-275) for a 2-period crossover study. Basically, animals were divided into 2 groups: treatment and control. Treatment animals were given the drug, and the dependent variable (i.e., intake or heat production) was measured in both groups. This testing was followed by a period of rest to allow any residual effects of the drug to pass. Finally, the control and treatment groups were reversed, and animals were again tested. Moose were randomly divided into the 2 groups. During intake and heat production trials, drugged animals were given 0.4 mg of R51163 per kg of body weight while they stood on the scale. Animals in the control group were weighed but not given the drug.

For studies of dry-matter intake, each moose was maintained in a separate 3.1- x 15.2-m pen while daily intake of dry matter was measured. Protocol followed that of Schwartz et al. (1984). Heat production was estimated using an indirect respiration chamber (Regelin et al. 1981), following recommendations and the protocol described by Hubbert (1987). We estimated the heat production of fed animals while they were lying calmly in the chamber.

Effects of various dosages, ranging from 0.2 to 0.6 mg/kg, were tested with individual moose. We evaluated the response of each moose to our presence as well as our ability to bleed each one while it stood on the scale. We monitored each individual for ataxia, noted recumbency, consciousness, respiration rate, and response to our approach at 1, 3, 6, and 12 hours after the injection.

Activity Monitoring (Job 3)

A paper illustrating the techniques used in this study has been submitted for publication to Alces; the abstract is presented in Appendix A. Results of the study have been analyzed and will be published in a Master of Science thesis that will be completed in 1988.

Total Body Fat Estimation (Job 4)

A study design to test the most promising techniques to estimate total body fat in vivo was prepared during this reporting period (Appendix B). Work on the project will begin during the winter of 1988-89.

Reproductive Studies (Job 5)

Seven female and 2 male moose (ages ≥ 2.5 years) were used to determine the length of estrus (i.e., the period of sexual receptivity), the length of the estrus cycle (i.e., number of days between each estrus), and gestation duration. All animals were semitame and maintained at the MRC. Animals were held in 2- to 10-acre enclosures during the study and fed a pelleted ration (Schwartz et al. 1985). We randomly divided the 7 cow moose into 2 treatment groups. Four cows in the control group were maintained in one of the holding pens with an intact (i.e., not vasectomized) mature bull. Three cows in the 2nd group were maintained in another pen with a surgically vasectomized bull. All animals were observed daily from the first week of September through mid-November. Dates of breeding (i.e., bull mounting a cow) were noted for each female.

Females in the holding pen with the vasectomized bull were then placed in the pen with the intact bull about 2 weeks after they had been observed mating with the vasectomized bull. These cows were again observed to determine the date of breeding with the intact bull.

Following breeding, females in both groups were observed to determine whether or not another estrus (i.e., 19 to 26-day cycle) had occurred (i.e., pregnant or not pregnant). Following the breeding season, all moose were maintained together and fed a pelleted ration throughout the winter.

During the calving season, each cow was checked several times daily to record time and date of calving. On the day of birth, calves were weighed on a spring scale (Salter No. 235, London, England), ear tagged, and fitted with a calf mortality transmitter (Telonics Inc., Mesa Arizona). When the calves were approximately 2 weeks old, they were released with their cows into the large enclosures of the MRC. Each cow had access to pen Nos. 2 and 3, which contained regrowth vegetation from the 1947 burn and recently crushed vegetation from our crushing program. Radio signals from each calf were checked daily for mortality mode, and the calves were observed every 3-5 days during the summer. Growth and development were measured (i.e., weight gain/day) from time of birth until fall.

Test Electric Fencing (Job 6)

This job has been completed (Schwartz 1987).

Miscellaneous Projects (Job 7)

We collected 15 saliva samples from bull moose during the major part of the rut. Determinations for androstenes were carried out by Dr. C. R. Claus (Institute for Animal Behavior and Animal Rearing, University of Hohenheim, Stuttgart, West Germany), following procedures (i.e., enzyme-immunoassay system) described by Claus (1974). Sample preparation included extraction with hexane followed by a solvent distribution against 90% methanol. Aliquot portions of the methanol containing the steroid were dried and measured in the assay system. Alternatively, for more specific determinations of the corresponding androstenols (i.e., musk odor), the extracts were transferred on thin-layer plates and chromatographed. The radio immunoassay was carried out after individual elution. The values were corrected for procedural losses.

We plan to test the ability of an electric fence to physically deter moose movements. During this reporting period, we met

with the distributor of The Gallagher Snell Power Fence. Preliminary arrangements have been made to construct approximately one-quarter mile of fence that will be divided into 2 holding pens. Testing will begin in the fall of 1988.

RESULTS AND DISCUSSION

Drug Testing (Job 2)

We tested R51163 on 6 bull moose in 2 separate trials. Because 1 bull was not tractable, we had an unbalanced design that resulted in complications in statistical analysis. Consequently, some statistical tests have not been included in this report.

We tested 2 dosages of R51163 in moose: 0.2 and 0.4 mg/kg of body weight (Table 1). We did not test the 0.6 mg/kg dosage because we observed adverse effects with our larger bulls at 0.4 mg/kg. Response was varied and somewhat dependent on individual personality of the moose; for example, Bill, a semi-wild bull, could not be bled with either the 0.2 or 0.4 mg/kg dosage, while Sockeye and Chief, both very tame bulls, were easily bled at a dosage of 0.4 mg/kg. The effect of R51163 on each moose varied, but the response was generally greater with larger individuals. This effect was expected because the calculated dosage for large mammals does not increase linearly with body weight; larger animals tend to require smaller dosages per unit weight.

Generally, we felt this sedative would not effectively allow us to repeatedly collect blood samples without significantly affecting other physiological parameters. Animals under the effect of R51163 exhibited a "sleepy state", except when approached or handled. When aroused, they were less tractable than when not drugged. Some showed a general fear response; on 3 occasions moose kicked violently when touched. The drug appeared to heighten this defensive response, which in tractable moose is normally not present. We also noticed that when Bando, the largest bull, was dosed with 0.4 mg/kg, he could not stand on all 4 feet, although he tried many times. He finally moved around his holding pen on his front carpel joints and rear hooves. This body stance resulted in an injury to the carpel joint that ultimately developed into an infection. During this time he would push his nose into the soil of his holding pen in an attempt to "push himself to his feet." He also filled his mouth with soil and gravel and chewed them.

Quivering of the major muscle groups of the hind legs was noted in 2 bulls dosed with 0.4 mg/kg. One bull, Sockeye,

that was normally very calm appeared to "fight the drug"; he stood in both the chamber and his holding pen for hours, when all other moose, including the others drugged in his treatment group, were lying down.

The effect of R51163 on seasonal metabolism was variable (Figs. 1-10). Heat production (median response) did not differ between drug and control trials (t = -0.072, P = 0.948, Table 2); however, response of drugged moose, most notably Bill (Fig. 1) and Chief (Fig. 4), exhibited cyclic fluctuations. Drugged moose appeared to be calmly sleeping in the metabolic chamber; however, heat production measurements reached peaks and troughs at 1- to 2-hour intervals. Physiologically, we do not know why this response occurred; it did not occur in the control animals.

Dry-matter intake was significantly impacted by R51163. Like other responses, the effect of depressed intake was most pronounced in large animals (Fig. 11). Significant declines in intake resulted in weight loss in treated animals (Table 3).

Based on the research reported here, we do not feel that R51163 meets the requirements for a sedative that will reliably allow us to draw blood samples from moose and yet have little or no long-term adverse affects on other physiological parameters.

Activity Monitoring (Job 3)

A manuscript describing the system used to monitor moose activity was prepared during this reporting period (Appendix A). A Master of Science thesis covering the results of field studies will be completed in 1988.

Total Body Fat Estimation (Job 4)

A study proposal was prepared for continuation of this job (Appendix B).

Reproductive Studies (Job 5)

Results of our reproductive observations (i.e., estrus cycles) (Table 4) agreed with data from last year. The length of time between 1st and 2nd estruses for 3 females was 22, 24, and 25 days. In 1986 the modal date between estrus cycles was 25 days.

Length of gestation for 5 females was 229.4 ± SD 4.2 days. If we include one observation (1985) from a female that bred on 7 Oct and birthed on 2 June (gestation of 238 days), the mean

becomes 230.8 ± SD 5.2 ($\underline{n}$ = 6; range, 224-238). This gestation length is longer than that (216-218 days) reported by Stewart et al. (1985), within the range reported by Markren (1969) for moose in Sweden and the Soviet Union (226-244 days), but shorter than that reported for North America (240-246 days) by Peterson (1974).

All calves were weighed (Table 4), fitted with radio-collars, and released into pen Nos. 2 and 3. No data on growth, development, or mortality were available for this reporting period.

Miscellaneous Projects (Job 7)

The mean concentration of androstenone identified in 15 saliva samples was 0.48 ng/ml ± SD 0.17 of 5a-androst-16-en-3-one. These concentrations were lower than those found in red deer ($\underline{X}$ = 40 ng/gm; range, 10-80) (A. Bubenik, unpubl. data). Using thin-layer chromatography, the musk scent components were identified as 3.5 ng/ml of 5a-androst-16-en-3a-ol (very strong musk-scent) and 3.5 ng/ml of 5a-androst-16-en-3b-ol (weak musk-scent).

We met with the distributor of Gallagher Snell Power Fencing and made arrangements to construct 2 holding pens. We will test this fencing in the fall and winter of 1988.

RECOMMENDATIONS

We will continue to evaluate new drugs and related products as they become available for use; no new products are currently available. Recommendations for the activity study will be included in the Masters thesis. Several techniques to estimate body composition of moose will be tested in the fall of 1988. Testing of the new electric fence will begin in the fall of 1988. We plan to collect saliva, urine, and serum samples from 2 bull moose beginning in mid-July and continuing through antler drop to determine the concentration of pheromones present. This project will be conducted in cooperation with Dr. A. B. Bubenik.

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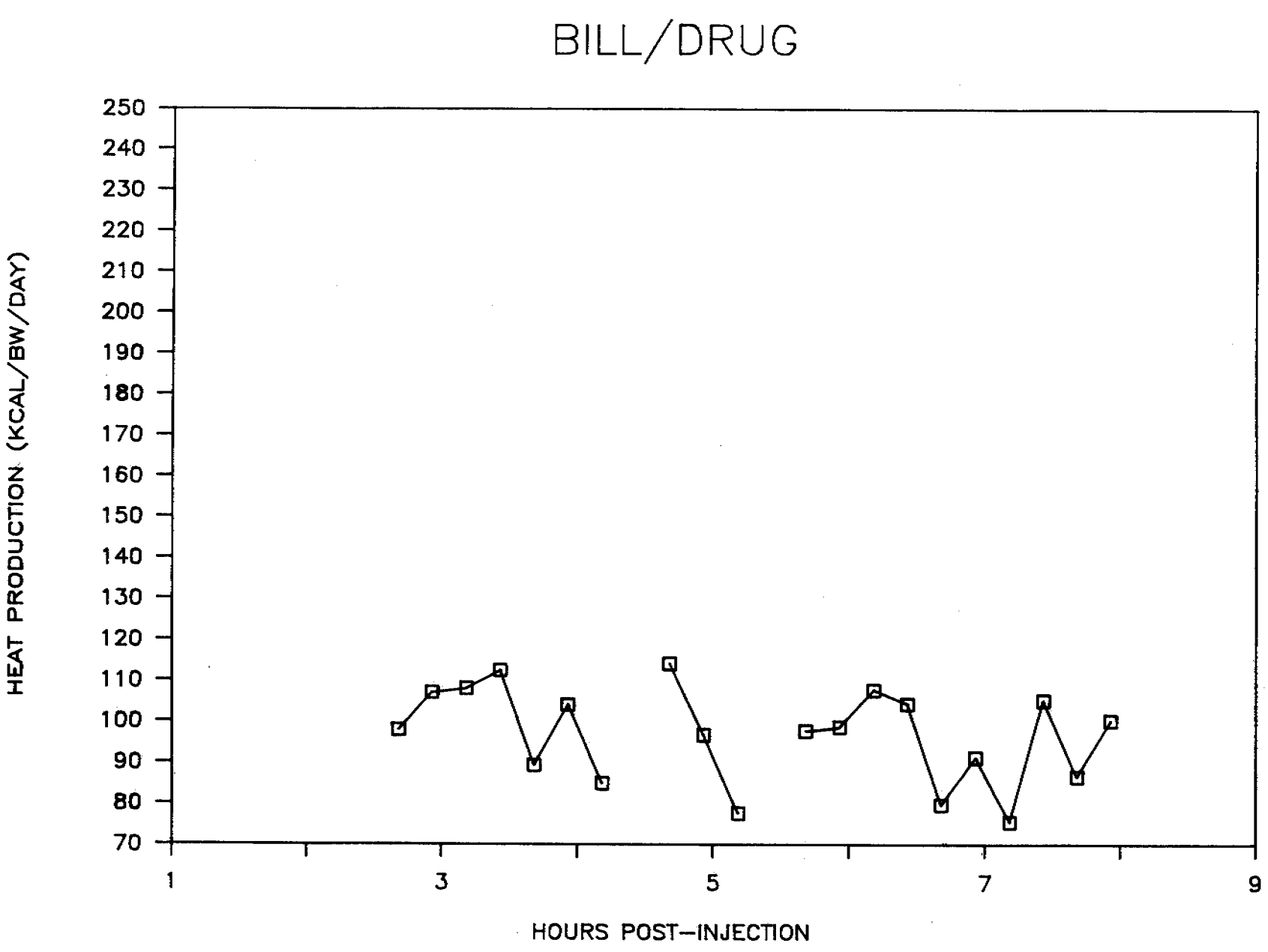

Figure 1. Resting heat production of adult male moose, "Wild Bill," after injection with 0.4 mg/kg R51163. Missing data indicate periods of activity.

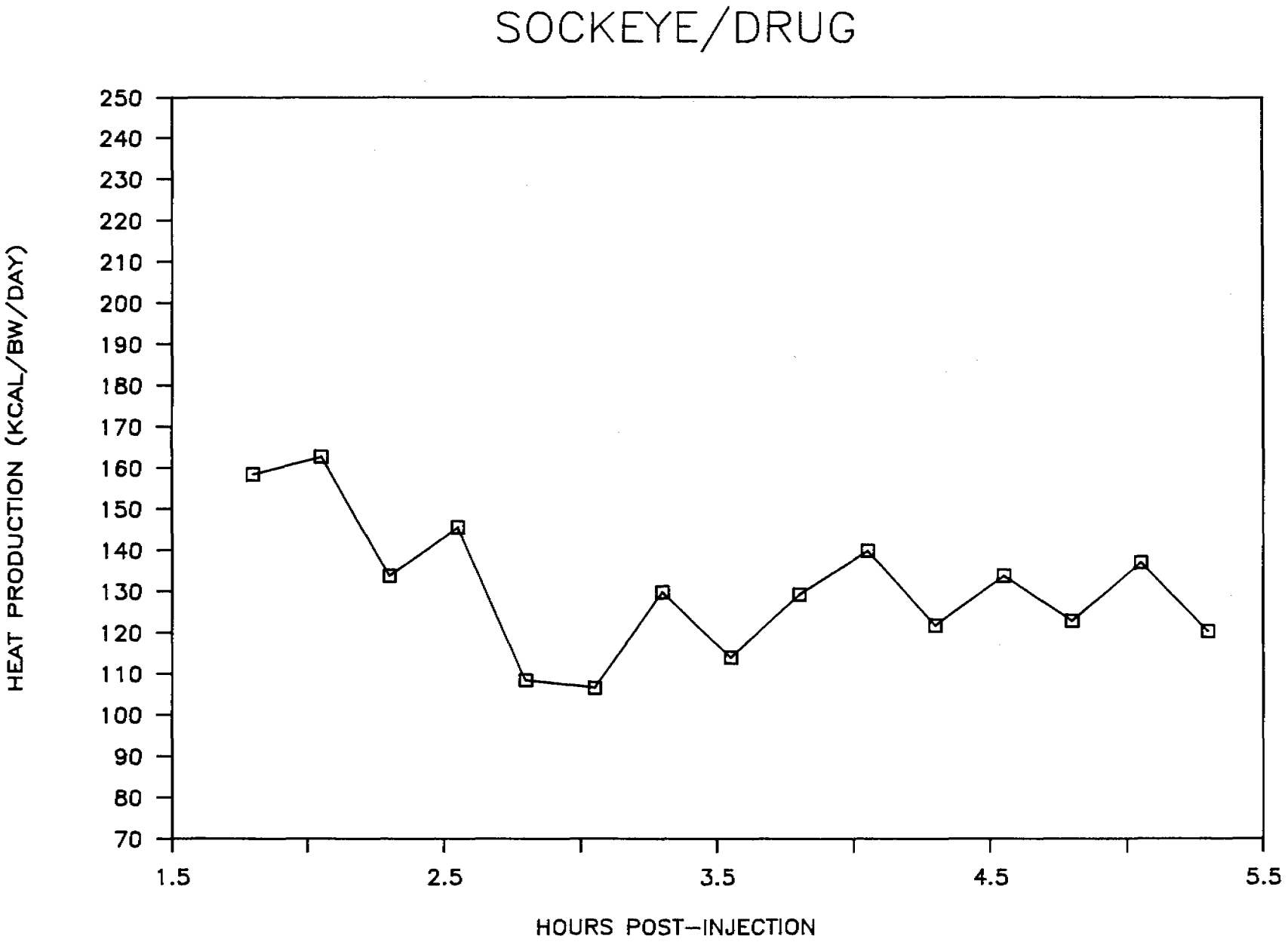

Figure 2. Resting heat production of adult male moose, "Sockeye," after injection with 0.4 mg/kg R51163. Missing data indicate periods of activity.

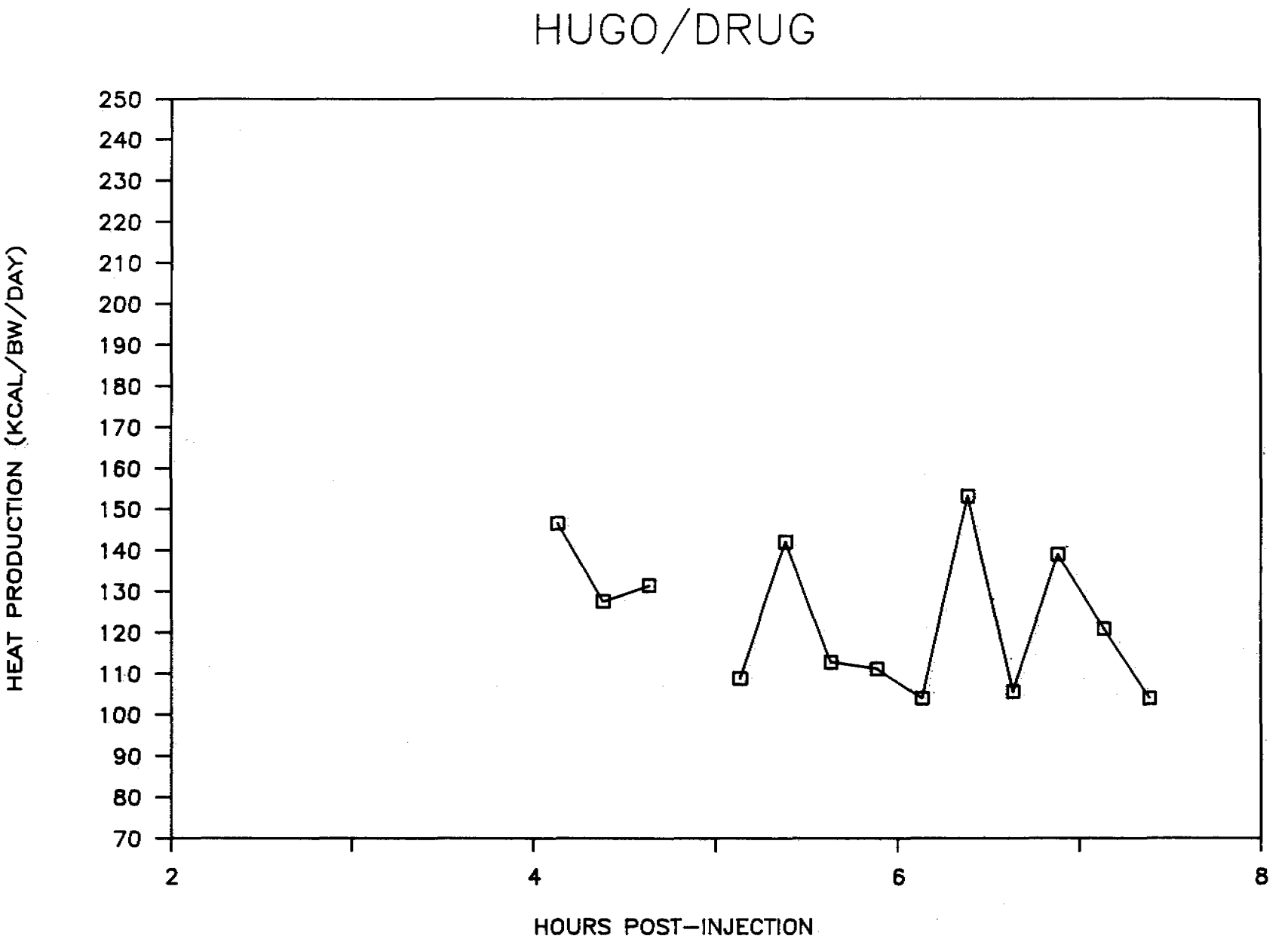

Figure 3. Resting heat production of adult male moose, "Hugo," after injection with 0.4 mg/kg R51163. Missing data indicate periods of activity.

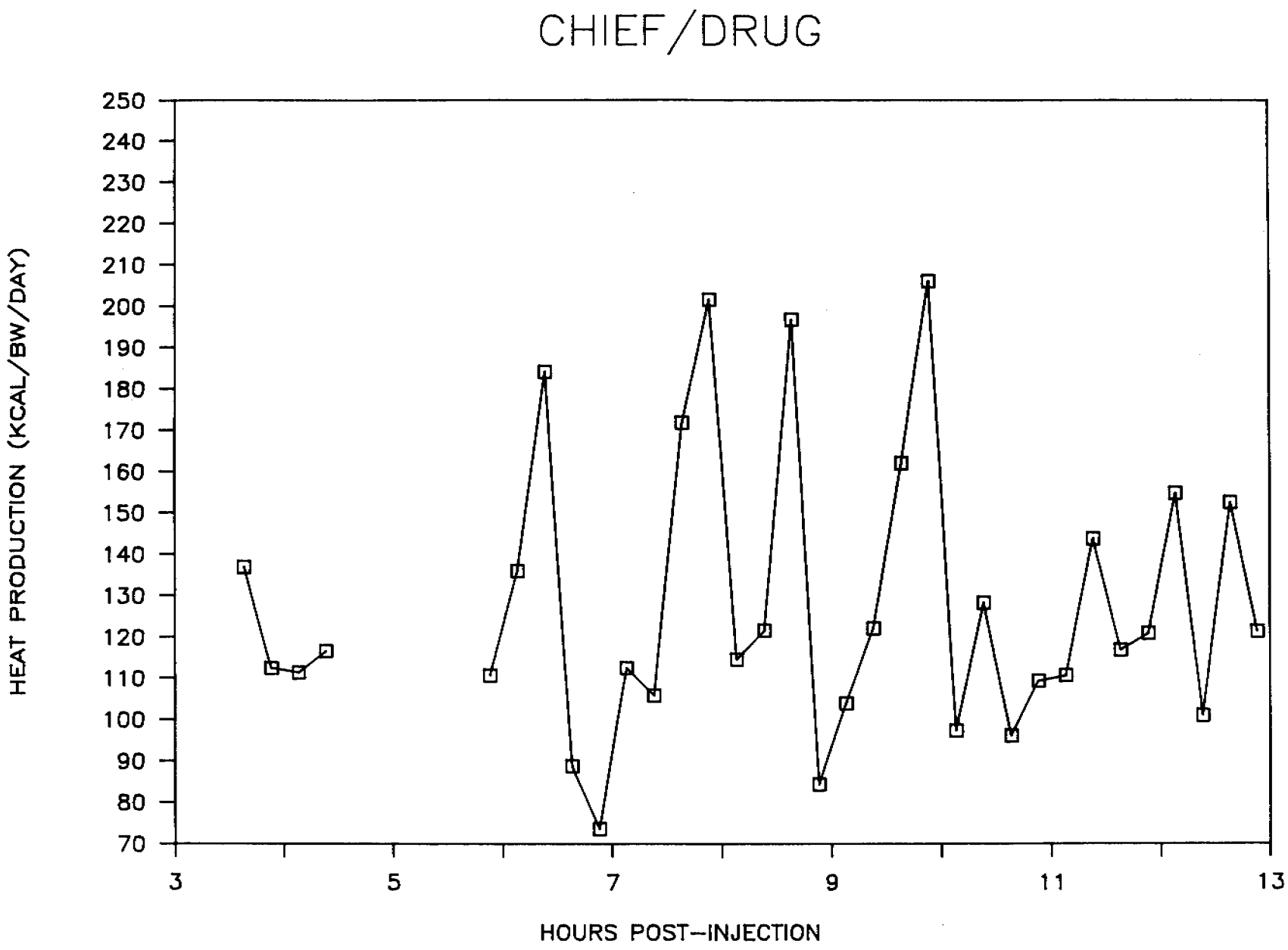

Figure 4. Resting heat production of adult male moose, "Chief," after injection with 0.4 mg/kg R51163. Missing data indicate periods of activity.

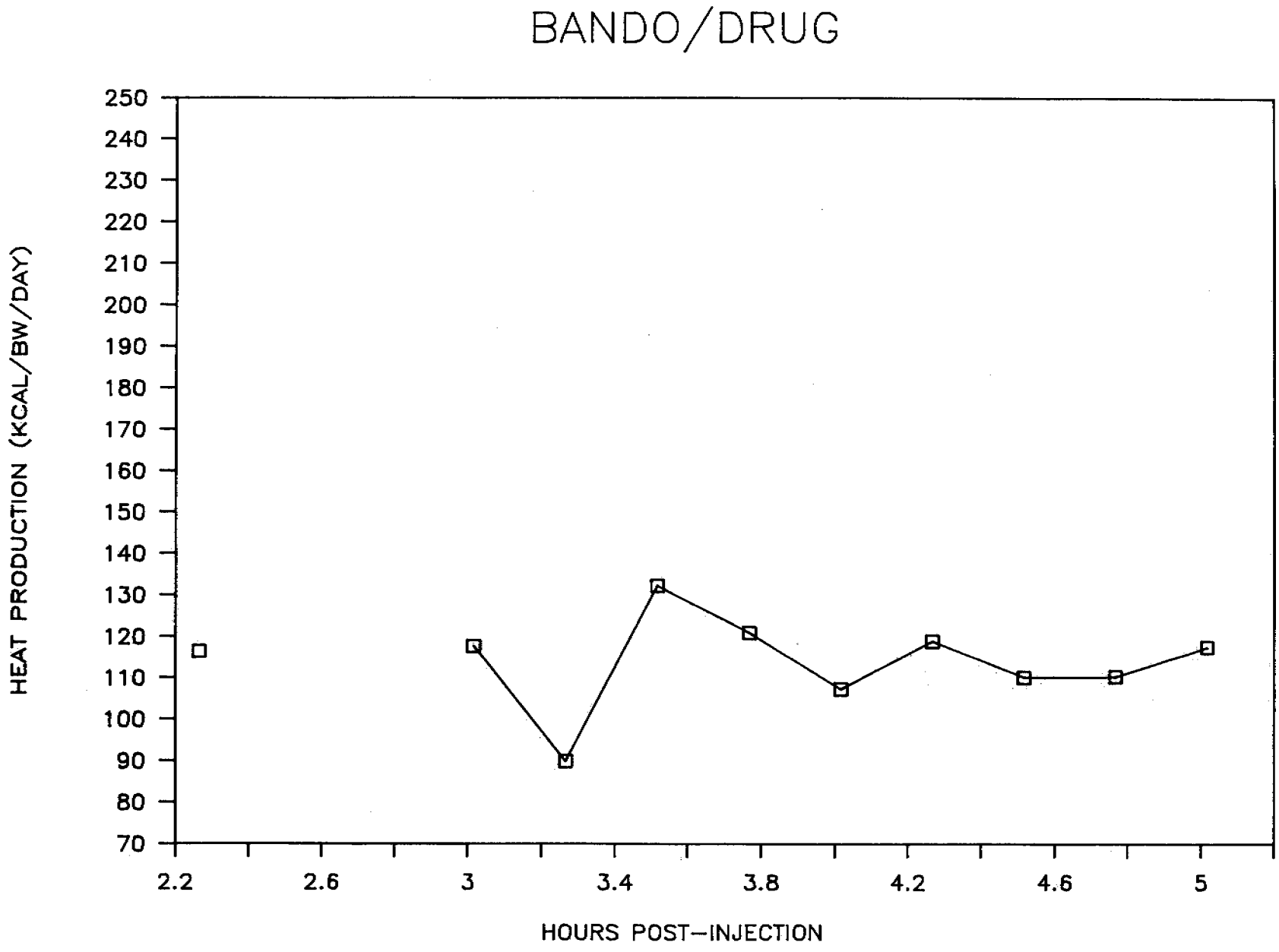

Figure 5. Resting heat production of adult male moose, "Bando," after injection with 0.4 mg/kg R51163. Missing data indicate periods of activity.

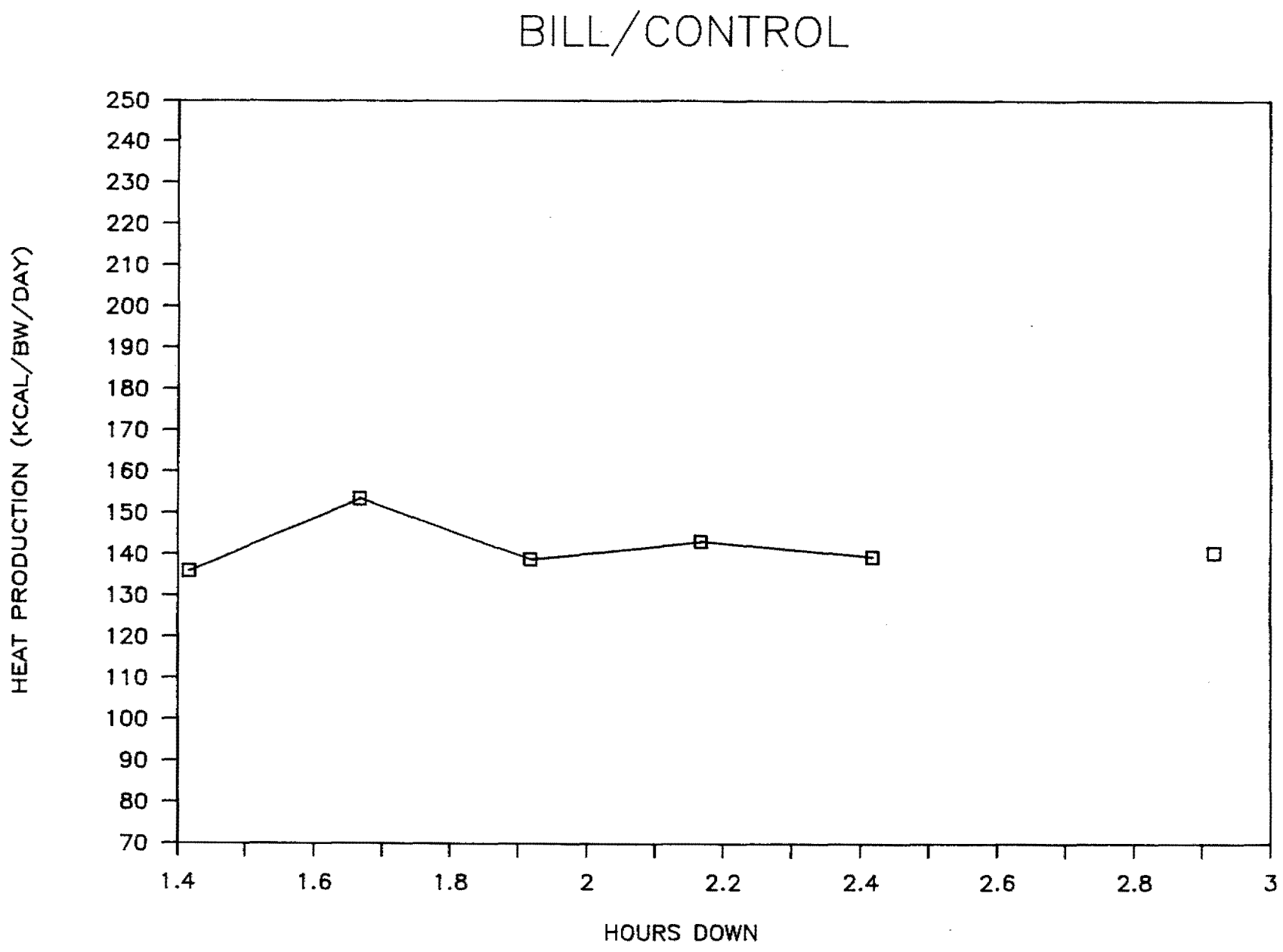

Figure 6. Resting heat production of adult male moose, "Bill," control. Missing data indicate periods of activity.

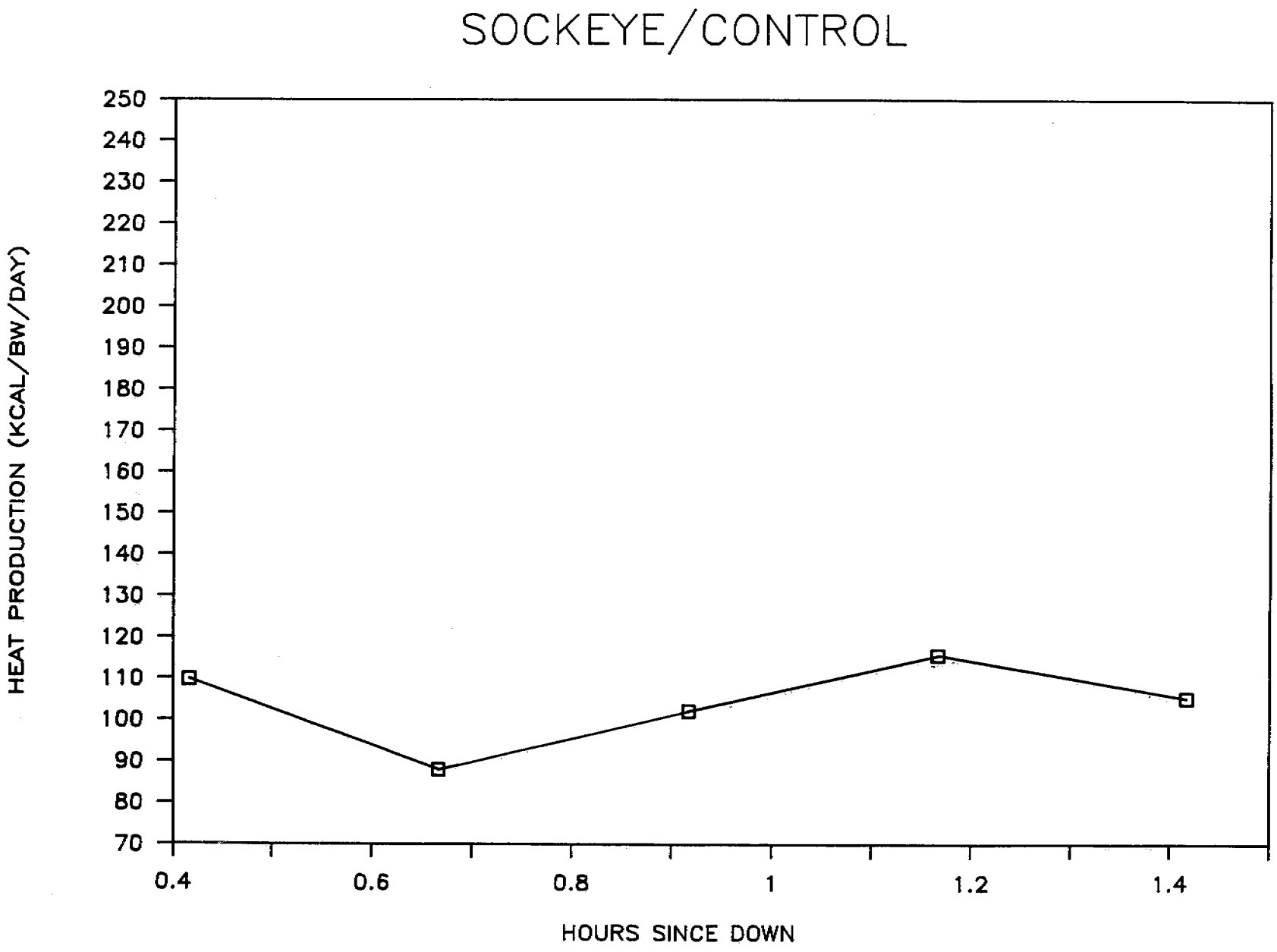

Figure 7. Resting heat production of adult male moose, "Sockeye," control. Missing data indicate periods of activity.

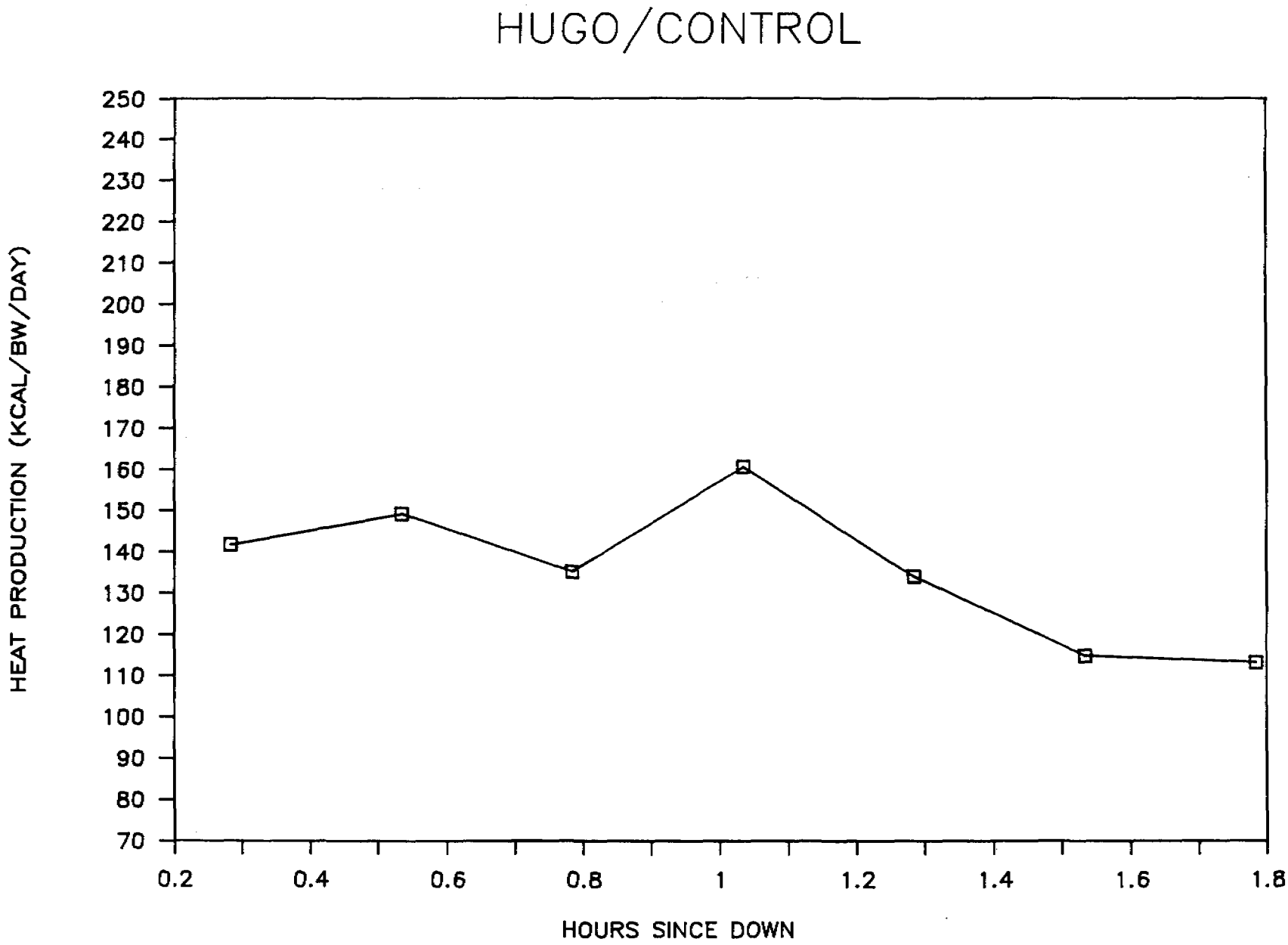

Figure 8. Resting heat production of adult male moose, "Hugo," control. Missing data indicate periods of activity.

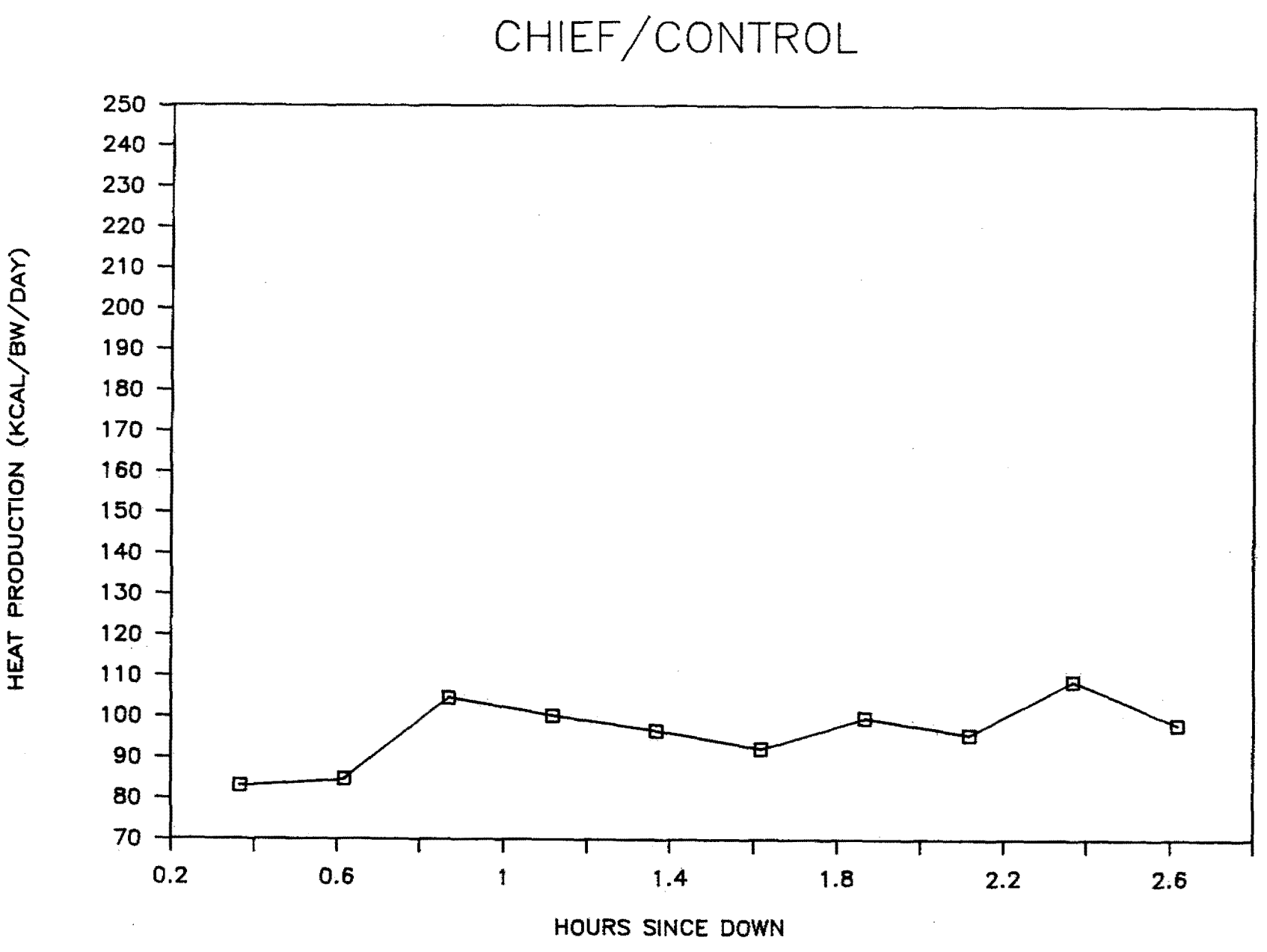

Figure 9. Resting heat production of adult male moose, "Chief," control. Missing data indicate periods of activity.

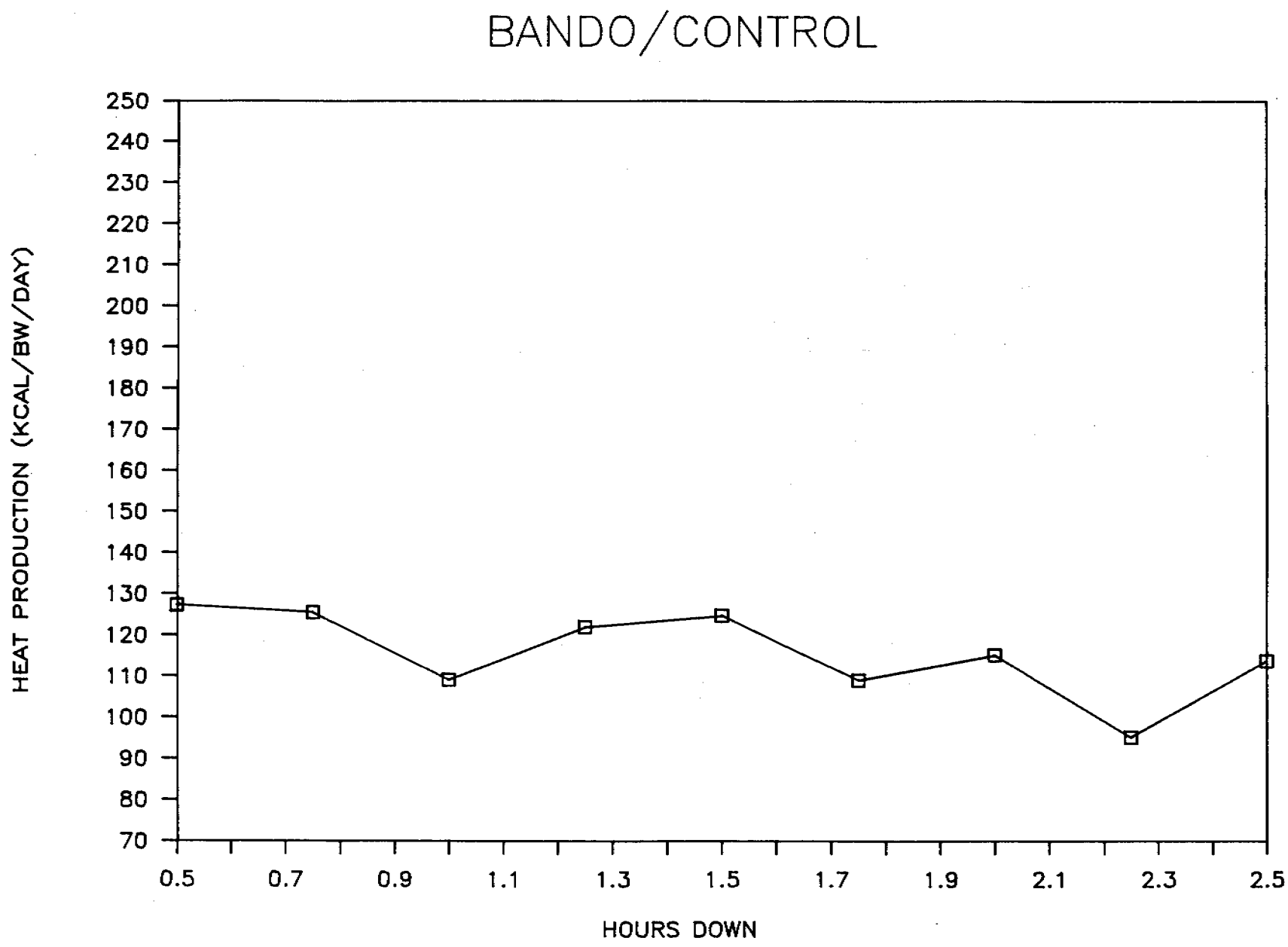

Figure 10. Resting heat production of adult male moose, "Bando," control. Missing data indicate periods of activity.

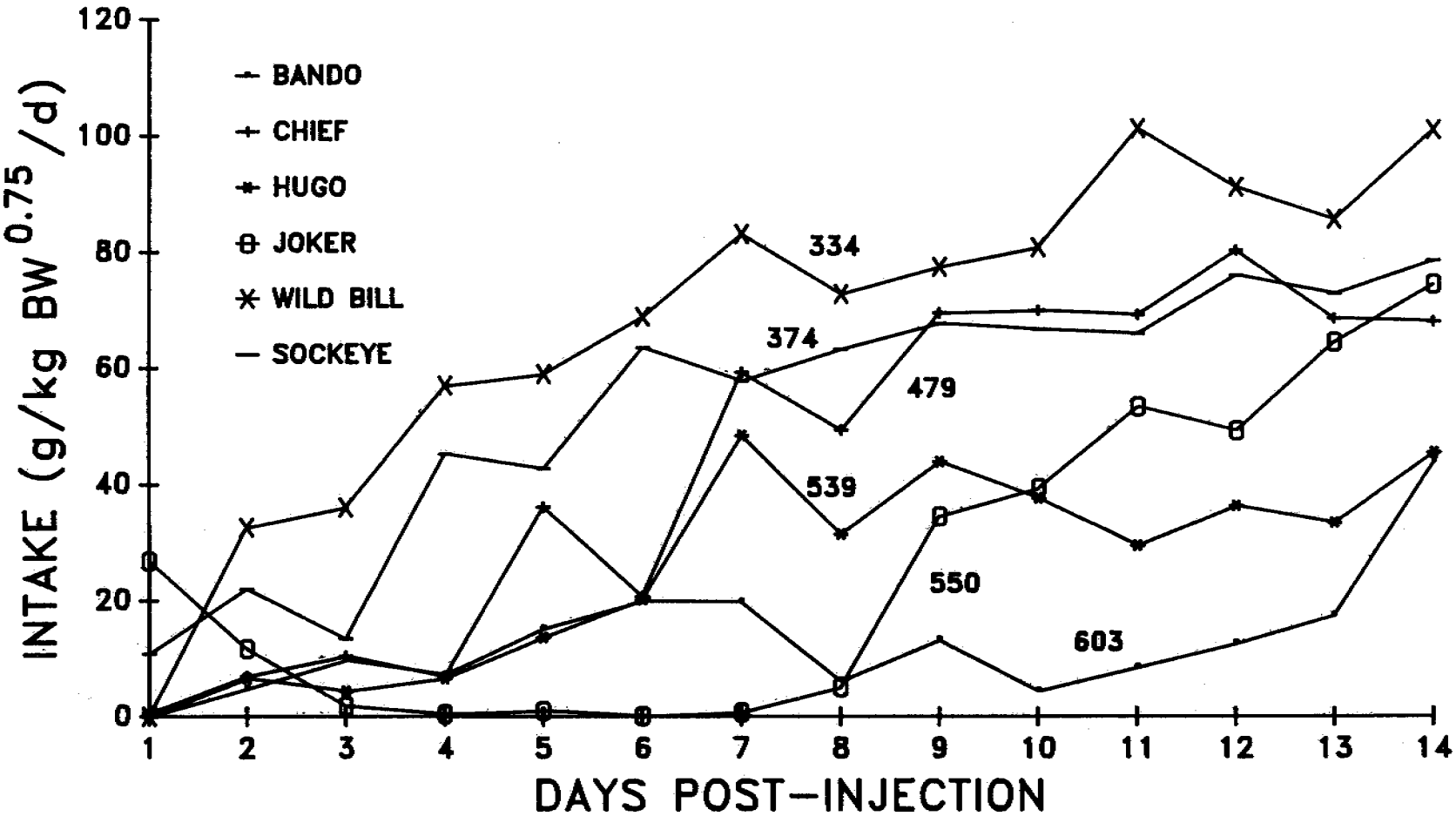

Figure 11. Dry matter intake of a pelleted ration after injection with 0.4 mg/kg R51163. Numbers next to lines indicate weight (kg) of corresponding animal.

Table 1. Dosage, animal weight, and response of animals to a test sedative R51163 at the Moose Research Center, 1988.

Animal name	Weight (kg)	Dosage (mg/kg)	Score (hours post injection) Ataxia[a] 1	3	6	12	Recumbency[b] 1	3	6	12	Consciousness[c] 1	3	6	12	Approach Reaction[d] 1	3	6	12
Sockeye	383	0.4	1	1	1	1	2	2	4	3	2	2	3	3	2	2	3	3
Bill	346	0.2	1	1	1	1	2	2	2	2	2	2	2	1	1	1	1	1
Chief	509	0.4	3				3	4	4	4	3	3	3	3	3			
Bill	334	0.4					2	2	2		2	2	2					
Hugo	547	0.4	3	3	3	3	2	2	2	2	3	3	3	3				
Bando	602	0.4	3	3	2		3	2	2		2	2	2					
Sockeye	371	0.4	2	2			3	3			2	2						
Hugo	539	0.4	1				3			4	2			3				
Chief	479	0.4					4			4	3			3				
Sockeye	374	0.4	1				3				2			3				
Bill	346	0.4	2	1	1	1	2	1	1	1	2	2	2	2	1	2	2	1
Bando	603	0.4	3	4	4		3		4	1	3		4	2	3			3

[a] Ataxia score: 1 = none, no staggering, 2 = slight stumbling, 3 = obvious difficulty in walking, 4 = cannot walk.

[b] Recumbency scores: 1 = standing with head up and alert, 2 = sitting or in sternal recumbency with head up, alert, 3 = standing with head down, not alert, and 4 = in sternal or lateral recumbency with head down.

[c] Consciousness scores: 1 = alert, no sign of tranquilization, 2 = alert, but calm and relaxed, 3 = somewhat aware of surroundings, but very slow to respond, and 4 = appears unaware of surrounding, dissociative.

[d] Approach Reaction scores: 1 = moves away as if not tranquilized, 2 = aware, attempts to move away but slow to respond, 3 = aware, but no attempt to move, very calm and relaxed, and 4 = no reaction, unaware of being approached.

Table 2. Median resting heat production (kcal/kg BW0.75/d) of adult male moose during drug (0.4 mg/kg R51163) and control trials at the Moose Research Center, 1988.

Animal	Trial sequence[a]	Heat Production	
		Trial 1	Trial 2
Bando	C/D	115	117.5
Sockeye	C/D	105	130
Chief	D/C	117	97.5
Hugo	D/C	121	135
Bill	D/C	98.5	140

[a] C/D signifies Trial 1 = control and Trial 2 = drug. D/C signifies Trial 1 = drug and Trial 2 = control.

Table 3. Animal, treatment, weight, and intake of dry matter for moose injected with R51163 at the Moose Research Center, Kenai, Alaska, 1988.

Animal	Beginning date of trial	Treatment	Body weight	Mean weight change (kg/day)		Mean intake (g/kg $BWO^{.75}$/d)	
				wk 1	wk 2	wk 1	wk 2
Bando	21 Mar	Control	574	2.6	1.6	78.0	84.8
Bando	4 Apr	R51163	603	-8.7	-0.9	10.9	15.1
Chief	21 Mar	R51163	479	-1.1	2.0	20.1	67.7
Chief	4 Apr	Control	485	-0.7	2.0	68.7	78.8
Hugo	21 Mar	R51163	539	-5.7	-1.6	14.2	36.8
Hugo	4 Apr	Control	488	1.9	3.1	75.3	89.0
Joker	21 Mar	Control	556	0.7	-1.6	80.3	67.3
Joker	4 Apr	R51163	550	-4.0	1.0	6.1	45.7
Bill	21 Mar	Control	334	0.6	1.1	70.0	78.7
Bill	4 Apr	R51163	346	-1.9	3.0	48.1	87.1
Sockeye	21 Mar	R51163	374	-0.3	0.3	36.5	70.1
Sockeye	4 Apr	Control	374	1.4	1.3	83.0	85.4

Table 4. Reproductive observations of seven captive female moose at the Kenai Moose Research Center from September 1987 to July 1988.

Moose	Date of estrus	Type of data[a]	Time between estrus periods (days)[b]	Date of vaginal discharge	Length of estrus (hrs)	Date of parturition	Length of gestation (days)	Calves sex	Calves weight (kgs)
Zumu	27 Sep	O		2 Oct	--	7 June	232	M	12.9
Zumu	19, 20 Oct	O	22	22 Oct	15-?			F	13.3
Oly	6 Oct	O			--	24 May	231	F	16.0
Janie	7 Oct	O			--	Not pregnant			
Trixie				26 Sep					
Trixie	11 Oct	O			--			F	17.3
Trixie	5, 6 Nov	O	25	8-9 Nov	24-?	18 June	226		
Deneki				22-23 Sep					
Deneki	12 Oct	O		14, 16 Oct	--	3-7 July		F	4.3
Betsy				1, 3 Oct				M	13.3
Betsy	14 Oct	S			--	25 May	224	F	12.3
Angel	30 Sep, 1 Oct[c]	S				14 June	234	M	13.4
Angel	24 Oct	O	24		--			F	5.4

[a] O = Observed breeding, S = suspected estrus based on indirect evidence.
[b] Time between first observed mounting of each estrus period.
[c] Estimated date based only on Angel's behavior in Pen No. 2 and Hugo's behavior across fence in Pen No. 2.

Appendix A.

DETERMINING MOOSE ACTIVITY BUDGETS USING LEG-MOUNTED TIP-SWITCH TRANSMITTERS AND A COMPUTERIZED DATA ACQUISITION SYSTEM

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Abstract: Leg-mounted mercury tip-switch radio transmitters used in combination with a computerized data acquisition system (Telonic's, Inc., Mesa, AZ) were tested for the detection of 3 activities in moose (Alces alces): lying, standing, and walking. Transmitters were mounted on the lower front legs of 9 study animals with a nylon harness. Mercury switches were positioned so that signal pulse interval was long during standing, short during lying, and variable during movement. The data acquisition system was programmed with frequencies to be sampled, sample period length, number of samples per sample period, and time between samples.

Signal patterns predicted active and inactive bouts correctly 99.2% and 89.4% of the time, respectively. Errors resulted when transmitter switches failed to trip when animals laid down or when animals held their legs at an angle while feeding. Error was reduced by using a sampling design that optimized the detection of movement during active periods (3-minute sample periods) and allowed comparisons of consecutive samples so that samples containing ambiguous data could be reevaluated (15-minute intervals). The number of steps taken within 808 15-second periods was predicted within 1 step 95% of the time. Lengths of individual walking bouts lasting over 5 seconds were predicted with a high degree of accuracy.

The system was further tested during a study in which 189 24-hour activity budgets were obtained. The accuracy of estimating time spent walking, time spent active, and length of individual active and inactive bouts is reported.

ALCES 24 (1988)

Appendix B.

ESTIMATION OF TOTAL BODY FAT IN MOOSE, A PROPOSAL

In Vivo Techniques

Wildlife managers have long sought to measure carrying capacity of wildlife habitat in an effort to better manage populations. Knowledge of habitat condition (quality and quantity) and animal requirements is necessary for ultimately determining carrying capacity. However, obtaining reliable habitat data is often costly and time-consuming (Regelin et al. 1986), and assessing animal requirements often requires critical assumptions concerning animal-habitat interactions (Schwartz et al. 1988).

An alternative to direct measurement of carrying capacity is using animal condition as an indicator of habitat quality (indicator animal concept [Franzmann 1971]). Measurement of body composition (% protein, fat, water, and ash) is a direct indicator of condition and an indirect measurement of nutritional carrying capacity of the habitat (Hubbert 1987, Schwartz et al. 1988).

Hubbert (1987) developed a carrying-capacity model for moose (Alces alces) that is based on animal condition. For the purposes of the model, body condition is expressed as percent body fat. Many methods exist for estimating percent body fat; however, they are impractical for use in the field with live animals. A technique is needed that will provide accurate estimates of percent body fat in vivo that is also suitable for use in the field.

Among the techniques available for measuring percent body fat in vivo, those utilizing the marker dilution principle seem to hold the most promise for meeting our needs (Berg and Butterfield 1976). In brief, this technique relies on a marker that equilibrates with the body water pool of the animal. The size of the body water pool is directly related to the fat-free mass of the animal (Pace et al. 1947). A known amount of marker is introduced into the blood, and its concentration in the blood is measured after it equilibrates with the body water pool. If the weight of the animal is known, the percent body fat and percent fat-free mass can be estimated from the marker dilution.

Substances suitable as markers should possess the following qualities: (1) they should diffuse evenly and rapidly throughout the body water pool; (2) they must be nontoxic and physiologically inert; (3) their concentration in plasma or urine must be easily measured; and (4) they should not be

substances foreign to the body (Preston and Kock 1973). Markers that have been used for estimating body composition in wildlife include tritiated water (Torbit et al. 1985, Schwartz et al. 1988) and deuterium oxide (Rumpler et al. 1987). However, these two substances suffer from two major disadvantages: (1) relatively long equilibration times (measured in hours) and (2) they provide a biased estimate of body fat because the heavy hydrogen isotopes tend to replace normal hydrogen atoms in water molecules (Rumpler et al. 1987, Torbit et al. 1985).

A method that uses urea as a marker, developed for use in the livestock industry, holds promise for use with free-ranging animals because of relatively short equilibration times (12 minutes in cattle) (Preston and Kock 1973) and unbiased estimates of body fat in adult cattle (Rule et al. 1986). Although the usefulness of this technique has been documented extensively in cattle (Preston and Kock 1973; Preston et al. 1974; Kock and Preston 1979; Bennet et al. 1982; Bartle et al. 1983, 1987; Hammond et al. 1984, 1986; Bartle and Preston 1986; Rule et al. 1986; Hammond et al. 1988), it has never been tested in moose. Preliminary information is needed: (1) equilibration time, (2) form of the regression equation relating urea space to body fat, (3) sex- and age-related differences, and (4) effect of immobilizing drugs and excitability on urea dilution. This study will focus on determining equilibration time of urea in moose and describing the relationship between urea space and body fat.

Techniques Using Specimens From Dead Animals

It has long been recognized that animals on a declining nutritional plane catabolize body fat stores in the following order: (1) subcutaneous fat, (2) abdominal fat, and (3) bone marrow fat (Harris 1945). Techniques used to quantify condition of dead animals, short of a full necropsy, rely on this principle by using fat content of one or more organs to indicate which fat stores are being catabolized at a given time. Techniques based upon carcass fat (Bear 1971, Anderson et al. 1972), visceral fat (Bear 1971), bone marrow fat (Cheatum 1949), perinephric fat (Riney 1955), and combinations of several indicators (Connolly 1981, Kistner et al. 1980, Riney 1955) have been devised. All of these indices are useful to some extent but suffer from two major disadvantages: (1) they are useful only over a limited range of body condition and/or (2) they require specimens that are often difficult to obtain.

Use of muscle fat content as an indicator of total body fat has the potential to overcome the disadvantages associated with other techniques. Ringberg et al. (1981) reported

correlations of over 90% between percent carcass fat and percent fat of M. gastrochnemius (sic) and M. biceps femoris of reindeer (Rangifer t. tarandus). Huot and Goudreault (1985) reported a similar correlation between percent fat of M. gastrochnemius (sic) and percent body fat of caribou (R. t. caribou) collected in October, but the correlation was nonsignificant for animals collected in April. Fat content of a muscle group consisting of M. peroneus tertius, M. extensor digitorum longus, and M. extensor digiti III proprius was highly correlated ($P < 0.01$) with percent body fat (i.e., range, 2-15%) in both October and April (Huot and Goudreault 1985).

The peroneus muscle group is located in the lower hind leg; thus it is easily accessible, of little food value to humans, and could be collected at hunter check stations and from road kills. The potential for obtaining samples and the reported accuracy of this technique indicate that it may be useful for moose management.

METHODS

At least 3 male moose calves and 1 mature bull (age 3) will be used as experimental animals. These animals will be kept in captivity at the MRC and will be fed a formulated ration (Schwartz et al. 1985). Dry-matter intake will be controlled to produce animals on different nutritional planes. Animals will be weighed weekly.

Beginning in November, the animals will be subject to monthly urea space measurements. These measurements will be attempted initially by physically restraining the animals in a "squeeze chute" to be built adjacent to the scale house. If this proves impractical the animals will be chemically immobilized with xylazine hydrochloride (Rompun, Haver-Lockhart, Shawnee, Kansas) prior to sampling.

The urea dilution technique (Preston and Kock 1973) requires placement of a polyethylene catheter into the jugular vein through a No. 12 needle. A blood sample will be drawn. A solution containing 20% urea in physiological saline will be administered through the catheter at a rate of 66 ml/100 kg live weight (130 mg/kg). Blood samples will be drawn at 5, 8, 10, 12, 15, 20, 30, 60, and 120 minutes postinfusion (time 0) will be considered as the midpoint of the infusion; the infusion will take approximately 2 min to complete. Blood samples will be centrifuged at the MRC immediately after collection, and serum and blood cell fractions will be stored frozen until analyzed. The blood will be analyzed for condition-related parameters: blood urea nitrogen (BUN) (Preston and Kock 1973), packed cell volume, hemoglobin, total serum protein, phosphorus, and calcium (Franzmann et al. 1987).

Analysis will be performed by a contracted vendor facilitated through the Anchorage lab.

Urea space (US) will be calculated as follows:

$$US(\%)t = \frac{100\% \times \text{solution infused (ml)} \times \text{mg UN/100 ml}}{\text{live weight (kg)} \times 1000 \text{ ml/kg} \times \Delta \text{ BUN (mg/100ml)}}$$

where Δ BUN occurs between time t and time 0. These values will be plotted against the postinfusion time to determine equilibration time (identified by a leveling-off of the rate of decay of BUN in the plasma).

In March, these animals will be killed (i.e., one per week) and the percent fat of the carcasses will be determined. The animals will be eviscerated and skinned (with as much fat as possible being left on the carcass). The empty carcasses will be bisected along the spinal column. The right side of each carcass will be frozen. The digestive tract will be emptied, ingesta weighed, and the viscera frozen. The frozen right side of the carcass and the entire visceral mass will be cut into 25 mm slices on a commercial band saw. The sawdust that collects at the base of the blade will be collected, thoroughly mixed, and sampled for fat, protein, ash, and water content (Huot and Goudreault 1985). The muscles M. peroneus tertius, M. extensor digitorum longus, and M. extensor digiti III proprius will be dissected from the left hind leg of each carcass, weighed, ground, and sampled for fat, protein, ash and water content. The band saw technique will be considered as the true estimator of body fat. Fat content of muscle groups and urea space estimates will be compared with the band saw results to determine their accuracy.

SCHEDULE

Report due: July 1 (with Techniques report)

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Appendix C.

OBSERVATIONS OF FREQUENCY OF BREEDING AND LENGTH OF RECEPTIVE PERIOD IN 7 FEMALE MOOSE AT THE KENAI MOOSE RESEARCH CENTER FROM 27 SEPTEMBER TO 6 NOVEMBER 1987.

Moose	Date	Observation
Zumu	27 Sep.	8:43 p.m., Joker attempted to mount Zumu. Within a minute, he did mount. Zumu's hind legs soon buckled and she moved away. However, I think Joker was successful because he quit following her and yawned. Soon Joker made a rutting pit and lay down in it. Zumu got excited, ran over to him and lay down beside him. After a minute or two, Joker got up, but Zumu remained. She then got up and splashed urine by pounding her hooves in the rutting pit. Then she lay down in it again. No more mountings were observed in this estrus period.
Oly	6 Oct.	Oly put into Pen 2A with Bando and other cows. She had been in Pen 2 and was caught in Trap 2N. At about 9:30 a.m., Bando approached Oly slowly as he grunted softly. They rubbed against each other; he sniffed her genital area and lip-curled. He mounted her 4 times (9:39, 9:44, 9:46, 9:49). I don't know if he achieved intromission. Oly soon moved toward feeder. Although moose were observed several times during the day, no more mountings were observed and Oly was one of 3 cows that Bando chased away from a rutting pit in the evening.
Janie	7 Oct.	In morning, Bando approached Janie as she was lying down. She got up, vocalizing, and moved away. A few minutes later, Bando again approached. Janie moved a short way, but didn't vocalize. Bando licked at her genital area and lip-curled. After a few more similar preliminaries, Bando mounted Janie at about 9:50 a.m. They stood close to each other for a few minutes, then moved apart. Bando yawned. No more mountings observed.

Trixie	11 Oct.	About 8:45 a.m., Joker followed Trixie into a small group of trees. When next seen, it looked as if Trixie had been mounted. At about 9:10 a.m., Joker was following her again. He finally approached with much tongue flicking and head lowered. He licked Trixie's genital area and she nuzzled him. Finally, Joker mounted successfully and observations were terminated. When Joker was seen in evening, he was not with Trixie.
Deneki	12 Oct.	At about 8:47 a.m., Bando mounted Deneki twice and was probably successful the 2nd time. Later in the morning, Deneki ran and vocalized several times when Bando tried to approach. She didn't run far, however, and finally lay down. At about 10:40 a.m., Bando lay down nearby. No more mountings observed.
Betsy	14 Oct.	Bando seen checking Betsy's genital area on previous evening. This morning Joker was definitely interested in Betsy (across fence). When observed this evening, Betsy had marking ink on her rump and her hair was roughed up. Bando approached Betsy (and she approached him) a few times this evening, but one or the other always moved away. Betsy vocalized a little. About 8 hours passed between morning and evening observations and I may have missed Betsy's entire receptive period.
Zumu	19 Oct.	In evening, Bando and Zumu were lying down near each other. Bando got up and stood over Zumu until she got up. He licked and smelled her genital area. At about 6:11 p.m., he attempted to mount but failed. At about 6:17 p.m. he again failed in an attempt to mount, then tried again successfully. Bando yawned and stood near to Zumu. After about 1/2 hour he became interested. Between 6:50 and 6:53 p.m., he attempted to mount 3 or 4 times as Zumu moved around, I believe he was again successful on the last mount.

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