IMMOBILIZATION OF MOOSE BY CARFENTANIL AND XYLAZINE AND REVERSAL BY NALTREXONE, A LONG-ACTING ANTAGONIST

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Abstract: Sixty-six moose(Alces alces), in Ontario, were darted from helicopters with 3 mg carfentanil (5.6-8.6 ug/kg) and either 25 mg xylazine (42-72 ug/kg) or 150 mg xylazine (299-399 ug/kg). Twenty moose processed for 25-82 minutes, were radio-collared, given 300 mg naltrexone (598-679 ug/kg) intravenously to antagonize the carfentanil, and released. Thirty-three moose were slung by helicopter to a road for radio-collaring, crating, and weighing. Thirty moose were trucked overnight to Michigan for release. A dose of 300 mg naltrexone (567-860 ug/kg) intravenously and 200 mg naltrexone (378-573 ug/kg) subcutaneously was used to reverse the effects of carfentanil. Naltrexone provided complete antagonism of carfentanil with no evidence of renarcotization. Naltrexone should be considered the drug of choice to antagonize carfentanil in moose.

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Carfentanil hydrochloride (Wildnil, Wildlife Laboratories, Inc., Fort Collins, CO), a powerful opioid agent of the fentanyl family, has been used previously to immobilize moose (Alces alces) (Haigh et al. 1982, Franzmann et al. 1984, Meuleman et al. 1984, Seal et al. 1985, Schmitt and Aho 1987, Franzmann et al. 1987). Seal et al. (1985) carried out hematology, red and white blood cell counts, and serum urea nitrogen studies of carfentanil, and carfentanil/xylazine hydrochloride(Rompun, Bayvet, Shawnee, KS) immobilized moose.

The effects of carfentanil have been antagonized by diprenorphine hydrochloride (M50-50, Lemon Company, Inc., Sellersville, PA) (Franzmann et al. 1984, Meuleman et al. 1984) and/or naloxone hydrochloride(Dupont Pharmaceuticals, Garden City, NJ) (Seal et al. 1985, Schmitt and Aho 1987, Franzmann et al. 1987). However, the short half-life of these drugs allows renarcotization of the moose in some cases (Haigh 1982, Franzmann et al. 1984, Seal et al. 1985, Schmitt and Aho 1987). Diprenorphine's agonistic properties are another disadvantage when using high dosages to antagonize carfentanil.

Naltrexone hydrochloride (Dupont Pharmaceuticals, Garden City, NJ) combines pure narcotic antagonist properties with long duration of action and no clinically significant agonistic effects (Archer 1981). In humans, naltrexone is approximately twice as potent as naloxone, and has a much longer duration of action (Martin et al. 1973). Schmitt and Aho (1987) successfully antagonized 11 captive moose with naltrexone to reverse the effects of

carfentanil. This report presents our experience in immobilizing 66 free-ranging moose with carfentanil and xylazine and then reversing the narcotic effects with naltrexone.

METHODS

Two separate capture projects make up this study. Moose tranquilized 18-19 Dec. 1986 and 13-17 Jan. 1987, in western Ontario (49°N 92°30'W), were fitted with radio collars for monitoring studies. The other study translocated moose from Algonquin Provincial Park (45°40'N 78°30'W), Ontario, during 3-11 Feb. 1987, to northwestern Marquette County near Champion, Michigan, to re-establish a viable population.

In both projects, carfentanil in combination with xylazine was used to immobilize the animals. Naltrexone was selected to antagonize the effects of carfentanil.

Radio-Collaring in Western Ontario

Moose in western Ontario were located in or near cutovers and herded to an opening suitable for a close approach by a Bell 206L Jet Ranger. Cap-Chur syringes were shot from the pilot side rear seat with a long-range Cap-Chur gun (Palmer Chemical and Equipment Company, Douglasville, GA) using a medium power (yellow) .22 blank. Moose were shot from a distance of 5-30 m under circumstances which were often difficult due to residual timber

in cutovers. The target area was the large muscle mass of the hind leg.

Syringes with 3 cc barrels and 38 mm (1.5 inch) barbed needles, were loaded with 3 mg of carfentanil, 150 mg of xylazine, and 0.5 ml distilled water.

The handling procedure was initiated by placing cotton batten in the moose's ears to muffle sound and reduce stress. An antibiotic opthalmic solution (V-sporin, Coopers Agrophram Inc., Willowdale, Ont.) was applied to the eyes to prevent damage to the corneas from drying. A blindfold was secured to calm the moose, and prevent damage to the cornea from abrasion and to the retina from light (G.J. Glover et al. pers. comm. content of paper in prep.). The dart location was noted, the dart removed, and the wound was sterilized with rubbing alcohol. A fecal sample was collected and the rectum cleared of feces to insure an accurate rectal temperature. A rectal thermometer was inserted and the time noted. If the temperature was above 40.5°C (105°F) the antagonist was administered immediately. Ear tags and a radio-collar were attached. Blood samples were collected at the ventral metatarsal and an incisiform canine was extracted. The temperature was taken again. A 7,000 mg intramuscular (IM) injection of oxytetracycline, a long-acting antibiotic (Liquamycin LA - Pfizer, New York, NY), was given to prevent bacterial infection. Up to 4 body measurements were recorded (Franzmann et al. 1978): total length, hind

foot, neck, and chest girth. Carfentanil was antagonized with 300 mg of naltrexone administered intravenously (IV) at the metatarsal. Moose were monitored until they were standing and moving away from the site.

Translocation of Moose to Michigan

Capture procedures in Algonquin Provincial Park during 1987 were the same as during the 1985 capture (Schmitt and Aho 1987) except that naltrexone was used to antagonize carfentanil instead of diprenorphine and naloxone. In summary after spotting a moose near a lake it was herded onto the lake by a Hughes 500 helicopter. A 3 cc dart was fired from a distance of 8-12 m using a very low power (brown) .22 blank. The syringe contained 3 mg carfentanil, 25 mg of xylazine, and 1.75 ml sterile 0.9% NaCl.

Heart rate, respiratory rate, and rectal temperature were monitored, with temperature being the key factor. Any animal with a rectal temperature above 40.28°C (104.5°F) was reversed immediately and let go. An antibiotic ointment (Chloromycetin 1%, Veterinary Opthalmic Ointment, Parke-Davis, Morris Plains, NJ) was applied to the animal's eyes. Moose were blindfolded, and foam rubber placed in their ears. Darting wounds were sprayed with a topical antibacterial spray, Furazolidone aerosol powder (Veterinary Products Laboratories, Phoenix, AZ). A 500 mg IM injection of flunixin meglumine (Banamine, Schering Corporation, Kenilworth, NJ) was given for its anti-inflammatory properties. The moose were positioned in a

reinforced canvas sling designed by the Utah Division of Wildlife Resources (J. Kimball, pers. comm.) and airlifted by a Bell Jet Long Ranger helicopter to the staging area.

At the staging area workers continually monitored rectal temperature, respiration, and heart rate. A 10,000 mg IM injection of long-acting oxytetracycline, was given. A 100 mg subcutaneous (SQ) injection of Ivermectin, (Ivomec, Merck and Company, Inc., Rahway, NJ) was given to attempt to eliminate internal and external parasites, especially winter ticks (Dermacentor albipictus). An IM injection of 25 mg sodium selenite and 54.75 mg Vitamin E (Mu-Se, Burns-Biotec Laboratories, Inc., Omaha, NE) was given to prevent capture myopathy (Spraker 1982).

A truck-mounted crane lifted the moose into a crate. Before the crate was sealed, the effects of carfentanil were reversed by 300 mg naltrexone IV and 200 mg naltrexone SQ. The crate, with moose, was weighed and the crate placed on a truck. By late afternoon a 2-man crew began the 17 hour, 940-km journey, to the release site in Michigan. All moose transferred were given an IM injection of 200 mg of naltrexone prior to release from the crate.

RESULTS

In the Algonquin Park project, a total of 45 moose were darted (Table 1). Forty moose were immobilized, the remaining 5 were given naltrexone by capture dart before

Table 1. February 1987 translocation of moose to Champion, Mich. Chases were <10 min. in duration. Immobilization was with carfentanil(3 mg) and xylazine(25 mg). Moose captured in Algonquin Park, Ont., were slung to a staging area, processed, crated, weighed, and reversed. Of 45 moose darted, 30 were moved.

RADIO[1] COLLAR NUMBER	SEX	AGE[2]	WEIGHT (KG)	AREA HIT ON BODY	(MIN.) TO EFFECT	RECTAL TEMP. MIN. (°F)	RECTAL TEMP. MAX. (°F)	NALTREXONE DOSAGE(mg) IV	NALTREXONE DOSAGE(mg) SQ	(MIN.) TO STAND	TOTAL (MIN.) DOWN
31A E	F	MATURE ADULT	450.00	HIP	12	102.0	103.2	300	200	7	59
31B T	F	YOUNG ADULT	438.75	HIP	4	98.0	101.8	400	400	3	53
32 T	F	YOUNG ADULT	438.75	HIP	6	103.5	106.0	300	200	4	40
33 T	M	YOUNG ADULT	-	HIP	3	102.5	103.2	300	200	3	50
34 T	M	MATURE ADULT	515.25	HIP	4	102.0	103.5	300	200	3	52
35 T	M	YEARLING	-	HIP	6	100.8	102.5	300	200	9	47
36 T	F	YOUNG ADULT	432.00	HIP	7	100.6	103.6	300	200	2	56
37 T	M	YOUNG ADULT	348.75	HIP	5	102.2	104.5	300	200	6	39
38 T	F	MATURE ADULT	472.50	HIP	5	99.5	101.8	300	200	3	50
39 T	M	MATURE ADULT	483.75	HIP	8	100.4	101.8	300	200	3	43
40 T	M	YOUNG ADULT	416.25	HIP	8	98.0	101.8	300	200	3	43
41 T	F	MATURE ADULT	508.50	HIP	9	100.0	103.6	300	200	2	48
42 T	F	MATURE ADULT	528.75	HIP	5	103.0	104.0	300	200	4	74
43 T	M	YOUNG ADULT	472.50	HIP	5	100.2	102.2	300	200	4	47
44 T	M	MATURE ADULT	483.75	HIP	4	103.0	103.8	500	250	2	27
45 T	M	MATURE ADULT	501.75	HIP	6	102.0	103.6	300	200	2	40
46 T	M	YOUNG ADULT	405.00	HIP	7	102.0	104.0	300	200	2	33
47 T	M	YOUNG ADULT	517.50	HIP	8	102.2	104.0	300	200	2	57
48 T	M	YEARLING	360.00	HIP	7	98.2	102.0	300	200	5	51
49 T	M	MATURE ADULT	452.25	HIP	6	100.5	101.6	300	200	5	32
50A E	M	MATURE ADULT	461.25	BACK	10	104.0	106.9	300	200	7	41
50B R	F	MATURE ADULT	461.25	HIP	9	101.2	102.0	300	200	2	30
50C T	F	OLD	396.00	HIP	4	101.0	102.0	300	200	4	46
51 TD	F	MATURE ADULT	472.50	HIP	5	101.1	102.0	300	200	3	71
52 T	F	YOUNG ADULT	416.25	FLANK	7	97.4	103.0	300	200	5	81
53 T	M	MATURE ADULT	510.75	REAR HIP	6	99.9	103.0	300	200	5	42
54 T	F	MATURE ADULT	461.25	HIP	4	101.0	103.0	300	200	4	35
55 T	F	MATURE ADULT	483.75	REAR HIP	9	102.4	103.4	300	200	4	34
56 T	F	MATURE ADULT	501.75	HIP	6	102.1	103.5	300	200	3	29
57 TD	F	MATURE ADULT	-	HIP	8	101.0	102.8	300	200	5	53
58 T	F	MATURE ADULT	450.00	REAR HIP	5	101.2	102.8	300	200	5	49
59 T	F	MATURE ADULT	427.50	ABOVE KNEE	8	99.0	102.0	300	200	3	45
60 T	M	YOUNG ADULT	483.75	HIP	5	101.2	102.2	300	200	3	46
- R	M	MATURE ADULT	-	UPPER HIP	9	-	-	300	200	4	17
- R	?	-	-	HIP	4	-	104.0	300	200	4	23
- R	?	-	-	RIBS	15	-	105.0	300	200	7	19
- R	F	-	-	FLANK	25	-	106.0	300	200	7	20
- R	F	YEARLING	-	HIP	9	104.0	105.2	300	200	5	67
- R	F	-	-	HIP	6	-	105.0	300	200	6	20
- R	M	-	-	LOWER HIP	7	-	103.0	500 IM		-	-
- RC	M	-	-	FLANK	>23	-	-	350 IM		-	-
- RC	M	MATURE ADULT	-	FETLOCK	>30	-	-	350 IM		-	-
- RC	F	-	-	BACK/HIP	>35	-	-	350 IM		-	-
- RC	M	MATURE ADULT	-	FLANK	>20	-	-	350 IM		-	-
- RC	F	-	-	FLANK	>20	-	-	350 IM		-	-

[1] (T)ranslocated, (D)ied, (E)uthanized, (R)eleased Algonquin, (C)ap-Chur dart reversal.
[2] Yearling - 1 year, Young adult - 2-4 years, Mature adult - 5-9 years, Old - 10+ years.

immobilization occurred. Seven moose were released without being airlifted due to elevated temperatures and/or having retreated into the bush before being immobilized. Thirty-three moose were airlifted, handled, and placed in crates. Three moose did not stand after crating and were removed from their crates. One walked away and appeared normal (#50B), and 2 were euthanized (#31A, #50A). Of the 30 moose transported to Michigan, 2 died within a week (#51, #57).

The 21 moose darted in western Ontario were immobilized with 1 injection (Table 2). Most needles were bent due to using yellow blanks, and were discarded. Syringe barrels did not penetrate the hide. Typically the impact bruise was 2-3 cm in diameter with total hair loss.

Moose laid down in upright sternal postures (on haunches), sternal recumbency with legs in the sleeping /resting position, or lateral recumbency with legs out to one side. When possible, laterally recumbent moose were shifted to sternal recumbency. In one case the legs were uphill and the moose was rolled over. The latter procedure is not recommended as a twisted abomasum may result. Moose should be pivoted when necessary, rather than rolled.

Morphometric Measurements and Moose Weights

Physical measurements were obtained from 33 moose captured in Algonquin Park (Table 3). Two of the 16 bulls were yearlings while the others were 2-1/2 years or older. The 14 bulls for which weights were taken averaged 458 kg

Table 2. December 1986 and January 1987 radio-collaring of moose in western Ontario. A Bell 206L Jet Ranger located and pursued moose until darting with carfentanil (3 mg) and xylazine (150 mg). Moose were processed by a crew of two and released at the capture site.

EAR TAG	SEX	AGE[1] (YR)	CHASE[2] (MIN)	AREA HIT ON BODY	TIME TO EFFECT (MIN)	ACCESS DELAY[3] (MIN)	RECTAL TEMPERATURE (°F)	(MIN[4])	(°F)	(MIN[4])	COMMENTS ON APPARENT STRESS[5]	REVERSAL - NALTREXONE DOSAGE (mg) IV	IM	RECOVERY TIME TO STANDING (MIN)	TIME DOWN (MIN)
1	M	10.5	4	HIP	5	3	103.6	24	103.7	54	NO STRESS, HEAD DOWN	300	-	42[6]	86
2	F	10.5	1	SHOULDER	10	12	101.1	40	102.3	51	NO STRESS, HEAD UP	300	-	27	76
3	F	9.5	6	NECK	6	3	102.2	27	102.8	35	NO STRESS, HEAD DOWN	300	-	6	55
4	M	4.5	4	HIP	8	4	102.7	33	102.9	43	GRUNTING, FLINCHING	300	-	5	49
5	M	7.5	17	HIP	5	6	103.6	31	103.8	59	NO STRESS, HEAD DOWN	300	-	6	63
6	F	13.5	3	HIP	5	11	98.7	41	98.7	94	NO STRESS, HEAD DOWN	300	-	10	96
7	F	4.5	1	RIBS	14	21	104.2	60	104.8	89	TREMORS, LIFTS HEAD	300	-	4	84
8	M	7.5	<5	RIBS	9	6	101.2	31	101.0	38	ATTEMPTS TO STAND	300	-	6	51
9	F	13.5	1	RIBS	6	10	103.8	42	-	-	NO STRESS, HEAD UP	300	-	9	87
10	M	8.5	13	RIBS	6	5	105.4	25	106.1	36	RESP. HEAVY, HEAD UP	300	-	24	63
11	F	6.5	4	RIBS	10	3	105.5	36	-	-	TREMORS, RESP. HEAVY	300	-	8	40
12	M	6.5	6	FLANK	28	23	104.6	66	105.0	75	TREMORS, AWARE	300	-	8	60
13	F	4.5	7	RIBS	4	13	104.7	33	104.7	51	TREMORS, HOLDS BREATH	300	-	7	74
14	F	12.5	3	HIP	4	20	101.9	38	101.6	45	NO STRESS, HEAD DOWN	300	150	26	71
15	F	7.5	8	HIP	6	11	101.0	41	101.0	46	NO STRESS	300	-	7	58
16	F	5.5	10	REAR HIP	9	2	103.5	31	104.4	44	TREMORS, PUSHING LEGS	300	-	6	51
17	M	3.5	1	SHOULDER	12	12	THERMOMETER LOST				TREMORS, RESP. NORMAL	300	-	7	73
18	M	ADULT	1	RIBS	6	10	102.1	31	-	-	ALERT, TRIES TO STAND	300	-	7	42
19	M	6.5	2	RIBS	11	3	102.6	46	102.6	53	NO STRESS, HEAD DOWN	300	-	5	58
20	F	4.5	4	SHOULDER	6	4	101.1	40	101.2	44	NO STRESS	300	-	18	55
21	F	3.5	5	NECK	4	3	X	27	102.3	35	NO STRESS, HEAD DOWN	300	-	11	57

[1] Cementum age from an incisiform canine.
[2] Duration from sighting until dart in place.
[3] Minutes from effect until team with moose.
[4] Minutes from placement of dart.
[5] Tremors = mild muscle shaking, usually of hind legs only.
[6] Moose was wedged between tree and slope.

Table 3. Morphometric data for moose (A. a. americana) captured February 1987 in Algonquin Park, Ontario.

COLLAR NUMBER	SEX	AGE[1]	WEIGHT (KG)	LENGTH (CM) TOTAL	HINDFOOT	EAR	NECK
31A	F	MATURE ADULT	450.00	283	80	25	87
31B	F	YOUNG ADULT	438.75	234	76	26	79
32	F	YOUNG ADULT	438.75	-	-	-	-
33	M	YOUNG ADULT	-	-	82	25.5	97
34	M	MATURE ADULT	515.25	292	80	27.5	105
36	F	YOUNG ADULT	432.00	262	79	26	90
37	M	YOUNG ADULT	348.75	251	80.5	25	80
38	F	MATURE ADULT	472.50	260	77	25.5	84
39	M	MATURE ADULT	483.75	283	80	26	94
40	M	YOUNG ADULT	416.25	263	79	28	87
41	F	MATURE ADULT	508.50	258	78.5	25.5	81
42	F	MATURE ADULT	528.75	249	80	26	91
43	M	YOUNG ADULT	472.50	271	79	27	-
44	M	MATURE ADULT	483.75	279	-	23.5	79
45	M	MATURE ADULT	501.75	259	77	27.5	118
46	M	YOUNG ADULT	405.00	249	79	25	97
47	M	YOUNG ADULT	517.50	275	79	28	109
48	M	YEARLING	360.00	247	77	22	98
49	M	MATURE ADULT	452.25	261	83	25	88
50A	M	MATURE ADULT	461.25	254	79	26	114
50B	F	MATURE ADULT	461.25	270	77	25	87
50C	F	OLD	396.00	256	80	27	87
51	F	MATURE ADULT	472.50	253	79	24.5	82
52	F	YOUNG ADULT	416.25	262	80	26	81
53	M	MATURE ADULT	510.75	263	82	28	106
54	F	MATURE ADULT	461.25	255	78	23	82
55	F	MATURE ADULT	483.75	254	78	26	76
56	F	MATURE ADULT	501.75	246	77	25	85
57	F	MATURE ADULT	-	248	78	24	80
58	F	MATURE ADULT	450.00	265	78	27	88
59	F	MATURE ADULT	427.50	263	77	26	85
60	F	YOUNG ADULT	483.75	277	79	26.5	100
N	M+F	YOUNG ADULT +	28	28	28	29	28
MEAN		MATURE ADULT	446.28	262.1	76.5	25.8	88
SD			93.08	13.1	13.7	1.28	19
N	M+F	MATURE ADULT	18	19	18	19	19
MEAN			479.25	262.9	78.8	25.6	90
SD			27.49	13.0	1.8	1.35	12
N	M	MATURE ADULT	7	7	6	7	7
MEAN			486.96	270.1	80.2	26.2	100
SD			24.05	14.4	2.2	1.6	14
N	F	MATURE ADULT	11	12	12	12	12
MEAN			474.34	258.7	78.1	25.2	84
SD			29.49	10.5	1.1	1.1	4

[1] Yearling - 1 year of age, Young adult - 2 to 4 years old, Mature adult - 5 to 9 years old, Old - 10+ years old.

(range 349-518). All 17 cows were 2-1/2 years or older. The 16 cows for which weights were taken averaged 459kg (range 396-529).

Physical measurements of moose from western Ontario (Table 4) were taken to obtain an approximation of weight. Western Ontario moose weights (Table 4) calculated with the formula (Wt.(kg) = -239.7 + 2.07(total length), n=502, r=0.94) designed by Franzmann et al. (1978) ranged from 277.8 kg to 375.1 kg. Body measurements were close to those made by Franzmann et al. (1978) for A.a. gigas. The physical measurements were also similar to the moose captured in Algonquin Park (Table 3). The Algonquin moose weights (Table 3) were regressed (Wt.(kg) = 119.0 + 1.29(total length), n=29, r=0.36) and the recalculated weights of western Ontario moose (Table 4) ranged from 441.5 kg to 502.1 kg.

Immobilization with Carfentanil-Xylazine Mixture

Immobilization time in Algonquin Park ranged from 3 minutes to 12 minutes and averaged 6.47 minutes (Table 1, n=38); 7 outliers were excluded: 15 minutes (ribs hit), 25 minutes (flank hit), and 5 moose not immobilized after 20+ minutes were given naltrexone by capture dart.

Moose in western Ontario went down in 4 to 14 minutes, with 1 outlier at 28 minutes (flank hit) (Table 2). The average induction (n=20) was 7.3 minutes excluding the outlier.

Table 4. Morphometric data for moose (A. a. andersoni) captured for radio-collaring in December 1986 and January 1987 in western Ontario.

EAR TAG	SEX	AGE (YR)	LENGTH (CM) TOTAL	HINDFOOT	NECK	GIRTH	WEIGHT (KG) see[1]	see[2]
2	F	10.5	283	86	79	188	346.1	484.1
3	F	9.5	259	80	-	-	296.4	453.1
4	M	4.5	256	79	77	-	290.2	449.2
5	M	7.5	272	81	83	-	323.3	469.9
6	F	13.5	265	85	83.5	201	308.8	460.8
7	F	4.5	262	79	86	200	302.6	457.0
8	M	7.5	270	80	81	-	319.2	467.3
9	F	13.5	297	86	83	207	375.1	502.1
10	M	8.5	290	75	101.5	197	360.6	493.1
12	M	6.5	288	81	88	-	356.5	490.5
13	F	4.5	286	86	76	196	352.3	487.9
14	F	12.5	279.5	82	69.5	-	338.9	478.9
15	F	7.5	269	78	74	-	317.1	466.0
16	F	5.5	251.5	73	85	178	279.9	442.8
17	M	3.5	251	83	90	175	280.9	442.8
19	M	6.5	260	79	92	193	298.5	454.4
20	F	4.5	264	74	75	187	306.8	459.6
21	F	3.5	250	75	79	165	277.8	441.5
N	M+F	3.5+	18	18	17	11		
MEAN			269.6	80.1	82.5	189.7		
SD			14.6	4.1	7.7	12.7		
N	M	3.5+	7	7	7	3		
MEAN			269.6	79.7	87.5	188.3		
SD			15.2	2.5	8.1	11.7		
N	F	3.5+	11	11	10	8		
MEAN			269.6	80.4	79.0	190.3		
SD			14.9	5.0	5.4	13.8		

[1] Franzmann et al. 1978. Wt(kg) = -239.7 + 2.07(Body length) Alces alces gigas, n=502, r=0.94

[2] This paper, Table 3, Wt(kg) = 119.0 + 1.29(Body length) Alces alces americana, n=29, r=0.36

Rate of Induction to Effect of Carfentanil-Xylazine

The data from western Ontario and Algonquin Park were combined in a contingency (Table 5, n=65) to examine the rate of induction given dart impact at various general sites. One moose from Algonquin Park was excluded because it was hit in the lower hind leg near the fetlock. Data from injections in large muscle masses (hip, shoulder, neck), were combined in a single column. Back and rib injections are combined. Rear hip refers to muscles near the spine at the base of the tail.

Table 5. Contingency examination of induction time versus area of dart impact.

	Large Muscles	Rear Hip	Ribs	Flank
< 6 min.	18	1	1	0
6 - 10	24	3	6	1
11 - 15	2	0	3	0
15+	1	0	0	5

The shortest time to effect was generally obtained with injections in large muscle mass. The 4 hits on the rear hip averaged only marginally longer induction. Hits in the ribs took longer to immobilize moose, yet did achieve induction, and none were outside the range of induction rates for large muscle mass hits. Five of 6 hits in the flank area resulted in moose not going down inside of 15 minutes. Temperatures were obtained for 3 of these moose, and 2 had elevated temperatures. The moose with a normal temperature was the one induced in under 15 minutes.

Body Temperature

Rectal temperatures of the Algonquin moose ranged from a mean minimum of 38.33°C (101.0°F) to a mean maximum of 39.5°C (103.1°F) (Table 1). At the nearby Petawawa Forest Research Center the ambient daily maximum temperatures ranged from -10.8°C to +3.4°C. Most moose were captured within a 16 km radius of the staging area, resulting in a helicopter flight time of 10-15 minutes. Due to cooling while being slung to the staging area, rectal temperatures below 38.33°C were common.

Rectal temperatures for western Ontario moose ranged from 37.05°C (98.7°F) to 41.16°C (106.1°F) (Table 2). The ambient daily maximum temperatures in western Ontario (Fort Frances) varied from -17.5°C to +5.5°C.

A contingency table (Table 6, n=16) was employed to examine temperature stability of western Ontario moose. A stable temperature was defined as a maximum variation of 0.17°C (0.3°F) between measurements.

Table 6. Contingency of first rectal temperature reading versus stability of temperature, for western Ontario Moose.

	Stable	Increasing
Low	1	0
Normal	8	3
High	1	3

No adjustment was made for the time between measurements. Two trends were seen. Normal temperatures (38.33°C (101.0°F) <= normal <= 39.9°C (103.9°F)) tended to remain

stable. High temperatures tended to get higher. One animal's temperature in the normal/increasing cell exceeded the normal limit on the second measurement.

Visible Stress Symptoms Related to Elevated Temperatures

A contingency was drawn (Table 7, n=20) to examine the relationship between the highest temperature measured for each individual and the level of visible stress.

Table 7. Highest temperature versus visible stress symptoms, western Ontario captures.

	No Stress	Moderate	Obvious
Low	1	0	0
Normal	10	3	0
High	0	0	6

Again, 2 trends were seen. Animals with normal temperatures did not show visible stress, however, almost all animals maintained muscle tightness as evidenced by constricted rectal muscles. Animals with high temperatures had obvious stress symptoms: accelerated heavy breathing or depressed respiration, muscle tremors, muscle straining. Three animals with normal temperatures exhibited signs of alertness and/or made attempts to stand. These animals did not show stress symptoms and were calm and relaxed.

Prolonged Induction Contributed to Elevated Temperature

A contingency to examine the time to effect of carfentanil versus the maximum temperature recorded for each animal was compiled (Table 8, n=59).

Table 8. Contingency to examine the interaction of the duration of induction and the highest temperature (°C) recorded.

	<39.7	39.7-40.2	>40.2
<6 min.	14	5	2
6 - 7	11	3	3
8 - 9	9	2	1
10 - 11	2	0	2
12+	1	0	4

Moose which took longer than 10 minutes to go down tended to have elevated temperatures. However, 12% of moose which were induced in less than 10 minutes also had elevated temperatures, and 33% of moose with longer inductions did not have a high temperature.

Antagonism by Naltrexone

Following injection of naltrexone, Algonquin Park moose stood up in 2 to 9 minutes (Table 1), with an average of 4.1 minutes (n=39). Total time immobilized (from when the animal first went down to when it stood up in the crate) ranged from 27 to 81 minutes, and averaged 46.8 minutes (n=33).

After administering naltrexone, western Ontario moose were on their feet in 4 to 27 minutes(Table 2). One moose took 42 minutes but was wedged between a tree and the adjacent slope. The average recovery to standing was 10.4 minutes in a skewed distribution where only 5 moose (n=20) exceeded a 10 minute reversal. At least 2 of these were apparently unaware of being drugged as they simply did not

stand. Their heads came up, they assumed resting postures and proceeded to chew their cuds. The team flushed these animals and they reacted with typical startle reflexes. The length of recovery did not appear to be related to the level of visible stress.

Western Ontario moose were followed up within 1-5 days after handling (except #21 who was not radio-collared). No narcotic recycling was observed. Female number 20 carried her hind quarters low and had a shortened gait one day following capture. Four days after capture this female showed no sign of muscle soreness. Weekly telemetry and observations to September 1987 confirmed nil mortality.

Narcotic recycling was not observed in the Algonquin moose. All 28 moose surviving one week after release in Michigan were alive as of October 1987.

Capture Related Mortality

The 4 deaths in the Algonquin moose (Table 1) were capture related but were not a direct result of the drugs used. Cow #31A accidentally ruptured large muscles in the hind leg when it broke through thin ice. It's death appeared to be a function of unfortunate and unpreventable capture circumstances rather than being due to carfentanil. It is not clear why bull #50A ruptured hind leg muscles except that exertion while being chased may have resulted in a slip or stumble which went unnoticed. Both animals were alert after naltrexone was given but could not stand up and were euthanized.

Cow #57 died one day after being released in Michigan. She was 11.5 years old and was suffering from hepatitis and peritonitis at the time she was captured in Algonquin Park. Cow #51 died approximately one week after being released in Michigan. She was 8.5 years old, heavily parasitized with Echinococcus granulosus tapeworm cysts, and suffering from metritis. Both of these animals were poor choices, as it turned out, to be put through the stresses of capture and transport.

DISCUSSION

In 1985, 31 moose were captured in Algonquin Park for release into Michigan's Upper Peninsula (Schmitt and Aho 1987). The immobilizing drugs used were carfentanil and xylazine, antagonized by naloxone and diprenorphine. Recycling was observed and resulted in the deaths of 2 cows. Apparently, naloxone and diprenorphine are often metabolized before carfentanil, with the result that moose are renarcotized.

Renarcotizing of moose was more pronounced during the 1985 capture in Algonquin Park than during a capture of moose on Isle Royale (Seal et al. 1985). There were 2 differences which might explain this. Overall metabolism of the moose was probably lower during the January drugging in Algonquin Park than during the May drugging on Isle Royale. Moose on Isle Royale were reversed and released

immediately after a radio-collar was attached. They were closely observed, but were free to move about and left undisturbed; they probably metabolized the carfentanil more quickly than the Algonquin Park moose, which were placed in transport crates and held for approximately 24 hours.

No recycling, or drug effects, were seen before or after release in the 1987 Algonquin capture project where naltrexone (300 mg IV + 200 mg SQ) was used to reverse carfentanil. Schmitt and Aho (1987) used a single 300 mg IV naltrexone injection to effectively antagonize 3 mg of carfentanil used on captive moose with no recycling problems.

No recycling was seen on inspection of moose 1 to 4 days after handling in western Ontario. The 300 mg intravenous dose of naltrexone was apparently sufficient to antagonize the 3 mg of carfentanil used.

Seal et al. (1985) suggested that to prevent muscle hypertonicity, moose should receive xylazine mixed with carfentanil. In the 1987 Algonquin Park study moose pursued by helicopter received 25 mg xylazine. Moose pursued by helicopter in western Ontario were given 150 mg xylazine. The higher dose of xylazine may account for some of the longer recovery times seen in the western Ontario study. However, it is more likely due to differences in external stimuli received by the 2 groups. The Algonquin moose were exposed to a great deal of external stimuli (crate doors bolted in place, weighing moose in crates,

loading moose in crates onto trucks) minutes after being given naltrexone. The western Ontario moose were allowed to recover in quiet, familiar surroundings after being reversed with naltrexone.

The high concentration (100 mg/ml) of naltrexone solution used in western Ontario caused it to crystalize at temperatures above freezing. A 50 mg/ml mixture worked well in the Algonquin Park study and is the recommended concentration. In the future, naltrexone will be provided to investigators in vials with 1 gram of powder to which the investigator will add 20 ml of sterile physiological solution (W. Lance, pers. comm).

Although naltrexone is the drug of choice to antagonize carfentanil, it will not be available in large quantities for 3-5 years (W. Lance, pers. comm.). It is available to investigators dependent on supply. Naloxone will probably be made available in large quantities, and therefore may be easier to obtain. Southern Research Institute of Birmingham, Alabama, is pursuing micro-encapsulation of naloxone for a 48 hour release curve.

The injection location of the capture dart is very important. Large muscle masses are needed for quick absorption of the drug. The heavy muscles of the hip and shoulder are best. Lightly muscled areas such as the flank and lower legs or areas with large amounts of subcutaneous fat such as the lower back are poor. In these locations,

the drug is so slowly absorbed that it usually takes more than 15 minutes to tranquilize a moose.

The longer it takes for the animal to become immobile, the more likely that high body temperatures will result. Animals which exhibit stress symptoms often have an accompanying high temperature. Animals with rectal temperatures above 40°C (104°F) are stressed whether they show visible symptoms or not. Moose with high temperatures and/or symptoms of stress should not be transferred, and should be reversed immediately to avoid death due to hyperthermia or capture myopathy. Any moose still on its feet 15 minutes after darting with carfentanil should be reversed with naltrexone administered by capture dart. In neither study was it considered appropriate to immediately administer a second dose of carfentanil if the first failed to immobilize the moose.

Weight regressions for Alaskan versus Algonquin Park moose are contradictory. Franzmann et al. (1978) noted that penned adult moose were significantly lighter than free-ranging Alaskan moose. However, the few free-ranging adult moose weights obtained in February were in the same range as the penned moose. There was a clear separation between Alaskan and Algonquin Park adult moose weights in February. Although body measurements were similar, Algonquin Park moose were heavier. Adult moose fall weights in Alaska were similar to February Algonquin weights. Alaskan moose had sexually dimorphic fall weights

with convergence in mid-winter (op. cit., Figure 4). Similarly, male and female adult Algonquin moose weights were approximately equal in mid-winter. We would expect fall weight dimorphism also. This sub-species difference may be related to a life history optimization tied to environmental stresses, which conceivably are different between Alaska and Algonquin Park.

Franzmann et al. (1984) considered 9 to 11 ug/kg carfentanil ideal for tranquilizing Alaskan moose. A 400-500 kg moose would require 4-5 mg of carfentanil. An anonymous reviewer pointed out that moose captured in the fall (prime animals) require up to 6 mg carfentanil for tranquilization. In our studies, 3 mg of carfentanil (6 to 7.5 ug/kg) was adequate for moose in the 400-500 kg range in mid-winter. This dose was also adequate in late May when body weights were lowest (Seal et al. 1985). Prolonged induction in our studies was due to poor injection location of the capture dart, not insufficient drug. For properly injected moose, induction time can be reduced with an increased dosage (Schmitt and Aho 1987, Franzmann et al. 1987).

At this time, we recommend 3 mg carfentanil and 25 mg xylazine for mid-winter immobilization of moose 1 year of age and older. A dose of 300 mg naltrexone IV and 200 mg naltrexone SQ is excellent to antagonize this dosage of carfentanil, with a wide safety margin.

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