FEDERAL AID FINAL RESEARCH PERFORMANCE REPORT

ALASKA DEPARTMENT OF FISH AND GAME
DIVISION OF WILDLIFE CONSERVATION
PO Box 115526
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PROJECT TITLE: Response of moose and their predators to wolf reduction and short-term bear removal in a portion of Unit 19D

PRINCIPAL INVESTIGATOR: Mark A. Keech

FEDERAL AID GRANT PROGRAM: Wildlife Restoration

GRANT AND SEGMENT NUMBERS: W-33-10

PROJECT NO.: 1.62

WORK LOCATION: Interior Alaska. Unit 19D East, the upper Kuskokwim River drainage upstream of the Selatna River. Intensive study area (also known as the "experimental micromanagement area" or "EMMA"). The 528 mi^2 area along the Kuskokwim and Takotna rivers within Unit 19D East that immediately surrounds the community of McGrath.

STATE: Alaska

PROJECT DURATION: 1 July 2005–30 June 2012

I. PROBLEM OR NEED THAT PROMPTED THIS RESEARCH

The demand for increased sustained yield of moose (*Alces alces*) has been the impetus for predator reduction efforts within selected areas of Alaska in recent years. The north and eastern portion of Unit 19D, in western Interior Alaska, was one area selected by the Alaska Board of Game to provide higher harvests of moose. As a result, a portion of Unit 19D East, primarily around the community of McGrath, has been the focus of active predator reduction efforts that began in spring 2003 and have continued to present. The goal of this research project was to document the effect of predator reductions, as well as other environmental and individual factors, on moose survival and population dynamics.

Predator reduction efforts to increase moose harvests in Unit 19D East differed from predator reduction efforts elsewhere in Alaska in 2 principal ways. First, the Alaska Board of Game and the Alaska Department of Fish and Game (ADF&G) focused private aircraft-assisted take of wolves (*Canis lupus*) in the most heavily utilized portion of Unit 19D East, as opposed to authorizing aircraft-assisted take throughout the entire unit. Secondly, ADF&G conducted thorough experimental translocations of black bears (*Ursus americanus*) and brown bears (*U. arctos*) from a small portion of Unit 19D East surrounding McGrath to increase survival of newborn moose.

Concurrent with predator reduction efforts, this research project (federal aid project 1.62) in conjunction with its predecessor (federal aid project 1.58), documented abundance of wolves, bears, and moose within a study area that encompassed the core area of predator reductions.

These studies also estimated changes in survival and causes of mortality for all age classes of moose within the study area.

II. REVIEW OF PRIOR RESEARCH AND STUDIES IN PROGRESS ON THE PROBLEM OR NEED

Effective management of moose populations in many northern systems requires that managers understand the effects of predation by wolves, brown bears, and black bears. These 3 predators have been important sources of mortality for moose at both low (Boertje et al. 1988, Larsen et al. 1989, Bowyer et al. 1998, Bertram and Vivion 2002) and relatively high moose densities (Franzmann and Schwartz 1980, Ballard et al. 1981, Gasaway et al. 1983). Moose survival and density have been increased by reductions in predator numbers (Gasaway et al. 1983, Stewart et al. 1985, Ballard and Miller 1990, Boertje et al. 1996, Hayes et al. 2003). However, relevant detailed individual and environmental covariate data have been lacking in manipulative moose predation studies to date.

Identifying the effects of predator treatments requires evaluating the contribution of variables other than predator treatments that can influence survival (White et al. 2010). Condition of individual moose affects their susceptibility to predation (Testa and Adams 1998, Keech et al. 2000, Swenson et al. 2007), and factors such as density, age, and weather can influence moose survival independent of predator treatments (Van Ballenberghe and Ballard 1997; Boertje et al. 2007, 2009). By assessing survival in this broader ecological context, we could potentially increase our understanding of additive versus compensatory mortality and proximate versus ultimate factors affecting predator-ungulate dynamics (Linnell et al. 1995, Ballard and Van Ballenberghe 1998, Zager and Beecham 2006).

Literature Cited

BALLARD, W. B., T. H. SPRAKER, AND K. P. TAYLOR. 1981. Causes of neonatal moose calf mortality in southcentral Alaska. Journal of Wildlife Management 45:335–342.

BALLARD, W. B., AND S. D. MILLER. 1990. Effects of reducing brown bear density on moose calf survival in southcentral Alaska. Alces 26:9–13.

BALLARD, W. B., AND V. VAN BALLENBERGHE. 1998. Moose–predator relationships: research and management needs. Alces 34:91–105.

BERTRAM, M. R., AND M. T. VIVION. 2002. Moose mortality in eastern interior Alaska. Journal of Wildlife Management 66:747–756.

BOERTJE, R. D., W. C. GASAWAY, D. V. GRANGAARD, AND D. G. KELLEYHOUSE. 1988. Predation on moose and caribou by radio-collared grizzly bears in east central Alaska. Canadian Journal of Zoology 66:2492–2499.

BOERTJE, R. D., P. VALKENBURG, AND M. E. MCNAY. 1996. Increases in moose, caribou, and wolves following wolf control in Alaska. Journal of Wildlife Management 60:474–489.

BOERTJE, R. D., K. A. KELLIE, C. T. SEATON, M. A. KEECH, D. D. YOUNG, B. W. DALE, L. G. ADAMS, AND A. R. ADERMAN. 2007. Ranking Alaska moose nutrition: signals to begin liberal antlerless harvest. Journal of Wildlife Management 71:1494–1506.

BOERTJE, R. D., M. A. KEECH, D. D. YOUNG, K. A. KELLIE, AND C. T. SEATON. 2009. Managing for elevated yield of moose in Interior Alaska. Journal of Wildlife Management 73:314–327.

BOWYER, R. T., V. VAN BALLENBERGHE, AND J. G. KIE. 1998. Timing and synchrony of parturition of Alaskan moose: long term versus proximal effects of climate. Journal of Mammalogy 79:1332–1344.
FRANZMANN, A. W., AND C. C. SCHWARTZ. 1980. Moose calf mortality in summer on the Kenai Peninsula, Alaska. Journal of Wildlife Management 44:764–768.
GASAWAY, W. C., R. O. STEPHENSON, J. L. DAVIS, P. E. K. SHEPERD, AND O. E. BURRIS. 1983. Interrelationships of wolves, prey, and man in interior Alaska. Wildlife Monographs 84.
HAYES, R. D., R. FARNELL, R. M. P. WARD, J. CARY, M. DEHN, G. W. KUZYK, A. M. BAER, C. L. GARDNER, AND M. O'DONOGHUE. 2003. Experimental reduction of wolves in the Yukon: ungulate responses and management implication. Wildlife Monographs 152.
KEECH, M. A., R. T. BOWYER, J. M. VER HOEF, R. D. BOERTJE, B. W. DALE, AND T. R STEPHENSON. 2000. Life-history consequences of maternal condition in Alaskan moose. Journal of Wildlife Management 64:450–462.
LARSEN, D. G., D. A. GAUTHIER, AND R. L. MARKEL. 1989. Causes and rate of moose mortality in the southwest Yukon. Journal of Wildlife Management 53:548–557.
LINNELL, J. D. C., R. AANES, AND R. ANDERSEN. 1995. Who killed Bambi? The role of predation in neonatal mortality of temperate ungulates. Wildlife Biology 1:209–223.
STEWART, R. R., E. H. KOWAL, R. BEAULIEU, AND T. W. ROCK. 1985. The impact of black bear removal on moose calf survival in east-central Saskatchewan. Alces 21:403–418.
SWENSON, J. E., B. DAHLE, H. BUSK, O. OPSETH, T. JOHANSEN, A. SODERBERG, K. WALLIN, AND G. CEDERLUND. 2007. Predation on moose calves by European brown bears. Journal of Wildlife Management 71:1993–1997.
TESTA, J. W., AND G. P. ADAMS. 1998. Body condition and adjustments to reproductive effort in female moose (*Alces alces*). Journal of Mammalogy 79:1345–1354.
VAN BALLENBERGHE, V., AND W. B. BALLARD. 1997. Population dynamics. Pages 223–245 *in* A. W. Franzmann and C. C. Schwartz, editors. Ecology and management of the North American moose. Smithsonian Institution Press, London, United Kingdom.
WHITE, C. G., P. ZAGER, AND M. W. GRATSON. 2010. Influence of predator harvest, biological factors, and landscape on elk calf survival in Idaho. Journal of Wildlife Management 74:355–369.
ZAGER, P., AND J. BEECHAM. 2006. The role of American black bears and brown bears as predators on ungulates in North America. Ursus 17:95–108.

III. APPROACHES USED AND FINDINGS RELATED TO THE OBJECTIVES AND TO PROBLEM OR NEED

OBJECTIVE 1: Monitor response of moose to recent management actions.

JOB/ACTIVITY 1A: Estimate moose numbers and population composition in Unit 19D East.

We used the geospatial population estimation (GSPE) technique to obtain population estimates and estimates of population composition during 2005–2010.

Surveys within the study area indicated an increasing trend in moose abundance between 2005 and 2010, which was largely the result of predator removal efforts that began in spring 2003. Early winter moose abundance estimates for the bear removal area (1,368 km^2) ranged from 621 (90% CI = ±69) in November 2005 to 883 (90% CI = ±129) in November 2007. Early winter moose abundance estimates for a larger area (2,896 km^2) including and surrounding the bear removal area ranged from 1,308 (90% CI = ±174) in November 2006 to 1,820 (90% CI = ±323) in November 2009 (Table 2). Early winter calf:cow ratios in these survey areas ranged from 38 to 58 calves:100 cows and were higher than in years prior to predator removals (<2003). Bull:cow ratios were also relatively high in these survey areas during the duration of this study, likely the result of the combined effects of predator reductions and a partial hunting closure in the study area.

JOB/ACTIVITY 1B: Determine primary causes of mortality of moose calves.
During 2005, 2006, 2007, and 2010 we captured and radiocollared ≥50 newborn moose annually within the study area. Calves were monitored with daily radiotracking flights for approximately 3 weeks following capture, after which tracking intervals gradually increased. During capture calves were weighed to compare their nutritional status with moose calves captured during previous years in the study area as well as from other areas of the state. Death sites were inspected as soon as practical to determine cause of death. During this study, annual survival rates for radiocollared moose calves ranged from 63% for the 2006 cohort to 35% for the 2007 cohort, and was higher than the period prior to predator removals. Most calf mortality occurred within 60 days of birth, and summer survival was generally much lower than winter survival. Combined predation by black bears, brown bears, and wolves accounted for most mortality of moose calves during the summer and fall of all years. During winter, nonpredation deaths accounted for most calf mortality and calf survival was negatively influenced by snow depth. In addition to predator removals and snow depth, variables of individual condition including number of siblings and birth weight also significantly influenced calf survival.

Despite increases in nonpredation mortalities following predator removals, predators were still the primary sources of mortality for radiocollared calves during this study (2005–2010). Although, nonpredation sources of mortality increased following predator removals, these increases did little offset increases in survival attributable to predator removals, which indicated predation mortality was largely additive.

JOB/ACTIVITY 1C: Determine condition, movements, and mortality rates of yearling moose.
We captured 15 female short yearling (10-month-old calves) moose in late March during each year of this study (16 captured in 2009). Short yearlings were weighed to compare their nutritional status with short yearlings captured elsewhere in the state. We also deployed radio collars on all short yearlings captured during 2008–2010, 9 captured in 2005, and 11 captured in 2006. Collars were not deployed in 2007. We monitored short-yearlings at least monthly for 14 months following capture to determine yearling movements and mortality rates.

Weights of short-yearling female moose ranged from 160.7 kg in 2009 to 185.3 kg in 2007. These weights fall between the values for moose populations with poor nutritional status (e.g., 155 kg, northcentral Unit 20A) and those with high nutritional status (e.g., 204 kg, Denali National Park, Unit 20C).

Annual survival rates for radiocollared yearling moose (hunting mortality removed) ranged from 96% for the 2005 cohort to 83% for the 2009 cohort, and were higher than in years prior to predator removals. Yearling mortalities occurred throughout the year; however, more deaths occurred during summer and fall than winter. Unlike moose calves, snow depth apparently had little effect on survival of radiocollared yearling moose. We observed yearling mortalities from wolves, hunting, and unknown causes; however, predation by wolves accounted for most mortality of radiocollared yearling moose.

Radiocollared yearling moose within and around the study area were essentially resident. We did not observe any discernible large-scale migratory pattern from the monthly location flights.

JOB/ACTIVITY 1D: Determine twinning rates and reproductive indices of moose in Unit 19D East.
To determine twinning rates and reproductive indices of moose we monitored radiocollared adult (>2 years of age) moose daily in May and early June in order to detect newborn calves. We also recorded observations of twin and single calves of uncollared females during May and June flights to determine twinning rates for uncollared females. Radiocollared adult females were either captured as adults during federal aid project 1.52, or had been captured as yearlings and had survived to the adult age class.

Annual twinning rates for radiocollared female moose ≥3 years old ranged 33–55% during 2006–2010 and were similar to those for uncollared females. These twinning rates fall between the values reported for moose populations with poor nutritional status (e.g., 7%, northcentral Unit 20A) and those with high nutritional status (e.g., 64%, Yukon Flats Unit 25D). Average weights of sampled calves estimated to be ≤3 days old at capture ranged 16.0 kg during spring 2006 to 17.6 kg during spring 2010, similar to other studies across Alaska.

JOB/ACTIVITY 1E: Monitor collared adult and yearling moose for survival and movement information.
We monitored radiocollared adult and yearling moose on a monthly basis to determine survival and movements. We accessed mortality sites as soon as practical after detection, generally within 1 week to determine causes of death.

Annual survival rates observed for radiocollared adult (≥2 years of age) moose ranged from 96% for the 2008 cohort to 98% for the 2005, 2007, and 2009 cohorts. These rates were high and likely resulted in part from the age structure of the radiocollared sample, which contained a disproportionate number of prime aged (2- to 7-year-old) moose relative to the overall population. However, results of modeling analysis that accounts for such covariate information indicated adult survival was higher following predator removals than prior to removals, despite the change in age structure of the sample population.

Most adult mortalities we observed were from nonpredation causes, however, we also observed adult mortalities from wolves and illegal take. Survival of adult females was not influenced by snow depth.

Radiocollared adult female moose within and around the study area were essentially resident moose. We did not observe any discernible large-scale migratory pattern from the monthly location flights.

OBJECTIVE 2: Characterize winter moose browse in Unit 19D East, with emphasis on the intensive study area.

Browse surveys were conducted in the study area during March 2009 using browse biomass removal techniques. A total of 42 plots (278 plants) were sampled using a helicopter to access 15 systematically selected floodplain-willow bar plots adjacent to the Kuskokwim River and 27 randomly chosen plots off the river. Randomly selected plots were based on selection of geospatial survey units.

Overall mean biomass removal for 2009 was 40.5% (95% CI: 33.2–47.1%). Browse biomass removal was 37.8% in randomly selected sites and 41.9% in high-use wintering sites. This indicates a substantial increase in browse removal compared to 2003 and is consistent with the population increase in the study area.

OBJECTIVE 3: Estimate wolf numbers in Unit 19D East with emphasis on the intensive study area.

We conducted surveys to estimate wolf density during March 2006 and March 2009 in the study area. Surveys were conducted several days following a fresh snowfall (<8 days) and we used 3–4 small aircraft flown by pilots experienced at snow-tracking wolves. We generally searched using parallel transects, with increased effort along likely wolf travel routes. We followed wolf tracks until we sighted the wolves or until the tracks were lost. If we did not observe wolves or if they were obscured by cover, we estimated wolf numbers from tracks where individuals traveled separate paths. To estimate population size, we totaled the number of wolves believed to occupy territories primarily within the survey area plus 50% of wolves believed to occupy territories substantially overlapping survey area boundaries.

We estimated 1.3 wolves/1,000 km^2 (n = 11 wolves) in the 8,314 km^2 wolf control zone during March 2006. During March 2009 we estimated 1.9 wolves/1,000 km^2 (n = 16 wolves) in the 8,314 km^2 wolf control zone. These surveys indicate the wolf population within the wolf control zone (which encompasses the study area) declined as much as 75% following wolf removals.

OBJECTIVE 4: Estimate black bear numbers in the intensive study area.

We used mark–resight techniques to estimate the abundance of independent black bears (all bear except dependent cubs) in the bear removal portion of our study area during May 2007 and May 2010. To premark individuals in our population, we captured and radiocollared 53 bears. For the 2007 survey, we partitioned the bear removal area into 5 sections, each approximately 275 km^2, and searched all sections daily 1–8 May. For the 2010 survey, the survey area was partitioned into 4 sections (each approximately 342 km^2) and we searched all sections daily 5–12 May. We used small aircraft (Piper PA-18, Piper Aircraft Corporation, Lock Haven, PA, or Bellanca

8GCBC, American Champion Aircraft Corporation, Rochester, WI) flown at a search intensity of approximately 1.2 min/km^2 to search for bears.

We estimated 70 (SE = 6.9) independent black bears used the bear removal area during our 2007 survey (27% fewer than the 2003 estimate prior to bear removals). By 2010, the black bear population had completely recovered from the 2003 and 2004 removal efforts; we estimated 123 (SE = 16.6) independent black bears used EMMA during our 2010 survey. These postremoval population estimates indicate a relatively rapid (6 year) population recovery of black bears in the bear removal area following a drastic reduction in population.

OBJECTIVE 5: Analyze hair and tissue samples for species, sex, and age information.
We collected samples of suspected predator hairs at mortality sites of radiocollared moose calves while investigating causes of death. Hairs were typically collected from branches, rough bark, or understory vegetation at the mortality site or on immediately adjacent (<25 m) travel paths. We placed hair samples in paper envelopes and stored samples in cool dry conditions. We sent samples to the University of Idaho for species, sex (bears only), and individual-specific DNA analysis.

Most samples provided adequate DNA for identification of species (wolves, black and brown bears were identified) and approximately 65% of samples identified as bears provided sex identification. Roughly similar numbers of male and female bears were identified, indicating both sexes of both species of bears are likely effective predators of moose calves.

OBJECTIVE 6: Review literature, write annual progress reports, write final project report, and publish results in peer reviewed journals.
During times when little fieldwork occurred, literature was reviewed, data was analyzed, and reports, presentations, and papers for publication in peer-reviewed journals were prepared.

See section VII.

IV. MANAGEMENT IMPLICATIONS

Removing moose predators in the McGrath area resulted in significant growth of the moose population. This growth resulted from increases in survival of all age classes of moose following removal of predators. Removal of primarily black bears, and to a lesser degree, wolves, resulted in increased summer and fall survival of moose calves. Removal of wolves resulted in increased summer and fall survival of yearling moose. Removal of wolves resulted in increased annual survival of adult female moose. We did not observe a benefit of predator removals to calves or yearlings during winter. However, winter calf survival was strongly and negatively influenced by deep snows. We observed no effect of snow depth on survival of yearling or adult moose. We did observe a significant increase in nonpredation mortalities following removals of predators, indicating some component of observed predation mortality on calves is compensatory. However, increases in nonpredation calf deaths did little to offset increases in survival following removals, indicating most calf mortality was additive. We observed the complete numerical recovery of the black bear population in the bear removal area within 6 years after a 96% population reduction. This illustrates the resilience of black bear populations to exploitation when harvests/removals occur in localized areas surrounded by unexploited habitat. We also concluded that male and female bears preyed on calves at similar rates; thus, both sexes of bears were effective calf predators.

This is a thorough study where 3 predators were treated to successfully increase moose survival and numbers. Given results of this and previous studies, wildlife managers and policymakers may expect similar results from predator treatment programs elsewhere, but use less costly and less thorough study designs. Managers, especially in multi-predator systems, should recognize that a substantial suite of covariates and confounding effects may complicate program results. Consequently, managers should be prepared to adapt study designs as well as treatment methods to increase the likelihood of program success and understanding. To accomplish this, we recommend managers implement programs that include collecting comparative data on 1) the relative abundance and harvest of moose and predators, 2) basic information on moose nutritional status and population composition, 3) the frequency of deep snowfall winters, and 4) the relative effects of different predators on moose survival, because the effects vary considerably among study areas.

V. SUMMARY OF WORK COMPLETED ON JOBS IDENTIFIED IN ANNUAL PLAN

JOB/ACTIVITY 6: Literature review, Data Analysis, Reporting Writing, and Publication of Results

KEECH, M. A. 2012 (*In prep*). Response of moose and their predators to wolf reduction and short-term bear removal in a portion of Unit 19D. Alaska Department of Fish and Game, Final Wildlife Research Report, ADF&G/DWC/WRR 2012, Project 1.62, Juneau, Alaska. (submitted final to HQ 9 August 2012).

KEECH, M. A., T. A. BOUDREAU, R. D. BOERTJE, AND B. D. TARAS. *In Review*. Importance of male versus female black bears as predators of moose calves. (submitted to *Wildlife Society Bulletin*, July 2012).

KEECH, M. A., M. S. LINDBERG, R. D. BOERTJE, P. VALKENBURG, B. D. TARAS, T. A. BOUDREAU, AND K. B. BECKMEN. 2011. Effects of predator treatments, individual traits, and environment on moose survival in Alaska. Journal of Wildlife Management 75:1361–1380.

KEECH, M. A., B. D. TARAS, T. A. BOUDREAU, AND R. D. BOERTJE. *In Review*. Black bear population reduction and recovery in western Interior Alaska. (submitted to *Wildlife Society Bulletin*, June 2012).

VI. PUBLICATIONS

BOERTJE, R. D., M. A. KEECH, AND T. F. PARAGI. 2010. Science and values influencing predator control for Alaska moose management. Journal of Wildlife Management 74:917–928.

BOERTJE, R. D., M. A. KEECH, D. D. YOUNG, K. A. KELLIE, AND C. T. SEATON. 2009. Managing for elevated yield of moose in Interior Alaska. Journal of Wildlife Management 73:314–327.

BOERTJE, R. D., K. A. KELLIE, C. T. SEATON, M. A. KEECH, D. D. YOUNG, B. W. DALE, L. G. ADAMS, AND A. R. ADERMAN. 2007. Ranking Alaska moose nutrition: signals to begin liberal antlerless harvest. Journal of Wildlife Management 71:1494–1506.

KEECH, M. A. 2012 (*In prep)*. Response of moose and their predators to wolf reduction and short-term bear removal in a portion of Unit 19D. Alaska Department of Fish and Game, Final Wildlife Research Report, ADF&G/DWC/WTR 2012, Project 1.62, Juneau, Alaska. (submitted to HQ 9 August 2012)

KEECH, M. A., M. S. LINDBERG, R. D. BOERTJE, P. VALKENBURG, B. D. TARAS, T. A. BOUDREAU, AND K. B. BECKMEN. 2011. Effects of predator treatments, individual traits, and environment on moose survival in Alaska. Journal of Wildlife Management 75:1361–1380.