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 and a computerized data acquisition system (Telonics 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 nylon harnesses. Mercury switches were positioned such 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 resting 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 which optimized the detection of movement during active periods (3-minute sample periods) and allowed comparisons of consecutive samples such that samples containing ambiguous data could be re-evaluated (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 resting bouts are reported.

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Radiotelemetry has helped biologists overcome some of the inherent problems associated with obtaining activity data on wildlife through visual or mechanical observation. Observational data may be biased towards daylight hours and towards habitats with highest visibility. Conventional radio collars were primarily designed to obtain location, but some authors (discussed in Garshelis *et al.*1981) have used the variation of signal strength (amplitude) to determine an animal's activity level. However, Lindsey and Meslow(1977) and Singer *et al.* (1981) reported that fluctuations in signal amplitude, which usually indicate that an animal is active, may occur during periods of inactivity as well. Also, topography and distance between transmitter and receiving station may influence amplitude.

Motion-sensitive radiocollars have been used to distinguish between activity types based on changes in signal pulse rate (Garshelis *et al.* 1981). Georgii (1981) and Cederlund (1981) distinguished between periods of activity and inactivity for red deer (*Cervus elaphus*) and roe deer (*Capreolus capreolus*), respectively, based on the animal's degree of movement. Gillingham and Bunnell (1985) however, found that specific behaviors could not be identified for black-tailed deer (*Odocoileus hemionus*) from pulse patterns using either tip-switch or variable-pulse collars. They found that predicted active/resting ratios which were based on patterns of pulse rates, differed significantly ($P < 0.05$) from actual ratios during 37.2% of trials using tip-switch collars and 55.3% of trials using variable-pulse collars.

Accurate assessment of activity budgets is dependant upon an ability to distinguish between activities of interest, based on unique signal patterns. To assess the effect that habitat quality may have on energy budgets of moose (*Alces alces*), we needed to distinguish between the 3 activity types having the greatest significance in terms of energy expenditure of the individual: resting (lying down), standing and walking (Reneker and Hudson 1983, Parker *et al.* 1984).

Motion-sensitive radiotransmitters differentiate between activities on the basis of movement of the animals. Since the transmitter is typically positioned on the animal's neck, the pulse patterns are sensitive to head movement as well as total body movement. Although head movement is associated with periods of activity, it may also occur during resting periods. In addition, if head position remains low and close to the ground while an animal feeds, fluctuations in signal pulse rate may not occur. Thus, a more appropriate location for the tip-switch transmitter is needed and we evaluated the leg, rather than the neck as such a location.

The purpose of this study was to assess the feasibility of using leg-mounted, tip-switch transmitters in combination with a computerized data acquisition system for obtaining 24-hour activity estimates for moose.

METHODS

Transmitter Design and Function

Nine mercury tip-switch transmitters, designed by the authors and Telonics Inc., and a data acquisition system (DAS) (Telonics Inc. Mesa, AZ) were tested at the Moose Research Center (MRC), Kenai Peninsula, Alaska, from November 1985 through March 1986 for detection of 3 activities: resting, standing and walking.

Each transmitter was housed in a metal cylinder approximately 18cm long with 2 D-cell batteries. The package was designed for maximum power output with an approximate battery life of 6 months. Radio frequencies were within the 148 to 149 MHz range.

Signal period (time between signals) was 1000 ± 50 msec when the transmitter was in the vertical position (Fig. 1). The unit included 2 mercury switches connected in series, such that when the tube was tipped either 20° forward or 60° backward, the period decreased to 650 ± 50 msec. An intermediate value (700 to 950 msec) resulted when the transmitter was pivoted forward to 20° or more and then brought back to the vertical position within 1 to 2 seconds. Continuous pivoting resulted in a fluctuating pattern of intermediate signal-period values.

Transmitters were mounted onto the outside of the right front leg of each moose using nylon-fabric harnesses. The harnesses were secured just above the dewclaws with velcro and nylon straps with buckles. A strap fastened under the dewclaws prevented the harness from pivoting around the leg.

A consistently slow signal pulse rate (long signal period) occurred when an animal stood motionless. The pulse rate changed from slow to fast (short signal period) as the animal bent its leg back to an angle greater than 20 °. The pulse rate remained fast if the animal laid down or if it continued to hold it's leg at that angle while standing. When a moose walked continuously, the instrumented leg moved every 2 seconds or less, resulting in a variable pulse rate and an alternating pattern of short and intermediate signal periods.The pulse rate slowed immediately after the walking bout terminated and the moose again stood motionless.

A slow pulse rate rarely occurred while an animal was lying down.This happened only when the animal held it's leg in a position such that the transmitter's switches were oriented approximately 90° from the plane at which the 'tip angle' was set (ie both switches were lying flat on their sides). This problem was identified as a potential source for error when associating signal patterns with activity types.

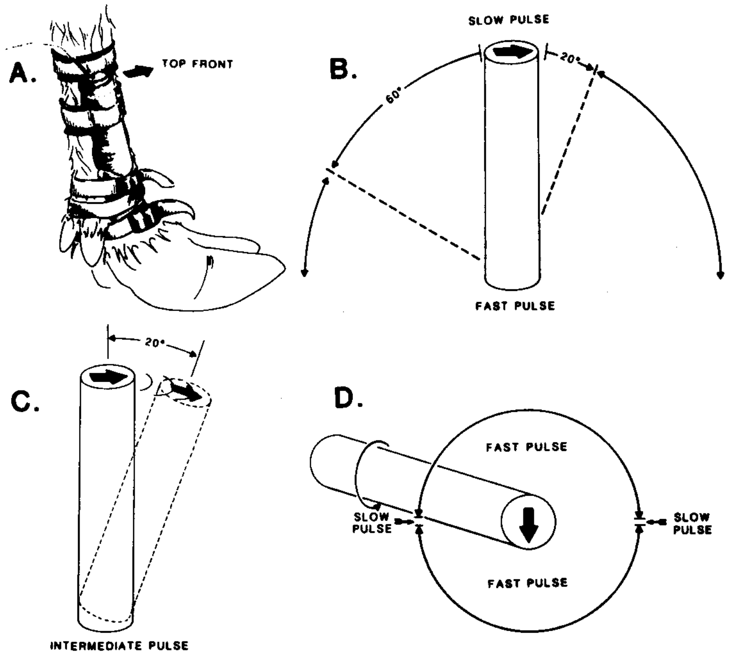

Figure 1: Design and function of leg transmitter used to detect 3 activities for moose. A) location of transmitter on moose's leg. B) and C) diagrams showing association of signal pulse rate with transmitter position and movement. D) signal pulse rates produced as transmitter is rotated 360° while in a horizontal position.

Data Acquisition System

The DAS was housed in a 44 x 67 x 24 cm metal carrying case and included a model TR2 receiver and model TDP-2 digital processor (Telonics Inc.), a Radioshack model 100 personal computer, a Radioshack CCR-82 computer cassette recorder, interface circuitry and software. The computer was programmed to instruct the receiver to sample a particular frequency and incoming data was stored in it's temporary memory. Data being stored included signal period and amplitude, as measured by the digital processor, date, time and radio frequency. Data were intermittently transferred to a cassette when the computer's Random Access Memory was filled. Sampling specifications, including frequencies to be sampled, sample-period length, number of samples per sample period and time between samples (minimum of 1 second), were entered into the computer by the user.The system was powered by a rechargable 12-volt battery.

The digital processor measured signal period to within 1 msec. A number was displayed approximately every second, since period varied from 600 to 1050 msec. Thus, a continuous record of the animal's movement was obtained by sampling every second. Clean data values were designated as slow, intermediate or fast, as discussed above. Values falling outside this range resulted from interference or weak signals.

Testing the Equipment

Nine moose were fitted with the harnesses containing the transmitters. Subsequently, 2 tests were used to determine the equipment's accuracy in detecting whether a moose was active (standing and walking) or resting (lying down), and 2 tests were used to determine it's usefulness in obtaining estimates of time spent walking by moose.

Test 1 (Active vs Resting)

The first test was conducted to determine if unique signal patterns occurred during active and resting periods. Signals were listened to for 30 seconds and pulse rates were classified as fast or slow/intermediate during 150 observed active and 131 observed resting bouts from 7 moose, using a hand-held H antenna and Telonics model TR-2 receiver.

Test 2 (Ground-Truthing Activity)

The second test was designed to compare signal patterns recorded on the DAS during 3-minute and 5-minute sample periods with observed activity. A single frequency was monitored continuously by the DASwhile an observer simultaneously recorded the instrumented moose's activity in the field. Exact times were noted by the observer when an animal switched between active and resting bouts. Signals were monitored from a receiving station connected to an omni-directional antenna mounted on a 30-m tower. Moose were allowed to roam freely in four 2.6-km enclosures, and ranged in distance from 400 m to 3 km from receiving stations.

The DAS was programmed to record signal-period measurements every second during each sample period. Initially, sample-period length was set at 5 minutes, with 300 measurements per sample period and a 2-minute gap between consecutive sample periods. Sample periods were later shortened to 3 minutes, with 180 measurements per sample period and 1.5 minute gaps. The shorter time period was more desirable because it allowed a frequency to be sampled more often. The data were transferred onto a Compaq desk computer using 4r communications software. A BASIC program was used to eliminate unusable data which resulted from interference or missed signals (values falling outside the acceptable range of 600 msec to 1100 msec) and to place each sample into one of 6 categories, based on previously determined associations between signal patterns and activity types (Table 1). Category 3 was designed to separate out samples containing a signal pattern which could occur during both active and restingbouts. Observed and predicted activity were compared for 100 5-minute and 754 3-minute sample periods.

Test 3 (Estimating Walking)

The third test was designed to determine how accurately steps taken by a moose could be predicted, based on patterns of series of values displayed on the digital processor. Four 1-hour trials were conducted, in which an observer recorded the number of steps a moose took with the transmittered leg in each of 240 15-second segments. A recorder simultaneously read each signal-period value into a portable cassette recorder as it was displayed on the digital processor.Signal patterns were later transcribed onto paper, with each 15-second segment containing 15 signal-period values.

Since an intermediate signal-period value was indicative of movement and a moose tended to move it's transmittered leg every 2 seconds when walking, one step was predicted for each 2-second segment in which at least one of the 2 values corresponding to that time fell into the intermediate range (Table 2). The observed number of steps taken in each 15-second segment was compared with those predicted.

Test 4 (Accuracy of Walking Predictions)

A final test was conducted to determine the accuracy with which walking bout duration could be measured. Due to the problem ofobtaining these data in the field, the test was performed by simulating the walking movement of a moose by manipulating the transmitter by hand. Each walking bout was performed by pivoting the transmitter forward to an angle of 20° and back again within a 2-second period, continuously for several sec-

Table 1. Criteria used to categorize transmitter signal patterns into 6 activity types based on signal-period measurements taken every second during 3-minute and 5-minute samples.

Predicted Activity	Signal Pattern Criteria
1. Active (stand/walk)	slow/intermediate pulse rate some movement indicated
2. Resting (lying down)	continuous fast pulse rate
3. Unsure (active or continuous	no movement indicated slow pulse rate resting)
4. Change, Active to Resting	single shift from slow pulse rate to fast pulse rate
5. Change, Resting to Active	single shift from fast pulse rate to slow pulse rate
6. Insufficient Data	<60 sec of clean measurements

onds. The transmitter washeld in the vertical position for at least 3 seconds before initiating a new bout. Over 330 simulated bouts, ranging in duration from 5 to over 45 seconds, were recorded.

Data were transferred from the DAS to the Compaq desk computerand analyzed using BASIC programming. Predicted bout length was equal to the total number of seconds between the first intermediate value of that bout and the first of 3 consecutive high values, signifying termination of that bout. The length of each bout, in seconds, was compared with the predicted length.

RESULTS AND DISCUSSION

Test 1 (Active vs Resting)

Signal patterns predicted active and resting bouts correctly 99.2% and 89.4% of the time, respectively (Table 3). A single active bout was misidentified when an individual fed with it's leg tilted back. The transmitters failed to trip into fast mode during 10.6% of resting bouts. Two transmitters accounted for 75% of the incorrect transmissions, indicating that alignment of the transmitter on the leg differed slightly between moose.

Test 2 (Ground-Truthing Activity)

Activity categories 1 and 2 predicted active and resting bouts with 99.8% and 100%

Table 2. Examples showing how the number of steps taken by a transmittered moose during 15-second periods was predicted from consecutive signal-period values displayed on the digital processor.Pairs of underlined numbers indicate a single step.

	Pulse period (seconds)															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Interp.
1)	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.76	0.87	1 step
2)	0.84	1.00	1.00	1.00	1.00	1.00	0.93	0.72	1.00	0.89	0.73	0.84	1.00	1.00	1.00	4 steps
3)	1.00	1.00	1.00	0.86	0.72	0.82	0.70	0.94	0.81	1.00	0.90	0.77	1.00	0.85	0.75	6 steps

accuracy, respectively (Table 4). A single misclassification within category 1 resulted from an individual holding it's leg at an angle while feeding.

One sample obtained during a resting bout was classified into category 3, indicating that during this trial, the transmitter failed to trip into fast mode only during a portion of 1 resting bout. Five samples collected during active bouts were classified into category 3, indicating that moose stood completely stationary during 1.6% of the 3-minute periods in which they were active.

Table 3. Relationship between leg transmitter signal pulse rate and activity type for 281 independent activity bouts from 8 moose.

Moose	Fast pulse rate		Slow pulse rate	
	Resting	Active	Resting	Active
1	17	-	1	24
2	18	-	1	18
3	7	-	-	7
4	8	-	-	8
5	16	1	8	21
6	14	-	4	18
7	23	-	2	27
8	26	-	-	12
Total(%)	129(99.2)	1(0.8)	16(10.6)	135 (89.4)

All activity changes which occurred during sampling periods (n =23) were correctly classified into categories 4 and 5. Signal patterns were misinterpreted as activity changes for 5 sample periods during which moose were resting. These errors resulted from switches tripping when animals shifted positions while bedded. Signal patterns were misinterpreted as activity changes for 3 sample periods in which moose were active when moose temporarily held their legs at an angle while standing.

All 4 samples containing insufficient data occurred consecutively during a single inactive bout. The remainder of that bout was correctly classified.

Misinterpretation of data can result w hen a slow pulse rate occurs during a resting bout and can cause serious error when calculating an individual 24-hour activity budget. Al-

Table 4. Relationship between activity categories based on leg transmitter signal patterns and observed activity for 854 3-minute sample periods from 7 moose.

Observed Activity	Activity Category					
	1(Active)	2(Resting	3(Unsure)	4(Active to Resting)	5(Resting to active)	6(Insufficient data)
Active	400	-	5	1	2	-
Resting	1	412	1	1	4	4
Active to Resting	-	-	-	13	-	-
Resting to Active	-	-	-	-	10	-
Total	401	412	6	15	16	4

though this problem occurred infrequently during testing, subsequent monitoring revealed that a slow pulse rate may persist throughout an entire resting bout, which may last between 3 and 4 hours.

To minimize ambiguity associated with a continuous slow pulserate, a sample period of fairly long duration and high sampling intensity is required, such that movement is detected during active bouts. We were able to detect movement in 98.4% of samples collected during active periods, using 3-minute samples.

Further accuracy can be obtained by monitoring an animal with adequate frequency so that it can be assumed that if an activity type occurred during 2 consecutive sample periods, it also occurred during the intervening unsampled period. Risenhoover (1986) reported that less than 2% of 420 active bouts and less than 1% of 341 resting boutsfor moose in Denali National Park were between 10 and 20 minutes long. Similarly, we observed only 2 of 164 active bouts and 1 of 182 resting bouts that lasted under 15 minutes and all were less than 5 minutes induration. Therefore, error resulting from extrapolation between samples of the same activity type occurring 15 minutes apart would be very small.

Once the data have been processed and each sample period categorized, samples assigned to categories with ambiguous interpretation (categories 3, 4 and 5) can be reevaluated based on interpretation of sequences of consecutive samples of the same animal (Table 5). A conservative reevaluation would allow reclassification of only those samples for which there is strong justification to doso.

Sample periods containing insufficient data are more likely to occur during resting bouts. However, if this situation occurs more than a few times during a single 24-hour period, the entire data sets should be eliminated from analysis anyway, due to the lack of continuous data. Those samples which fall into category 6 can be reevaluated by looking at the raw data for pattern which may suggest a particular activity and by comparing them with adjacent samples.

Test 3 (Estimating Walking)

The number of steps taken during sample periods ranged from 0 to 9. Ninety percent of samples where movement occurred contained 4 or fewer steps. The number of steps taken was correctly predicted 74% of the time, while over 95% of predictions were within 1 step (Table 6). Steps were overestimated ($n = 72$) slightly more frequently than those underestimated ($n = 59$). The predicted number of steps overestimated the true number by 3.5% for the entire 4 hours.

Test 4 (Accuracy of Walking Predictions)

Walking bouts from 5 to 15 seconds in duration were predicted within 1 second 90% of the time, while 94% of those lasting over 15 seconds were predicted within 2 seconds (Table 7). Underpredictions occurred almost 5 times more frequently than overpredictions. A regression analysis provided the predictive equation:

$$\text{ACTUAL} = 0.11 + 1.02(\text{PREDICT})$$
$$(r^2=0.97; S_{yx}=0.007; S_b=0.12)$$

Results of walking estimates indicated that the duration of individual walking bouts can be estimated very accurately by continuously sampling every second for several minutes. Bias may occur, however, if uninterpretable data are more likely to occur during either walking bouts or bouts of no movement. We anticipate that noisy data which occurs during active bouts will have 2 forms. A series of 6 or more uninterpretable data points results from the transmitter being out of antenna range and should not be biased toward either activity. These data should be eliminated from the data set. Groups of a few uninterpretable values occurring intermittently among clean data probably occur more frequently during walking bouts. These

Table 5. Schematic representation showing the procedure for reevaluating 3-minute samples of activity data which are assigned to activity categories found to show potential for misinterpretation.New classifications are based on the coherence between classifications of adjacent samples (15 minutes apart) and on whether or not movement is detected within the sample being evaluated. The assumption has been made that activity type cannot change twice during the intervening 15 minutes between samples.

Original Classification[a]	Compare with 2 adjacent values=	Movement[c]	New classification[a]	Justification[d]
3	1--3--1		1	4
	1--3--2		6	8
	2--3--1		6	8
	2--3--2		6	8
	3---3		6	8
	3--3--3		2	5
4	1--4--1		1	4
	1--4--2		4	1
	2--4--1	y	1	3
		n	6	8
	2--4--2	y	4	2
		n	6	8
	3--4--1	y	1	3
		n	3	6
	3--4--2	y	4	2
		n	3	6
	1--4--3	y	?	7
		n	3	6
	2--4--3	y	?	7
		n	3	6
5	1--5--1	1	4	
	2--5--1		5	1
	1--5--2	y		3
		n	6	8
	2--5--2	y		2
		n	6	8
	3--5--1	y	?	7
		n	3	6
	3--5--2	y	?	7
		n	3	6
	1--5--3	y	1	3
		n	3	6
	2--5--3	y	5	2
		n	3	6

a 1) active 2) resting 3) unsure 4) change, active to resting 5) change, resting to active 6) insufficient data to classify

b Value being evaluated and the previous and following values for the same animal, values are 15 minutes apart.

c y) movement detected during 'active' portion of sample n) no movement detected - activity unconfirmed.

d 1) No change, logical sequence with previous and next sample. 2)No change, 'active' portion shows movement, 'resting' portion consistent with adjacent sample. 3) Change to 'active', 'active' portion indicates movement, 'resting' portion is adjacent to a sample classified as 'active'. 4) Single sample between 2 samples classified as 'active', very unlikely to be resting. 5) 3 or more samples with no movement, possible during resting bouts, highly unlikely during active bouts. 6) No movement detected, doesn't follow a logical sequence and/or is adjacent to another sample indicating no movement, reevaluate as a 3. 7) Needs to be reevaluated using additional adjacent samples. 8) Insufficient data to accurately classify.

Table 6. Relationship between actual and predicted number of steps taken by moose during 960 15-second sample periods.

Actual number of steps	Predicted number of steps						
	Actual + 0	A - 1	A + 1	A - 2	A + 2	A - 3	A± 3
0	429[a]	-	18	-	2	-	1
1	192	15	22	-	7	-	1
2	79	16	12	2	1	-	-
3	54	7	11	2	4	-	1
4	26	4	6	-	-	-	-
5	11	-	1	-	-	-	-
6	7	5	4	-	1	-	-
7	8	2	1	-	-	-	-
8	2	1	-	3	-	-	-
9	-	1	-	1	-	-	-
Total	808	51	75	8	15	0	3

[a] Number of sample periods

patchy data can be used to determine low and high estimates for time spent walking.

APPLICATION/STATISTICAL ANALYSIS

Activity data were collected from 8 moose for a total of 199 moose/days from 1 Feb through 31 Aug 1986, using the described system (Bevins unpubl. data). Four individuals were monitored during each 24-hour period, by alternating between transmitter frequencies. Each moose's transmitter was monitored for a 3-minute period, during which 180 signal-period measurements (one per second) were collected. A 15-minute gap

Table 7. Relationship between actual and predicted number of seconds spent walking by moose, as simulated by manual manipulation of the leg transmitter, for 333 simulated walking bouts.

Actual number of seconds	Predicted number of seconds					
	Actual + 0	A - 1	A + 1	A - 2	A + 2	A ± 3
5--10	43a	3	8	6	1	3
11--15	35	4	9	4	1	3
16--20	19	2	7	1	-	1
21--25	10	1	4	6	-	-
26--30	4	8	-	9	-	1
31+	8	8	1	3	-	1
Total	119	125	29	39	2	9

occurred between consecutive samples of the same moose, and 80 samples were obtained for each moose/ day. Estimates of time spent active, time spent walking and length of active and resting bouts were obtained.

Estimating Time Spent Activity

Assuming that an individual's activity (active or resting) did not change twice between samples, the only portions of the activity budgets which were estimated (rather than measured) were those unsampled periods during which a change in activity occurred. Anactivity change was indicated by consecutive samples assigned to different activity categories. Thus, the amount of error around estimates was dependent on the number of bout changes. Since the bout changes occurred independently of sampling, the time each change occurred could be modeled as an uniform random variable with a range from 0 to 15 minutes and a mean of 7.5 minutes. The mean number of minutes active was calculated by adding 7.5 minutes for each bout change to the measured number of minutes active. A variance of 18.75 minutes for each estimate was derived by squaring the interval length (15 minutes) and dividing by 12 (Snedecor and Cochran 1977). In the few instances in which samples could not be classified, estimates were made by assuming that the activity change occurred halfway through the questionable period and variances were in proportion to the square of the interval length over which the change occurred. The total variance for the entire 24-hour period was equal to the sum of the individual variances, since each was independent. Variances around estimates for an individual moose within a given month were calculated using methods for a 2-stage sampling design, with within-day variance and between-day variance used as the 2 sampling levels (Cochran 1977).

Over 90% of the samples were found to be correctly classified as active, resting or as changing activities, while over 99% were classified into the 4 activity categories following reevaluation. Twenty-eight percent of the samples originally assigned to the 2 categories indicating an activity change were reclassified either as active or resting. The remaining 359 samples indicating a change were compared to the number of bout changes expected to be detected with this sampling design. This latter value was calculated by multiplying the total number of bout changes occurring for all days sampled (2645)by the percent of time in which the change could have been detected(140 seconds/1080 seconds). The adjusted value was within 5% of the expected value of 343 bout changes.

Estimates of the average time spent active during a 24-hour period ranged from 402 to 824 minutes. Standard errors ranged from 13.6 minutes to 56.4 minutes, with sample sizes ranging from 5 to 8 days per moose per month (Bevins unpubl. data). Standard errors were,on average, 4% higher than those determined from between-day variances alone. Thus, accuracy for individual estimates was sacrificed slightly to gain information on 4 individuals during a single 24-hour period.

Estimating Time Spent Walking

The number of minutes spent walking during each 3-minute sample period in which the animal was active was treated as a simple random sample and means and variances were calculated for each 24-hour data set. Estimates for an entire day were obtained by multiplying the mean number of minutes walking per sample by the number of 3-minute periods occurring during the active portion of a day. Variances for daily estimates were obtained by multiplying the variance of the mean for an individual estimate by the square of the number of 3-minute periods in which the animal was active. Variances around estimates for an individual moose, within a given month, were calculated using methods for a 2-stage sampling design, with within-day variance and between-day variance used as the 2 sampling levels (Cochran 1977).

The estimated average time a moose spent walking during a 24-hour period, for a given month, ranged from 7.8 to 173.4 minutes, while standard errors ranged from 1.7 to 25.7 minutes (Bevins unpubl. data).These estimates include movement involving at least 3 consecutive steps by the transmittered leg (6 seconds), since shorter movements could not be distinguished from shifting movements associated with feeding. Standard errors were positively correlated with estimates,the former being, on average, 22.3% of the latter. Time spent walking was often highly variable between sampling periods within a day, and within-day variance increased the standard error around estimates by an average of 15.8% and by as much as 42.3%.

The transmitters performed well within the distance range used in this study (≤= 2 km), and little data was lost as a result of poor-signal reception. Battery life, however, was sacrificed to obtain the high reception quality. Low and high estimates of time spent walking differed by less than 1% of the estimated time spent active for 32 of 38 estimates (Bevins unpubl data). The highest difference was 2.5%.

Estimating Active and Resting Bout Lengths

Individual bout lengths could only be estimated, since almost 90% of bout changes occurred between sample periods. Since gaps between samples were 15 minutes long, an individual bout could be estimated within a range of 30 minutes. For example, if an animal was found to be active during only 1 3-minute sample period, it may have been active for any length of time between 3 and 33 minutes. This range overlaps with the range indicated by activity for 2 consecutive samples (21 to 51 minutes). This overlap was eliminated by reducing the degree of confidence that a bout fell into a specific range of values from 100% to 83.6%; ranges were reduced from 30 minutes to 18 minutes wide. The degree of confidence was increased to 91.6% by lumping 2 adjacent categories together, thereby doubling the range to 36 minutes. These data were useful in constructing histograms of active and inactive bout lengths for individual moose (Bevins unpubl.data).

Transmitter and Harness Durability

Moose were instrumented with the leg transmitters in mid-November. One moose tore her harness 3 months after it was put in place, causing it to swing freely about her leg. The other harnesses held up through the time the transmitters were removed for battery replacement, after 4 to 5 months of service. New harnesses were put in place in late May and all but 1 functioned through August. The torn harness was replaced in July, after which it remained in place. Two antennas detached from their transmitters in August; 1 was repaired in the field while the other transmitter remained nonfunctional.

CONCLUSIONS AND RECOMMENDATIONS

This telemetry system performed well for our activity study. It allowed estimates of activity budgets for several moose during each 24-hour monitoring period. A slight modification of the transmitter would alleviate the problem of a slow pulse rate occurring while an animal is lying down. The improper signal occurs when the 2 switches are both laying flat on their sides while the transmitter is horizontal (Fig. 1d). The position of the switches could be adjusted so that they are not on the same horizontal plane when the transmitteris in this position.

This would reduce the sampling intensity necessary to differentiate activities based on signal patterns and eliminate the need to reevaluate ambiguous samples. A minimal number of signal-period values per sample (perhaps 10 to 20) would be required to classify individual samples as active or resting. This would allow a researcher to sample each transmitter more frequently and still greatly reduce the amount of data needed. Accuracy of estimates of daily activity level and of individual bout lengths could be improved by doing so. For instance, variances around daily activity estimates could be reduced tenfold by reducing the sample interval from 15 minutes to 5 minutes.

The data obtained for estimating walking activity is useful for calculating daily energy expenditure. Intensive sampling was required to obtain this information and data transfer from the DAS cassette recorder to a microcomputer for analysis was time-consuming (1 hour for 6 hours of data). This problem may be alleviated by modifying the DAS so that data is stored on disk rather than tape. Other limitations of obtaining this detailed information included reduced transmitter battery life due to the need for high power output and an effective range between transmitter and receiver of less than 3 km.

The DAS is very versatile and researchers could devise an optimal sampling design according to the questions which they wish to address. The leg proved to be a better position for an activity transmitter than the neck for our purposes. The harnesses held up well for from 3 to 5 months, but an improved design would be needed for longer periods.

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