Predator Control Plans – Relevant Literature Review

Colorado Parks and Wildlife

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This literature summary is in response to public comments on the proposed Piceance Basin and Arkansas predator research projects. Both of these projects have complete study plans and literature cited in those plans does not necessarily appear in this review. This review was prepared specifically in response to public comment. We have broken this review into broad categories that reflect the content of the referenced literature. The first category is Predator-prey study or review, which reflects actual studies of predator-prey dynamics or a review of the literature reflecting such studies. The second category is Deer nutrition or habitat study, which are studies documenting the effects of nutrition or habitat on deer population dynamics. The third category is Deer and energy research, which includes 5 papers pertaining to work occurring primarily in the Piceance Basin of northwest Colorado. The fourth category, Deer and development research, includes two papers pertaining to residential development (in part). The fifth category is Conceptual overview, which represent articles that report people's opinions or theories on predators, reporting little or no data and generally representing some global perspectives. The sixth and final category is Miscellaneous, which represents all other literature brought to our attention, but does not necessarily fit into one of the other categories.

Following a list of citations by category, we have summarized many of the individual publications in an attempt to capture the spirit or intent of the article. In doing so, we have attempted to directly synthesize the major findings, results, opinions and theories presented in an attempt to avoid staff bias (often quoting or closely paraphrasing the authors directly). CPW opinions or comments on any of these articles are in *italics*.

LIST OF CITATIONS BY CATEGORY

Predator-prey study or review

Ballard, W.B., D. Lutz, T.W. Keegan, L.H. Carpenter, and J.D. DeVos, Jr. 2001. Deer-predator relationships: a review of recent North American studies with emphasis on mule and black-tailed deer. Wildlife Society Bulletin 29:99-115.

Barber-Meyer, S.M., L.D. Mech, and P.J. White. 2008. Elk calf survival and mortality following wolf restoration to Yellowstone National Park. Wildlife Monographs 169:1-30.

Bright, J.L., and J. Hervert. 2005. Adult and fawn mortality of Sonoran pronghorn. Wildlife Society Bulletin 33:43-50

Cooley, H.S., R.B. Wielgus, G.M. Koehler, H.S. Robinson, and B.T. Maletzke. 2009. Does hunting regulate cougar populations? A test of the compensatory mortality hypothesis. Ecology 90:2913-2921.

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Elbroch, L.M., P.E. Lendrum, M.L. Allen and H. U. Wittmer. 2015. Nowhere to hide: pumas, black bears, and competition refuges. Behavioral Ecology 26:247-254.

Elbroch, L.M. and H. U. Wittmer. 2012. Table scraps: inter-trophic food provisioning by pumas. Biology Letters. 8:776-779.

Forrester, T.D. and H.U. Wittmer. 2013. A review of the population dynamics of mule deer and black-tailed deer Odocoileus hemionus in North America. Mammal Review.

Gill, R.B. et al. 1999. Declining mule deer populations in Colorado: reasons and responses. A Report to the State Legislature. Colorado Division of Wildlife, Denver.

Hurley, M.A., J.W. Unsworth, P. Zager, M. Hebblewhite, E.O. Garton, D.M. Montgomery, J.R. Skalski, C.L. Maycock. 2011. Demographic response of mule deer to experimental reduction of coyotes and mountain lions in Southeastern Idaho. Wildlife Monographs.

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Peebles, K.A., R.B. Wielgus, B.T. Maletzke, and M.W. Swanson. 2013. Effects of remedial sport hunting on cougar complaints and livestock depredations. PLoS One 8:e79713

Pojar, T.M., and D.C. Bowden. 2004. Neonatal mule deer fawn survival in west-central Colorado. Journal of Wildlife Management 68:380-388.

Prugh, L.R., and S.M. Arthur. 2015. Optimal predator management for mountain sheep conservation depends on the strength of mesopredator release. Oikos 124:1241-1250.

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Teichman, K.J., B. Cristescu, and C.T. Darimont. 2016. Hunting as a management tool? Cougar-human conflict is positively related to trophy hunting. BMC Ecology 16:44

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Lendrum, P.E., C.R. Anderson, K.L. Monteith, J.A. Jenks, and R.T. Bowyer. 2013. Migrating Mule Deer: Effects of Anthropogenically Altered Landscapes. PLoS One 8(5): e64548.

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Deer and development research

Johnson, H.E., J.R. Sushinsky, A. Holland, E.J. Bergman, T. Balzar, J. Garner, and S.E. Reed. 2016. Increases in residential and energy development are associated with reductions in recruitment for a large ungulate. Global Change Biology, doi: 10.1111/gcb.13385

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Zinn, H.C., M.J. Manfredo. 1996. Societal preferences for mountain lion management along Colorado's Front Range (Project Report No. 28) Project report for the Colorado Division of Wildlife. Fort Collins, CO. Colorado State University, Human Dimensions in Natural Resources Unit. 5th Mountain Lion Workshop Proceedings.

SUMMARY OF SELECT CITATIONS

Predator-prey study or review

Ballard, W.B., D. Lutz, T.W. Keegan, L.H. Carpenter, and J.D. DeVos, Jr. 2001. Deer-predator relationships: a review of recent North American studies with emphasis on mule and black-tailed deer. Wildlife Society Bulletin 29:99-115.

Reviewed results of published studies conducted since the mid-1970s concerning predator-deer relationships to determine whether predation could be a factor in the apparent deer population declines and whether there was evidence that predator control could be a viable management tool to restore deer populations. Study results were confounded by numerous factors. A deer population's relationship to habitat carrying capacity was crucial to the impacts of predation. Deer populations at or near carrying capacity did not respond to predator removal experiments. When deer populations appeared limited by predation and such populations were well below forage carrying capacity, deer mortality was reduced significantly when predator populations were reduced. Only one study, however, demonstrated that deer population increases resulted in greater harvests, although considerable data indicated wolf control resulted in greater harvests of moose and caribou. The most convincing evidence for deer population increases occurred when small enclosures were used. Review suggests that predation by coyotes, mountain lions, or wolves may be a significant mortality factor in some areas under certain conditions. Relation to habitat carrying capacity, weather, human use patterns, number and type of predator species, and habitat alterations all affect predator-prey relationships. Only through intensive radiotelemetry and manipulative studies can predation be identified as a major limiting factor. When it is identified, deer managers face crucial decisions. Reductions in predator densities have occurred only on relatively small study areas where predators were identified as a major limiting factor and deer populations were well below forage carrying capacity. Thus, a problem of scale, methods used to kill predators, benefit:cost ratios, results to hunters, and public acceptance are primary considerations.

Unfortunately, inconsistencies and significant variations among studies because of relationships to habitat carrying capacity, differing weather patterns, and the short-term

nature of most studies limit their usefulness in assessing overall importance of predation. Often small sample sizes limited usefulness of studies because of their low statistical power to actually detect significant differences. Additional experimental long-term research, particularly on coyote, mountain lion, and black bear predation is needed to clarify the role of predation on deer. An experimental approach is necessary whereby deer population performance in relation to predator removal is monitored in manipulated and unmanipulated areas. Such experiments should be conducted over sufficient time such that severe and favorable weather conditions occur.

Barber-Meyer, S.M., L.D. Mech, and P.J. White. 2008. Elk calf survival and mortality following wolf restoration to Yellowstone National Park. Wildlife Monographs 169:1-30.

Sixty-nine percent of calves died within the first year of life, 24% survived the first year, and 7% had unknown fates. Grizzly bears and black bears accounted for 58-60% of deaths, and wolves accounted for 14-17%. Summer predation increased, and winter malnutrition decreased, compared with a similar study during 1987-1990. Physiological factors may predispose calves to predation. Also, increase in bear numbers since wolf restoration and spatial components finer than the northern range should be considered when trying to determine the causes of the northern Yellowstone elk decline.

Bright, J.L., and J. Hervert. 2005. Adult and fawn mortality of Sonoran pronghorn. Wildlife Society Bulletin 33:43-50.

They addressed adult mortality and fawn recruitment of an endangered pronghorn population in Arizona (<30 animals). They used weekly telemetry to address adult survival and recorded group composition to document recruitment. Adult mortality factors included bobcat, coyote, cougar, drought and unknown causes. Fawn mortality varied annually and was correlated with amount and timing of rainfall. They concluded that drought conditions may be a major factor limiting fawn and adult survival, and was also likely related to adult predation rates. To improve Sonoran Pronghorn survival, they suggest providing nutrition forage during early spring and summer, and water sources where predators are less successful. They suggest that Predator control may be useful in limited situations but likely would be prohibitively expensive, with little chance of making a difference over the entire range of Sonoran pronghorn. They also propose that further research is needed to address pronghorn fawn predation. *This is an example of a severely habitat/climate-limited system in the desert southwest, where predator control would likely provide only short-term benefits.*

Cooley, H.S., R.B. Wielgus, G.M. Koehler, H.S. Robinson, and B.T. Maletzke. 2009. Does hunting regulate cougar populations? A test of the compensatory mortality hypothesis.

Many wildlife species are managed based on the compensatory mortality hypothesis, which predicts that harvest mortality (especially adult male mortality) will trigger density-dependent responses in reproduction, survival, and population growth caused via reduced competition for resources. Reject the compensatory mortality hypothesis because vital rates did not compensate for hunting mortality. Heavy harvest corresponded with increased

immigration, reduced kitten survival, reduced female population growth, and a younger overall age structure. Study area sizes were 735 km^2 (heavy hunting) and 594 km^2 (light hunting). Kittens were monitored beginning in 2005 (study from 2002 to 2007). VHF-collared animals were located at one-week intervals. Inferred cause of kitten mortalities by examining carcass and proximity of other collared cougars. Of 42 radio-collared kittens, 18 survived to one year of age, 16 died from natural causes, and four were censored. Six of the natural kitten mortalities in the heavy-hunting area (HH) were presumed to have been killed by male cougars. Overall survival and survival of adults was higher in light-hunting area than in HH *(given harvest mortality of uncollared animals, this statement may not be valid – see next paragraph)*.

Hunting mortality of collared-cougars was 0.24 in the heavy hunting area and 0.11 in the light hunting area. However, hunters killed 22 cougars (9 females, 13 males) in the heavy hunting area and 28 cougars (14 females, 13 males, 1 unknown) in the light hunting area. Given the sizes of the study areas, hunting mortality from the collared cougars does not seem representative of the uncollared population. Mortality rates from the collared animals is then used in their other estimates which would create a significant bias. Population density for adults in the heavy harvest area was 1.58 and in the light harvest area was 1.87, and were not significantly different. Both areas seem suppressed and don't appear to represent the heavy/light harvest scenarios as presented.

Eacker, D.R., M. Hebblewhite, K.M. Proffitt, B.S. Jimenez, M.S. Mitchell, H.S. Robinson. 2016. Annual elk calf survival in a multiple carnivore system.

Found no evidence that forage availability or winter weather severity mediated vulnerability to mountain lion predation risk in summer or winter, indicating that the effect of mountain lion predation was constant regardless of spatial variation in forage or weather. Mountain lions dominated known causes of elk calf mortality in summer and winter. Growing evidence suggesting that mountain lions may be the most important carnivore for ungulates in more settings than anticipated, especially where grizzly bears and wolves are absent. Regardless of specific migration strategy, found no evidence that higher forage availability compensated for the negative effects of mountain lion predation risk on elk calf survival in either season. This suggests that mountain lions are an additive mortality source for neonatal elk calves in our study system, especially during summer. Effects of predation may be the strongest in the lower quality habitat, exacerbating declines of ungulate populations. Reversing trends with changing harvest will be difficult, however, because of the general unimportance of human hunting to calf recruitment. In declining elk populations with recovering carnivores, reducing adult female harvest may be initially necessary as carnivores recover to allow time to identify the most effective strategy to balance ungulate and carnivore management objectives. As carnivore recovery continues, managers may need to consider a more aggressive policy toward habitat restoration or carnivore management for ungulates in less productive habitats.

Elbroch, L.M., P.E. Lendrum, M.L. Allen and H. U. Wittmer. 2015. Nowhere to hide: pumas, black bears, and competition refuges. Behavioral Ecology 26:247-254.

Tested for the effects of American black bear kleptoparasitism* on puma foraging in 2 systems in North America. Also tested whether partial prey consumption exhibited by pumas in the presence of bears was better explained by rules of optimal foraging or by kleptoparasitism by black bears, and whether pumas utilized spatial competition refuges to mitigate competition with bears over carcass remains. Puma kill rates in ungulates/week were equivalent across study systems, but 48% greater in the bear season than the no-bear season. Analyses of handling time did not support the notion that partial prey consumption exhibited by pumas followed patterns of optimal foraging. Rather, puma handling time and prey consumption were better explained by the presence of bears. Pumas did not utilize spatial competition refuges to mitigate competition with black bears, and instead results suggested they increase their kill rates to compensate for losses. Propose that future predation studies should differentiate between relative contributions of predators and competitors on prey dynamics. Further, results suggest kleptoparasitism may indirectly impact prey populations through their effects on top predators.

**Kleptoparastism: a form of feeding in which one animal takes prey or other food from another that has caught, collected, or otherwise prepared the food … (Wikipedia). Kleptoparasite: A bird, insect, or other animal which habitually robs animals of other species of food (English Oxford Living Dictionaries).*

Elbroch, L.M. and H. U. Wittmer. 2012. Table scraps: inter-trophic food provisioning by pumas. Biology Letters. 8:776-779.

Using new GPS technology, discovered that pumas in Patagonia provided 232 kg of edible meat/month/100km^2 to near-threatened Andean condors and other members of a diverse scavenger community. This is up to 3.1 times the contributions by Wolves to communities in Yellowstone National Park, and highlights the keystone role large, solitary felids play in natural systems. These findings are more pertinent than ever, for managers increasingly advocate controlling pumas and other large felids to bolster prey populations and mitigate concerns over human and livestock safety, without a full understanding of the potential ecological consequences of their actions.

Forrester, T.D. and H.U. Wittmer. 2013. A review of the population dynamics of mule deer and black-tailed deer Odocoileus hemionus in North America. Mammal Review.

The relative contribution of predation, forage availability and weather to observed population changes remain unclear and controversial. Predation was the primary proximate cause of mortality for all age classes, and was an important source of summer fawn mortality and of mortality in multi-prey, multi-predator systems. However, predator removal studies suggest that predation is compensatory, particularly at high deer densities, and that nutrition and weather shape population dynamics. Future research should be focused on: the effects of age-specific survival on population growth; possible interactions between predation, forage availability and weather; and the importance of multiple predator and prey species in shaping population dynamics. The contribution of environmental variables to vital rates is affected by population density, and it is important to note that most studies reviewed occurred at high density relative to nutritional carrying capacity (which leads to compensatory relationship).

Therefore, conclusions predominantly relate to high-density populations, since both predation and nutrition have different effects at different population densities. Based on these studies there is little evidence that predation is additive. The two notable exceptions to the pattern of compensatory predation mortality were summer fawn mortality and predation in multi-predator, multi-prey systems. The true effect of summer fawn predation on mule deer dynamics is currently hard to identify because few researchers have followed fawns for their entire first year of life (only 5 studies). The importance of mortality from predation, nutrition, and weather depends on both mule deer age class and on the community of predator and prey species, but at this time there are not enough data to evaluate whether these interactions are driving dynamics, and further investigation is needed. The role of disease appears to be minor in most mule deer declines. Interactions between predation, forage, and weather need to be studied. The suppression of both fawn and adult survival simultaneously from predation and other mortality sources can lead to marked and sustained population declines. Increasing wolf populations in Vancouver Island also caused a decline in a high-density black-tailed deer population, and the predator removal study that was conducted was successful in increasing deer populations. It is now acknowledged that both bottom-up [food limitation] and top-down [predation] mechanisms simultaneously affect ungulate dynamic and often interact.

Gill, R.B. et al. 1999. Declining mule deer populations in Colorado: reasons and responses. A Report to the State Legislature. Colorado Division of Wildlife, Denver.

Gill et al. addressed the Colorado state legislature to identify potential factors influencing mule deer declines in Colorado that occurred during the early 1990s. This report was later published as a Colorado Division of Wildlife technical report in 2001 (special report no. 77). They begin by describing the history of mule deer population trends in Colorado and suggest that deer densities were highest sometime between 1935 and 1955. Subsequently, mule deer populations fluctuated largely due to climate effects and hunting. Generally, mule deer populations have been declining since the late 1950s and early 1960s and numbers were about half peak levels of the 1940s by the late 1990s. They suggest that peak populations likely reduced habitat quality and quantity and in combination with other land use changes, this resulted in lower carrying capacity to the extent that mule deer habitats are no longer capable of supporting historic deer numbers. They address potential factors related to declining deer populations as follows:

- Elk populations have increased concurrently with declining deer populations. Elk and deer exhibit some diet overlap, but elk can exit on food that won't support deer. In theory, elk could exhibit a competitive advantage over deer where they overlap. Available data fail to show consistent relationships where increasing elk numbers have been associated with declining deer numbers.
- Disease can influence deer populations, but outbreaks are rarely widespread enough to cause large-scale declines in abundance. *At the time of this publication, CWD was limited to NE Colorado and therefore could not be linked to the previous declines.*
- They noted that coyote predation has been proposed as a primary factor causing deer declines throughout the west, but studies to date have not supported this premise.

They acknowledge that the contribution of predation on mule deer declines remains uncertain.

- Excessive deer harvests have also been proposed as a primary cause of deer population declines. However, studies indicate that low reproductive rates and high fawn mortality contradicts the idea of hunted populations below carrying capacity. They acknowledge that hunting has contributed to low buck:doe ratios, which could inhibit populations due to reduced breeding potential, but reproductive rates are comparable to periods when buck ratios were much higher.
- They conclude that important deer habitats have deteriorated through time and that the current capacity of those habitats to support deer is now lower. Habitat effects are amplified perhaps by increasing elk numbers, disease, predation, and hunting, but very few experiments have been conducted to test for effects at scales of entire deer herds. As a result, the answer to the question, "What caused mule deer numbers to decline?" remains both speculative and controversial. *The authors identify future projects (management experiments, research) to address some of these questions, which are summarized below to illustrate that many of these have been addressed at some level and the final project suggested will be addressed if the proposed studies are approved.*

Deer inventory procedures are being upgraded wherein deer population data are being collected frequently and intensively from a few areas that represent extensive mule deer habitat complexes:

- *This has been addressed by the establishment of 5 statewide mule deer monitoring areas.*

Enhanced analyses of mule deer population and hunting data will be routinely analyzed with rigorous statistical tests to evaluate benefits from changes in hunting seasons and regulations:

- *Partially addressed by Bergman et al. 2011. Biological and social-economic effects of deer licenses in Colorado. Journal of Wildlife Management 75:1443-1452*
- *Ongoing at the DAU, Area, Regional and statewide level*

Management experiments are proposed to evaluate the effects of high doe numbers and high buck numbers on fawn production as reflected in post-hunting season ratios of fawns per 100 does:

- *A study was initiated in Middle Park to address these questions, but was discontinued after year 2 due to local opposition. The potential influence of high buck ratios on fawn recruitment was discussed by Bergman et al. 2011 (referenced above).*

Management studies are underway to evaluate the effects of hunting seasons on buck mortality due to poaching and inadvertent wounding loss of bucks:

- *Buck survival data are being collected in the Northwest Region that can be used to address this question. We are not aware of the ongoing management studies referenced.*

Research studies will assess the contribution of long-term habitat changes to the mule deer decline:

- *Mule deer-habitat relationships have been addressed by Bishop et al. 2009, Bergman et al. 2014 (summarized previously) and the ongoing research in the Piceance Basin scheduled for completion in 2018. Johnson et al. (2016; summarized previously) addressed broad scale correlations of residential and energy development with early winter fawn recruitment.*

Ongoing research studies evaluate the contribution of diseases. Particularly chronic wasting disease [CWD], to declining mule deer numbers:

- *Has not formally been addressed relative to population level influences. Some of Dr. Mike Miller's research has used test and cull in an attempt to reduce prevalence rates and address clinical signs of CWD. Surveillance for BVD and EHD has been ongoing in the monitoring areas.*

Research experiments are proposed to assess the effects of high elk numbers on mule deer habitat use and fawn production:

- *Elk/mule deer competition has not yet been addressed. Experimental evaluations at landscape scales will be logistically challenging, but could be addressed in the future.*

Research experiments are proposed that will evaluate the contributions of predation vs. habitat quantity and quality to high fawn mortality rates:

- *The proposed two research projects would address this question in relation to predation and fawn mortality rates. The Piceance and Upper Arkansas research proposals are designed to evaluate how predation influences neonate mule deer survival.*

Hurley, M.A., J.W. Unsworth, P. Zager, M. Hebblewhite, E.O. Garton, D.M. Montgomery, J.R. Skalski, C.L. Maycock. 2011. Demographic response of mule deer to experimental reduction of coyotes and mountain lions in Southeastern Idaho. Wildlife Monographs.

Detected no strong effect of coyote or mountain lion removal alone on mule deer population trend; the best population-growth-rate model included previous year's mountain lion removal and winter severity, yet explained only 27% of the variance in population growth rate. Although mountain lion removal increased mule deer survival and fawn ratios, they were unable to demonstrate significant changes in population trend with mountain lion removal. In conclusion, benefits of predator removal appear to be marginal and short term in southeastern Idaho and likely will not appreciably change long-term dynamics of mule deer populations in the intermountain west. (*note: study areas were small and removal rates do*

not appear that high and were not much higher in treatment areas than control areas, with the exception of one or two years in just one of the treatment areas.) The effects of decreased mortality of fawns and adult deer (by mountain lions) were not manifested in population rate of increase, and results suggest other factors, especially climate and the interaction between predation and primary productivity, regulate mule deer population dynamics in southern Idaho. Density dependence, age structure, or climate variability may have influenced interpretation of the effect of predator removal on mule deer population growth. As examples of these influences, mule deer populations doubled in some GMUs during the study period, age structure likely changed where predator removal increased survival rates, and a 3-fold annual variation in precipitation was observed. The effect size of mountain lion removal that was observed on survival estimates may not have been large enough to overcome the sampling variance in the population surveys. Mountain lion-caused mortality appears to be mostly additive in the short-term, as evidenced by increased survival of adults and 6-month-old fawns and by fawn ratios following mountain lion removal. Predation by mountain lions, however, also appears compensatory in the longer time frame. Summary: 1. Mountain lion removal increased winter fawn survival, 2. Adult female mule deer survival increased with mountain lion removal, up to 5.5% annually at maximum removal rates, 3. Fawn-to-adult female ratios increased with mountain lion removal. Predicted at 6% increase at average removal and up to 27% at maximum mountain lion removal, 4. Mountain lion removal had a minimal, positive effect on mule deer population growth rates.

Laundre, J.W., L. Hernandez, and S.G. Clark. 2006. Impact of puma predation on the decline and recovery of a mule deer population in southeastern Idaho.

They modeled the impact of puma predation on the decline and recovery of mule deer in southern Idaho based on estimates of puma numbers, predation rates of pumas, and reproductive variables of deer. Conclude that pumas probably were a minor factor in the decline of the deer population in the area and did not suppress deer recovery. They propose that winter snowfall was the primary ultimate and proximate factor in the deer decline and suppression of their recovery.

Study area was small (940 km^2) and estimates were poor. Parameters were taken from literature from totally different areas. Modeling approach was poor and did not properly account for variation in parameters. Assumptions were weak and likely not valid. Assumes a puma will only kill 20 deer per year.

Laundre, J., and T.W. Clark. 2003. Managing puma hunting in the western United States: through a metapopulation approach. Animal Conservation 6: 159-170.

To achieve long-term viability of hunted puma populations (even at historically low densities), they propose a management plan based on the metapopulation concept that designates source areas (closed to hunting) and sink areas (open to hunting). They designate sink and source areas based on their size, accessibility to hunters and juxtaposition. They show that closing 63% of puma habitat to hunting would ensure long-term puma population viability while permitting traditional hunting levels in other areas.

This was a modeling exercise based on limited data and many assumptions. Lion densities used were very low and in our opinion not very realistic. It also isn't very applicable to Colorado as they were looking at very fragmented lion habitat.

Mitchell, C.D., R. Chaney, K. Aho, J.G. Kie, and R.T. Bowyer. 2015. Population density of Dall's sheep in Alaska: effects of predator harvest. Mammal Research 60:21-28.

The authors measured response in Dall's sheep density relative to reductions in wolf and coyote densities. They observed an increase in sheep density following the second year of predator control, but severe winter conditions the third year resulted in an overall reduction in sheep density. They conclude that in instances where populations of Dall's sheep are below carrying capacity (K) and not limited by forage productivity or weather, reducing canid numbers may increase sheep numbers dramatically, if only temporarily. They caution that reducing predators and increasing ungulate numbers can have deleterious effects if ungulate populations subsequently rapidly rebound toward K. Under those circumstances, weather-related phenomena can adversely influence ungulate populations because individuals near K are in poor physical condition.

Monteith, K.L., V.C. Bleich, T.R. Stephenson, B.M. Pierce, M.M. Conner, J.G. Kie, and R.T. Bowyer. 2014. Life-history characteristics of mule deer: effects of nutrition in a variable environment. Wildlife Monographs.

Goal was to provide a nutritional basis for understanding life-history strategies of mule deer, and to aid in the conservation and management of large herbivores. Both winter and summer survival were influenced positively by the preceding April snowpack relative to the density of the population. Nutritional condition offered a mechanistic link between factors that influence resource limitation and population performance, because condition of adult females in autumn and late winter was sensitive to the nutritional history of individual animals as related to forage growth, population density, migratory tactic, reproductive costs, and nutritional carryover. Provide a method to estimate the proximity of a population to nutritional carrying capacity that is based on nutritional status of the population relative to population performance. Propose that the consequences of mortality on population dynamics can be assessed by comparing the estimated nutritional capacity for survival and recruitment of young to that measured empirically. Approach is useful for quantifying the effect of predation. Nutrition was the dominant factor affecting survival of young on the east side of the Sierra Crest, whereas survival of young born on the west side was affected mostly by predation. Selective pressures for mule deer overwintering in Round Valley have shifted during the most recent decades to favor animals that reside on the east side of the Sierra crest during summer, ostensibly the result of greater predation on the west side. The poor recruitment of young despite greater nutritional potential on the west side of the Sierra crest indicates that high mortality of young caused by bear predation is limiting that migratory segment of the population. High rates of predation for particular migratory segments of populations that have a greater nutritional potential imply that some mortality is additive if their migratory counterpart is capable of successfully recruiting disproportionately more young while on an inferior nutritional plane. The interaction between mortality because of

predation or malnutrition is difficult to disentangle without manipulative experiments or other means of assessment. Suggest that attempts to conclude whether mortality is purely additive or purely compensatory are misguided. Truth lies between these two endpoints, mortality up to a certain point is compensatory, with higher levels of mortality becoming increasingly additive.

National Research Council. 1997. Wolves, bears, and their prey in Alaska. National Academy Press, Washington, D.C.

The committee's mandate was to synthesize what is known about the biological aspects of wolf and bear management in Alaska, with particular emphasis on the degree of certainty one can have about predictions about the impact of wolf or bear management on both predator and prey populations. In addition, the committee was asked to identify additional biological data that should be collected.

Here are the conclusions identified in this synthesis:

1. Wolves and bears in combination can limit prey populations.
2. Wolf control has resulted in prey increases only when wolves were greatly reduced over a large area for at least 4 years.
3. Expectations that managed populations in Alaska will remain stable are not justified.
4. Data on habitat quality are inadequate.
5. Modeling of population dynamics will enhance the use of data already collected and enable more efficient use of limited resources.
6. Wolves, bears, and their prey are vulnerable to human actions but in different ways.
7. The design of most past experiments and the data collected do not allow firm conclusions about whether wolf and bear reductions caused an increase in prey populations that lasted long after predator control ceased.
8. Perfect prediction is unattainable.
9. Many past predator control and management activities have been insufficiently monitored.
10. Benefit-cost analyses of management changes require at least three categories of information: biological relationships among predators, prey and their environment; human behavioral response to changes in perceived quality of the use in question; and frameworks for valuing the change in use of the resource.
11. Evaluations of Alaska predator control programs have not gathered, analyzed, and assessed the full economic costs and benefits.
12. Social science research in Alaska is needed to support the design and evaluation of predator control experiments.
13. Wildlife is, by definition, a public resource.
14. Greater potential for agreement may exist among Alaska's diverse constituency than is generally assumed.
15. Conflicts over management and control of predators are likely to continue indefinitely.

16. Decentralization of decision-making authority is not a panacea for solving wildlife management problems, but it is likely to be helpful in many circumstances, particularly in rural communities.
17. Interagency cooperation could improve management, reduce public confusion, and eliminate unnecessary duplication.

Mosnier, A., D. Boisjoly, R. Courtois, and J.P. Ouellet. 2008. Extensive predator space use can limit the efficacy of a control program. Journal of Wildlife Management 72:483-491.

Predator ecology is often overlooked because relevant data are difficult to obtain. The endangered Gaspesie caribou has benefitted from 2 periods of predator control that targeted black bears and coyotes in an attempt to reduce predation on caribou calves. To assess impact of predator movements on efficacy of a control program, they studied space use of 24 black bears and 16 coyotes over 3 years in and around the Gaspesie Conservation Park, Quebec, Canada, using Global Positioning System radiocollars. Annual home ranges of black bears averaged 260 km^2 and 10 individuals frequented area used by caribou. Simulations based on observed patterns showed that 314 bears and 102 coyotes potentially shared part of their home range with areas used by female caribou during the calving period. Despite low densities of both predator species, extensive movement and use of nonexclusive territories seem to allow predators to rapidly occupy removal areas, demonstrating the need for recurrent predator removals. Results underscore the necessity of considering complementary and alternative solutions to predator control to assure long-term protection of endangered species.

Black bears did show selection for calving areas.

Murie, A. 1940. Ecology of the coyote in the Yellowstone. *In* U.S.D. of Interior, editor. Fauna of the National Parks of the United State. U.S. Government Printing Office.

Because fear had been expressed that coyote depredations on mule deer, especially in winter, were so extensive that the future of the species in Yellowstone was threatened, he devoted much of his time during the winter of 1937-1938 to a study of factors affecting the deer. Since the advent of the modern conception of wildlife management a new attitude toward the question of predation is growing. One of its precepts is that control of potentially harmful or suspected species of birds and mammals should await precise data based on research. Special emphasis was given to the task of determining the effect of coyote pressure on prey species. The facts show that in the case of elk this is negligible, and that no appreciable inroads on the populations of deer, antelope, and bighorn are taking place. On the other hand it became clear that the big game species are seriously handicapped by a poor, crowded range. The problem of the big game species in Yellowstone is not one of predation, but of inadequate winter range.

This was purely an observational study conducted in the 1940's about the ecology of coyotes in Yellowstone. Evidence of predation was based on examining coyote scats. No

manipulation of the predator population was done and no direct study of the impacts of predation on ungulate populations was conducted.

Peebles, K.A., R.B. Wielgus, B.T. Maletzke, and M.W. Swanson. 2013. Effects of remedial sport hunting on cougar complaints and livestock depredations. PLoS One 8:e79713

Assessed the effects of remedial sport hunting on reducing cougar complaints and livestock depredations in Washington from 2005 to 2010. The number of complaints, livestock depredations, cougars harvested, estimated cougar populations (1.7 per 100km^2 for all available cougar habitat in state), human population and livestock populations were calculated for all 39 counties and 136 GMSs in Washington. Found that complaints and depredations were positively associated with human population, livestock population, and cougar population. However, contrary to expectations, found that complaints and depredations were most strongly associated with cougars harvested the previous year. The odds of increased complaints and livestock depredations increased dramatically with increased cougar harvest. Suggest that increased young male immigration, social disruption of cougar populations, and associated changes in space use by cougars-caused by increased hunting resulted in the increased complaints and livestock depredations. Widespread indiscriminate hunting does not appear to be an effective preventative and remedial method for reducing predator complaints and livestock depredations.

Year	Verified Reports	Livestock Dep	Total Dep	Cougar Harvest
2005	111	28	37	182
2006	86	32	41	199
2007	72	28	38	198
2008	61	28	31	188
2009	63	37	40	140
2010	30	13	19	161

The table above shows that all of their findings are driven by the low harvest in 2009 and low reporting and depredation in 2010. Otherwise, the reported relationships do not hold. Following the highest harvest rates in 2006 and 2007 reporting declined the following years, contrary to what they report. In 2007, harvest was high followed by low depredation.

Pojar, T.M., and D.C. Bowden. 2004. Neonatal mule deer fawn survival in west-central Colorado. Journal of Wildlife Management 68:380-388.

The authors addressed neonate mule deer survival on the Uncompahgre Plateau Colorado from 1999-2001. They observed a mean survival rate of 50% and reported that 76% of neonate mortalities occurred by July 31 (within ~the first 6 weeks). Cause specific mortality averaged 19.5% sick/starve, 12.5% coyote predation, 4.2% bear predation, 3.9% feline predation, 3.9% trauma (defined as whole carcasses with internal trauma?), and 4.6% unknown. They suspected that relatively high sick/starve losses (and low thymus weights) may suggest inadequate doe condition during late pregnancy, and suggest their results do not provide evidence that predation is limiting recruitment. They noted that recorded neonate survival through mid-December did not totally account for the observed low doe:fawn ratios, and

suspect that fetus mortality during late pregnancy or fawn mortality at birth (fawns were captured opportunistically, without VITs) as potential causes of poor recruitment.

Prugh, L.R., and S.M. Arthur. 2015. Optimal predator management for mountain sheep conservation depends on the strength of mesopredator release. Oikos 124:1241-1250.

Large predators often suppress ungulate population growth, but they may also suppress the abundance of smaller predators that prey on neonatal ungulates. Antagonistic interactions among predators may therefore need to be integrated into predator-prey models to effectively manage ungulate-predator systems. Present a modeling framework that examines the net impact of interacting predators on the population growth rate of shared prey, using interactions among wolves, coyotes, and Dall sheep as a case study. Hypothesized that the positive effects of wolf control on Dall sheep population growth could be counteracted by increased levels of predation by coyotes. Population models predicted that wolf control could increase sheep growth rate by 4% per year in the absence of mesopredator release. However, if wolf control released coyote populations, our models predicted that sheep growth rate could decrease by up to 3% per year. These results highlight the importance of integrating antagonistic interactions among predators into predator-prey models, because the net effect of predator management on shared prey can depend critically on the strength of mesopredator release.

Robinson, H.S., R.B. Wielgus, H.S. Cooley, and S.W. Cooley. 2008. Sink populations in carnivore management: cougar demography and immigration in a hunted population. Ecological Applications 18:1028-1037.

It is widely believed that sport hunting is effective in reducing carnivore populations and related human-carnivore conflicts, while maintaining viable populations. The way in which carnivore populations respond to harvest can vary greatly depending on their social structure, reproductive strategies, and dispersal patterns. Hunted cougar populations have shown a great degree of resiliency. Hunting cougars on a broad geographic scale (>2,000 km^2) has reduced densities, hunting of smaller areas (<1000 km^2), could conceivably fail because of increased immigration from adjacent source areas. The observed growth rate of 1.00 was significantly higher than predicted survival/fecundity growth rates of 0.89 and 0.84, with the difference representing an 11-16% annual immigration rate. They observed no decline in density of the total population or the adult population, but a significant decrease in the average age of independent males. Found that the male component of the population was increasing, masking a decrease in the female component. Data support the compensatory immigration sink hypothesis: cougar removal in small game management areas increased immigration and recruitment of younger animals from adjacent area, resulting in little or no reduction in local cougar densities and a shift in population structure toward younger animals. Hunting in high-quality habitats may create an attractive sink, leading to misinterpretation of population trends and masking population declines in the sink and surrounding source areas.

Smith, J.A., Y. Wang, and C.C. Wilmers. 2015. Top carnivores increase their kill rates on prey as a response to human-induced fear. Proc. R. Soc.

Study took place in Santa Cruz mountains in California. No hunting.

Observed strong behavioral responses by female pumas to human development, whereby their fidelity to kill sites and overall consumption time of prey decline with increasing housing density by 36 and 42%, respectively. Females responded to this decline in prey consumption time by increasing the number of deer they killed in high housing density areas by 35% over what they killed in areas with little residential development.

Not very comparable to anything in Colorado. Also, in the front-range study we did not see an effect of housing density on kill rates.

Stoner, D.C., M.L. Wolfe, and D.M. Choate. 2006. Cougar exploitation levels in Utah: Implications for demographic structure, population recovery, and metapopulation dynamics. Journal of Wildlife Management 70:1588-1600.

Impacts of sustained harvest on cougar population dynamics and demographic structure are not well understood. Evaluated the effect of hunting on cougar populations by comparing the dynamics and demographic composition of 2 populations exposed to different levels of harvest. (1300 km^2 and 950 km^2). Exploited population declined with 17.6 to 51.5% harvest and the other area was closed to hunting. Females from the hunted population were significantly younger than those from the protected population, whereas male ages did not differ between sites.

Teichman, K.J., B. Cristescu, and C.T. Darimont. 2016. Hunting as a management tool? Cougar-human conflict is positively related to trophy hunting. BMC Ecology 16:44

Overexploitation and persecution of large carnivores resulting from conflict with humans comprise major causes of declines worldwide. Although little is known about the interplay between these mortality types, hunting of predators remains a common management strategy aimed at reducing predator-human conflict. Emerging theory and data, however, caution that such policy can alter the age structure of populations, triggering increased conflict in which conflict-prone juveniles are involved. Using a 30-year dataset on human-caused cougar kills in British Columbia, Canada, they examined relationships between hunter-caused and conflict-associated mortality. Individuals that were killed via conflict with humans were younger than hunted cougars. Accounting for human density and habitat productivity, human hunting pressure during or before the year of conflict comprised the most important variables. Both were associated with increased male cougar-human conflict. Moreover, in each of five regions assessed, conflict was higher with increased human hunting pressure for at least one cougar sex. Although only providing correlative evidence, such patterns over large geographic and temporal scales suggest that alternative approaches to conflict mitigation might yield more effective outcomes for humans as well as cougar populations and the individuals within populations.

Vales, D.J., M.P. Middleton, and M. McDaniel. 2016. Additive and compensatory predation mortality by cougar on elk. PeerJPreprints 4:e1915v1

Removing cougars in both study areas allowed elk to recover to, or exceed, herd objectives. Data strongly indicates that cougar were limiting elk, and that cougar removals allowed elk to escape the predator pit they were in. 15% of cougar mortality on elk was compensatory and 75% was likely additive. Cougar predation on elk calves was strongly additive.

Watkins, B.E., J.H. Olterman, and T.M. Pojar. 2002. Mule deer survival studies on the on the Uncompahgre Plateau, Colorado 1997-2001. Page 78 *in* J.A. Mortenson et al. editors. Proceedings of the western states & provinces deer and elk workshop, Wilsonville, OR, USA.

Modeled post-hunt population estimates suggest the Uncompahgre Plateau mule deer herd declined from about 60,000 in the early 1980s to <30,000 in the late 1990s with concomitant declines in buck harvest and December doe:fawn ratios. This study began in 1997 to improve model estimates and address potential reasons for the decline. They report cohort specific survival rates and mortality causes, and conclude the observed decline is most likely related to poor fawn survival during the first 6 months and possibly poor fetal survival. They hypothesize that poor quality winter range conditions and possibly disease are contributing to subsequent poor survival of fetal and neonatal fawns.

Yoakum, J.D. 2008. The use of science-based literature for predator control to enhance bighorn sheep, mule deer and pronghorn in Nevada. Transactions of the Western Section of the Wildlife Society 44:30-36.

Presents a concise but comprehensive review of science-based literature regarding the influence of predator control programs on bighorn sheep, mule deer, and pronghorn in Nevada and adjacent states. For mule deer, the importance of predation depended on the relation of deer herds to habitat carrying capacities. When deer populations were low and habitat conditions were poor, predation could limit population growth. Concludes that, the majority of science-based publications within the last 25 years have indicated that wildlife predation generally had not been and were not now the limiting factor controlling most free-living ungulate populations. Publications have provided data indicating that the primary factor limiting populations were the quality and quantity of forage and survival vegetation cover conditions.

This is somewhat of a rehash of Ballard's manuscript but at a smaller scale and is not very comprehensive.

Deer nutrition or habitat study

Bishop, C. J. et al. 2009. Effect of enhanced nutrition on mule deer population rate of change. Wildlife Monograph No. 172.

They addressed the potential for enhanced habitat conditions to improve mule deer condition and survival by simulating high quality habitat on winter range through supplemental feeding (representing "optimal" forage conditions). They observed a slight increase in neonate survival, a large increase in winter fawn survival and a moderate increase in doe survival

ultimately representing a population growth rate ~13% higher than the control area. They proposed that the Uncompahgre Plateau mule deer population was primarily limited by habitat conditions rather than predation or disease and suggested evaluating habitat treatments to improve deer populations on winter range. The authors cautioned against extrapolating their findings to other areas: "We specifically chose the Uncompahgre Plateau as a study site because the deer population had declined and there were competing hypotheses with respect to habitat versus predation as limiting factors. Our results should not be extrapolated beyond the Uncompahgre Plateau for these reasons."

Bergman, E.J, C.J. Bishop, D.J. Freddy, G.C. White, and P.F. Doherty, Jr. 2014. Habitat management influences overwinter survival of mule deer fawns in Colorado. Journal of Wildlife Management 78:448-455.

Bergman et al. (2014) followed up on the work of Bishop et al. (2009) and evaluated the benefit of existing and improved PJ habitat treatments in increasing deer survival rates. They reported a 9% increase in winter fawn survival and conclude that PJ treatments can benefit mule deer vital rates.

Bergman, E.J, P.F. Doherty, Jr., G.C. White, and A.A. Holland. 2015. Density dependence in mule deer: a review of evidence. Wildlife Biology 21:18-29.

The authors address density dependence in mule deer by conducting a review of scientific evidence on Colorado's mule deer population dynamics. This review was done in the context of a conceptual model that portrays population growth as a function of population size, per capita growth rate and population carrying capacity. The topics addressed include: harvest, predation, intraspecific competition, disease, interspecific competition, and habitat loss and degradation. The conventional working hypothesis in Colorado is that mule deer herds are limited by winter range habitat, but they identify new gaps in knowledge and suggest potential future research topics as well as potential management strategies (e.g., collecting harvest data to estimate deer demographics, manage for higher harvest levels to match the carrying capacity evident during severe winters). They suggest a focus on integrated studies of multiple herbivores with density reduction experiments to address intra- and inter-specific competition. In addition, they propose focused experiments that address the roles of mountain lion predation, black bear predation, and disease in mule deer population dynamics.

Deer and Energy Research

Anderson, C. R., Jr., and C. J. Bishop. 2014. Migration patterns of adult female mule deer in response to energy development. Pages 47-50 in R. A. Coon & M. C. Dunfee, editors. Transactions of the 79th North American Wildlife and Natural Resources Conference. Wildlife Management Institute, Gardners, PA, USA. ISSN 0078-1355.

Lendrum, P.E., C.R. Anderson, R.A. Long, J.G. Kie, and R.T. Bowyer. 2012. Habitat selection by mule deer during migration: effects of landscape structure and natural-gas development. Ecosphere 3:art82.

Lendrum, P.E., C.R. Anderson, K.L. Monteith, J.A. Jenks, and R.T. Bowyer. 2013. Migrating Mule Deer: Effects of Anthropogenically Altered Landscapes. PLoS One 8(5): e64548.

Northrup, J.M., C.R. Anderson Jr., and G. Wittemyer. 2015. Quantifying spatial habitat loss from hydrocarbon development through assessing habitat selection patterns of mule deer. Global Change Biology 21:3961-3970

Northrup, J.M., C.R. Anderson Jr., B.D. Gerber, and G. Wittemyer. In Review. Behavioral plasticity buffers mule deer from demographic impacts of energy development. Intended for publication in Wildlife Monographs

The five papers directly above pertain to a larger study initiated in 2008 to address mule deer-energy development interactions to better understand mule deer behavioral and demographic responses to varying aspects of energy development and to evaluate winter range habitat treatments as a mitigation approach. This project is scheduled to continue until 2018, but publications addressing migration, winter range habitat use and demographic influences of energy development have been completed. Based on data collected thus far: (1) migratory mule deer selected for areas with increased cover and increased their rate of travel through developed areas, and avoided negative influences through behavioral shifts in timing and rate of migration, but did not avoid development structures; (2) mule deer exhibited behavioral plasticity in relation to energy development, where disturbance distance varied relative to diurnal extent and magnitude of development activity, and were able to behaviorally offset demographic influences by modifying behavioral habitat selection patterns to take advantage of foraging areas during quite periods (night) and in areas of lower disturbance (in areas of producing versus drilling pads); (3) late winter mule deer densities have similarly increased in developed and undeveloped areas, suggesting that energy development activity is not currently limiting this population; and (4) post treatment vegetation responses have provided evidence of improved forage conditions with improved winter fawn condition, but longer term monitoring will be required to address the full potential of habitat mitigation efforts. Our results suggest that deer under existing conditions shift their behavior during migration and on winter range to avoid any negative demographic influences from development activity. However, there is likely some threshold where deer densities and/or well pad densities interact to limit ultimate population growth; this population is not currently limited by habitat conditions and directional drilling of natural gas allowed for lower pad densities then might have occurred otherwise. *The Northrup et al. paper above in review cautions against assuming demographic effects from behavioral studies.*

Deer and Development Research

Johnson, H.E., J.R. Sushinsky, A. Holland, E.J. Bergman, T. Balzar, J. Garner, and S.E. Reed. 2016. Increases in residential and energy development are associated with reductions in recruitment for a large ungulate. Global Change Biology, doi: 10.1111/gcb.13385

This study addressed the association of weather, energy development and residential development with early winter mule deer fawn recruitment in Colorado from 1980–2010. A negative relationship between residential development, oil and gas development and certain weather conditions and early winter recruitment of mule deer fawns (annual December doe:fawn ratios) was documented, particularly on winter range. As residential development increased, the association of decreasing early winter recruitment of young mule deer was about twice that of energy development or climate variables. They acknowledge that these results are correlative and provide course scale analyses. They suggest that further increases in these development types on deer ranges are not compatible with the goal of maintaining highly productive deer populations. Their results underscore the significance of expanding residential development on mule deer populations, a factor that has received little research attention in recent years, despite its rapidly increasing footprint across the landscape. *This study did not seek to correlate other potentially limiting factors such forage conditions, disease, competition with elk, and predation.*

Polfus, J.L., and P.R. Krausman. 2012. Impacts of residential development on ungulates in the Rocky Mountain West. Wildlife Society Bulletin 36:647-657.

Rural residential development in the Rocky Mountain West of North America is resulting in increased conflict between ungulate habitat and infrastructure. Subdivisions, houses, and roads affect ungulates both behaviorally and demographically and reduce management options available to agencies. Reviewed literature on the effects of land-use change on elk, mule deer, white-tailed deer, American pronghorn, and bighorn sheep. Literature suggests most ungulates exhibit short-term behavioral reactions to human disturbance. Few studies link these responses to population-level consequences or test the cumulative impact that multiple developments and development type have on seasonal habitat use and migratory behavior. Short-term and small-scale observational studies have articulated the conflict between humans and ungulates on shared habitat. Those studies need to be followed with well-designed experiments and large-scale multi-jurisdictional projects so that managers and planners can make more credible recommendations to direct future exurban development that benefits wildlife and humans.

Conceptual overview

Carter, N.H., and J.D.C. Linnell. 2016. Co-adaptation is key to coexisting with large carnivores. Trends in Ecology and Evolution. 31:575-578.

There is pressing need to integrate large carnivore species into multi-use landscapes outside protected areas. However, an unclear understanding of coexistence hinders the realization of this goal. Provide a comprehensive conceptualization of coexistence in which mutual adaptations by both large carnivores and humans have a central role. First steps should comprise studies from a range of cultural and/or institutional settings, and from a broad range of species other than carnivores, such as wild herbivores, to identify factors promoting, and inhibiting, sustainable interactions between humans and wildlife in general.

Chapron, G., and J.V. Lopez-Bao. 2016. Coexistence with large carnivores informed by community ecology. Trends in Ecology and Evolution. 31:578-580.

Conserving predators on an increasingly crowded planet brings difficult challenges. Argue that community ecology theory can help conserve these species in human-dominated landscapes. Letting humans and predators share the same landscapes is similar to maintaining a community of predatory species, one of which is humans. They acknowledge that coexistence may not be possible everywhere, but argue that it is essential that conservation strategies embrace coexistence to ensure that large carnivores persist throughout the 21st century.

Darimont, C.T., C.H. Fox, H.M. Bryan, and T. E. Reimchen. 2015. The unique ecology of human predators. Science 349:858-860.

Compared patterns of predation by contemporary hunters and fishers with those of other predators that compete over shared prey (terrestrial mammals and marine fishes). Global survey revealed that humans kill adult prey, the reproductive capital of populations, at much higher median rates than other predators (up to 14 times higher), with particularly intense exploitation of terrestrial carnivores and fishes. Given this competitive dominance, impacts on predators, and other unique predatory behavior, they suggest that humans function as an unsustainable "super predator," which—unless additionally constrained by managers—will continue to alter ecological and evolutionary processes globally.

Estes, J.A. et al. 2011. Trophic downgrading of planet earth. Science 333:301-306.

The loss of large apex consumers may be humankind's most pervasive influence on nature. Recent research reveals extensive cascading effects of their disappearance in marine, terrestrial and freshwater ecosystems worldwide. Empirical work supports long-standing theory about the role of top-down forcing in ecosystems but also highlights the unanticipated impacts of trophic cascades on processes as diverse as the dynamics of disease, wildfire, carbon sequestration, invasive species, and biogeochemical cycles. Emphasize the urgent need for interdisciplinary research to forecast the effects of trophic downgrading on process, function, and resilience in global ecosystems.

Prugh, L.R., C.J. Stoner, C.W. Epps, W.T. Bean, W.J. Ripple, A.S. Laliberte, and J.S. Brashares. 2009. The rise of the mesopredator. BioScience 59:779-791.

Present an overview of mesopredator release and illustrate how its underlying concepts can be used to improve predator management in an increasingly fragmented world. Examine shifts in North American carnivore ranges during the past 200 years and show that 60% of mesopredator ranges have expanded, whereas all apex predator ranges have contracted. In the face of costly mesopredator control programs, apex predators may offer an "ecosystem service" by providing cheaper and more effective mesopredator control. The loss of apex predators as a result of persecution and habitat conversion has created outbreaks of mesopredator populations throughout the world. As songbird populations precipitously decline and other prey populations collapse as a result of, in part, elevated predation rates,

the full ecological, social, and economic implications of mesopredator release are beginning to emerge. Restoration of apex predators to areas where they have been extirpated could do much to stem the tide of undesirable consequences of mesopredator release. However, the daunting task of apex predator conservation will require substantial habitat restoration, greater public acceptance of large carnivores, and compromises among the people most directly affected by these predators.

Ripple, W.J. and R.L. Beschta. 2006. Linking a cougar decline, trophic cascade, and catastrophic regime shift in Zion National Park. Biological Conservation

Ripple, W.J. and R.L. Beschta. 2008. Trophic cascades involving cougar, mule deer, and black oaks in Yosemite National Park.

We question the value of publishing the Ripple papers above. Both of these papers use anecdotal information from park reports about numbers of deer and mountain lions seen. Possibly some rough deer surveys. The Zion paper actually suggests that mountain lions left the park because of increased human visitation during the 1930's causing a release of the deer population. They then do some vegetation sampling of cottonwoods and oaks to suggest that differences in the vegetative community are caused by increased herbivory by deer that increased in number following decreases in lions. Essentially there are no data to support these claims. There are also a lot of other explanations, such as changes in fire in these systems. One could conclude that reducing predators does increase deer numbers, but again, the data are poor and therefore we believe the information from these papers should be viewed with some skepticism.

Ripple et al. 2014. Status and ecological effects of the world's largest carnivores. Science

We would not argue with the premise of this paper. Large carnivores certainly impact ecosystems and they are vulnerable to human manipulations. However, this paper suffers from a lack of data and is primarily speculation and opinion on the part of the authors.

The section of this paper that covers mountain lions is based on the two Ripple papers listed above. The section reads, the range of the puma in the Western Hemisphere remains larger than that of any other terrestrial mammal, even though they have been extirpated from most of the eastern United States. In the absence of pumas and sometimes other large carnivores, hyperabundant cervids in the eastern United States and Canada now affect many aspects of ecosystem function, including plant recruitment and survival, endangered species status, forest stand structure, nutrient dynamics, and socioeconomics through vehicle collisions. Where pumas are present, they can be important drivers of cervid populations and associated trophic relations, as in canyon settings in western North America, where they locally limit mule deer densities, releasing woody plants from browsing suppression. Pumas also appear to influence processes affecting terrestrial and aquatic species, including hydrophytic plants, wildflowers, amphibians, lizards, and butterflies. Their presence may also help stabilize stream banks and channels. Pumas may induce their prey to engage in "human shielding" as

an antipredator strategy. Deer at risk from pumas, for example, associated themselves with human development at high densities, in turn causing plant damage.

Ripple et al. 2016. Saving the world's terrestrial megafauna. BioScience 66:807-812.

Large bodied mammals are typically at a higher risk of extinction than smaller ones. Their objectives are to raise awareness of how these megafauna are imperiled and to stimulate broad interest in developing specific recommendations and concerted action to conserve them. Megafauna provide a range of distinct ecosystem services. Many of the surviving mammalian megafauna remain beset by longstanding and generally escalating threats of habitat loss, persecution, and exploitation. Large mammals are extremely vulnerable to these threats because of their large area requirements, low densities (particularly carnivores), and relatively slow life-history traits. The current depletion of megafauna is also due to overhunting and persecution: shooting, snaring, and poisoning by humans.

This article is really focused on African and Asian species. Maps provided show very few declining or threatened megafauna in North America.

Weaver. J.L., P.C. Paquet, and L.F. Ruggiero. 1996. Resilience and conservation of large carnivores in the rocky mountains. Conservation Biology 10:964-976.

Synthesize empirical information for each large carnivore species (wolves, cougars, grizzly bears and wolverines) in the Rocky Mountains regarding three basic mechanisms of resilience at different hierarchical levels: (1) behavioral plasticity in foraging behavior that ameliorates flux in food availability, (2) demographic compensation that mitigates increased exploitation, and (3) dispersal that provides functional connectivity among fragmented populations. Cougars appear to have slightly less (than wolves) resiliency because of more specific requirements for stalking habitat and lower biennial productivity. By accelerating the rate and expanding the scope of disturbance, humans have undermined the resiliency mechanisms of large carnivores and have caused widespread declines. Both the resiliency profiles and the historical record attest to the need for some form of refugia for large carnivores.

Miscellaneous

Beck, T.D.I., D.S. Moody, D.B. Koch, J.J. Beecham, G.R. Olson, and T. Burton. 1995. Sociological and ethical considerations of black bear hunting. Proceedings of the Western Black Bear Workshop 5:119-131.

This is a summary of an open round-table discussion. Each participant was asked by the moderator to summarize the arguments for or against a particular hunting methodology. The intent of the session was to stimulate debate, not to arrive at definitive answers.

Cain, S.A., Advisory Committee on Predator Control, Council on Environmental Quality, and U.S. Department of the Interior. 1971. Predator control—1971; report to the President's Council on Environmental Quality by the Advisory Committee on Predator Control.

This report considers several major topics and makes fifteen recommendations. These are based on knowledge of wildlife biology and management an interpretation of such data as exist for analysis of the predator-control program. The recommendations include: (1) proposed changes in the federal predator-control machinery, and legislation to implement them; (2) steps which might be taken by individual states to coordinate their interests with the federally financed program; (3) steps which might be taken by the livestock industry to protect its interests against unusually heavy losses, such as improved husbandry and participation in an insurance program; and (4) to provide a better factual basis for whatever predator control is found to be necessary, a statement of areas of research which need to be undertaken by federal and state agencies, including the economics of losses and the control program, the ecology of losses and the control program, the ecology of predator populations, and the agencies' values in the maintenance of ecological systems.

Recommendations:

1. Recommend that federal-state cooperation in predator control be continued, and that all funds in its support come from appropriations by Congress and by the legislatures.
2. Recommend that immediate Congressional action be sought to remove all existing toxic chemicals from registration and use for operational predator control.
3. Recommend that the field force of the Division of Wildlife Services be professionalized to emphasize employment of qualified wildlife biologists capable of administering and demonstrating a broadly-based program of predator management.
4. Recommend that in all states a cooperative trapper-trainer extension program be established as a means of aiding landowners in the minimum necessary control of predators on private land.
5. Recommend that Congress provide some means of alleviating the economic burden of livestock producers who experience heavy losses by predators.
6. Recommend that grazing permits and leases written by federal land management agencies provide for possible suspension or revocation of grazing privileges if regulations governing predator control are violated.
7. Recommend that all methods of predator control be prohibited on statutory Wilderness Areas.
8. Recommend that federal and state legislation be passed that would make the shooting from aircraft of wildlife, including predators and game animals, illegal except under exceptional circumstances and then only by authorized wildlife biologists of the appropriate federal and state agencies.
9. Recommend to the Federal Aviation Authority that a provision be made for suspending or revoking the license of a private pilot and the confiscation of the aircraft—when he knowingly carries a passenger whose acts lead to conviction for illegal predator control, such as shooting from the aircraft or distributing poisons.
10. Recommend that action be taken by Congress to rule out the broadcast of toxicants for the control of rodents, rabbits, and other vertebrate pests on federal

lands, and that the possibility of correlative action be explored for private lands as well.

11. Recommend a long-term research program based in the Division of Wildlife Research, Bureau of Sport Fisheries and Wildlife, that would cover the gamut of ecological problems associated with predators.
12. Recommend that the Division of Wildlife Research of the Bureau of Sport Fisheries and Wildlife undertake a detailed socio-economic study of cost-benefit ratios of predator control as a means of evaluating the need for and efficacy of the program and its separate parts.
13. Recommend that the Division of Wildlife Research of the Bureau of Sport Fisheries and Wildlife be delegated the responsibility for the study of the epidemiology of rabies in the field by a team of specialists provided with adequate funding.
14. Recommend that Congress give the Secretary of Interior authority to take measures necessary to protect all species of predators that have been placed on the Endangered Species List by the Federal Government.
15. Recommend that the several states take measures to supplement the federal protection of rare and endangered species by enacting laws and taking measures to protect locally rare populations.

The remainder of this document is supporting discussion for these recommendations.

Corona Research. 2006. Public opinions and perceptions of mountain lion issues, Statewide Summary.

This was a statewide survey of public opinions and perceptions of mountain lion issues in the state funded by the Colorado Division of Wildlife. The key findings demonstrate a generally positive attitude towards mountain lions and knowing that they exist in the state. However, people have various levels of knowledge about them. Depending on people's activities and where they live their concerns are different. Issues of hunting mountain lions and various management strategies related to human conflict differ among people, especially related to where they live and recreate in the state. Public support for research to learn more about mountain lion populations was expressed by 88.1% of respondents.

Enders, M.S. and S.B. Vander Wall. 2012. Black bears are effective seed dispersers, with a little help from their friends. Oikos 121: 589-596.

Showed that removal of seeds from bear feces by seed-caching rodents in the Sierra Nevada, represents a second phase of seed dispersal that benefits some fleshy-fruited plants.

Gilbert, S.L., K.J. Sivy, C.B. Pozzanghera, A. Dubour, K. Overduijn, M.M. Smith, J. Zhou, J.M. Little, and L.R. Prugh. 2016. Socioeconomic benefits of large carnivore recolonization through reduced wildlife-vehicle collisions. Conservation Letters 00:1-9.

This is the paper that suggested re-introducing cougars to several eastern states would result in reducing deer populations which would in turn reduce vehicle collisions.

Maehr, D.W., M.J. Kelly, C. Bolgiano, T. Lester, and H. McGinnis. 2003. In My Opinion. Eastern cougar recovery is linked to the Florida panther: Cardoza and Langlois revisited. Wildlife Society Bulletin 31:849-853.

Here they expand on their (Cardoza and Langlois) recommendations for a science-based approach to eastern cougar investigations and suggest that recovery efforts on behalf of a nearby conspecific are far from trivial to the return of the cougar in the East.

This article is an opinion piece that uses examples from the Florida panther to make suggestions about the potential recovery of or reintroduction of the Eastern cougar. They do make some statements in the introduction about the role of cougars in the ecosystem. They state that "Browse lines, highway collisions, Lyme disease, loss of biodiversity, and other problems associated with overabundant white-tailed deer hint at the benefits of returning such a predator to the East."

Takahashi, K. and K. Takahashi. 2013. Spatial distribution and size of small canopy gaps created by Japanese black bears: estimating gap size using dropped branch measurements.

Japanese black bears, a large-bodied omnivore, frequently create small gaps in the tree crown during fruit foraging. Their findings suggest that the ecological interaction between black bears and fruit-bearing trees may create a unique light regime, distinct from that created by tree falls, which increases the availability of light resources to plants below the canopy.

Treves, A., G. Chapron, J.V. Lopez-Bao, C. Shoemaker, A. R. Goeckner, and J.T. Bruskotter. 2015. Predators and the public trust. Biological Reviews.

Some information about Public Trust and how that relates to game management. Not really any information on predators. CPW is proposing to manipulate predators to gain better information on the predator-prey system, which is something promoted in this paper.

The authors review the role of public trust principles in the restoration and preservation of controversial species. Argue for the essential roles of scientists from many disciplines concerned with biological diversity and its conservation. The scientific community has not reached consensus on sustainable levels of human-caused mortality for many predator populations. Dynamic responses exacerbate clashes between uses that deplete wildlife and uses that enhance or preserve wildlife. Environmental assets demand sophisticated, careful accounting by disinterested trustees who can both understand the multidisciplinary scientific measurements of relative costs and benefits among competing uses, and justly balance the needs of all beneficiaries including future generations. Without conservation informed by public trust thinking predator populations will face repeated cycles of eradication and recovery. Sax (a federal judge) framed the Public Trust Doctrine explicitly as evolutionary not revolutionary, protecting customary uses but allowing for change in societal priorities and cultural uses. Neither Sax (1970) nor we (the authors) are making the positivist claim that scientific evidence will settle debates that are fundamentally about values. Determining

sustainable levels of human-caused mortality demands that managers understand the effects of vehicle collisions, poaching, legal take, etc., together with variability in birth and mortality factors that affect census and effective population size. As a result the science behind sustainable use of predators remains contentious and unsettled, even for gray wolves, one of the best-studied predators globally.

Treves, A., M. Krofel, and J. McManus. 2016. Predator control should not be a shot in the dark. Frontiers in Ecology and the Environment 14:380-388.

Livestock owners traditionally use various non-lethal and lethal methods to protect their domestic animals from wild predators. Many of these methods are implemented without first considering experimental evidence of their effectiveness in mitigating predation-related threats or avoiding ecological degradation. Systematically evaluated evidence for interventions against carnivore predation on livestock in North American and European farms. Also reviewed a selection of tests from other continents to help assess the global generality of findings. Twelve published tests—representing five non-lethal methods and 7 lethal methods—met the accepted standard of scientific inference without bias in sampling, treatment, measurement, or reporting. Of those twelve, prevention of livestock predation was demonstrated in six tests (four non-lethal, two lethal); the remaining four showed no effect on predation. Only two non-lethal methods assigned treatments randomly, provided reliable inference, and demonstrated preventive effects. They recommend that policy makers suspend predator control efforts that lack evidence for functional effectiveness and that scientists focus on stringent standards of evidence in tests of predator control.

Ulev, E. 2007. Ursus americanus. Fire effects information system, USDA, Forest Service Rocky Mountain Research State, Fire Sciences Laboratory. http://www.fs.fed.us/database/feis/animals/mammal/uram/all.html

This is a USDA report providing general information about black bears, including food habits and other general information. There is no research involved in this report; it is more of a general list of information about black bears.

Wild, M.A., N. T. Hobbs, M.S. Graham, and M.W. Miller. 2011. The role of predation in disease control: a comparison of selective and nonselective removal on prion disease dynamics in deer. Journal of Wildlife Diseases.

Review theoretic relationships between predation and host-parasite dynamics and describe a mathematical model to evaluate the potential influence of random removal through harvest or culling and selective predation by wolves upon CWD dynamics in deer populations. Suggest that as CWD distribution and wolf range overlap in the future, wolf predation may suppress disease emergence or limit prevalence. Suggest a link with wolves being absent in Colorado since 1943 and mountain lion populations being suppressed by bounty hunting at the time of likely CWD emergence in the mid-1900s. Cite Krumm et al. (2005) that mountain lions selected for CWD infected deer. *(note: CPW looked at this in the front-range lion study and did not see any selection).*

Zinn, H.C., M.J. Manfredo. 1996. Societal preferences for mountain lion management along Colorado's Front Range (Project Report No. 28) Project report for the Colorado Division of Wildlife. Fort Collins, CO. Colorado State University, Human Dimensions in Natural Resources Unit. 5th Mountain Lion Workshop Proceedings.

This report was based on a public survey about attitudes towards cougars and agency responses towards cougar-human interactions. Surveys were given to four groups of people: 1) the developed core of the Denver metropolitan area, 2) Colorado Springs and suburbs, 3) the partially-developed suburban fringe west of Denver, and 4) individuals who have reported encounters with cougars to the Colorado Division of Wildlife Central Region office. In general, people had positive attitudes about cougars and how they were managed. Some differences in attitudes towards cougars were evident among groups, but in general they did not differ much. The group with people that had encounters with cougars did have stronger opinions about cougars, especially in cases where people were attacked or killed.