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Commentary

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ABSTRACT We encourage informed and transparent decision-making processes concerning the recently expanded programs in Alaska, USA, to reduce predation on moose (*Alces alces*). The decision whether to implement predator control ultimately concerns what society should value; therefore, policymakers, not objective biologists, play a leadership role. From a management and scientific standpoint, biological support for these predator-control programs requires convincing evidence that 1) predators kill substantial numbers of moose that would otherwise mostly live and be available for harvest, 2) low predation can facilitate reliably higher harvests of moose, 3) given less predation, habitats can sustain more moose and be protected from too many moose, and 4) sustainable populations of Alaska's brown bears (*Ursus arctos*), black bears (*Ursus americanus*), and wolves (*Canis lupus*) will exist in and out of control areas. We reviewed 10 moose mortality studies, 36 case histories, 10 manipulative studies, 15 moose nutrition studies, and 3 recent successful uses of nutrition-based management to harvest excess female moose. Results of these studies support application of long-term, substantial predator control for increasing yield of moose in these simple systems where moose are a primary prey of 3 effective predators. We found no substantive, contradictory results in these systems. However, to identify and administer feasible moose population objectives, recently established moose nutritional indices must be monitored, and regulatory bodies must accept nutrition-based management. In addition, the efficacy of techniques to reduce bear predation requires further study. Predicting precise results of predator control on subsequent harvest of moose will continue to be problematic because of a diversity of changing interactions among biological, environmental, and practical factors. In Alaska, the governor has the prerogative to influence regulations on predator control by appointing members to the Board of Game. At least annually, the Board of Game hears a wide spectrum of public opinions opposing and favoring predator control. We summarized these opinions as well as the societal and cultural values and expectations that are often the primary basis for debates. Advocates on both sides of the debate suggest they hold the higher conservation ethic, and both sides provide biased science. We recommend a more constructive and credible dialogue that focuses openly on values rather than on biased science and fabricated conspiracies. To be credible and to add substance in this divisive political arena, biologists must be well informed and provide complete information in an unbiased and respectful manner without exaggeration.

KEY WORDS Alaska, *Alces alces*, bear, *Canis lupus*, moose, predator control, *Ursus americanus*, *Ursus arctos*, values, wolf.

Predator-control programs generate controversy among the public, policymakers, and wildlife professionals. Incomplete and outdated information, as well as purposeful misinformation, often contributes to this controversy. In addition, arguments over science in this arena are often a surrogate venue for arguments over commonly undefined values and preferences (Lackey 2007). Thus, periodic review of relevant science, politics, values, and expectations is an essential step toward clarifying motives for arguments and encouraging informed decisions and transparent decision-making processes.

We reviewed the science and values of this arena from the perspective of agency research biologists. The senior author (R. D. Boertje) has conducted relevant Alaska, USA, studies since 1981 on predator–prey relationships, wildlife nutrition, and ecology, under diverse administrations. Several administrations banned predator control. Three recent administrations embraced predator control, particularly for elevating moose (*Alces alces*) harvest. Harbo and Dean (1983), Stephenson et al. (1995), the National Research Council (1997), Regelin et al. (2005), and Titus (2007) reviewed the history of predator management in Alaska and the relevant political discourse, litigation, and status of predator and prey populations. Other reviews present arguments against Alaska's predator management, based largely on selective social values and selective review of the subject (Schwartz et al. 2003, Van Ballenberghe 2006, Zager and Beecham 2006). Decker et al. (2006) surveyed Alaskans and found that citizens most supportive of brown bear (*Ursus arctos*) and wolf (*Canis lupus*) management were also most reliant on moose and caribou (*Rangifer tarandus*) for food.

We reviewed data and results from simple predator–prey systems, where one large prey species (moose) was usually the primary prey of 3 large effective predators (brown bears, black bears [*Ursus americanus*], and wolves). Caribou and Dall sheep (*Ovis dalli*) were the only other large prey in these systems (Gasaway et al. 1983). Caribou are generally a less-reliable prey than moose because seasonal distribution is more clumped and unpredictable, and voids exist in caribou distribution in inland Alaska. Most of our review covered inland areas of Alaska and Yukon, Canada, because most predator-management programs for moose were in taiga environments with minor maritime influences. However, we also reviewed relevant Alaska studies from in and near the Anchorage area, including studies from Kalgin Island and the Kenai Peninsula.

One overriding impetus for our review was a resurgence of controversial predator control plans requested and approved by the Board of Game to increase harvestable surplus of moose and caribou to meet defined consumptive needs of largely Alaska residents pursuant to 1994 legislation (Alaska Fish and Game Laws and Regulations Annotated 2008:27–29). Since statehood (1959), predator-control programs focused on reducing wolf predation. Recent plans added a novel emphasis on reducing bear predation, which intensi-

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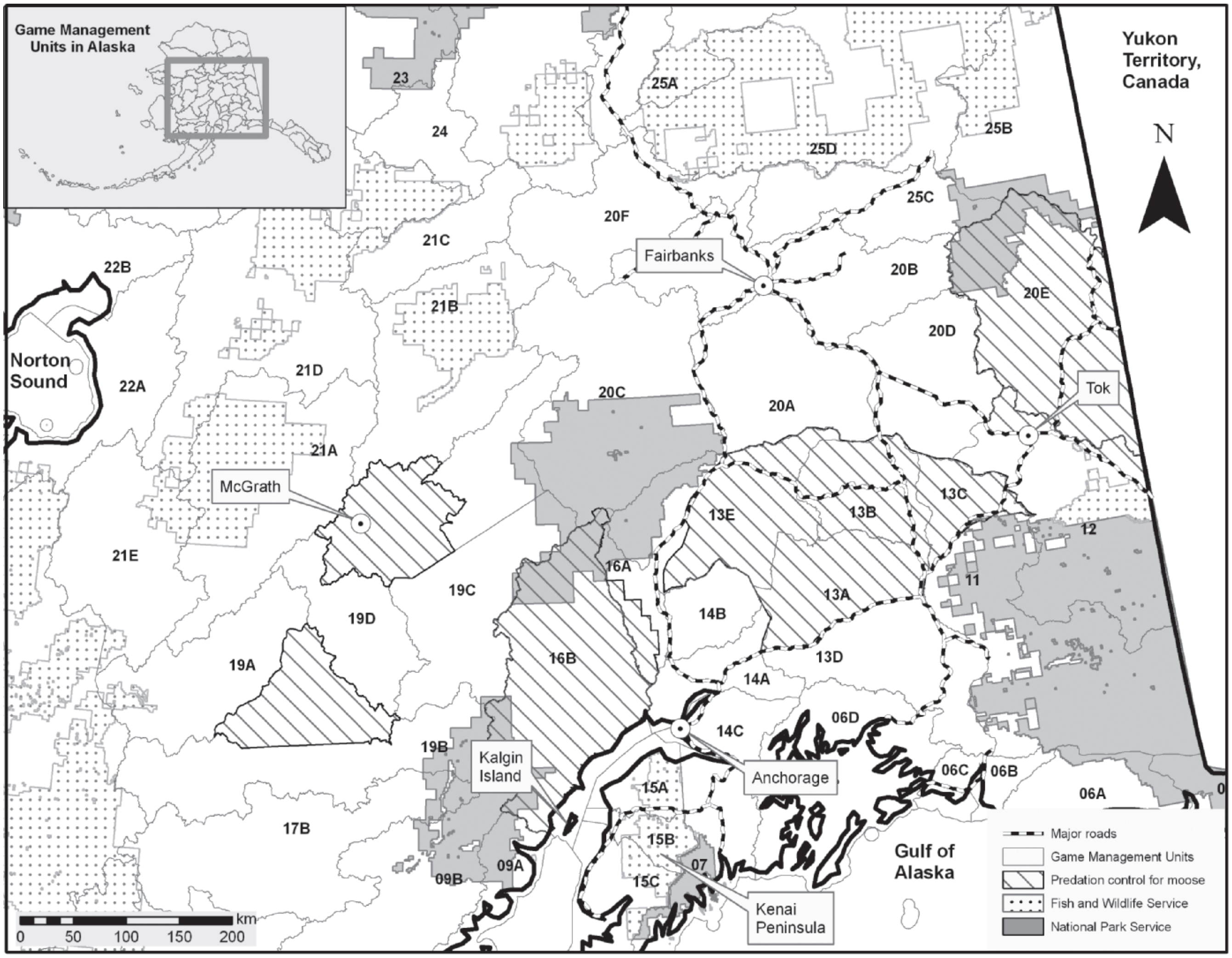

Figure 1. Areas where bear and wolf regulations and control programs were implemented to increase the harvestable surplus of moose in Alaska, July 2009, in relation to areas managed by the United States Fish and Wildlife Service and National Park Service. Control programs were implemented in 7% of the state; we excluded National Park Service lands that overlapped control areas. Alaska has 2 additional control programs not depicted here to increase caribou numbers.

fied the debate on predator control (Schwartz et al. 2003, Van Ballenberghe 2006). Recent programs began in winters 2003–2004 and 2004–2005 to control wolves for moose management (Titus 2007). Associated new, area-specific programs to reduce black bear or brown bear numbers began annually during 2002–2007 and in 2009. The Board of Game's intent was to find effective methods for private citizens to decrease bear predation on summer moose calves to increase yield of moose.

Our objectives were to 1) review studies and case histories to identify major and minor factors affecting moose population dynamics in inland Alaska; 2) review manipulative studies in Alaska that investigated whether moose survival could be increased by substantially reducing predation; 3) review case histories that tested whether a lower level of predation was associated with higher yield of moose; 4) review the practical realities of evaluating whether habitats can support more moose, be protected from too many moose, and be improved in anticipation of more moose following predator control; 5) evaluate the security of large predator populations in Alaska in the context of control programs; and 6) provide a basic legal background and relate some of the divisive values, opinions, and expectations in this arena, as well as the unique role of biologists.

RELATIVE EFFECT OF PREDATION AND OTHER FACTORS ON MOOSE POPULATIONS

If predator control is to be biologically justified to increase harvest of moose, predation must be a major factor limiting the moose population. In 9 of 10 multiyear, telemetry-based studies in moose–bear–wolf systems, predation (primarily on calves) was the dominant factor affecting moose population dynamics compared with harvest, malnutrition, disease, and adverse weather (Gasaway et al. 1983, 1992; Larsen et al. 1989; Ballard et al. 1991; Osborne et al. 1991; Bowyer et al. 1998; Bertram and Vivion 2002*a*; Testa 2004; Keech 2005). In the remaining study area (Game Management Unit [Unit] 20A; Fig. 1), predation was the lowest among the 10 studies, and moose reached the highest densities; as a result, density-dependent food limitation and predation had similar major limiting effects on the population (Boertje et al. 2009). Other factors in Unit 20A had minor effects.

During a brief historical period, harvest played a substantial role in moose population dynamics in inland Alaska. For example, harvests (10–19% of prehunt no.) were well above sustainable levels during winter-induced declines in moose populations in the early 1970s (Gasaway et al. 1983). Managers during that period did not adequately evaluate 1) the precipitous decline from synergistic effects of predation and severe winters, 2) a lag time before moose would regain elevated rates of reproduction, and 3) improved success rates of hunters given the arrival of snowmobiles (Gasaway et al. 1983; Boertje et al. 1996, 2007).

Winterkill also occasionally affected moose population dynamics. Ballard et al. (1991) documented substantial winterkill among radiocollared calves (not radiocollared yearlings or ad) in winter 1978–1979 in Unit 13 (9 of 14 Oct calves died from winterkill). In addition, Boertje et al. (2009) documented that 16 of 42 October calves (38%) died from winterkill during winter 2004–2005 near McGrath, Alaska, although the moose population continued to increase (Keech 2005, 2008). Winterkill was negligible in 19 other mortality studies where biologists radiocollared moose calves in Alaska and Yukon (Keech 2005, 2008; Boertje et al. 2009, table 4). The most severe, documented cases of winterkill affecting moose populations in inland Alaska occurred during 1965–1966 and 1970–1971, when substantial numbers of calves, as well as some adults, died (Bishop and Rausch 1974). These results indicate that winters in inland Alaska infrequently caused substantial winterkill. Winterkill of moose is more common where severe cold is combined with deep snow (e.g., some coastal and Arctic regions; Alaska Department of Fish and Game [ADF&G] 2008*a*), so predator control would be less effective at increasing yield of moose in those areas.

Gasaway et al. (1992) studied various factors affecting a low-density Alaska moose population and concluded that predation was the primary factor keeping moose densities low. Gasaway et al. (1992) also presented data from 36 study areas in Alaska and Yukon and concluded that combined predation by lightly harvested wolf and bear populations kept moose at a low-density, dynamic equilibrium in large study areas where moose were not seasonally concentrated. Moose densities fluctuated in these systems but remained $\leq$417 moose/1,000 km^2 and well below food-limited densities. A more recent compilation of moose nutritional data from 15 sites in Alaska confirmed that moose nutrition was moderate or high, except where humans substantially mitigated predation (Boertje et al. 2007, 2009). Moose densities were >417 moose/1,000 km^2 in large study areas with a single or no predator species, where predators were limited by harvest or by human presence, where moose were a secondary prey of wolves and bears, and following effective predator control (Gasaway et al. 1992).

In 4 studies, investigators analyzed and modeled annual mortality of postcalving moose populations, which consisted of all yearlings and adults in early May plus all newborn calves born in the ensuing weeks (Boertje et al. 2009, table 5). In 3 studies of low-density postcalving moose populations, where bear predation dominated, predators annually killed 31–41% of moose populations. Investigators indicated that this level of predation was sufficient to maintain moose populations at low densities. In contrast, in the study area with lowest bear predation (Unit 20A), predators annually killed only 19% of the postcalving moose population, and the population was increasing. In all 4 studies, 75–88% of predator-killed moose each year were calves (Boertje et al. 2009). These studies clarified that predators limit moose populations primarily by preying on juvenile moose. Predators rarely killed moose aged 2–6 years regardless of moose density (Gasaway et al. 1983, 1992; Boertje et al. 2009).

Predators killed 60–72% of radiocollared calves in 5 study areas associated with little or no predator control, in contrast to 30–53% of radiocollared calves in 3 studies where predation was substantially reduced (Keech 2008; Boertje et al. 2009, table 4). Methods were similar among calf mortality studies (Ballard et al. 1979). Scavenging was a minor factor affecting the results in these studies, as determined by observing carcasses (capture-induced mortalities) left afield for several days. In a few cases, investigators observed bears and wolves killing calves. Later investigations of these kill sites allowed investigators to verify differences between kill sites of bears and wolves. Bears usually left only a concentration of bone chips with the collar after killing young calves. In contrast, wolves left major portions of calf carcasses or scattered the remains and often carried the blood-stained collar some distance from the kill site.

To further address the effect of brown bear predation on moose, Boertje et al. (1988) investigated whether brown bears were scavenging or killing their prey. Boertje et al. (1988) located collared bears daily using a Piper PA-18 aircraft (Piper Aircraft, Inc., Vero Beach, FL) and immediately returned to all carcasses of adult moose via helicopter. All collared, adult brown bears sampled, for >11 bear–days during the spring, killed moose calves, but some bears were more effective predators than others were. For example, during the first 20 days after calving, 4 of 9 (<50%) radiocollared bears killed 21 of 29 calves killed by bears (72%). Adult, male brown bears were important predators of adult moose in spring. Brown bears appropriated and consumed more wolf kills of adult moose than vice versa, yet brown bears killed 4 times more animal biomass than they scavenged. Evidence of attacks on adult moose, including direct observations and evidence at kill sites, indicated brown bears were efficient predators on moose.

Identifying the dominant predator in a specific study area is important when designing effective predator-control programs. In the 4 studies of annual mortality on postcalving moose populations, bears killed 9–27% and wolves killed 8–15% of moose populations annually (Boertje et al. 2009, table 5). In 7 of 8 calf mortality studies (88%) to date (Boertje et al. 2009, table 4), investigators concluded that black bears or brown bears were the most important predators of moose calves. In all 8 studies (100%), investigators identified combined predation by black bears and brown bears as the major cause of mortality among moose calves.

MANIPULATIVE STUDIES

A second step to biologically justifying predator control is to test whether predators kill healthy moose that would mostly live to be available for harvest. The definitive test is to substantially reduce predation and measure whether survival increases (Bergerud 1971). For example, if bear predation is reduced, and moose calves ultimately die anyway from other causes (e.g., wolf predation, drowning, hypothermia, disease, or starvation), then reducing bear predation alone cannot be scientifically sanctioned to increase yield of moose. In practice, wolves have been reduced to some extent in all areas where bears were reduced per recommendations by Gasaway et al. (1992), who proposed moderate reduction of bears and wolves rather than substantial reduction of either predator.

Investigators observed an increase in moose survival in 10 areas where predation was reduced or absent:

1. During 1976–1982, ADF&G aerial wolf control and private efforts temporarily reduced wolf density 55–80% below the precontrol density in Unit 20A (Gasaway et al. 1983, Boertje et al. 1996). Wolf numbers subsequently recovered in $\leq$4 years in most of the 13,044-km^2 study area and increased to new high numbers during a period of deep snowfall winters (1989–1990 through 1992–1993) and remained at those high levels at least through 2008 (Boertje et al. 2009). Early winter moose:wolf ratios increased from 13:1 precontrol to >40:1 postcontrol at least through 2008. The posthunt moose population increased rapidly ($\lambda = 1.15$) during the 7 years of wolf control and more slowly ($\lambda = 1.05$) during the subsequent 21 years until 2004. During 2004–2006, hunters harvested substantial numbers of female moose and reduced moose density as intended ($\lambda = 0.96$; Boertje et al. 2009). Moose densities remained low in areas where predation was not substantially reduced (Gasaway et al. 1992, Boertje et al. 1996, ADF&G 2008*a*). In the early 1990s, a second wolf control program in Unit 20A removed 100 wolves, which resulted in an additional 18 moose calves/100 females ($\geq$29 months) in early winter at high moose density (960 moose/1,000 km^2); this response was identical to that observed after the previous control action when moose density was low (250 moose/1,000 km^2; Boertje et al. 2009). Thus, the largely additive effect of wolf predation on calves was similar over a wide range of moose densities and moose:wolf ratios (18–62 moose/wolf) where bear predation was the lowest measured in Alaska (Boertje et al. 2009).
2. In 1979, translocation efforts temporarily reduced brown bear numbers about 60% in 3,346 km^2 of the upper Susitna River drainage (moose count area 3) on the border of Units 13B and 13E (Ballard and Miller 1990). During May–June 1979, 47 bears were removed. Wolves were rare in and near the study area by spring 1980 because of aircraft-assisted wolf hunting and ADF&G wolf control (Ballard et al. 1987). The November moose calf:100 female (>1 yr) ratio in count area 3 subsequently increased from 34 in 1978 to 58 in 1979 ($t = 5.9$, $P < 0.05$); no changes were observed during the same period in 2 count areas just south of the translocation study area (7 and 13), where bear numbers were not reduced. Before 1979, calf:100 female (>1 yr) ratios in count area 3 were correlated with ratios in count areas 7 and 13; the 1979 observed ratio of 58:100 in count area 3 fell outside the 95% confidence intervals for both prior correlations. These researchers calculated that bear removal resulted in a 78% reduction in calf mortality during the first 5 months of life. The following April, high calf survival persisted. High overwinter survival was attributed to favorable winter weather and scarcity of wolves. Following the translocation, Ballard and Miller (1990:12) concluded, "A 60% reduction in bear density during the first 6 weeks following moose parturition was sufficient to significantly improve calf moose survival. Whether lesser reductions in bear density would automatically result in proportional increases in moose calf survival is unknown and warrants further study."
3. In May and June 1985, Boertje et al. (1987) air-dropped 12 metric tons of moose carcasses and scrap meat in a 1,000-km^2 area to attract brown bears for collaring, in and around a concentrated moose calving area, north of Tok, Alaska (Unit 20E). The early winter 1985–1986 calf:100 female (>1 yr) ratio (53:100 F) was the highest observed to date and was significantly higher than those recorded during the preceding 3 years (11–15:100 F; χ^2 test of independence; $P < 0.005$) as well as during the following 2 years, when baits were not available (26–36:100 F, $P < 0.10$; Boertje et al. 1995). Similarly, the calf:100 female ratio was significantly higher than that found in 3 untreated adjacent areas in 1985 (10–19:100 F, $P < 0.005$). Wolves and black bears were minor predators of moose calves in Unit 20E during this period (Gasaway et al. 1992). The study was preceded by wolf control during 1981–1983 (Gasaway et al. 1992). Boertje et al. (1995) concluded that brown bears were successfully diverted from preying on calf moose, and these calves survived to early winter.
4. To retest the effect of diversionary feeding of predators, researchers distributed 26 metric tons of moose carcasses in a 1,650-km^2 area west of Tok in Unit 20D in May 1990 primarily using UH-1 helicopters (Bell Helicopter, Fort Worth, TX; 15.8 tons/1,000 km^2; Boertje et al. 1995). Moose calf:100 female (>1 yr) ratios were higher ($P < 0.005$) in early winter 1990 (42:100 F) compared with the 8 prior years (12–38:100 F) and 1990 untreated sites (11–27:100 F). An attempt to repeat this experiment in 1991 failed to produce a significant result, presumably because researchers distributed only 16 metric tons (9.7 tons/1,000 km^2) of moose carcasses, and the

distribution pattern was focused more along roads and rivers. No helicopters were available in 1991, but a DHC-2 Beaver (de Havilland Canada, now Bombardier Aerospace, Quebec, PQ, Canada) was used for a brief period in early May. Implications are that substantially reducing brown bear predation on moose calves can lead to increased moose calf survival to early winter. The value of these diversionary feeding experiments was in evaluating the additive versus compensatory nature of predation on neonatal calves using a nonlethal technique, as recommended by Boutin (1992) and Gasaway et al. (1992).

5. In May 2003, 75 black bears (all >1 yr old) and 8 brown bears (including 2 cubs-of-the-yr) were translocated from and adjacent to a 1,368-km^2 study area encompassing McGrath, Alaska (Unit 19D; Keech 2005). This study was part of an adaptive management program (National Research Council 1997). The translocation experiment was again conducted in May 2004; researchers translocated 34 black bears (all >1 yr old) and 1 adult brown bear from the same area. In subsequent years, bears were not translocated. Approximate, independent black bear numbers were 96 in April 2003 (preremoval), 4 in June 2004 (postremoval), and 70 in May 2007. Wolves were harvested at rates of about 30% each winter before February 2004 when private aircraft-assisted wolf control began, and wolf numbers declined. Biologists annually monitored 50–81 newborn, radiocollared moose calves within the study area during 2001–2006 to determine survival rates and causes of death. Keech (2008) considered cohorts from 2001–2002 as untreated, and cohorts from 2003–2006 as fully or partially treated. Survival rates (May–Aug) for collared moose calves were 43%, 40%, 63%, 81%, 56%, and 75%, for the 2001 through 2006 cohorts, respectively. Bears were determined or inferred to be the source of mortality for 45%, 43%, 24%, 6%, 30%, and 18% of collared calves for the 2001 through 2006 cohorts, respectively. Annual respective survival rates for collared moose calves were 33%, 27%, 51%, 40%, 42%, and 63%. Keech (2008) concluded that bear translocation and wolf control resulted in a decrease in the number of calves killed, a corresponding increase in moose calf survival through the end of autumn in all 4 of the treated cohorts (2003–2006), and an increase in moose population size each year.
6. During 1957–1959, ADF&G introduced 6 moose calves to the 60-km^2 Kalgin Island west of Anchorage, Alaska (Paul 2009). In the absence of large predators, moose attained among the highest densities in Alaska by 1981 (2,700 moose/1,000 km^2), and regulations allowed hunters to reduce the density to about 390 moose/1,000 km^2 by 1985 (Peltier 2008*a*). By 2003, the moose population attained the highest year-round density (2,983 moose/1,000 km^2) reported in Alaska in early winter. This high density was accompanied by high calf:100 female (>1 yr) ratios (36–89:100 F during 1998–2005; Peltier 2008*a*).
7. Wolves were absent from the Kenai Peninsula south of Anchorage during 1915–1960 and held below food-limited densities through at least 1980 (Peterson et al. 1984). Moose attained among the highest densities recorded on Alaska's mainland in habitats exceeding 2,000 km^2 (1,447 moose/1,000 km^2; Gasaway et al. 1992).
8. Other than Unit 20A, the areas in Alaska with the highest densities of moose include Units 14 and central 20B, which contain the largest human settlements, and southwest Unit 20D, which has widespread agricultural development (Fig. 1; Gasaway et al. 1992, ADF&G 2008*a*, DuBois 2008). Predators are well below food-limited levels in each of these 3 areas (ADF&G 2006, 2007, 2008*b*).

We conclude from these studies that wolves and bears at food-limited densities kill substantial numbers of calf moose that otherwise would mostly live and be available for harvest. Furthermore, where brown bears are the dominant predator, substantial wolf control alone can produce a slow increase in moose numbers (Ballard et al. 1987, 1991). Where wolves are the dominant predator, substantial wolf control alone can produce a fast increase in moose numbers (Boertje et al. 2009). Alternatively, moderate reductions in only bear predation may produce only a slow increase in moose because of the efficiency of wolf predation and the remaining bear predation (Hayes and Harestad 2000). Our conclusions agree with those from 3 studies in Canada, where wolf or bear numbers were substantially reduced, and moose numbers increased (Stewart et al. 1985, Larsen and Ward 1995, Hayes et al. 2003). We know of no contrary findings in these simple systems, where predation was substantially reduced, and moose survival was monitored. However, a response in moose calf survival will be moderated when deep snow and extreme cold prevail (Ballard et al. 1991, Boertje et al. 2009).

RELATIVE YIELDS OF MOOSE AND HABITAT ISSUES

Sustainable yields of moose clearly increased in areas with reduced predation. Within inland Alaska, the highest sustainable yields have come from portions of Unit 20 adjacent to and including the largest city, Fairbanks, Alaska, where predation has been low (Boertje et al. 2009). The highest sustained harvest density reached 57 moose/1,000 km^2 (5% of the prehunt population) in Unit 20A during 1996–2003. The moose population increased during this period ($\lambda = 1.05$), but male:female ratios declined. Managers implemented liberal antlerless harvests to increase harvests to 97 moose/1,000 km^2 (7% of the prehunt population), which had the intended effect of reducing the moose population. In most areas of inland Alaska, harvests are restricted largely to males (2–4% of prehunt numbers) to prevent harvest-induced declines in moose numbers while protecting adequate male:female ratios. In these areas, moose populations are at low, predator-limited densities, and sustainable yields are correspondingly low (<10 moose/

1,000 km^2; Gasaway et al. 1992). In contrast, yields temporarily increased to >100 moose/1,000 km^2 in portions of south-central Alaska within and adjacent to Alaska's largest population center, Anchorage, and on the adjacent Kenai Peninsula before and shortly after reestablishment of wolves (Gasaway et al. 1992). In Sweden, sustainable yields reached 33% of a prehunt moose population and 650 moose/1,000 km^2 in high-quality habitat where predation was absent, and calves constituted 48% of the harvest (Cederlund and Sand 1991). However, Lavsund et al. (2003), Nilsen et al. (2005), and Swenson et al. (2007) recently documented the largely additive effect of predation on Scandinavian moose by recolonizing wolves and bears.

Further evidence of elevated, sustained yields with reduced predation came from southwestern Unit 20D (55 moose/1,000 km^2, 2000–2006, 3,310 km^2), which included Alaska's second largest agricultural area (DuBois 2008). Elevated sustained yield also came from portions of central and western Unit 20B (38 moose/1,000 km^2, 1996–2003, 12,600 km^2; Boertje et al. 2009), which includes Fairbanks and adjacent communities. During 2003–2007, moose habitat in Units 20A, 20B, and 20D (3% of the state) supported an average of 26% of the statewide reported harvest despite low moose reproductive rates (Boertje et al. 2007). These case histories have been particularly pivotal in stimulating additional predator control programs and have stimulated the monitoring of moose nutritional indices to identify and administer biologically feasible moose management objectives.

Boertje et al. (2007, 2009) provided several indices to rank moose nutritional status in Alaska and provided evidence that unwise stockpiling of moose could be prevented when nutritional status is monitored and nutrition-based management is approved by regulatory bodies. Ranking nutritional status also allowed managers to conclude that most moose habitats in Alaska can support more moose. In 3 case histories to date of low moose nutritional status (but increasing moose populations, Units 20A, 20B, and 20D), ADF&G successfully encouraged and managed elevated harvests of female moose to intentionally reduce moose population density. After harvest-induced declines, ADF&G successfully argued for lower but continued harvests of female moose to moderate potentially extreme population fluctuations. For example, extreme population fluctuations occurred in the 1960s after federal predator control and before establishment of convincing nutritional indices and population estimates (Gasaway et al. 1983, Ballard et al. 1991, Boertje et al. 2007).

Central Unit 20A moose exhibited the lowest nutritional status among 15 moose populations during 1997–2004 because population density was correspondingly high (Boertje et al. 2007, 2009). Low nutritional status in central Unit 20A was documented based on the lowest multiyear twinning rates of 7% (n = 9 yr), highest removal of current annual browse biomass (42%), the lowest average mass (155 kg) among March or April female short-yearlings in Alaska, delayed twinning until moose reached 60 months of age, and the lowest parturition rate among 36-month-old moose (28%, n = 151; Boertje et al. 2007). However, the moose population continued to increase until liberal harvests of female moose were initiated.

Likewise, in adjacent central Unit 20B and southwestern Unit 20D, elevated moose densities resulted from low predation, and ADF&G used nutritional indices to manage elevated harvest of female moose to reduce moose density (DuBois 2008, Young 2008). Thus, ADF&G defined the nutritional level at which regulatory bodies have been convinced to authorize elevated yields. If moose numbers increase from predator control, managers are obligated to monitor twinning rates and $\geq$1 additional nutritional index to enhance credibility in the public regulatory process (Boertje et al. 2007).

Most biologists recognize that, as predation is reduced, moose populations will increase, and twinning rates will decline as habitat becomes more limiting (Blood 1974, Boer 1992, Boertje et al. 2007). We currently recommend that, as moose numbers increase and twinning rates gradually decline to a 2-year average of <20%, female moose should be harvested in increasing numbers to stabilize population size and to maintain a 2-year average twinning rate of between approximately 10% and 17%. This strategy appears to manage moose responsibly below the long-term carrying capacity and to provide for elevated yield (Boertje et al. 2007, 2009).

Ideally, habitat would be improved simultaneously with increases in moose numbers to help maintain the moose population's nutritional status. The most practical way to improve large-scale habitat for moose is to burn mature habitats. However, ADF&G has no authority to use prescribed fire and limited authority to develop policies on wildland fires. In Unit 20A, ADF&G staff prioritized habitat management because of increases in prehunt moose numbers from 2,500 in 1975 to >17,000 in 2003 (Boertje et al. 1996, 2009). In eastern and western Unit 20A during 1996–2006, ADF&G successfully encouraged state, federal, and native land managers to allow 5 wildland fires to burn sizeable areas ($\bar{x}$ = 370 km^2, total 1,852 km^2). Despite having a burn plan with the Alaska Department of Natural Resources since 1995, no prescribed fires occurred because of unfavorable weather for burning; alternative objectives, including protecting Fairbanks from smoke; and competition for qualified personnel and specialized equipment. In contrast, 3 prescribed fires burned 362 km^2 in a remote portion of Unit 20E during 1997 and 1998.

SUSTAINABILITY OF WOLF AND BEAR POPULATIONS IN INLAND ALASKA

Alaska's predator control programs for moose (Fig. 1) are largely restricted to Alaska's extensive boreal forest biome with an unusual setting. Inland Alaska is about 530,000 km^2 of intact wildlife habitat and large predator–prey systems, not fragmented by agriculture or human settlements. For example, <1% of Alaska is privately owned land, exclusive of lands transferred to Alaska natives. In contrast to Europe, southern Canada, and the other states of the United States, Alaska's boreal forest retains abundant and widely distributed populations of wolves and bears. Large predators exist near all human settlements in forested areas of inland Alaska. Predator control programs were conducted on 9% of Alaska's land area during 2006–2008; this area decreased to 7% in July 2009. Low human density and an urban-focused human population contribute to the abundance of large predator populations. Currently, there are 686,300 people living on 1,481,346 km^2 of land in Alaska, with an overall population density of 0.46 people/km^2. Most Alaskans (67%) live in or near the population centers of Anchorage (364,700) and Fairbanks (97,970; U.S. Census Bureau 2008). Other settlements are much smaller and occur mostly in coastal biomes, not inland Alaska.

Land is fragmented between state, federal, and private owners in Alaska, which limits the possibility for creating additional, large-scale predator control areas. For example, state wolf and bear control programs are not allowed on the 32% of Alaska's land area managed by the United States Fish and Wildlife Service and National Park Service, which includes parks, preserves, and refuges (Fig. 1; Alaska Department of Natural Resources 2000). Remaining federal lands total 28% of Alaska's land area, and predator control may be implemented on portions of these lands. The state owns widely dispersed parcels totaling 29% of Alaska's land area, and Alaska Native American corporations and individuals own 12%.

Several additional factors help ensure the long-term security of sustainable wolf and bear populations. Alaska's predator control areas are dispersed across mostly rural areas of Alaska with few roads and without large settlements (Fig. 1). Control areas are mostly forested, which provides cover for predators. In addition, managers must leave prescribed low levels of wolves in wolf-control areas each spring. In addition, wolves and bears recovered from more severe control programs before statehood (Harbo and Dean 1983, Ballard et al. 1991, Stephenson et al. 1995), and the most extreme programs, which included widespread poisoning, have been illegal since statehood. Specifically, prestatehood control programs employed federal staff to drop poisoned baits from aircraft and to set cyanide bait guns on the ground (Harbo and Dean 1983). Moose populations were at peak, probably unsustainable, densities at statehood, partly as a result of these poisoning programs and because of recent wildland fires (Bishop and Rausch 1974).

Since statehood, the only proven, legal methods for private citizens to reduce wolf populations in rural, forested, inland Alaska has been to use aircraft, including either shooting while airborne or land-and-shoot methods. One or both methods have been approved by the Board of Game for each control area (Fig. 1). Aerial gunning was used in the mid-1979s, and recovery of wolf populations was well documented (Ballard et al. 1987, Boertje et al. 1996). Before aircraft can be used to effectively reduce wolf numbers, snow conditions for tracking wolves are necessary. Adequate snow conditions in most areas do not prevail every winter and often prevail for only short periods. In less-forested, coastal areas of western Alaska, local hunters using snowmobiles have been able to limit wolf numbers (Ballard et al. 1997). Also, rabies has occasionally limited wolf numbers, but rabies has only been documented in and near coastal areas of western and northern Alaska in recent times (Ballard et al. 1997, Ballard and Krausman 1997).

Given low to moderate rates of human-caused mortality and low rates of disease and starvation in inland Alaska, most local wolf densities are regulated by food-supplies, predominately moose and caribou numbers (Ballard et al. 1987, Mech et al. 1998, Adams et al. 2008). For example, wolf densities in inland Alaska are greatest immediately south of Fairbanks in Unit 20A (Fig. 1), where moose densities are the highest in Alaska (Boertje et al. 1996, 2009). Wolf densities are less in other areas of inland Alaska, largely because prey densities are less (Boertje et al. 1996, National Research Council 1997, Mech et al. 1998). Seven telemetry studies on wolves in mostly forested areas of inland Alaska and wolf density estimates across most of inland Alaska confirm that wolf densities are largely proportional to prey biomass (Mech et al. 1998, Boertje and Gardner 2000, Adams et al. 2008), as elsewhere in North America (Fuller 1989).

Exceptions to food-limited wolf populations occur if humans regularly take $\geq$30% to $\geq$39% of autumn wolf numbers annually, yet wolf populations are well adapted to high harvest rates (Fuller et al. 2003, Adams et al. 2008). Adams et al. (2008) discussed how wolves adjust dispersal rates as a primary mechanism to compensate for human take. Wolves mostly disperse from areas with negligible harvest, for example Denali National Park (Mech et al. 1998). Wolves disperse less as harvest increases, although wolves continue to disperse even with moderate harvest rates (Ballard et al. 1987, Adams et al. 2008). Extensive movements occur regularly and have reached 700 km in Alaska (Stephenson et al. 1995, Adams et al. 2008). Thus, localized reductions in wolf numbers are offset by immigration and subsequent reproduction of dispersing wolves (Peterson et al. 1984, Ballard et al. 1987, Adams et al. 2008). Based on these studies, wolves in most of Alaska and northern Canada are one contiguous population.

Brown bears and black bears are widely distributed in Alaska, and only the highest elevations are avoided (Miller et al. 1997; ADF&G 2007, 2008*b*). Bear densities vary depending on food sources and habitat, with the highest densities in coastal regions where salmon are abundant (Miller et al. 1997). Bears commonly come in conflict with human settlements in inland and coastal Alaska each year (ADF&G 2007, 2008*b*). Telemetry studies on bears in inland Alaska include 10 studies on brown bears (Boertje et al. 1988, Ballard et al. 1990, Reynolds 1999, Miller et al. 2003, Tobey and Kelleyhouse 2007, Gardner 2009) and 4 on black bears (Ballard et al. 1990, Hechtel 1991, Bertram and Vivion 2002*b*, Keech 2008).

New, experimental methods to increase the take of bears in control areas (Fig. 1) included liberalizing bear harvest regulations as early as 2002 and encouraging control of bears by private, state-authorized permittees as early as 2004. The most notable, new, area-specific harvest regulations included no closed season for brown bears without cubs or yearlings (2003), a bag limit of 2 brown bears (2004), sale of black bear hides and skulls (2006), and shooting black bears without cubs over bait same-day-airborne (2006; yr shown in parentheses is initial yr for ongoing regulatory programs). These regulations did not necessarily apply in all the control areas (Fig. 1) but were experimented with primarily in Unit 20E and portions of Units 13, 16, and 19. These regulations were ineffective at increasing the harvest of bears, except in Unit 16 (ADF&G 2007, 2008*b*). In Unit 16, near Anchorage, liberalized hunting regulations and heightened interest in black bear hunting stimulated substantially increased harvest of black bears beginning in autumn 2006 (Peltier 2008*b*).

New, area-specific (Fig. 1) control methods allowed permittees to 1) shoot brown bears under a quota system, over bait, and same-day-airborne (2004); 2) sell brown bear skulls and raw hides (2006); 3) shoot any black bear over bait and same-day-airborne with no individual limit (Unit 16 only, 2007); and 4) foot-snare black bears (Unit 16 only, 2009). These control measures too were only effective, to date, at contributing to increased take of black bears in Unit 16 (ADF&G 2007, 2008*b*; Peltier 2008*b*). Also in Unit 16, a private, nonprofit organization facilitated the take of black bears beginning in 2007. The Board of Game terminated control methods for brown bears in Unit 20E in 2009 after experimentation failed to increase the take of brown bears during 1 April 2005 to 30 June 2009 (Gross 2007).

Lessons from settled areas showed that manipulation of bear and wolf populations can result in elevated sustained yield of moose (Gasaway et al. 1992, Boertje et al. 2009). In more remote areas, where bear habitat is contiguous and access is poor, no data are available to evaluate whether private take of bears can be a successful, long-term management tool to decrease bear numbers and to elevate sustained yield of moose. Where new control measures and regulations result in an increased take of bears, as in Unit 16, documenting effects on the bear and moose populations will require study.

Currently, the primary practical factors ensuring that Alaska predator populations remain sustainable include 1) lack of tradition and interest in harvesting wolves and bears relative to harvesting moose or caribou, and 2) the greater challenge and cost associated with harvesting wolves and bears because predators are elusive, particularly in forested areas, and usually occur at low densities compared with moose or caribou. A substantial, long-term change in ≥ 1 of these factors will warrant a reexamination of whether sustainability of predator populations is adequately ensured.

LEGAL BACKGROUND, VALUES, AND EXPECTATIONS

Alaska is unique among the states in having a legislative mandate to provide for elevated harvests of moose through intensive management, defined in statute as "management of an identified big game prey population consistent with sustained yield through active management measures to enhance, extend, and develop the population to maintain high levels or provide for higher levels of human harvest, including control of predation and prescribed or planned use of fire and other habitat improvement techniques" (Alaska Fish and Game Laws and Regulations Annotated 2008:29). Sustained yield was defined as "the achievement and maintenance in perpetuity of the ability to support a high level of human harvest of game, subject to preferences among beneficial uses on an annual or periodic basis." This 1994 legislation also defined "harvestable surplus," "high level of harvest," and "identified big game prey population." Young et al. (2006) discussed recent achievements and limitations of intensive management.

Philosophical direction on predator control is initiated through the governor, who appoints the legislature-approved Board of Game, comprising 7 nonagency individuals. The Board of Game is responsible for identifying big-game prey populations for intensive management and for passing regulations and plans to provide for elevated yield of moose. The governor also appoints agency policymakers and administrators responsible for implementing predator control in Alaska. The judicial branch provides oversight on these regulatory and legislative processes. In addition, statewide, voters passed initiatives (1996, 2000) related to banning same-day-airborne hunting of wolves (Regelin et al. 2005). Thus, a system of checks and balances governs this process.

The ADF&G, Division of Wildlife Conservation, provides biological and harvest information to the Board of Game. Likewise, the ADF&G, Subsistence Division, provides information on current and past wildlife uses and needs among rural households.

To clarify philosophical differences in this arena, we contrasted activities, preferences, and values of 4 primary stakeholder groups (Table 1). Our rationale came from prior published reviews, public and professional interactions (1978–2009), and public testimony at Board of Game meetings (1981–2009).

Opponents of predator control opined that 1) bears and wolves should be given equal or greater value compared with moose; 2) predators should be valued in a context of intact ecosystem function and a symbol of wilderness rather than as an impediment to ungulate management; 3) methods of control are unethical, unproven, uneconomical, and unsustainable; 4) reducing wolves and bears to increase moose harvest will fail because ecosystems are complex and incompletely understood; 5) alternatively, reducing wolves and bears will succeed, and moose will overpopulate and starve because population objectives are too high and long-term habitat degradation is likely; 6) Alaska should value its relatively unmanipulated predator–prey systems over manipulated systems; and 7) the public has a fundamental right to see wildlife managed without predator control.

Proponents of predator control opined that 1) there exists a legitimate demand, need, and legal mandate for additional moose harvest in portions of Alaska, and hunting is a fundamental right; 2) most of Alaska's lands have relatively unmanipulated moose–bear–wolf systems with intact ecosystems where hunters play a minor role; 3) only the hunting

Table 1. Contrasting activities, preferences, and values of 4 principal stakeholder groups influencing predator control for Alaska moose management. We define these contrasting viewpoints because arguments over science are often a surrogate venue for arguments over commonly undefined values and preferences (Lackey 2007). Individuals may identify with multiple stakeholder groups.

Activities, preferences, or values	Stakeholder groups			
	Opponents of predator control	Proponents of predator control	Objective biologists	State policymakers
Involvement in process	Prevent or limit take of predators	Advocate for management to facilitate elevated harvest of moose	Collect, analyze, and disseminate data on populations and habitat	Maintain or improve political stance
Preferred outcome or process	Constrained options for predator take	Broad management options	Objective and informed use of data	Constituent satisfaction
Primary motivation	Limits to population manipulation	Manage moose for abundance	Scientific process	Constituent view of success
Primary loyalty	Nonconsumptive users	Consumptive users	Wildlife profession	Most supportive constituents
Perceived losses at risk	Individual predator welfare, persistence of predator populations, intact ecosystems	Hunting tradition, food, hunting revenue, cultural ties to the land	Role of science in public process	Elected or appointed office

public pays for wildlife management, and they and ADF&G should be empowered to manage predator–prey relationships in some areas; 4) local residents generally support intensive management actions and argue that local uses of state land (29% of the state) should be decided in Alaska; 5) wolf and bear populations in most of Alaska are healthy and largely limited by available prey and other food supplies; 6) everyone should recognize that predators are renewable natural resources, and the intention is to increase harvest of moose locally, not pursue eradication of predators; and 7) the primary threats to predator populations worldwide include expansion of human settlements and loss of habitat to agriculture and development, yet Alaska predator populations are contiguous over vast areas of wilderness and can rebound from actions taken near a few, dispersed human settlements.

Commonality exists in that both sides of the predator control debate refer to themselves as conservationists, and both sides often claim their position is based on sound science. Differences, however, are commonly irreconcilable. Opponents of predator control generally favor the protectionist side of conservation issues, whereas proponents of control favor the consumptive side of conservation issues (Decker et al. 2006). Opponents generally exhibit higher psychological and intrinsic values for ecosystems with minimal human influences (National Research Council 1997, Schwartz et al. 2003). More specifically, predator-control opponents frequently place a higher value on protection and ethical treatment of individual predators than on managing wildlife populations for consumptive use. Predator-control proponents place a higher value on the heritage and culture, including Native American culture, of moose harvest, compared with protection of individual predators (Titus 2007). Key proponents also point to the role of hunters and hunting in achieving the successful North American model of wildlife conservation (Geist et al. 2001).

Opponents of predator control often ignore or misinterpret the host of informative case histories and prior applied research and favor future, nonapplied research or extremely expensive applied research. Opponents deem continuous predator control as impractical and often rule out predator control as a viable option if stochastic factors, such as adverse weather, can contribute to limiting moose numbers.

In contrast, proponents of predator control often expect a low to moderate level of applied research and monitoring. Proponents often simply seek empowerment through a particular regulatory action or control program that may reduce predation (e.g., aircraft-assisted control or new techniques) and typically view implementation of these programs favorably, regardless of whether efficacy is demonstrated. Proponents testify that 1) adverse weather in inland Alaska is shown to be a minor factor limiting moose populations compared with predation, and 2) adverse weather is uncontrollable, whereas predation is controllable.

Managers and objective biologists search for the most effective but least controversial methods of predator control. Ideally, ineffective techniques will be abandoned in part to reduce controversy. For example, the Board of Game eliminated ineffective measures to control brown bears in Unit 20E in 2009 (Gross 2007).

Both opponents and proponents of predator control advertise simplistic biology-based statements to garner support. For example, opponents of predator control often focus on low reproductive rates of bears to suggest bear populations are at a high risk of extirpation. This focus disregards other bear life-history traits, including high survival of a long-lived, elusive species and that hunted bear populations have greater recruitment rates than unhunted populations near carrying capacity (Miller et al. 2003, McLellan 2005, Czetwertynski et al. 2007). A relevant case history exists in Unit 13, where hunters failed to achieve objectives for strongly reduced brown bear numbers despite long-term elevated harvests (Tobey and Kelleyhouse 2007). Opponents of predator control also frequently exaggerate the effect of wolf control by announcing the cumulative tally of wolves taken among multiple years, with no reference to the annual proportions of wolf populations taken and the compensating rates of increase that occur from high annual rates of reproduction and immigration (Adams et al. 2008).

A simplistic biological goal among key Alaska proponents of predator control is to elevate moose-harvest densities to the high levels found in Scandinavian systems with few or no large predators (Cederlund and Sand 1991, Boertje et al. 2009). However, in Alaska, bears and wolves are well established and managed for sustainability. In addition, carrying capacity of Alaska moose habitats appears low compared with Sweden, as indicated by low birth rates (75 calves vs. 117 calves/100 F $\geq$36 months when at similar, high, prolonged densities; Boertje et al. 2009). Proponents of control often have an additional simplistic view that moose will be added to the population with each predator killed, when in reality 1) predator populations in remote contiguous habitat can sustain kill rates that are often difficult to attain; and 2) substantial, long-term reduction in predation is apparently necessary to increase the sustainable yield of moose.

Policymakers, not biologists, play a leadership role in this arena partly because decisions are about what society should value (Table 1). Policymakers should also evaluate intended and unintended outcomes (levels of public satisfaction) of policies, while objective biologists focus on outputs (efforts and products) of management programs (Birkland 2005). Objective biologists can play a unique and vital role in presenting, evaluating, and interpreting data and reviewing efficacy and practical limitations of programs (Table 1). Impassioned biologists on both sides have a special duty to distinguish their judgments based on personal values from judgments based on science (Lackey 2007). When biologists make biased comments, valid collection and interpretation of data can be discredited in the public arena, and the role of biologists and science is diminished. To be credible and to add substance to these programs, biologists must avoid exaggerating potential consequences of predator control and be well-informed, unbiased, and respectful of political, social, and economic checks and balances that ultimately govern decision-making in this arena.

CONCLUSIONS AND RECOMMENDATIONS

Substantially reducing predation for several years can result in more moose and elevated yields of moose in inland Alaska's moose–bear–wolf systems. We base this conclusion on the results of 10 moose mortality studies, 36 case histories, 10 manipulative studies, and 15 moose nutrition studies, as well as the lack of substantive, contradictory results. Where moose numbers recently increased in response to low predation, ADF&G convincingly used nutrition-based guidelines to halt the unwise stockpiling of moose and further density-dependent declines in moose nutritional status. Also, the sustainability of Alaskan predator populations remains secure. Thus, valid biological and management support exists for predator control to increase yield of moose, if established nutrition-based guidelines are used to identify and administer feasible moose population objectives.

Evaluating the biological basis and management support for these control programs is a simple process compared with evaluating the management feasibility of most new programs and predicting results. To implement a program, administrators must consider the local, practical realities of integrating a host of factors and adapt the management as important, new information becomes available. Factors include public expectations of outcomes, biological interrelationships, environmental variables, predator control methods, current policies, changing political and societal values, budget and time constraints, potential benefits, legal issues, competing programs, personnel qualifications, public participation, logistics, landownership, access for predator control and harvest of moose, conflicts among moose hunters from different geographical areas, and study design. Many biologists ignore most of these considerations and focus comments largely on the biology and potential for improving study design. Given the complexity of this issue, predicting results of most predator control programs will continue to be problematic.

We recommend opponents and proponents of predator control openly communicate their value-laden perspectives without distorting the science, maligning objective biologists, or fabricating conspiracies. Communicating biased science immediately reduces one's credibility and often strongly reduces opportunity for constructive dialogue and transparent decision-making. We also recommend future reviews provide complete relevant results from biological studies and case histories, both sides of the local and larger debates, and clarification that the governor is ultimately empowered to lead these programs for favored constituents. Selective information fuels unnecessary controversy and can diminish the value of objective, evidence-based science.

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LITERATURE CITED

Adams, L. G., R. O. Stephenson, B. W. Dale, R. T. Ahgook, and D. J. Demma. 2008. Population dynamics and harvest characteristics of wolves in the central Brooks Range, Alaska. Wildlife Monographs 170.

Alaska Department of Fish and Game [ADF&G]. 2006. Wolf management report of survey and inventory activities 1 July 2002–30 June 2005. P. Harper, editor, Project 14.0, Juneau, Alaska, USA. <http://www.wildlife.alaska.gov/pubs/techpubs/mgt_rpts/06_wolf.pdf>. Accessed 13 Jan 2010.

Alaska Department of Fish and Game [ADF&G]. 2007. Brown bear management report of survey and inventory activities 1 July 2004–30 June 2006. P. Harper, editor, Project 14.0, Juneau, Alaska, USA. <http://www.wildlife.alaska.gov/pubs/techpubs/mgt_rpts/07_brbear.pdf>. Accessed 13 Jan 2010.

Alaska Department of Fish and Game [ADF&G]. 2008*a*. Moose management report of survey and inventory activities 1 July 2005–30 June 2007. P. Harper, editor, Project 1.0, Juneau, Alaska, USA. <http://

www.wildlife.alaska.gov/pubs/techpubs/mgt_rpts/08_moose.pdf>. Accessed 13 Jan 2010.

Alaska Department of Fish and Game [ADF&G]. 2008*b*. Black bear management report of survey and inventory activities 1 July 2004–30 June 2007. P. Harper, editor, Project 17.0, Juneau, Alaska, USA. <http://www.wildlife.alaska.gov/pubs/techpubs/mgt_rpts/08_blb.pdf>. Accessed 13 Jan 2010.

Alaska Department of Natural Resources. 2000. Fact sheet: land ownership in Alaska. Juneau, Alaska, USA. <http://dnr.alaska.gov/mlw/factsht/land_own.pdf>. Accessed 13 Jan 2010.

Alaska Fish and Game Laws and Regulations Annotated. 2008. ADF&G laws and regulations annotated, 2008–2009 edition. LexisNexis Matthew Bender, Charlottesville, Virginia, USA.

Ballard, W. B., L. A. Ayres, P. R. Krausman, D. J. Reed, and S. G. Fancy. 1997. Ecology of wolves in relation to a migratory caribou herd in northwest Alaska. Wildlife Monographs 135.

Ballard, W. B., A. W. Franzmann, K. P. Taylor, T. Spraker, C. C. Schwartz, and R. O. Peterson. 1979. Comparison of techniques utilized to determine moose calf mortality in Alaska. Proceedings of the North American Moose Conference and Workshop 15:362–387.

Ballard, W. B., and P. R. Krausman. 1997. Occurrence of rabies in wolves of Alaska. Journal of Wildlife Diseases 33:242–245.

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., S. D. Miller, and J. S. Whitman. 1990. Brown and black bear predation on moose in Southcentral Alaska. Alces 26:1–8.

Ballard, W. B., J. S. Whitman, and C. L. Gardner. 1987. Ecology of an exploited wolf population in south-central Alaska. Wildlife Monographs 98.

Ballard, W. B., J. S. Whitman, and D. J. Reed. 1991. Population dynamics of moose in south-central Alaska. Wildlife Monographs 114.

Bergerud, A. T. 1971. The population dynamics of Newfoundland caribou. Wildlife Monographs 25.

Bertram, M. R., and M. T. Vivion. 2002*a*. Moose mortality in eastern Interior Alaska. Journal of Wildlife Management 66:747–756.

Bertram, M. R., and M. T. Vivion. 2002*b*. Black bear monitoring in eastern Interior Alaska. Ursus 13:69–77.

Birkland, T. A. 2005. An introduction to the policy process: theories, concepts, and models of public policy making, Second edition. M. E. Sharpe, Armonk, New York, USA.

Bishop, R. H., and R. A. Rausch. 1974. Moose population fluctuations in Alaska, 1950–1974. Naturaliste Canadien 101:559–593.

Blood, D. A. 1974. Variation in reproduction and productivity of an enclosed herd of moose (*Alces alces*). Transactions of the International Congress of Game Biologists 11:59–66.

Boer, A. H. 1992. Fecundity of North American moose (*Alces alces*): a review. Alces Supplement 1:1–10.

Boertje, R. D., and C. L. Gardner. 2000. The Fortymile caribou herd: novel proposed management and relevant biology, 1992–1997. Rangifer Special Issue 12:17–37.

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., W. C. Gasaway, D. V. Grangaard, D. G. Kelleyhouse, and R. O. Stephenson. 1987. Factors limiting moose population growth in Subunit 20E. Alaska Department of Fish and Game, Federal Aid in Wildlife Restoration, Research Progress Report, Grant W-22-5, Project 1.37R, Juneau, USA.

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., D. G. Kelleyhouse, and R. D. Hayes. 1995. Methods for reducing natural predation on moose in Alaska and Yukon: an evaluation. Pages 505–513 *in* L. N. Carbyn, S. H. Fritts, and D. R. Seip, editors. Ecology and conservation of wolves in a changing world. Canadian Circumpolar Institute, Occasional Publication No. 35. University of Edmonton, Alberta, Canada.

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 harvests. Journal of Wildlife Management 71:1494–1506.

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.

Boutin, S. 1992. Predation and moose population dynamics: a critique. Journal of Wildlife Management 56:116–127.

Bowyer, R. T., V. Van Ballenberghe, and J. G. Kie. 1998. Timing and synchrony of parturition in Alaskan moose: long-term versus proximal effects of climate. Journal of Mammalogy 79:1332–1344.

Cederlund, G. N., and H. K. G. Sand. 1991. Population dynamics and yield of a moose population without predators. Alces 27:31–40.

Czetwertynski, S. M., M. S. Boyce, and F. K. Schmiegelow. 2007. Effects of hunting on demographic parameters of American black bears. Ursus 18:1–18.

Decker, D. J., C. A. Jacobsen, and T. L. Brown. 2006. Situation-specific "impact dependency" as a determinant of management acceptability: insights from wolf and grizzly bear management in Alaska. Wildlife Society Bulletin 34:426–432.

DuBois, S. D. 2008. Unit 20D moose. Pages 386–423 *in* P. Harper, editor. Moose management report of survey and inventory activities 1 July 2005 through 30 June 2007. Alaska Department of Fish and Game, Project 1.0, Juneau, USA. <http://www.wildlife.alaska.gov/pubs/techpubs/mgt_rpts/08_moose.pdf>. Accessed 13 Jan 2010.

Fuller, T. K. 1989. Population dynamics of wolves in north-central Minnesota. Wildlife Monographs 105.

Fuller, T. K., L. D. Mech, and J. F. Cochrane. 2003. Wolf population dynamics. Pages 161–191 *in* L. D. Mech and L. Boitani, editors. Wolves: behavior, ecology, and conservation. University of Chicago Press, Illinois, USA.

Gardner, C. L. 2009. Grizzly and black bear distribution and abundance relative to the 2004 wildfires in eastern Alaska: possible intensive management consequences. Alaska Department of Fish and Game, Federal Aid in Wildlife Restoration, Research Performance Report, Grants W-33-7, Project 4.39, Juneau, USA. <http://www.wildlife.alaska.gov/pubs/techpubs/research_pdfs/4.39_09.pdf>. Accessed 13 Jan 2010.

Gasaway, W. C., R. D. Boertje, D. V. Grangaard, D. G. Kelleyhouse, R. O. Stephenson, and D. G. Larsen. 1992. The role of predation in limiting moose at low densities in Alaska and Yukon and implications for conservation. Wildlife Monographs 120.

Gasaway, W. C., R. O. Stephenson, J. L. Davis, P. E. K. Shepherd, and O. E. Burris. 1983. Interrelationships of wolves, prey, and man in interior Alaska. Wildlife Monographs 84.

Geist, V., S. P. Mahoney, and J. F. Organ. 2001. Why hunting has defined the North American model of wildlife conservation. Transactions of the North American Wildlife and Natural Resources Conference 66:175–185.

Gross, J. A. 2007. Unit 20E brown bear. Pages 240–252 *in* P. Harper, editor. Brown bear management report of survey and inventory activities 1 July 2004–30 June 2006. Alaska Department of Fish and Game, Project 4.0, Juneau, USA. <http://www.wildlife.alaska.gov/pubs/techpubs/mgt_rpts/07_brbear.pdf>. Accessed 13 Jan 2010.

Harbo, S. J., and F. C. Dean. 1983. Historical and current perspectives on wolf management in Alaska. Pages 51–65 *in* L. N. Carbyn, editor. Wolves in Canada and Alaska: their status, biology, and management. Canadian Wildlife Service Report Series 45, Ottawa, Ontario, Canada.

Hayes, R. D., R. Farnell, R. M. P. Ward, J. Carey, M. Dehn, G. W. Kuzyk, A. M. Baer, C. L. Gardner, and M. Donoghue. 2003. Experimental reduction of wolves in the Yukon: ungulate responses and management implications. Wildlife Monographs 152.

Hayes, R. D., and A. Harestad. 2000. Wolf functional response and regulation of moose in the Yukon. Canadian Journal of Zoology 78:60–66.

Hechtel, J. L. 1991. Population dynamics of black bear populations, Fort Wainwright, Alaska. Final Report to the U.S. Army, Natural Research Report 91-2, Fairbanks, Alaska, USA.

Keech, M. A. 2005. Factors limiting moose at low density in Unit 19D East, and response of moose to wolf control. Alaska Department of Fish and Game, Federal Aid in Wildlife Restoration, Final Research Performance Report, Grants W-27-5 and W-33-1 through W-33-3, Project 1.58, Juneau, USA. <http://www.wildlife.alaska.gov/pubs/techpubs/research_pdfs/mo-19d-wolf05.pdf>. Accessed 13 Jan 2010.

Keech, M. A. 2008. Response of moose and their predators to wolf reduction and short-term bear removal in a portion of Unit 19D East. Alaska Department of Fish and Game, Federal Aid in Wildlife Restoration, Research Performance Report, Grant W-33-6, Project 1.62, Juneau, USA. <http://www.wildlife.alaska.gov/pubs/techpubs/research_pdfs/1.62_08.pdf>. Accessed 13 Jan 2010.

Lackey, R. T. 2007. Science, scientists, and policy advocacy. Conservation Biology 21:12–17.
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.
Larsen, D. G., and R. M. P. Ward. 1995. Moose population characteristics in the Frances Lake and North Canol areas. Yukon Fish and Wildlife Branch Report PR-95-1, Whitehorse, Canada.
Lavsund, S., T. Nygrén, and E. J. Solberg. 2003. Status of moose populations and challenges to moose management in Fennoscandia. Alces 39:109–130.
McLellan, B. N. 2005. Sexually selected infanticide in grizzly bears: the effects of hunting on cub survival. Ursus 16:141–156.
Mech, L. D., L. G. Adams, T. J. Meier, J. W. Burch, and B. W. Dale. 1998. The wolves of Denali. University of Minnesota Press, Minneapolis, USA.
Miller, S. D., R. A. Sellers, and J. A. Keay. 2003. Effects of hunting on brown bear cub survival and litter size in Alaska. Ursus 14:130–152.
Miller, S. D., G. C. White, R. A. Sellers, H. V. Reynolds, J. W. Schoen, K. Titus, V. G. Barnes, Jr., R. B. Smith, R. R. Nelson, W. B. Ballard, and C. C. Schwartz. 1997. Brown and black bear density estimation in Alaska using radiotelemetry and replicated mark-resight techniques. Wildlife Monographs 133.
National Research Council. 1997. Wolves, bears, and their prey in Alaska. National Academy Press, Washington, D.C., USA.
Nilsen, E. B., T. Pettersen, H. Gundersen, J. M. Milner, A. Mysterud, E. J. Solberg, H. P. Andreassen, and N. C. Stenseth. 2005. Moose harvesting strategies in the presence of wolves. Journal of Applied Ecology 42:389–399.
Osborne, T. O., T. F. Paragi, J. L. Bodkin, A. J. Loranger, and W. N. Johnson. 1991. Extent, cause, and timing of moose calf mortality in western Interior Alaska. Alces 27:24–30.
Paul, T. W. 2009. Game transplants in Alaska: technical bulletin 4. Second edition. Alaska Department of Fish and Game, Juneau, USA. <http://www.wildlife.alaska.gov/pubs/techpubs/research_pdfs/game_transplants_alaska.pdf>. Accessed 13 Jan 2010.
Peltier, T. C. 2008*a*. Unit 16B moose. Pages 233–245 *in* P. Harper, editor. Moose management report of survey and inventory activities 1 July 2005–30 June 2007. Alaska Department of Fish and Game, Project 1.0, Juneau, USA. <http://www.wildlife.alaska.gov/index.cfm?adfg=pubs.mgt#moose>. Accessed 13 Jan 2010.
Peltier, T. C. 2008*b*. Unit 16 black bear. Pages 187–198 *in* P. Harper, editor. Black bear management report of survey and inventory activities 1 July 2004 through 30 June 2007. Alaska Department of Fish and Game, Project 17.0, Juneau, USA. <http://www.wildlife.alaska.gov/pubs/techpubs/mgt_rpts/08_blb.pdf>. Accessed 13 Jan 2010.
Peterson, R. O., J. D. Woolington, and T. N. Bailey. 1984. Wolves of the Kenai Peninsula, Alaska. Wildlife Monographs 88.
Regelin, W. L., P. Valkenburg, and R. D. Boertje. 2005. Management of large predators in Alaska. Wildlife Biology in Practice 1:77–85.
Reynolds, H. V. 1999. Effects of harvest on grizzly bear population dynamics in the northcentral Alaska Range. Alaska Department of Fish and Game, Federal Aid in Wildlife Restoration, Research Progress Report, Grants W-24-5 and W-27-1, Project 4.28, Juneau, USA.
Schwartz, C. C., J. E. Swenson, and S. D. Miller. 2003. Large carnivores, moose and humans: a changing paradigm of predator management in the 21st century. Alces 39:41–63.
Stephenson, R. O., W. B. Ballard, C. A. Smith, and K. Richardson. 1995. Wolf biology and management in Alaska, 1981–1992. Pages 43–54 *in* L. N. Carbyn, S. H. Fritts, and D. R. Seip, editors. Ecology and conservation of wolves in a changing world. Canadian Circumpolar Institute, Occasional Publication No. 35. University of Edmonton, Edmonton, Alberta, Canada.
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. Söderberg, K. Wallin, and G. Cederlund. 2007. Predation on moose calves by European brown bears. Journal of Wildlife Management 71:1993–1997.
Testa, J. W. 2004. Population dynamics and life history trade-offs of moose (*Alces alces*) in south-central Alaska. Ecology 85:1439–1452.
Titus, K. 2007. Intensive management of wolves and ungulates in Alaska. Transactions of the North American Wildlife and Natural Resources Conference 72:366–377.
Tobey, R. W., and R. A. Kelleyhouse. 2007. Unit 20E brown bear. Pages 143–154 *in* P. Harper, editor. Brown bear management report of survey and inventory activities 1 July 2004–30 June 2006. Alaska Department of Fish and Game, Project 4.0, Juneau, USA. <http://www.wildlife.alaska.gov/pubs/techpubs/mgt_rpts/07_brbear.pdf>. Accessed 13 Jan 2010.
U.S. Census Bureau. 2008. American factfinder. Washington, D.C., USA. <http://factfinder.census.gov/servlet/SAFFPopulation?_event=Search&geo_id=01000US&_geoConte>. Accessed 13 Jan 2010.
Van Ballenberghe, V. 2006. Predator control, politics, and wildlife conservation in Alaska. Alces 42:1–11.
Young, D. D. 2008. Unit 20B moose. Pages 348–372 *in* P. Harper, editor. Moose management report of survey and inventory activities 1 July 2005 through 30 June 2007. Alaska Department of Fish and Game, Project 1.0, Juneau, USA. <http://www.wildlife.alaska.gov/pubs/techpubs/mgt_rpts/08_moose.pdf>. Accessed 13 Jan 2010.
Young, D. D., R. D. Boertje, C. T. Seaton, and K. A. Kellie. 2006. Intensive management of moose at high density: impediments, achievements, and recommendations. Alces 42:41–48.
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.

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