2. EFFECT OF CAPTURE AND HANDLING ON BISON SURVIVAL

Capture of bison for research and management has a long history in WBNP. From 1925 to 1928, 6,673 bison were relocated from Wainwright Buffalo National Park in central Alberta to WBNP (see review by Carbyn et al. 1993). These bison were shipped on rail using cattle cars from Wainwright to Waterways, Alberta where they were loaded onto scows for transport to release sites along the western shore of the Slave River in WBNP, a distance of about 1,100 km. Carbyn et al. (1993) reported eyewitness accounts of "many" injuries and mortalities; they also reported the belief of local people that maybe one half of the bison perished on route or shortly after release.

WBNP staff conducted annual round-ups of bison to vaccinate against anthrax from 1965 to 1977 (Carbyn et al. 1993). During this time period, over 27,000 bison were vaccinated. Hudson et al. (1976) describe the protocol: "One day prior to vaccination, 1110 bison were assembled and herded by helicopter from meadow ranges at the northern tip of Lake Claire to handling facilities at Sweetgrass. The following day subgroups of 75-100 animals were separated by bombadier [snowmobile] and herded to a trap at the entrance of the shute [sic]. From these subgroups, smaller numbers were swept into the shute with a canvas curtain for vaccination and ear tagging." Carbyn et al. 1993 cited injuries from handling in chutes, trampling, cow-calf separation, goring, capture myopathy, and increased risk of abortion as possible consequences of this method. Although the reported capture-related mortality rate for bison during the vaccination programs averaged 2%, this is likely a significant underestimate of the true mortality rate (Carbyn et al. 1993).

WBNP staff conducted a radio-telemetry study of bison movements in the park in 1991-1993. Bison were darted from the ground using the opiod carfentanil, a drug whose effect was reversed with naloxone (WBNP 1995). Haigh and Gates (1995) reported that 12 of 64 (19%) of bison in which naloxone was used died within 15 days of capture. Data from the official report of the study (WBNP 1995) differed from Haigh and Gates (1995): the authors of the WBNP report stated that nine of 59 (15%) bison died within 30 days of capture. In any case, both reports concluded that opiod re-narcotization (Haigh 1990) was the likely cause of mortality.

2.1 Methods

2.1.1 Capture and handling techniques

I used three techniques to capture and handle bison. In all four years (February and March of 1997 - 2000), adult males too large to be slung under the helicopter were darted from the air using carfentanil and xylazine hydrochloride (see Appendix A for dosages of all drugs; Haigh and Gates 1995). Hereafter I refer to this technique as "darting". Once captured, handling procedures were the same as described below, with the difference that the bulls were anaesthetized. After handling, naltrexone hydrochloride was used to reverse the immobilizing agent. Bulls were re-immobilized after 72 hours to determine the results of the caudal fold test (see Chapter 4).

In February and March of 1997 and 1998, female and juvenile bison were captured with a net-gun fired from a Hughes 500D helicopter (Helicopter Wildlife Management, Salt Lake City, Utah). As the caudal fold test for tuberculosis requires a 72-hour wait period before the results can be determined (Monoghan et al. 1994), bison were held in captivity during this period. Each animal was slung blindfolded under the helicopter to a portable corral for handling and disease testing (hereafter, I refer to this handling technique as "captivity"). The corral was constructed from twelve welded steel panels (3 m long) that linked at the corners with steel pins. Four panels were erected in the centre at right angles and the remaining eight panels linked around the outside. This configuration resulted in a four-cell corral that could be opened at the corner for entry and exit of bison. A thick, white vinyl tarp was suspended on each panel to prevent strife among bison during captivity, and to discourage attempts to escape. Initially, I used a carfentanil and xylazine hydrochloride mixture to sedate the bison for handling at the corral (n = 6). However, I found that physical immobilization was sufficient to safely handle bison. Azaperone was administered as a short-acting tranquilizer to calm the bison during handling.

Adult (>3 years) and sub-adult (1-2 years) animals were kept in individual pens, while calves (<1 year) were paired to reduce isolation stress. A long-acting neuroleptic, Clopixol-Acuphase, was administered to keep the bison calm during captivity (Ebedes 1992). Second-cut alfalfa hay or alfalfa cubes were provided for food, and fresh snow was provided for water. After 72 hours in the corral, the bison were immobilized with carfentanil and xylazine hydrochloride in order to read the results of the caudal fold test for tuberculosis. In 1998, the xylazine was reversed using tolazoline. Naltrexone hydrochloride was used to reverse the carfentanil, and bison were released in a manner that encouraged individuals to leave as a group.

The third technique was similar to that described above, except that bison were not held in portable corrals (hereafter referred to as "net-gun"). Bison were captured with a net gun fired from a Hughes 500D helicopter (Helicopter Wildlife Management and Helicopter Capture Services, Salt Lake City, Utah). Handling (in the same manner as described above) was done at the capture site and bison were released immediately after handling and radio-collaring. Bison were relocated in three days and recaptured by net gunning to determine the results of the caudal fold test. I did not attempt to recapture any of the six bison released at capture sites in 1997 for logistical reasons.

A sample of adult bison was released with radio-transmitters to monitor survival (Telonics, Mesa, Arizona). Each radio-transmitter was equipped with a mortality switch that altered the rate of transmission when the collar was immobile for four hours. Bison were relocated using a Cessna 180 (Big River Air, Fort Smith, NT) approximately every three weeks after release.

In February and March of 2000, all bison with functioning radio collars were recaptured for removal of radio collars (n = 104). All males were darted as described above, and females were captured by net gun. Bison were handled briefly to draw blood and conduct a short physical examination (see below), the radio collars were removed, and the animals released.

2.1.2 Processing

In all three methods I assigned a subjective, relative body condition score for each bison based on criteria in Gerhart et al. (1996). For all analyses, I converted this five-category scale to a two category scale: "poor" (i.e., less than the median score) and "good" (i.e., greater than the median score). Bison were aged based on tooth eruption patterns (Fuller 1959b) and by counting cementum annuli on the third incisor (Matson's Laboratory, Milltown MT). Serum samples from each bison were taken for disease testing, and a physical examination was conducted to note signs of disease.

2.1.3 Data analysis

In this report, I refer to a capture-related mortality that occurred within 3 days of capture as "acute". In contrast, I refer to a capture-related mortality that occurs after this time period as "chronic" (with one exception; see page B6). Analysis of factors associated with chronic mortality excluded cases of acute mortality.

A major problem in determining the effect of handling on wildlife survival is the lack of a reference group with which to compare survival rates. I compared survival rate of radio-collared bison that were recently handled with the survival rate of radio-collared bison that were not handled that year (i.e., were equipped with a radio-collar in a previous year). The only year in which I used all three techniques (darting, captivity, net-gun) was 1998, and only a small number in that year were released and recaptured ($n = 11$). No bison were held in captivity in 1999. This makes it difficult to compare the effect of captivity against recapture for a given year. However, I can compare survival in each technique to that of the reference group, and infer the relative effects.

I used a generalized linear model (logistic regression) to examine factors affecting probability of mortality due to acute (ϕ_a) or chronic capture-related sources (ϕ_c; STATISTICA Release 5.5, StatSoft, Inc. Tulsa OK). In order to determine the effect of each factor on the probability of mortality, I employed the model-averaging technique advocated by Burnham and Anderson (1998:324-327). I used small sample size corrected Akaike information criteria (AICc) to rank the possible models of mortality based on the best compromise between parsimony and bias (Burnham and Anderson 1998: 51), and estimated parameter coefficients using model-averaging (see Anderson et al. 2000, Burnham and Anderson 1998: 326-327). Model-averaging results in coefficients that have better precision and less bias relative to the coefficients associated with the model with the lowest AICc value, in addition to incorporating uncertainty associated with model selection (Anderson et al. 2000). I assessed the goodness of fit of each model to the data using a likelihood ratio test (Sokal and Rohlf 1995: 686-697). Coefficients are presented as odds ratios (i.e., $e^{\text{coefficient}}$) and 95% confidence intervals to facilitate interpretation of data. For categorical variables, the odds ratio approximates how much more likely it is for the outcome (mortality) to be present among those animals with a particular trait (e.g., treatment vs. reference) than those without it (Hosmer and Lemeshow 1989). For a continuous variable, the odds ratio approximates how the odds for the outcome increase (or decrease) with an increase of one unit of the independent variable (e.g., age; also see example in Sokal and Rohlf 1995: 771-778).

Factors contributing to acute mortality (i.e., within 3 days of capture) associated with the captivity technique were examined for bison captured in 1997 and 1998. As low numbers of juvenile males were handled using this technique, I restricted this analysis to female bison. I hypothesized that probability of acute mortality would be correlated with the length of time that a bison was handled (i.e., from first pursuit by the helicopter to release from the physical restraints in the pen). Unfortunately, I was unable to consistently record handling times of bison. Therefore, following Beringer et al. (1996) I tested whether probability of acute mortality (ϕ_a) was associated with the number of bison captured at the same time, under the assumption that individual handling time would be correlated with the number of bison handled as a group. The probability of capture myopathy may be related to ambient temperature during capture and handling (Lewis 1977; Chalmers and Barret 1982; Spraker 1982; Beringer et al. 1996). I averaged the daily maximum temperature recorded at Fort Smith, NT, for the 3 days each animal was in captivity (°C; data from Environment Canada, http://www.weatheroffice.com/products) and included this factor in the analysis. I also included age of the bison in this analysis to control for possible age-related risk of acute mortality. As the effect of capture on survival may not have been constant for all age classes (e.g., Basson and Hofmeyr, 1973) I also tested for an interaction between age and capture.

I compared survival from time of capture (February 25 - March 12, 1998) to May 5, 1998. I chose May 5 as the end of the at-risk period for two main reasons:

1) May 5 is the median date of break-up on the Slave River (1953-1981; data in Carbyn et al. 1993:60), and so I felt that this date represented a biologically relevant transition between late winter and spring; and

2) May 5, 1998 was on average 61 days after capture (SD = 5 days). As re-narcotization associated with carfentanil in bison may have happened up to 15 days after capture

(Haigh and Gates, 1995), I assumed that 60 days would encompass any possible mortality associated with re-narcotization.

I was unable to employ the model-averaging technique when comparing probability of mortality among treatment and reference bison for the darting and net-gun techniques as there were no mortalities among reference animals for each treatment. Consequently, I used the G-test for independence (Sokal and Rohlf 1995: 729-733) to compare mortality probabilities among reference and treatment bison for analysis of these two capture techniques. I applied William's correction as some expected cell frequencies were less than five (Sokal and Rohlf 1995: 702).

2.2 Results

Captures were distributed using an approximate 3:3:1 ratio (Peace-Athabasca Delta: Hay Camp: Nyarling River; Figure 2.1). No males or females <2 years of age were captured in the Nyarling River area. I deployed 80, 75, and 72 radio-collars on bison in 1997, 1998, and 1999, respectively. A summary of captures and mortalities is presented in Table 2.1, while a discussion of all mortalities after capture is presented in Appendix B.

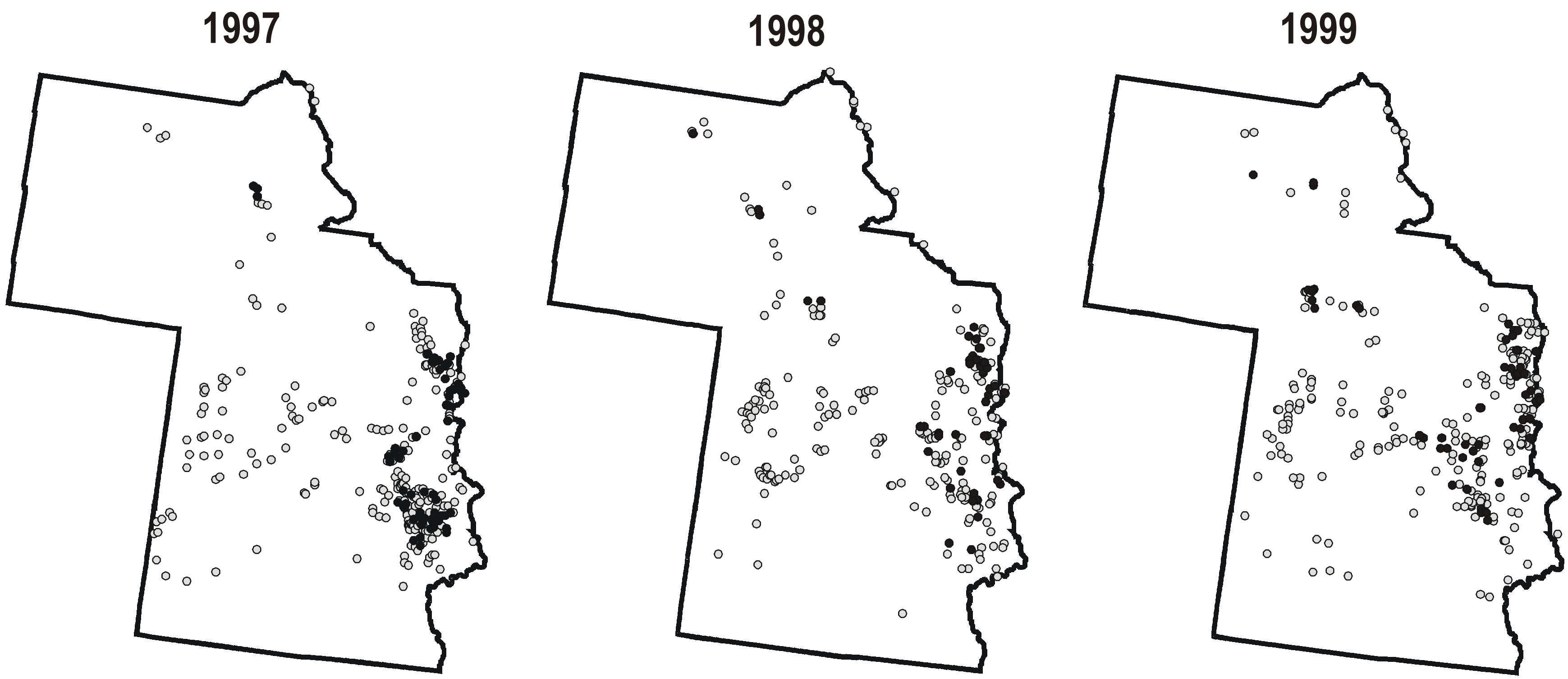

Figure 2.1. Location of bison captures (1997-99). Solid circles indicate locations of captures and open circles indicate observations of bison herds on WBNP bison surveys in February and March of each year.

Table 2.1 Summary of bison captures in Wood Buffalo National Park (February and March 1997-2000). See section 2.1 for description of capture techniques. Capture-related mortalities that occur within three days of capture were considered "acute", while those that occurred within 60 days were considered "chronic". Natural mortalities were those that occurred within 60 days of capture but were unrelated to capture. All mortalities during this time period are discussed in Appendix B.

Technique	Year	Bison captured	Acute	Chronic[a]	Natural
Captivity	1997	120	3	6	3
	1998	116	3	7	1
Net-gun	1997	6[b]	0	0	0
	1998	11	0	0	0
	1999	62	0	1	1[c]
Darting	1997	10	0	0	0
	1998	13	0	0	2[d]
	1999	13	1	1	0
	2000	21[g]	-	-	
Collar removals	1999	23	-	-	
	2000	104	-	-	

[a] excluded from survival analysis

[b] single captures as logistical constraints prevented recaptures that year.

[c] one female was killed by wolves within three days of capture, but there was no indication that capture stress was involved (see section 2.2.3)

[d] one bull fell through thin ice one day after capture

2.2.1 Captivity

Six acute capture-related mortalities occurred using the technique based on captivity, three in each of 1997 and 1998 (Table 2.1). Causes of acute mortality included: trauma associated with capture (n = 1); capture myopathy (n = 3); aspiration pneumonia (n = 1); and acute capture-related stress (n = 1). The most parsimonious model of acute mortality probability included only the number of bison captured at the same time (factor group), although models including temperature and group, or temperature alone preformed nearly as well (AIC_c values differed by less than 2; Table 2.2). Only the best model fitted the data reasonably well (Likelihood ratio goodness of fit test, $\chi^2 = 2.83$, d.f. = 1, p = 0.09) and no model had a high probability of being the best model, given the data (best model Akaike weight, $\omega_i = 0.32$).

There were 13 chronic capture-related mortalities associated with the captivity technique (6 in 1997 and 7 in 1998; Table 2.1). For three bison mortalities in 1997, wolf predation within 10 days of release from the pen was the proximate source of mortality; however, to be conservative I have classified these as capture-related. Wolf predation was implicated in the deaths of two more bison that were detected in 32-37 days after release from the pen. I was unable to investigate the final case of bison mortality in 1997 until two months later, at which time I could not determine the cause of death. To be conservative I have also classified these three mortalities as capture-related. In 1998, causes of mortality included: colonic impaction related to dehydration during captivity (n = 1), capture myopathy (n = 2), predation (n = 2), and unknown causes (n = 2).

Table 2.2 Comparison of models of mortality (ϕ_a) in the three days after capture for female bison handled using the capture and captivity techniques. The χ^2 and p-value refer to the likelihood ratio goodness of fit test. Relative AIC_c is presented as Δ_i, and the Akaike weight (ω_i) refers to the probability that the model is the Kullback-Liebler best model, given the data (see Anderson et al. 2000).

Model[a]	d.f.	χ^2	p	Δ_i	ω_i
Group[b]	1	2.83	0.09	0.00	0.32
Temperature[c], group	2	4.03	0.13	0.87	0.21
Temperature	1	1.26	0.26	1.57	0.15
Age[d], group	2	2.88	0.24	2.01	0.12
Age, temperature, group	3	4.06	0.26	2.92	0.07
Age	1	0.00	0.96	2.83	0.08
Age, temperature	2	1.26	0.53	3.63	0.05

[a] model-averaged odds ratios (95% CI): age, 1.00 (0.93 - 1.09); temperature, 1.07 (0.93 - 1.22); group, 1.27 (0.73 - 2.21).
[b] number of bison captured at same time
[c] average maximum daily temperature (ºC) during captivity
[d] age of bison determined by tooth eruption (< 3 years) or cementum annuli

I excluded male bison less than one year of age in this analysis due to small sample sizes and a lack of a reference group. However, wolves killed three of 6 male calves in 1998. All three were the result of natural predation, unrelated to capture. There were no mortalities among eight male calves handled with this technique in 1997. Overall acute capture-related mortality rate for the captivity technique was 2.5% (n = 236). The overall chronic capture-related mortality rate for this technique was 5.6% (n = 230). I could not detect any differences in mortality rates for the 60 days after capture between treatment and reference groups of bison (Likelihood ratio test, $p > 0.20$ for all models; Table 2.3).

2.2.2 Net-gun

In seven cases, recapture was delayed until the fourth day, as the bison were in habitat where net gunning was impossible. I was unable to recapture one bison for the same reason. One bison with a radio ear-tag was not relocated for recapture due to a transmitter problem, although he was relocated alive in August of the same year. There were no mortalities among bison handled with this technique in 1998 (n = 11). In 1999, an adult female was killed by wolves within two days of the first capture. While this mortality occurred within 3 days of capture, I elected to treat this mortality in the analysis as a chronic mortality as the distance travelled from the capture site (20 km) suggested she did not suffer from acute capture myopathy. Another mortality occurred within 60 days of capture using this technique: a sub-adult female was relocated dead eight days after release. The bison was in a remote location and so I could not investigate the mortality until late spring, at which point I was unable to determine the

Table 2.3 Comparison of models of mortality (ϕ_c) in the 61 (SD = 5) days after capture for reference and treatment (corral) female bison. The χ^2 and p-value refer to the likelihood ratio goodness of fit test. Relative AIC_c is presented as Δ_i, and the Akaike weight (ω_i) refers to the probability that the model is the Kullback-Liebler best model, given the data (see Anderson et al. 2000).

Model[a]	df	χ^2	p	Δ_i	ω_i
Age[b]*corral	1	1.65	0.20	0.00	0.26
Age	1	1.05	0.30	0.60	0.19
Corral	1	0.80	0.37	0.85	0.17
Age, age*corral	2	2.46	0.29	1.33	0.13
Corral, age	2	2.06	0.36	1.72	0.11
Corral, age*corral	2	1.73	0.42	2.06	0.09
Corral, age, age*corral	3	2.46	0.48	3.51	0.04

[a] model-averaged odds ratios (95% CI): age, 0.97 (0.93 - 1.01); corral, 1.07 (0.75 - 1.53); age*corral, 1.03 (0.97 - 1.08).

[b] age of bison determined by tooth eruption (< 3 years) or cementum annuli

cause of death. To be conservative I assume that capture myopathy played a role in this case. The overall acute and chronic capture-related mortality rate associated with this technique was 1.3% (n = 79).

I compared probability of mortality in the first 60 days post capture for bison handled with this technique to reference female bison using the G-test for independence (treatment n = 11 (1998), n = 50 (1999); reference n = 45 (1998), n = 60 (1999)). Combining the two years, I found no difference in probability of mortality during the 60 days after capture (reference, 3 mortalities, n = 105; treatment, 2 mortalities, n = 61; G-test for independence G = 0.02, df = 1, p = 0.88).

2.2.3 Darting

Two of the 10 bulls were not recaptured in 1997. Two adult males died within three days of capture, one in each of 1998 and 1999. The first bison drowned after falling through thin ice (unrelated to capture). The second bison required two darts of carfentanil to achieve immobilization and fifteen minutes after the second dart he died. There were two mortalities among darted adult males that occurred within 60 days of capture (n = 1 for 1997 and 1998). The cause of death is unknown in the first case; however as he was relocated alive at least 22 days after capture the mortality was likely not capture related. The second bison was killed by wolves 10 days after capture, and as this is a rare occurrence, I assume that capture stress was involved. No mortalities of reference adult males occurred during 1998 and 1999 (n = 22). I could not detect a difference in mortality probability among reference and treatment bison (G-test for independence, G = 2.22, df = 1, p = 0.14).

2.3 Discussion

2.3.1 Captivity

I found that models incorporating age, handling group size and temperature while in captivity did not adequately predict acute mortality. However, the sum of the Akaike weights for models including group size was 0.72 (Table 2.2), suggesting that the number of bison captured, and consequently handling time, increased risk of acute mortality. The odds of acute mortality increased 1.3 times for every bison added to the capture group, although the odds ratio did not differ from one (95% confidence interval, 0.73 - 2.21), indicating an uncertain response. A precautionary measure in future bison operations using captivity would be to limit the number of bison captured and handled at one time to a maximum of two animals. However, it is important to note that animal care and human safety concerns, as well as other logistical constrains, must be factored into determining these limits. To achieve a target sample size, limiting the number of bison captured at one time (and therefore from one group) means that more bison groups must be disturbed while capturing animals. The effect of helicopter pursuit on non-target bison has not been quantified. In addition, limiting the number of bison that can be handled at one time decreases the total number of bison that can be handled in one day as more time is spent searching for herds. This results in a longer capture operation necessary to achieve a target sample size, increasing fatigue of the capture crew.

There was also some evidence that mean maximum temperature during captivity was related to acute mortality (Table 2.2), although I could not determine if the odds ratio differed from one. The warmest mean maximum temperature during captivity was

-2.2°C; perhaps the range of temperatures was not sufficient to capture the true effect of temperature on acute mortality. I suspect that above this range, temperature would become a significant factor in capture-related acute mortality. I recommend that a conservative "rule of thumb" would be to avoid handling bison in this manner above temperatures of -5°C. Age did not appear to affect probability of acute capture mortality (Table 2.2).

None of the models I considered to describe chronic capture-related mortality adequately fit the data, and the odds ratios did not differ from one for any of the factors considered (age, corral, age*corral; Table 2.3). This result could be interpreted in one of three ways: 1) the capture does not increase mortality of bison released from the pen; 2) mortality for individuals is too variable for us to detect an effect given my sample size; or 3) individuals that died as a result of handling may have had an intrinsic susceptibility to natural mortality. I reject the first interpretation as cases of capture myopathy were observed during this period. I suspect that a combination of the latter two interpretations is probably responsible for these results. To be conservative in subsequent survival analyses, I removed bison for which there was evidence for chronic, capture-related mortality (Appendix B).

2.3.2 Net-gun

No bison handled using the net-gun technique suffered acute mortality, and only 1 of 79 (1.3%) bison possibly died of chronic capture-related mortality. This conservative mortality rate did not differ from that experienced by reference bison over the same period. The main drawback of this technique with respect to tuberculosis testing with the caudal fold test is the requirement to recapture bison in 72 hours. Weather conditions may prevent capture within this time period. Further, in my study, recapture was delayed in seven cases (out of 79 cases) until the fourth day, and one recapture was prevented, because bison were in habitat that made net gunning impossible. Recapture in 72 hours also increases the number of animals that must be captured in one day, as new captures as well as recaptures of bison from 3 days previous must be captured each day. This increase may cause increased fatigue and potential for injury among capture personnel.

Nevertheless, this technique involves rapid capture and handling of female bison without the use of chemical immobilization, and allows bison to resume their normal activities after release. The ability to handle bison without the use of immobilizing drugs is an important consideration. At present, the most effective immobilization and reversal combination in bison is carfentanil and naltrexone (Haigh and Gates 1995). However, carfentanil poses a risk to capture personnel, as this drug is highly potent and medical staff may have little or no experience treating accidents involving carfentanil (Haigh 1990). The use of a physical restraint technique eliminates the need for narcotics to immobilize female bison. This technique should be considered in planning for future bison captures where tuberculosis testing is required.

2.3.3 Darting

I did not find a difference in mortality between bison handled with the darting technique and reference bison. However, as chronic capture-related stress may have contributed to the death of at least one of the two bison that died (see section 2.2.3), I reject the hypothesis of no difference among the reference and treatment bison. Haigh and Gates (1995) did not observe mortalities associated with carfentanil when a high dose of naltrexone was administered. It is possible that two captures in three days induces a higher risk of capture-related mortality than a single capture as a result of greater stress. Although I did not attempt to capture bulls with a net gun, it is my belief that this would be unsuccessful. Consequently, in view of the low risk of mortality I recommend the use of carfentanil and naltrexone as an effective technique for capturing adult male bison. Further, my data demonstrate that the rate of mortality associated with capture is low, and that exclusion of bison with known or suspected capture-related mortalities will allow an unbiased estimate of survival.

2.3.4 Conclusions

Each of the capture methods employed above incurred some probability of capture-related mortality. However, in each case I found that the mortality rate was low, and the probability of chronic mortality due to capture was not distinguishable from that for bison that were not handled during the same period. I conclude that the net-gun and darting methods represent the best possible compromise between animal care concerns and efficiency of methods. I also conclude that excluding the known capture-related mortalities allows the remaining bison to be used in further survival analyses without incurring a substantial bias.