



Bleats and Blats

Official Newsletter of the Desert Bighorn
Council



November 2009

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Hello DBC members!

I hope you all enjoyed this past summer, and are welcoming some cool fall weather. This newsletter includes updates on bighorn sheep management, as well as recent literature on bighorn sheep. Also, for those interested in publishing a paper in the upcoming DBC Transactions, please take special note of the upcoming deadline for submitting papers.

As some of you know, I recently moved to Arizona and have joined the Research Branch of the Arizona Game and Fish Department. So please make a note of my new contact information below.

The next newsletter is scheduled for early February so if you have updates or announcements to share, please send them to me by January 15th. Also, if you'd like to share your bighorn sheep photos on our website, they would be most welcome. We hope to hear from you!

Esther Rubin (DBC Secretary)

*Research Branch
Arizona Game and Fish Department
5000 W. Carefree Highway
Phoenix, AZ 85086
Phone: 623-236-7379
FAX: 623-236-7918
erubin@azgfd.gov*

DBC TRANSACTIONS – DEADLINE REMINDER

The deadline for submitting papers for the 2009 *Desert Bighorn Council Transactions* is quickly approaching. If you would like your paper considered for inclusion in the 2009 Transactions, you must submit your paper to Brian Wakeling (DBC Transactions Editor) by November 20, 2009. We strongly encourage all state representatives to submit status reports by this date to help us provide a complete status update in the upcoming transactions. Papers need not have been presented at the meeting to be eligible for publication. Papers expressing science-based opinions as well as those focusing on research are welcome. Please get your submissions in to accommodate the time needed for the review process. Manuscripts should use the format followed by the *Wildlife Society Bulletin* (guidelines available from Brian upon request). Authors should include a brief biography to accompany the paper. Papers and status reports should be submitted to Brian Wakeling (bwakeling@azgfd.gov) by November 20, 2009.

THE PAYETTE SITUATION

Contributed by Rick Brigham (DBC Tech Staff member)

Contributor's note: I retired from the BLM in 2003 after 39 years of service, 35 of which were as a wildlife biologist. Fortuitous circumstances led me and my wife to Clarkston in southeast Washington, just across the Snake River from Lewiston, Idaho. I joined the Hells Canyon Initiative, a multi-agency group studying the Hells Canyon bighorn die-off of 1995. Because of that, I was invited to record meeting minutes of another group, the Payette Advocates, as it continues to challenge the U.S. Forest Service, state of Idaho, and BLM to properly manage the much-reduced metapopulation(s) of Rocky Mountain bighorns living in the Hells Canyon (Snake River) and Salmon River drainages of west-central Idaho and adjoining Oregon and Washington. The Payette Advocates include the Hells Canyon Preservation Council (HCPC), The Wilderness Society (TWS), Nez Perce and Umatilla Indian tribes, the Wild Sheep Foundation (WSF; formerly Foundation for North American Wild Sheep), Oregon, Idaho, and Washington chapters of WSF, Idaho Conservation League, Idaho Wildlife Federation, Idaho Sportsman Caucus Advisory Counsel (ISCAC), and representatives of the Oregon Fish and Game Department and Forest Service. Besides recording minutes, I have prepared a series of articles published in the Washington WSF newsletter "Wild Sheep". This Bleats and Blats submission is a recap of those articles, plus what has occurred since then. I am submitting it for your information because what results from all of these efforts will probably set federal land management grazing policy (both Forest Service and BLM) for the future. This is a multi-faceted situation and many things are happening at once. Each paragraph below will address separate facets. I have not covered all aspects of this situation, just the highlights.

Bighorn numbers in Hells Canyon and the Salmon River drainage have been declining for many years, due mostly to death from pneumonia following contact with domestic sheep. The Payette National Forest (NF) in central Idaho updated its land use plan in 2003 without adequately addressing the domestic sheep-bighorn disease/pneumonia issue. The plan was protested by a coalition of groups, and the USFS Washington office directed the Payette NF to follow established Forest Service guidelines. The Payette NF then requested and received help from two groups. The first consisted of knowledgeable state fish and game biologists, who assessed the risk of contact between bighorns and the domestic sheep grazed on 24 allotments on the Payette NF. The second group was made up of wildlife and domestic veterinarians and researchers, including the DBC's Dr. Dave Jessup of California Department of Fish and Game. That group, in late 2006, developed the *Payette Principles* which in essence stated that bighorns and domestic sheep should be kept apart, to eliminate contact leading to bighorn deaths by pneumonia.

Affected domestic sheep grazers and the Idaho Woolgrowers went to the Idaho Governor, who in late 2007 convened a task force to address the issue, which resulted in the *Interim Strategy for Managing Separation between Bighorn Sheep and Domestic Sheep in Idaho*. The task force included members of the Idaho Agriculture and Fish and Game departments, Idaho Wildlife Federation, Nez Perce Tribe, and others, but it was dominated by agricultural interests. The *Payette Principles* and the Western Association of Fish and Wildlife Agencies (WAFWA) recommendations on managing domestic sheep in bighorn habitat were not used or recognized by the task force. The Idaho legislature addressed the issue as well. After earlier attempts, which the governor vetoed, the final outcome was SB 1232, which was signed into law by Governor Otter on May 7, 2009. This bill required the Idaho Department of Fish and Game to prepare allotment specific management plans within 90 days of passage. To date, 12 plans have been prepared, and two are on hold. These plans last for only one year. They embrace the Idaho Interim Strategy, including holding domestic grazers harmless if bighorn are lost to disease following nose-to-nose contact, and the use of Best Management Practices (BMPs), such as extra guard dogs and/or sheep herders, or penning of animals at night. Bighorns near domestic bands must be controlled, even if it means shooting the bighorns, and bighorn transplants and reintroductions are prohibited. There is no knowledge throughout the Forest Service that BMP's have ever fully worked. All BMP's recommended for the domestic-bighorn situation are methods to reduce the risk of contact between domestics and bighorns, but none eliminate the risk. The Governor's Task Force continues to meet, because the Governor and his Natural Resources advisor feel SB1232 does not affect the task force at all, whereas the other viewpoint is that the law completely eliminates the need for the task force. In May 2009, the Nez Perce tribe, WSF, and Idaho Wildlife Federation left the Task Force. They have since been invited back, but only WSF has accepted.

The domestic sheep grazers filed a 500+ page lawsuit against the Payette NF, in Boise, Idaho, federal court overseen by Judge Lynn Winmill. The case was thrown out, only because it was not filed in a timely manner, and that action has been protested. Several additional motions have been filed by the permittees, but nothing significant has been ruled upon. Late in 2008, U.S. Undersecretary of Agriculture, Mark Rey (a political appointee) required that all bighorn sheep to be used for translocations on National Forest lands must first be tested for disease. This was done by crafting a Memorandum of Understanding between the US Forest Service and a sister agency, the Animal Plant Health Inspection Service (APHIS). The WAFWA strongly protested the action, as it went against rights of states to manage native wildlife species, and it also went against Forest Service land use policy. The MOU and Rey's letter have both gone by the wayside with the change in administration.

The Payette NF issued a Draft Supplemental Environmental Impact Statement (DSEIS) in 2008 addressing the bighorn-domestic issue. Several additional alternatives were added, including (1) elimination of domestic sheep grazing in occupied bighorn habitat including a nine-mile wide buffer (USFS preferred alternative), and (2) total elimination of domestic sheep grazing on the Payette NF (which would affect only four permittees). The comment period closed in March 2009, about 14,000 comments were received, and the vast majority were in support of bighorns. The Payette NF will issue a Record of Decision in February 2010. In the interim, the PNF has closed all domestic sheep allotments to grazing until the final Record of Decision is issued (and any resulting lawsuits are settled). And, to its credit, the Nez Perce National Forest (NPNF) has also closed a domestic grazing allotment and is preparing its own supplemental EIS (see below).

The bighorn populations along the lower Salmon River, from Riggins, Idaho, east to and including the south fork of the Salmon River, have been studied the past 15 months by the Nez Perce Tribe using data collected from 30 radio- and GPS-collared bighorns, with assistance from several agencies including the two U.S. Forests and the BLM Cottonwood Resource Area. Results indicate that there are about 125 bighorns along about 100 river miles. There is one band of rams which spends 11 months a year in the BLM Partridge Creek allotment, which starts just east of Riggins along U.S. Highway 95, and is adjacent to the Salmon River. Upriver several miles is the Manning Bridge, which provides easy crossing for the rams. These rams move up and down the river during the year. The Nez Perce National Forest (NPNF) manages the north side of the river and has, based on information gathered in the bighorn study, closed its Allison-Berg allotment to

domestic sheep grazing until it has prepared an environmental impact statement. The Payette NF has allotments on the south side of the river except for the low-lying BLM Partridge Creek allotment. The Payette NF has shut off all domestic grazing until it issues a final decision in February 2010. The BLM, meanwhile, as per its recently updated Cottonwood Resource Management Plan (RMP), continued to allow domestic sheep grazing on the Partridge Creek allotment. The Cottonwood RMP does not address the bighorn-domestic issue, nor does it address Indian Tribal rights. The BLM in Idaho has adopted the Governor's Interim Task Force recommendations from last year. A coalition comprised of Western Watershed, TWS, and the HCPC appealed the BLM's actions to the Secretary of Interior, as the BLM did not establish special standards (BMP's) for domestic sheep grazing on the Partridge Creek (and three other allotments) to keep bighorns and domestics apart. The BLM continued to allow grazing on Partridge Creek. The coalition then petitioned the BLM to cease grazing by September 15, 2009. The BLM did not answer that petition so on September 23rd the coalition went to federal court in Boise to seek an injunction to cease domestic grazing on the Partridge Creek allotment, where it was scheduled to resume on October 15. The goal of the coalition was to get the Forest Service and BLM to follow similar management protocols. The judge granted a temporary injunction against the BLM to cease grazing in the Partridge Creek allotment. The BLM has since announced that it will cease domestic sheep grazing in this allotment until the environmental assessment is completed.

Other tidbits: the Forest Service, Region 4, has identified Rocky Mountain bighorn sheep as a "sensitive" species, which requires each forest to more closely consider actions that may be detrimental to bighorns. Two reasons listed were: (1) BHS numbers are less than 10% of historical numbers and (2) BHS distribution is less than a third of its pre-settlement distribution. Dr. Marie Bulgin (who sat on a panel at a past DBC meeting; see Transactions Volume 39, page 93) testified in federal court and in front of the Idaho legislature during the past two years that there was no problem with nose-to-nose contact between domestic and bighorn sheep. She is currently the head of the Caine Veterinary Center of the University of Idaho, which has processed thousands of blood samples collected from bighorns throughout the west. She has also served as president of the Idaho Woolgrowers. Her actions have been challenged, primarily by the Wild Sheep Foundation, she is currently being investigated by the University of Idaho, and she is currently suspended as Chair of the Caine Vet Center.

That is all for now. Stay tuned!

DBC COMMITTEE UPDATES

Bruce Garlinger and Vern Bleich have graciously stepped forward to assist the DBC, and have been assigned as new members of the Awards Committee. They will be assisting Dick Weaver and Rick Brigham on this committee. Thanks to both of you!

Committee work is a great way to become involved and support the DBC, and there are a number of committees that could use additional members. If you are interested in serving on any of the following committees, please contact the Council Chair, Brian Wakeling (BWakeling@azgfd.gov). (Please note that you must be a DBC member to serve on a committee):

- Meeting Committee
- Awards Committee
- Feral Burro Committee
- Constitution and Resolutions Committee
- Transactions Committee
- Nominating Committee

MOUNTAIN LION MANAGEMENT IN RELATION TO A DESERT BIGHORN SHEEP DECLINE ON THE KOFA NATIONAL WILDLIFE REFUGE, NOVEMBER 2009

An Update from the Arizona Game and Fish Department

On August 4, 2009, the U. S. Fish and Wildlife Service's Kofa National Wildlife Refuge (NWR), acting as lead agency in cooperation with the Arizona Game and Fish Department (AGFD), the U. S. Department of Agriculture's Animal and Plant Health Inspection Service (APHIS), and the Bureau of Land Management released for public comment the *Draft Assessment for Limiting Mountain Lion Predation on Desert Bighorn Sheep*. The 60-day comment period closed on October 2, and the agencies have begun review of comments and preparation of a final Environmental Assessment (EA). Hunting of mountain lions is not permitted on the Kofa NWR.

The Kofa NWR was established in 1939. Of its 665,400 acres, in 1990 the U.S. Congress designated 516,200 acres (about 82 percent of the refuge) of the refuge as Wilderness, which adds to the uniqueness of the situation and management efforts.

The Kofa NWR sheep herd has been an important source herd for transplants throughout the Southwest for nearly 50 years, with population estimates at approximately 800 bighorn sheep in the early 1990s. Population estimates on the Kofa NWR have trended downward since the mid-1990s, with a precipitous decline revealed in the 2006 triennial survey, which resulted in an estimate of only 391 animals. Annual surveys conducted since 2006 suggest the herd has stabilized at an approximate average of 400 bighorn sheep. The 2009 survey results should be available in November or December 2009. Transplant efforts have been suspended indefinitely since 2006 due to the herd's record low population levels.

Predation: a new dynamic?

There are no verified records of mountain lions on the Refuge between 1944 and 2001, and if any, they were historically suspect as transient animals. During 1993-1997 two separate studies did not detect lions on the Kofa NWR. Furthermore, a research project in 1993-1996 of 50 radio collared bighorn sheep showed no sign of predation from the investigation of 17 bighorn sheep mortalities. However, in 2003 three lions were spotted during an aerial survey and more were detected by motion- and infrared sensing cameras, which triggered a collaring and monitoring of mountain lion efforts on the Kofa NWR. The collaring efforts revealed four radio collared lions have killed 28 bighorn sheep from March 2007 to August 2009 in and near the Kofa NWR. One particular lion killed 15 bighorn sheep in a six-month period. These observations suggest that mountain lions numbers have increased and/or that lions are becoming more resident than transient on and around the Kofa NWR since 1997.

In 2007, the Kofa NWR and AGFD completed the *Investigative Report and Recommendations for the Kofa Bighorn Sheep Herd*. The agencies evaluated predation, impacts of refuge visitors, health of the sheep, causes of mortality, maintenance of critical waters and many other management strategies. During the same year, AGFD finalized *The Kofa Mountains Complex Predation Management Plan*, to address predation and to help bighorn sheep restoration efforts. Under the plan's authority, the AGFD removed two offending collared lions (collared lions that prey on bighorn sheep) from areas surrounding the Kofa NWR since June 2007. However, to assist in the EA process a self-imposed one year moratorium was instated on April 18, 2008, and then extended until July 31, 2009. Mountain lion removal has since been reinitiated with the removal of a third lion in September. No other lions are currently collared. Monitoring of radio collared bighorn sheep is ongoing to investigate how body condition relates to reproductive success, how bighorn sheep use water developments and to examine how disease and other factors influence the herd.

The draft EA mentions six alternatives in mountain lion/bighorn management on the Kofa NWR. Three of the alternatives are fully analyzed and three are considered but not deemed feasible (thus not fully analyzed). The three not fully analyzed alternatives include:

- sport hunting of mountain lions to reduce predation rates
- mountain lion translocation
- non-lethal mountain lion harassment.

The fully analyzed alternatives include:

- “no action” alternative in which no mountain lion management would occur on the Kofa NWR, yet AGFD’s efforts to remove offending lions off the refuge would continue.
- indiscriminate lion removal, in which approximately two lions would be removed from the refuge per year until bighorn sheep numbers increase to 800 animals. This alternative would not involve collaring or identification of offending lions. This alternative creates some challenges based upon new NWR wilderness policies concerning predation management activities within wilderness areas.
- (Proposed Action Alternative and supported by Arizona Game and Fish Department) active lion removal using radio collars to identify offending lions while bighorn sheep numbers are below 600. Lion removal would cease once the bighorn sheep population is at or above 800 animals. When bighorn numbers are between 600 and 800 animals, active lion management may or may not be employed based on the totality of the circumstances at the time. Decisions to apply any active management approaches will be based on many factors.

The final EA is expected in early 2010.

Recent Literature Related to Bighorn Sheep

Bender, L. C. and M. E. Weisenberger. 2009. Criticisms biologically unwarranted and analytically irrelevant: reply to Rominger et al. *Journal of Wildlife Management* 73(5):806-810

Abstract: The criticisms of Rominger et al. (2008) of our retrospective analysis of desert bighorn sheep (DBS; *Ovis canadensis mexicana*) dynamics in the San Andres Mountains of south-central New Mexico, USA, contained many biological errors and analytical oversights. Herein, we show that Rominger et al. (2008) (1) overstated both magnitude and potential effect of predator removal; (2) incorrectly claimed that our total precipitation (TP) model did not fit the data when TP correctly classed $\geq 66\%$ of subsequent population increases and declines ($P \leq 0.063$); (3) presented a necessary prerequisite of the exponential model (serial correlation between N_t and N_{t+1}) as the key relationship in the DBS data, when it merely reflected that DBS are strongly K-selected and was irrelevant to our hypothesis tests specific to factors affecting the instantaneous rate of population increase (r); (4) greatly oversimplified relationships among precipitation, arid environments, and DBS; and (5) advocated a time for collection of lamb/female (L/F) ratio data that was unrelated to any meaningful period in the biological year of DBS and consequently presented L/F ratio data unrelated to observed dynamics of DBS. In contrast, the L/F ratios used in Bender and Weisenberger (2005) correctly predicted annual changes and were correlated with long-term population rates of change.

Espinosa-T., A., A. J. Contreras-Balderas, A. V. Sandoval, and M. A. Garcia-A. 2009. Selection of desert bighorn sheep (*Ovis canadensis*) transplant sites in Sierra Maderas del Carmen and Sierra San Marcos y del Pino, Coahuila, Mexico. Texas Journal of Science 61(1):15-30.

Abstract: Between January 2004 and November 2006, a Geographic Information System (GIS) based habitat evaluation was conducted on the Sierra Maderas del Carmen (MDC) and Sierra San Marcos y del Pino (SMP). The objective of this study was to identify the most suitable sites for the restoration of desert bighorn sheep (*Ovis canadensis*) in Coahuila, Mexico. Priority transplant sites were selected based on potential contact with domestic sheep and goats and free ranging aoudads (*Ammotragus lervia*), amount and juxtaposition of escape terrain, and water availability. Priority transplant sites contain ≥ 15 km² of escape terrain, water, and are spatially segregated from exotic ungulates. A total of 1,159 km² of MDC was evaluated; 23% (271 km²) was suitable habitat for desert bighorn sheep. Two priority transplant sites consisting of 25 and 34 km², respectively, were delineated in MDC. In the SMP, a total of 871 km² was evaluated, and 20% (175 km²) was classified as suitable habitat. One area consisting of 18 km² was selected in SMP as a priority transplant site.

Ezard, T. H. G., S. D. Cote, F. Pelletier. 2009. Eco-evolutionary dynamics: disentangling phenotypic, environmental and population fluctuations. Philosophical Transactions of the Royal Society of London B Biological Sciences 364:1491-1498.

Abstract: Decomposing variation in population growth into contributions from both ecological and evolutionary processes is of fundamental concern, particularly in a world characterized by rapid responses to anthropogenic threats. Although the impact of ecological change on evolutionary response has long been acknowledged, the converse has predominantly been neglected, especially empirically. By applying a recently published conceptual framework, we assess and contrast the relative importance of phenotypic and environmental variability on annual population growth in five ungulate populations. In four of the five populations, the contribution of phenotypic variability was greater than the contribution of environmental variability, although not significantly so. The similarity in the contributions of environment and phenotype suggests that neither is worthy of neglect. Population growth is a consequence of multiple processes, which strengthens arguments advocating integrated approaches to assess how populations respond to their environments.

Bonenfant, C., F. Pelletier, M. Garel, and P. Bergeron. 2009. Age-dependent relationship between horn growth and survival in wild sheep. Journal of Animal Ecology 78:161-171.

Abstract: Trade-offs in resource allocation underline the evolution of life-history traits but their expression is frequently challenged by empirical findings. In large herbivores, males with large antlers or horns typically have high mating success. The fitness costs of large horns or antlers have rarely been quantified although they are controversial. Here, using detailed longitudinal data on $n = 172$ bighorn (*Ovis canadensis*, Shaw) and the capture-mark-recapture methodology, we tested whether early horn growth leads to a survival cost in rams ('trade-off' hypothesis) or if males that can afford rapid horn growth survive better than males of lower phenotypic quality ('phenotypic quality' hypothesis). We also quantified how hunting increased survival costs of bearing large horns. We found an age-specific relationship between horn growth and survival. In all age classes, natural survival was either weakly related to (lambs, adult rams) or positively associated (yearling rams) with early horn growth. Hunting mortality was markedly different from natural mortality of bighorn rams, leading to an artificial negative association between early horn growth and survival. Beginning at age 4, the yearly harvest rate ranged from 12% for males with the smallest horns up to more than 40% for males with the largest horns. Growing large horns early in life is not related to any consistent survival costs, hence supporting the phenotypic quality hypothesis in males of a dimorphic and polygynous large herbivores. Rapid horn growth early in life is, however, strongly counter selected by trophy hunting. We suggest that horn size is a very poor index of reproductive effort and that males modulate their mating activities and energy allocation to horn growth to limit its impact on survival.

Colchero, F., R. A. Medellin, J. S. Clark, R. Lee, and G. G. Katul. 2009. Predicting population survival under future climate change: density dependence, drought and extraction in an insular bighorn sheep. *Journal of Animal Ecology* 78: 666-673.

Abstract: Our understanding of the interplay between density dependence, climatic perturbations, and conservation practices on the dynamics of small populations is still limited. This can result in uninformed strategies that put endangered populations at risk. Moreover, the data available for a large number of populations in such circumstances are sparse and mined with missing data. Under the current climate change scenarios, it is essential to develop appropriate inferential methods that can make use of such data sets. We studied a population of desert bighorn sheep introduced to Tiburon Island, Mexico in 1975 and subjected to irregular extractions for the last 10 years. The unique attributes of this population are absence of predation and disease, thereby permitting us to explore the combined effect of density dependence, environmental variability and extraction in a 'controlled setting.' Using a combination of nonlinear discrete models with long-term field data, we constructed three basic Bayesian state space models with increasing density dependence (DD), and the same three models with the addition of summer drought effects. We subsequently used Monte Carlo simulations to evaluate the combined effect of drought, DD, and increasing extractions on the probability of population survival under two climate change scenarios (based on the Intergovernmental Panel on Climate Change predictions): (i) increase in drought variability; and (ii) increase in mean drought severity. The population grew from 16 individuals introduced in 1975 to close to 700 by 1993. Our results show that the population's growth was dominated by DD, with drought having a secondary but still relevant effect on its dynamics. Our predictions suggest that under climate change scenario (i), extraction dominates the fate of the population, while for scenario (ii), an increase in mean drought affects the population's probability of survival in an equivalent magnitude as extractions. Thus, for the long-term survival of the population, our results stress that a more variable environment is less threatening than one in which the mean conditions become harsher. Current climate change scenarios and their underlying uncertainty make studies such as this one crucial for understanding the dynamics of ungulate populations and their conservation.

Foreyt, W. J., E. J. Jenkins, and G. D. Appleyard. 2009. Transmission of lungworms (*Muellerius capillaris*) from domestic goats to bighorn sheep on common pasture. *Journal of Wildlife Diseases* 45:272-278.

Abstract: Four domestic goats (*Capra hircus*) that were passing first-stage dorsal-spined larvae of *Muellerius capillaris* were copastured on a 0.82-ha pasture for 11 mo from May 2003 to April 2004 with seven Rocky Mountain bighorn sheep (*Ovis canadensis*) that were not passing dorsal-spined larvae. During the 11-mo experiment, two bighorn sheep died from pneumonia caused by *Mannheimia (Pasteurella) haemolytica* biotype A, serotype 2. The remaining five bighorn sheep and the four domestic goats remained healthy throughout the experiment. *Muellerius* larvae were detected from all domestic goats on a monthly basis throughout the experiment and were first detected from all five surviving bighorn sheep approximately 5 mo after the copasturing began. Once the bighorn sheep began passing *Muellerius* larvae, larvae were detected in low numbers from all bighorn sheep every month thereafter for the 6 mo the goats were still in the enclosure and continued to pass larvae, for more than 3 yr after the goats were removed from the experiment. Six bighorn sheep in two similar enclosures that did not contain goats did not pass *Muellerius* larvae before, during, or after the experimental period. Results of this experiment indicate that *M. capillaris* from domestic goats is capable of infecting bighorn sheep when animals are copastured together on a common range.

Hamel, S., M. Garel, M. Festa-Bianchet, J-M. Gaillard, and S. D. Cote. 2009. Spring Normalized Difference Vegetation Index (NDVI) predicts annual variation in timing of peak faecal crude protein in mountain ungulates. *Journal of Applied Ecology* 46:582-589.

Abstract: In recent years, the Normalized Difference Vegetation Index (NDVI) has been used to assess the

relationships between habitat quality and animal life-history traits. Since numerous ecological studies now use NDVI rather than perform direct vegetation assessments, field validations are essential to provide confidence in the biological significance of NDVI estimates. While some studies have compared NDVI with plant biomass, very few examined the relationship between NDVI and changes in vegetation quality. Using data from two long-term studies of alpine ungulates, we assessed the relationship between two NDVI indices and the date of peak in faecal crude protein (FCP), which represents temporal variability in the availability of high-quality vegetation. We also evaluated if NDVI data could predict annual variation in the timing of spring green-up. In both populations, integrated NDVI in June was negatively correlated with the date of the peak in FCP, indicating that high integrated NDVI values corresponded to early springs in alpine habitats. Maximum NDVI increase during spring green-up was positively correlated with the timing of peak FCP, illustrating that rapid increases in NDVI represented delayed springs. Predicted values of date of peak FCP estimated each year from NDVI data satisfactorily fitted observed values, and prediction intervals included all observed values. These results suggest that NDVI can reliably predict variation over years in the timing of spring. Synthesis and applications: Our long-term studies demonstrate that a multi-year time series of Normalized Difference Vegetation Index (NDVI) can reliably measure yearly changes in the timing of the availability of high-quality vegetation for temperate herbivores. This finding therefore supports the use of NDVI as a proxy for vegetation attributes in population ecology and wildlife management studies.

Hamel, S., J.-M. Gaillard, M. Festa-Bianchet, and S. D. Cote. 2009. Individual quality, early-life conditions, and reproductive success in contrasted populations of large herbivores. *Ecology* 90:1981-1995.

Abstract: Variations among individuals in phenotypic quality and fitness often confound analyses of life-history strategies assessed at the population level. We used detailed long-term data from three populations of large herbivores with generation times ranging from four to nine years to quantify heterogeneity in individual quality among females, and to assess its influence on mean annual reproductive success over the lifetime (MRS). We also determined how environmental conditions in early life shaped individual quality and tested A. Lomnicki's hypothesis that variance in individual quality should increase when environmental conditions deteriorate. Using multivariate analyses (PCA), we identified one (in sheep and deer) or two (in goats) covariations among life-history traits (longevity, success in the last breeding opportunity, adult mass, and social rank) as indexes of individual quality that positively influenced MRS of females. Individual quality was reduced by unfavorable weather, low resource availability, and high population density in the year of birth. Early-life conditions accounted for 35-55% of variation in individual quality. In roe deer, we found greater variance in individual quality for cohorts born under unfavorable conditions as opposed to favorable ones, but the opposite was found in bighorn sheep and mountain goats. Our results demonstrate that heterogeneity in female quality can originate from environmental conditions in early life and can markedly influence the fitness of females in species located at different positions along the slow-fast continuum of life-history strategies.

Keating, K. A. and S. Cherry. Modeling utilization distributions in space and time. *Ecology* 90:1971-1980.

Abstract: W. Van Winkle defined the utilization distribution (UD) as a probability density that gives an animal's relative frequency of occurrence in a two-dimensional (x, y) plane. We extend Van Winkle's work by redefining the UD as the relative frequency distribution of an animal's occurrence in all four dimensions of space and time. We then describe a product kernel model estimation method, devising a novel kernel from the wrapped Cauchy distribution to handle circularly distributed temporal covariates, such as day of year. Using Monte Carlo simulations of animal movements in space and time, we assess estimator performance. Although not unbiased, the product kernel method yields models highly correlated (Pearson's $r = 0.975$) with true probabilities of occurrence and successfully captures temporal variations in density of occurrence. In an empirical example, we estimate the expected UD in three dimensions (x, y, and t) for animals belonging to each of two distinct bighorn sheep (*Ovis canadensis*) social groups in Glacier National

Park, Montana, USA. Results show the method can yield ecologically informative models that successfully depict temporal variations in density of occurrence for a seasonally migratory species. Some implications of this new approach to UD modeling are discussed.

Marshal, J. P., J. W. Cain III, V. C. Bleich, and S. S. Rosenstock. 2009. Intrinsic and extrinsic sources of variation in the dynamics of large herbivore populations. Canadian Journal of Zoology 87:103-111.

Abstract: We evaluated the relative importance of intrinsic (density-dependent) and extrinsic (density-independent) sources of resource variability in the dynamics of bighorn sheep (*Ovis canadensis* Shaw, 1804) populations in southwestern USA. We tested the hypothesis that populations experiencing greater variation in forage availability are less likely to be at equilibrium density with forage supplies, and thus, would demonstrate weaker evidence of intraspecific competition. We used regression to relate population growth rate to rainfall (forage conditions) and to abundance (intraspecific competition) for 20 sheep populations, and we estimated the strength of the effects of density and rainfall for each population. Then we compared among populations to look for relationships between the strengths of rainfall and density effects and the variability in rainfall experienced by each population. Populations demonstrating a density effect were associated with environments having lower variability than those that did not. Populations showing a rainfall effect were associated with environments having a variability higher than those that lacked a rainfall effect. These findings are consistent with the hypothesis that populations experiencing higher variation in forage resources are less likely to achieve an equilibrium density with forage supplies where intraspecific competition would be a large determinant to the dynamics of that population.

Meldrum, G. E. and K. E. Ruckstuhl. 2009. Mixed-sex group formation by bighorn sheep in winter: trading costs of synchrony for benefits of group living. Animal Behaviour 77:919-929.

Abstract: Animals commonly form groups and most sexually dimorphic ungulates form sex-specific groups outside the breeding season. Differences in diet, in vulnerability to predation, and in behaviour between the sexes are hypothesized to drive sexual segregation; however, low-density conditions sometimes favour aggregation. This may occur because larger groups provide greater antipredator benefits that overcome the cost of association between the sexes. In this study we sought to determine whether bighorn rams and ewes (*Ovis canadensis*) aggregate during winter as an antipredator strategy and whether they alter their behaviour to maintain mixed-sex groups. We compared the occurrence of mixed-sex groups during winter against the population size and sex ratio, and assessed vigilance as an indication of predation risk. We also analysed activity budgets to determine whether group cohesion required departure from sex-specific time budgets. We observed a low proportion of mixed-sex groups in all years of our study except one, in which the population size was very small and the proportion of females was the smallest on record. Mixed-sex groups were larger than single-sex groups, and vigilance was lower in larger groups, indicating that mixed-sex groups provided greater antipredator benefits. However, there was evidence of the oddity effect for older females, which displayed greater vigilance in groups composed primarily of males. Females modified their activity budgets in mixed-sex groups by spending less time foraging and travelling and more time bedding, providing support for the activity budget hypothesis. The costs of mixed-sex group formation limit the circumstances under which aggregation of the sexes is favourable.

Poissant, J., A. B. A. Shafer, C. S. Davis, J. Mainguy, J. T. Hogg, S. D. Cote, and D. W. Coltman. 2009. Genome-wide cross-amplification of domestic sheep microsatellites in bighorn sheep and mountain goats. Molecular Ecology Resources 9:1121-1126.

Abstract: We tested for cross-species amplification of microsatellite loci located throughout the domestic sheep (*Ovis aries*) genome in two north American mountain ungulates (bighorn sheep, *Ovis canadensis*, and mountain goats, *Oreamnos americanus*). We identified 247 new polymorphic markers in bighorn sheep (≥ 3 alleles in one of two study populations) and 149 in mountain goats (≥ 2 alleles in a single study population)

using 648 and 576 primer pairs, respectively. Our efforts increased the number of available polymorphic microsatellite markers to 327 for bighorn sheep and 180 for mountain goats. The average distance between successive polymorphic bighorn sheep and mountain goat markers inferred from the Australian domestic sheep genome linkage map (mean \pm 1 SD) was 11.9 \pm 9.2 and 15.8 \pm 13.8 centimorgans, respectively. The development of genomic resources in these wildlife species enables future studies of the genetic architecture of trait variation.

Reale, D., J. Martin, D. W. Coltman, J. Poissant, and M. Festa-Bianchet. 2009. Male personality, life-history strategies and reproductive success in a promiscuous mammal. *Journal of Evolutionary Biology* 22:1599-1607.

Abstract: Recent theoretical work suggests that personality is a component of life history, but links between personality and either age-dependent reproductive success or life-history strategy are yet to be established. Using quantitative genetic analyses on a long-term pedigree we estimated indices of boldness and docility for 105 bighorn sheep rams (*Ovis canadensis*), born between 1983 and 1999, and compared these indices to their reproductive history from 2 years of age until death. Docility and boldness were highly heritable and negatively genetically correlated. Docile and bold rams survived longer than indocile and shy rams. Docility and boldness had a weak negative effect on reproductive success early in life, but a strong positive effect on older rams. Our findings highlight an important role of personality on reproductive success and suggest that personality could be an important component of life-history strategy.

Rubin, E. S., C. J. Stermer, W. M. Boyce, and S. G. Torres. 2009. Assessment of predictive habitat models for bighorn sheep in California's Peninsular Ranges. *Journal of Wildlife Management* 73:859-869

Abstract: We developed predictive habitat models for a bighorn sheep (*Ovis canadensis*) population in the Peninsular Ranges of southern California, USA, using 2 Geographic Information System modeling techniques, Ecological Niche Factor Analysis (ENFA) and Genetic Algorithm for Rule-set Production (GARP). We used >16,000 Global Positioning System locations from 34 animals in 5 subpopulations to develop and test ENFA and GARP models, and we then compared these models to each other and to the expert-based model presented in the United States Fish and Wildlife Service's Recovery Plan for this population. Based on a suite of evaluation methods, we found both ENFA and GARP to provide useful predictions of habitat; however, models developed with GARP appeared to have higher predictive power. Habitat delineations resulting from GARP models were similar to the expert-based model, affirming that the expert-based model provided a useful delineation of bighorn sheep habitat in the Peninsular Ranges. In addition, all 3 models identified continuous bighorn sheep habitat from the northern to southern extent of our study area, indicating that the Recovery Plan's recommendation of maintaining habitat connectivity throughout the range is an appropriate goal.

Weiser, G. C., D. S. Miller, M. L. Drew, J. C. Rhyan, and A. C. S. Ward. 2009. Variation in *Pasteurella (Bibersteinia)* and *Mannheimia* spp. following transport and antibiotic treatment in free-ranging and captive Rocky Mountain bighorn sheep (*Ovis canadensis canadensis*). *Journal of Zoo and Wildlife Medicine* 40:117-125.

Abstract: Morbidity and mortality associated with respiratory disease following capture and translocation of bighorn sheep (*Ovis canadensis canadensis*) is a significant concern, particularly when establishing new or augmenting existing bighorn populations. Administration of prophylactic antibiotics at the time of capture is often done to minimize the risk of respiratory disease, but the efficacy of this practice is unknown. The effects of oxytetracycline and florfenicol on the *Pasteurella (Bibersteinia)* and *Mannheimia* spp. isolated from samples collected from the oropharynx at the time of capture and 3 or 42 day later were evaluated in two groups of bighorn sheep. The most evident change in the isolation rates or types of *Pasteurella (Bibersteinia)* spp., *Mannheimia* spp., or both was an increase of beta-hemolytic strains isolated from

bighorn sheep 3 days following oxytetracycline treatment. Both groups of bighorn sheep carried *Pasteurella (Bibersteinia) trehalosi* identified as the same biovariants, but they did not share biovariants of *Mannheimia* spp. No animals had signs of respiratory disease. Isolates representative of all biovariants present in cultures from the two bighorn sheep groups were sensitive to in vitro tests to both oxytetracycline and florfenicol and the majority were also sensitive to seven other antibiotics tested. The administration of neither oxytetracycline nor florfenicol eliminated *Pasteurella (Bibersteinia)* or *Mannheimia* from the oropharyngeal mucosa. Resistance to either antibiotic used in these animals was not noted. Although the prophylactic benefits of these drugs in preventing disease are uncertain, therapeutic levels of antibiotics in lung tissue during times of stress may reduce the risk of disease. Representative sampling of the oropharyngeal microflora of bighorn sheep source and recipient populations prior to being intermingled should be considered as one of the tools to minimize exposure of naive populations to potentially pathogenic bacteria.

Whiting, J. C., R. T. Bowyer, and J. T. Flinders. 2009. Annual use of water sources by reintroduced Rocky Mountain bighorn sheep *Ovis canadensis canadensis*: effects of season and drought. *Acta Theriologica* 54:127-136.

Abstract: Water sources are important for the conservation and management of bighorn sheep *Ovis canadensis* (Shaw, 1804). Little is known, however, regarding the use of water by reintroduced Rocky Mountain bighorns *O. c. canadensis* (Shaw, 1804). Our purpose was to quantify use of water sources by bighorns to test hypotheses related to the value of these sites on Antelope Island, Utah, USA, from July 2005 to December 2006. We predicted that bighorns would increase the number and duration of visits to water during summer. Moreover, we predicted that animals would visit and spend more time at water during drought. Our results indicate that bighorns visited and spent more time around water in summer. These animals, however, did not visit and spend more time at water during drought. Nevertheless, use of water sources increased during times of similar precipitation that followed drought, indicating a potential time-lag in water use by bighorns. Our results underscore the importance of water for reintroduced bighorns in the deserts of western USA, and indicate that animals congregate in riparian areas near water and thereby may facilitate the spreading of diseases and parasites.

