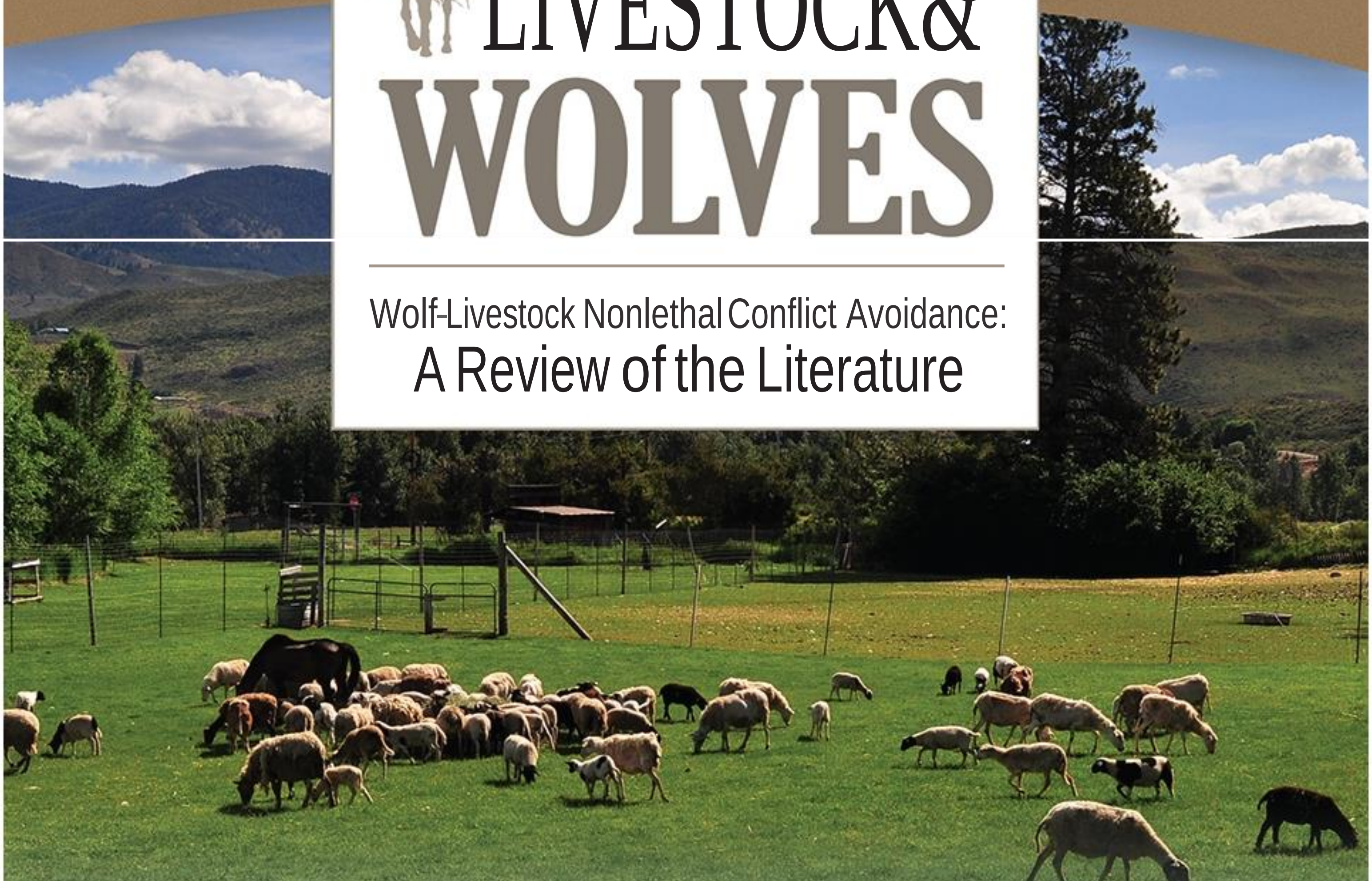
Living with LIVESTOCK & WOLVES

Wolf-Livestock Nonlethal Conflict Avoidance: A Review of the Literature



Livestock producers, their animals, and wolves can coexist by implementing some straightforward measures.

Western Wildlife OUTREACH

WOLF-LIVESTOCK NONLETHAL CONFLICT AVOIDANCE: A REVIEW OF THE LITERATURE

With Recommendations for Application to Livestock Producers in Washington State

A Project of Western Wildlife Outreach

With funding provided by

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It is the intent of the authors of this report that frequent updates shall be made as more research in this field is specifically targeted to Washington State. For copies of this report and/or further information regarding the studies reviewed, please contact:

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"Effective management of predator damage is also a conservation issue, and the edges – that is the intersections of carnivores, people, and livestock – are where efforts need to be focused."

John A Shivik, Utah State University
USDA/APHIS/WS National Wildlife Research Center Predator Research Center

INTRODUCTION

Gray Wolf on the Landscape

In 2008 the first breeding pack of Gray Wolves (*Canis lupus*) in Washington was documented near Twisp in the Methow Valley following an absence of nearly 70 years. In response to the wolves' reappearance in Washington, the Fish and Wildlife Commission adopted the ***Wolf Conservation and Management Plan for Washington (Plan)*** in December 2011, following a lengthy scientific and public involvement process. The Plan provides the framework for how wolf conservation and management will be addressed during the gray wolf population recovery phase and beyond. The *Plan* states:

> *"No wolves have ever been or will be reintroduced into Washington from areas outside the state as part of this plan. This is a state plan. There is no requirement for federal approval of the plan because the U.S. Fish and Wildlife Service (USFWS) has not established federal recovery criteria for wolves in Washington…The purpose of the plan is to ensure the reestablishment of a self-sustaining population of gray wolves in Washington and to encourage social tolerance for the species by addressing and reducing conflicts (Wiles et al 2011)."*

Since 2008 wolves have continued to re-establish themselves in Washington on their own through immigration, most likely from the neighboring states and provinces of Idaho, Montana, Oregon, and British Columbia, and through reproductive success of established breeding packs. By the end of 2013, Washington Department of Fish and Wildlife (WDFW) had documented thirteen packs comprised of fifty-two individual wolves, including five successful breeding pairs, residing in eastern Washington and the eastern Cascade foothills (Becker et al 2014). Gray wolves are currently protected as an endangered species by both federal and state law in the western two-thirds of the state. The wolf population in the eastern one-third of the state, where a number of packs have become established, are only protected under state law.

During the recovery period for Washington's wolves, lethal control options are limited in order to give the maximum protection to the recovering population. Although there have been few documented conflicts between wolves and livestock to date in Washington, as wolf numbers continue to grow it is anticipated that conflicts will also increase (Becker et al 2014). Nonlethal conflict avoidance methods are the preferred option recommended by WDFW to ensure livestock and human safety as well as gray wolf recovery.

Fortunately, Washington State livestock producers and wildlife managers can benefit from the extensive research that has already been conducted throughout North America, where wolves have re-established a foothold, and in places like Europe, where wolves have always been present but whose numbers have been increasing in recent years. This report should prove beneficial to biologists, wildlife managers, livestock producers and conservationists as these groups continue to work together to identify and utilize the most practical and cost effective nonlethal wolf-livestock conflict avoidance practices.

Organization and Research Methods

In 2013 Western Wildlife Outreach (WWO), a nonprofit organization dedicated to disseminating science in order to advance human and carnivore coexistence, was contracted by WDFW to conduct a review of published research on the effectiveness of **nonlethal carnivore and livestock conflict avoidance methods.** University of Washington student intern, Jane Hutchinson, headed up this research effort under the direction of WWO's Executive Director, Lorna Smith. Unless otherwise noted, the research studies focus on the following canid species: Gray Wolf (*Canis lupus*), Coyote (*Canis latrans*), and Domestic Dog (*Canis lupus familiaris*). The primary research tool was the University of Washington Library's online "**Articles & Researches Databases**" website with the majority of the studies located through the ***Web of Science,*** a Thomson Reuters research platform containing multidisciplinary scholarly and scientific research articles. Search terms were generated from relevant combinations of the following key words: "**wolf, gray, canid, canine, livestock, conflict, predation, depredation, cattle, lethal, nonlethal, control, method**, **wildlife, mitigation, husbandry, ranch, range, farm, management, stockmanship, planning, guardian, fencing, and conservation**." These references were cross-compared with those provided by wildlife biologists with WDFW and other stakeholder groups, faculty and research staff from various educational institutions, and those cited in the Plan. All research was reviewed for relevancy regarding what might confront wildlife managers, livestock producers, biologists and conservationists working towards identifying the most practical, cost effective nonlethal conflict avoidance practices, protecting livestock as well as Washington's still-recovering population of gray wolves.

In total 103 research studies dating from 1979 to 2014 were selected for review. Of these, fifty-four of the studies are summarized and their findings reported on. A list of these cited studies is in Appendix A. The other forty-nine studies are located in Appendix B, suggested as further reading to provide more in-depth information on a particular topic. WWO and WDFW intend to make these studies available through an online library operating in the public domain. The sections of this report are organized in the following manner:

- "Conclusion: Applicability to Washington" provides an overall summary of the findings, with recommendations and ratings for those management strategies considered most applicable to livestock producers operating in the state of Washington.
- "Research Studies" provides a summary of the study location, purpose and methods, organized chronologically and then assigned a number for easy citation and identification throughout the paper.
- "Summaries of Study Findings" highlights pertinent findings from these studies categorized into three focus areas– Husbandry Practices, Nonlethal Predator Control Methods, and Wildlife Management Strategies.

Abbreviations Used Throughout this Document

CAN--Canada
CFA--Conditioned Food Aversion
CI--Central Idaho Gray Wolf Recovery Zone
CTA--Conditioned Taste Aversion
ESA--Endangered Species Act
EU--Europe
GIS--Geographic Information System
GYA--Greater Yellowstone Area Gray Wolf Recovery Zone
LGA--Livestock Guardian/Guarding Animal
LGD--Livestock Guardian/Guarding Dog
LiCl--Lithium Choride
LPD--Livestock Protection Dog
MAG--Motion Activated Guard
NRM--Northern Rocky Mountain Gray Wolf Recovery Zone
NWMT--Northwest Montana Gray Wolf Recovery Zone
NWRC-- National Wildlife Research Center
RAG--Radio Activated Guard
RTVF--Real Time Virtual Fencing
USA--United States of America
USFWS--United States Fish & Wildlife Service
USDA--United States Department of Agriculture
WDFW--Washington Department of Fish & Wildlife
WS--USDA Wildlife Services
WWO--Western Wildlife Outreach

APPLICABILITY TO WASHINGTON

A summary of the findings contained in the review with recommendations and ratings for those management strategies considered most applicable to livestock producers operating in the state of Washington.

APPLICABILITY TO WASHINGTON STATE

IN SUMMARY

Gray wolves are a territorial species, therefore their use of space is routine and determined by their biological need for reproductive success (21, 29, 48, 50). Home ranges are variable in size with dynamic margins that fluctuate seasonally and across the years (Spotte 2012). The territories they establish within these ranges will depend on many environmental factors including elevation, weather patterns and wild prey migrations. Generally speaking, wolves limit their movements in order to mate, den and rear pups becoming nomadic when the pups are old enough to follow. Some packs will reside in the same location all year round.

While winter and spring are considered the highest risk seasons for wolf depredations in general, regional studies have demonstrated that the greatest number of depredations occur in August in western Canada and the northwestern United States (29). WDFW data from 2007 through 2013 show that in Washington most depredations occur during the summer months (53). Livestock likely constitute a secondary prey item, one killed opportunistically by wolves when they encounter them while hunting their wild prey sources (21, 24, 30). Researchers have demonstrated that wild prey density and livestock proximity to den location correlate with higher wolf depredations (24, 29, 30, 36). This growing body of research about a wolf's use of space can help develop management strategies that move livestock away from wolf core areas during periods of intense activity (1, 8, 21, 24, 30, 36, 39).

Improving husbandry practices around wolf territories during high risk seasons is one of the leading factors in reducing wolf depredations (1, 8, 29, 25). Because every operation has its own set of challenges, ranches should be individually assessed to determine which methods are most applicable to their livestock system given the time of year and sites where depredations are occurring or have occurred (30, 36). Personal contact with producers coupled with a monthly reporting system, which reduces reliance on memory, greatly increases the accuracy and reliability of the livestock loss data gathered (1, 21, 29, 30, 32, 36, 39, 52, 53). To aid with depredation management, there are a variety of nonlethal conflict avoidance strategies managers can employ.

When it comes to nonlethal methods for predator control there are two conceptual approaches: disruptive stimuli and aversive stimuli. Disruptive stimulus tools act by disrupting appetitive behaviors and frightening predators away from resources. Aversive stimulus approaches seek to modify behavior through aversive conditioning of the predator (33). The effectiveness of nonlethal tools seems to be enhanced when several types are used in combination with each other (32, 35). Circumstances are different for each livestock operation, and the key is to select nonlethal tools that are economically feasible and have the greatest potential to decrease conflict in each situation. The following table provides a 5-star rating of recommendations from the findings for applicability in the state of Washington.

RECOMMENDATIONS

NONLETHAL CONFLICT-AVOIDANCE MANAGEMENT STRATEGIES	RATING	STUDY #
HUSBANDRY PRACTICES		
Develop livestock management plan based on producer's site conditions	*****	1, 21, 24, 29, 30, 32, 34, 36, 35, 39, 52, 53
Graze livestock away from wolf activity, especially denning and rendezvous sites	*****	1, 8, 21, 24, 29, 30, 36, 39
Livestock maintained near human habitation when possible	*****	4, 30, 39, 52
Confine livestock during birthing activities	*****	1, 4, 21, 25
Delay turnout on open range for cow-calf pairs	*****	8, 21
Permanent, wire mesh fencing on smaller operations	*****	9, 36
Expeditious carcass removal and proper disposal	*****	1, 8, 13, 18, 25, 30, 36
Night corrals and night lighting in permanent corrals	****	1, 4, 9, 25, 45, 52
Maintain pastures away from native ungulates	****	21, 24, 25, 30, 39
Range Rider or Herder presence on open range system	****	4, 5, 32, 36
Manage herds/flocks away from wooded areas	****	4, 8
LGD/LPD's effective with right breed and operator commitment.	***	1, 4, 5, 6, 13, 15, 20, 26, 32, 36, 42, 49

NONLETHAL TOOLS		
Electric Fencing (wire mesh, higher than 145 cm)	****	7, 18, 32, 52
Fladry / Turbo Fladry (short term effectiveness)	****	20, 22, 32, 33, 36, 37, 39, 43, 44
Bio-Boundary (Needs more research)	***	48, 50, 54
MAG Devices (Needs more research, good for multiple predator system)	**	22, 33
RAG Devices (Needs more research on wolves, requires radio collars)	**	19, 32, 33, 36
Visual and Acoustic Scare Devices (largely untested on wolves)	*	8, 16

NONLETHAL CONFLICT-AVOIDANCE MANAGEMENT STRATEGIES	RATING	STUDY #
WILDLIFE MANAGEMENT		
Pool resources to establish range rider, herder programs	*****	36, 41, 51
Outreach/Education	*****	33, 34, 38, 51
Remote Alarm Aid / Real-Time Virtual Fence (Needs more research)	***	28, 54
Compensation to build public acceptance, tied to husbandry methods	**	8, 20, 21, 41, 46
Contraception/Sterilization (not recommended for wolves)	*	17, 31, 33, 39
Translocation /Lethal Control (ineffective at reducing depredation)	*	23, 27, 29, 32, 33, 35, 37, 39, 47
Aversion Chemicals (not proven effective with wolves)	*	2, 3, 8, 9, 12, 16, 33

RESEARCH STUDIES

This section provides a brief descriptive paragraph for each of the fifty-four research studies selected for analysis. Included in the summary is the study's location, purpose and methods. The research is organized chronologically and assigned a number for easy identification throughout the rest of the paper. Complete citations for each study are provided in Appendix A.

RESEARCH STUDIES

1. ROBEL ET AL 1981 (USA-KS). This study evaluated the efficacy of several husbandry methods in reducing sheep losses to coyotes and domestic dogs. Sheep losses of 109 producers were monitored monthly in a nine-county area of south central Kansas to assess the effects of husbandry practices. At the time of the study, Kansas had the third highest index of predator abundance of the seventeen western states with the study area equal to or exceeding the statewide average. Principal information collected included method of sheep-carcass disposal, season and location of lambing, presence of large dogs in the farmyard, method and success of predator control, season of shearing, breed of sheep, poultry (if any), management practices, types of pasture used, use of bells, time of day sheep were turned out to pasture and returned to corrals, and general confinement practices. Flock sizes ranged from 4-913 (mean=154). No large-scale commercial operations (>1000 head) were included in the study. Findings are considered applicable to most sheep operations managed under farm-flock conditions.

2. GUSTAVSON ET AL 1982 (CAN-SASKATCHEWAN). Taste aversion programs using lithium chloride (LiCl) in sheep baits and carcasses have been applied in Washington to one sheep herd for two years; applications have been made in California and in Saskatchewan on forty-six herds over three years. Ten of these forty-six herds were available for statistical analysis, indicating a significant reduction in the percent of sheep lost to coyotes. All applications have suggested reduced sheep losses to coyotes. This method of predation control may cost less than traditional techniques, save sheep, and should allow coyotes to carry out positive functions in the ecosystem.

3. BOURNE & DORRANCE 1982 (CAN-ALBERTA). Researchers in the 1970's concluded that baits treated with LiCl were effective in reducing coyote predation on domestic sheep (Gustavson et al 1974, 1976, 1977). In order to test this assertion, and the research methods used to support it, predation rates and lethal control actions were studied at seventeen farms located in four areas of Alberta – Grande Prairie, Barrhead, Rocky Mountain House, and Cardston. The study area was located in the Boreal Mixedwood Forest Region, the Boreal Aspen Grove Forest Region, and the Boreal Lower Foothills Forest Region. Cardston, located in SW Alberta, had the greatest native habitat, which consisted of grassland and quaking aspen groves, with only one-half of the land in cultivation at the time of the study. In this region sheep grazed on native grass pastures where they still remained. The farms ranged in size from 64-1036 ha (mean distance between farms=24 km). In 1978 baits and placebos were placed around the farms beginning 3-6 weeks before sheep went to pasture in April and continued being maintained until the following September. Six radio-collared coyotes with home ranges of 2-8 km were present in the area from April-September in 1977 and 1978. Flock size and number of sheep lost to predation were obtained from farmers for 1976 & 1977 and confirmed by government compensation records. Predation losses in 1978 were reported directly to researchers by the farmers and then confirmed by predator specialists. When predation was confirmed lethal control activities were initiated.

4. BLACK & GREEN 1984 (USA-NAVAJO). The 70,000-km^2 Navajo Reservation is located on the Colorado Plateau situated across the southwestern United States of Arizona, Utah, and

New Mexico. Seventy-two Navajo ranchers were questioned about their mixed-breed guarding dogs and their role in general livestock operations, the extent of dog care and training, and what kinds of dog-coyote-sheep interactions occurred. Fifty eight flocks were studied, ranging in size from 17-300 individuals. On the homesteads visited, 230 mixed-breed dogs were used as livestock protection dogs (LPD). Navajo dogs function primarily as guardians of sheep and goats to whom they have developed social bonds. Mixed breed dogs of the Navajo appear to exhibit all behavioral traits believed to be important in protecting flocks from predators, especially coyotes: they are attentive, defensive and trustworthy. Navajo dogs could be quickly deployed in a variety of ranching situations to help reduce predation on livestock.

5. COPPINGER & COPPINGER 1988 (USA). This paper presents data from a ten-year study on livestock guarding dogs (LGD) conducted by researchers at Hampshire College known as the Livestock Dog Project. The project began in 1976 after consultations with livestock industry leaders about staggering losses of sheep to coyotes (*Canis latrans*) and the associated costs to producers, as well as the renewing effort on the part of the industry, the federal government and environmental groups to find an effective, nonlethal method of predator control. Initially, guarding dogs were observed during a 1–month tour of a dozen ranches in the United States where producers were reportedly working with guarding dogs, and a 3-month tour of sheep-producing regions in Europe and Turkey where the best dogs available were purchased. Dogs from working stock were obtained in Italy (*Maremma*), Turkey (*Anatolian Shepherd*), and Yugoslavia (*Shar Planinetz*). These three main breeds were used as breeding stock to produce pups for the various programs. Hampshire College mitigated financial impacts of dog ownership and kept ownership of dogs at the college so placement and breeding could be regulated. Producers volunteered for the program but were required to have at least two dozen sheep or goats for commercial production and a history or threat of predation. They were sent an annual form to complete with 32 database fields. The Livestock Dog Project permitted researchers to see the variety of habitats and management schemes used by the growers. Over the decade, project staff members logged a half-million miles and placed 1,091 pups with producers across thirty-seven states.

6. GREEN & WOODRUFF 1988 (USA & CAN). A survey of LGD users in the USA and Canada in order to determine effectiveness of particular guarding dog breeds and how successfully they are being used by livestock producers. Comparisons were made on effectiveness of breed and sex of guarding dog, how guarding dogs were utilized and how effective they were in general and economically. Sheep and goats were livestock protected in herds of variable size managed in both pasture and open rangeland situations. Small pasture operations ran 4-50 head (median=25), large pasture operations had 56-8,000 head (median=200) and range operations had from 12-16,000 head (median=1,000). Of these operations, 4 range operators and 11 pasture operators ran mixed herds of goat and sheep. The study was conducted from January to August 1986.

7. NASS & THEADE 1988 (USA-OR, WA, CA). The use of anti-predator electric fences for reducing predation on sheep was investigated by interviewing 101 sheep producers in the Pacific Northwest region of the United States. Significant reductions in sheep losses to predators were reported after installation of electric fences compared to pre-fence losses. Low sheep losses to predation were also reported by those producers that acquired sheep after installation of electric fences. The expenses of construction and maintenance were important considerations in management plans; however, most producers were satisfied with electric fences for sheep containment and predator exclusion.

8. FRITTS ET AL 1992 (USA-MN). The nature and extent of wolf-livestock conflicts in Minnesota during 1975-86 was studied as part of a wolf depredation control program. The level of gray wolf depredation on livestock in Minnesota, as determined from the total number of complaints verified annually during 1975-86, showed a slight upward trend but did not increase significantly. A significant portion of the annual variation in verified complaints, perhaps the best index on severity of the depredation problem, was explained by variation in severity of the winter before the depredation season (inverse relation). The addition of a time variable did not account for a significant portion of the remaining variation. Verified complaints of depredations averaged 30 per year, affecting an average of 21 farms (0.33% of producers) annually. Conflicts were highly seasonal and involved primarily cattle (mainly calves), sheep, and domestic turkeys. Annual variation in losses of sheep and turkeys was higher than for cattle. In recent years, sheep and turkey losses in two northwestern counties have increased; preventive control may be warranted in those areas. Site-specific trapping and removal of wolves in response to depredations was the primary control method, resulting in captures of 437 wolves in 12 depredation seasons. This experience with active depredations in the state may lend insight into problems and solutions that may occur where wolves become established naturally or by reintroduction, and can provide background for developing effective control programs in those areas.

9. CONOVER & KESSLER 1994 (CAN-SASKATCHEWAN). In 1990, researchers surveyed 49 Saskatchewan sheep producers who participated in a large- scale conditioned food aversion (CFA) program administered by the Saskatchewan Agriculture Department beginning in 1976 and a random sample of 81 Saskatchewan sheep producers to determine how many were still using CFA to protect their sheep from coyote predation and if use of the method had spread to other producers in the area. With CFA, sheep carcasses or sheep bait packages are treated with the emetic agent, lithium chloride (LiCl), and distributed in areas where coyotes may prey on sheep. In theory, coyotes become ill after ingesting the bait, develop an aversion to the taste of mutton, and subsequently avoid killing sheep. This theory prompted an abundance of research, but results have been inconsistent, and therefore, the concept has been controversial. In this study, we examined producer perceptions of the Saskatchewan Program (SP) after >10 years. Researchers for this study assumed that if CFA effectively reduced coyote predation, producers who had participated in the SP would still be using the technique. Hence, producers were contacted who had participated in the SP to determine how many were still using CFA and to assess their experiences and attitudes about this method.

10. FRANKLIN & POWELL 1994 (USA-IA). In 1990 Iowa State University initiated research on guard llamas (*Lama glama*) in order to determine how North American sheep producers were using them, if they significantly reduced sheep losses to predation and what management practices gave the best results. The average flock size of those ranchers interviewed was 250-300 sheep maintained in a pasture of 100-125 hectares. Producers had used guard llamas an average of 3 years, but some for as long as 12 years. Nearly all llamas in this study had no experience with sheep before being introduced into the flock they were to protect. Llamas averaged 2 years of age at introduction with the average age being 6-11 months. Before producers obtained their guard llamas they had been losing about 11 percent of their flocks. Intensive field studies revealed that 41 percent of all sheep losses were from canid predators (coyotes and dogs).

11. CAVALCANTI & KNOWLTON 1998 (USA-UT). Llamas are frequently used as guard animals by sheep producers as part of their predation management programs. However, few data are available concerning physical and behavioral attributes that distinguish between effective and ineffective guardian llamas. This study was conducted at the Predator Research Facility of the National Wildlife Research Center (NWRC) near Millville, UT. Twenty llamas were randomly assigned to one of four groups. Focal group sampling techniques were used to rank individual llamas according to frequencies with which they displayed alertness, leadership, dominant, aggressive, and threatening behaviors as well as postures indicating dominance or subordination. Researchers then examined the behavior of individual llamas with sheep. Finally, interactions among llamas, sheep, and a surrogate predator border collie were documented.

12. ANDELT ET AL 1999 (USA-UT). This study tested the effectiveness of an electronic dog-training collar to deter captive coyotes from killing domestic lambs by shocking coyotes whenever they attempted to attack lambs during a 22-week period.

13. ANDELT & HOPPER 2000 (USA-CO). Research compares sheep mortalities to predators for producers in Colorado who did and did not have guard dogs, presenting the effects of herd size, sheep/dog, dogs/herd, and number of years dogs were used on predation rates. Data include changes in proportion of sheep mortalities from 1986-1993 for producers with and without dogs in both years, and producers who obtained dogs between those years. Sheep occurred in varying densities across differing operation types (fenced pasture, feedlot, open range). Coyote, black bear, mountain lion and domestic dog were predators reported by producers.

14. MECH ET AL 2000 (USA-MN). Gray wolf depredations on livestock cause considerable conflict and expense in Minnesota. Furthermore, claims are made that such depredations are fostered by the type of animal husbandry practiced. Thus, researchers tried to detect factors that might predispose farms in Minnesota to wolf depredations. This study compared results of interviews with 41 cattle farmers experiencing chronic cattle losses to wolves (chronic farms) with results from 41 nearby "matched" farms with no wolf losses to determine farm characteristics or husbandry practices that differed and that therefore might have affected wolf depredations. Geographic Information System (GIS) was used to detect any habitat differences between the 2 types of farms.

15. SMITH ET AL 2000a (EU & USA). The use of domestic animals to protect livestock was reviewed through visits to actual users, discussions with experts and a thorough literature search.

16. SMITH ET AL 2000b (EU & USA). The use of aversive conditioning, repellents and deterrents in the management of predator–livestock problems is evaluated based on a comprehensive literature review, contact with leading authorities and visits to areas with similar predation problems. The status of these management tools is reported and their applicability under Scandinavian conditions evaluated.

17. BROMLEY & GESE 2001 (USA-UT). Researchers examined whether surgical sterilization of coyote packs would modify their predatory behavior and reduce predation rates on domestic sheep as compared to coyote packs with pups. The study area was located on Deseret Land and Livestock Ranch, comprising 400-km^2 in northeastern Utah. While sheep grazing was a historical use of the area, sheep had not grazed the study area recently while cattle were grazed intermittently. Coyotes were distributed throughout the study area and were relatively unexploited. Winter carrion in the form of cattle and elk carcasses was plentiful. Mule deer and pronghorn antelope were common in the area. The most abundant small prey were white-tailed jackrabbits, cottontail rabbits, Uinta ground squirrels, deer mice, and least chipmunks. The study area is primarily sagebrush steppe, with an understory of western wheatgrass, needle-and-thread grass, Indian rice grass, and planted crested wheatgrass.

18. APPROPRIATE TECHNOLOGY TRANSFER FOR RURAL AREAS (ATTRA) 2002 (USA). It is virtually impossible to eliminate all predators and the damage they cause to livestock, but good management can reduce this damage and still be consistent with sustainable or organic livestock production. Because every farm is different, there is no single practice or single combination of practices that will be right for every situation. Therefore, when predators strike, it is important to be aware of all options available for their control and to act at once. Many species of animals can be classified as predators, but coyotes and dogs account for more than three-quarters of all livestock lost to predators. Highlighted predators include coyotes and wolves with goats and sheep as the primary livestock for protection efforts with discussion on how to identify predator attacks from other types of death. Presented are various sustainable management practices, such as fencing, proper carcass disposal and the use of livestock guardian animals (LGA).

19. BRECK ET AL 2002 (USA-ID). In response to the need to manage wolf predation in a non-lethal manner, wildlife managers developed and are currently testing a Radio Activated Guard (RAG) scare device that is behaviorally contingent and designed to disrupt predation events in small areas (<15-25 hectares). Preliminary results of ongoing testing of RAG boxes is reported. The two questions addressed are 1) do RAG boxes effectively deter wolves from depredating cattle, and 2) how long does it take wolves to habituate to RAG boxes? The study describes the equipment, reports three case histories from central Idaho in which RAG boxes were used to protect cattle, and discusses limitations of the method. Conclusions describe plans for more rigorous testing of the device.

20. MUSIANI ET AL 2003 (CAN-ALBERTA, USA-GYA). Trends in wolf depredation on livestock in Alberta, Canada, during the 1980s and 1990s are compared with trends in Idaho, Montana, and Wyoming in the United States during 1987–2001. Researchers report on experiments to evaluate the effectiveness of fladry for deterring wolves from accessing food in captivity and in the wild and for separating social groups of wolves in captivity. Finally, the study documents the use of fladry barriers in field situations in Alberta and Idaho for protecting livestock from depredation by wild wolves.

21. OAKLEAF ET AL 2003 (USA‐ID). Researchers examined interactions between wolves and domestic calves within a grazing allotment in central Idaho, USA, to evaluate the role of wolves on calf survival and movements. During the 1999 and 2000 grazing seasons, 231 calves/year‐representing 33% of the calf population were radio marked‐on the Diamond Moose Association grazing allotment and their survival and movements relative to wolf distribution monitored.

22. SHIVIK ET AL 2003 (USA–MN). Aversive and disruptive stimulus approaches for managing predation were evaluated with captive wolves at the NWRC in Minnesota. Because experimental evaluations of depredation control technologies are difficult to implement in actual management situations, researchers tested two repellents for their efficacy in reducing consumption only. They then tested the effectiveness of a Motion Activated Guarding (MAG) device with two other disruptive stimulus approaches (fladry with wild wolves, shock collar with penned wolves), and using deer carcasses as the attracting resource.

23. TREVES & KARANTH 2003 (WORLD WIDE). Carnivore conservation depends on the sociopolitical landscape as much as the biological landscape. Changing political attitudes and views of nature have shifted the goals of carnivore management from those based on fear and narrow economic interests to those based on a better understanding of ecosystem function and adaptive management. In parallel, aesthetic and scientific arguments against lethal control techniques are encouraging the development of nonlethal approaches to carnivore management. Researchers for this study anticipate greater success in modifying the manner and frequency with which the activities of humans and domestic animals intersect with those of carnivores. Success should permit carnivore populations to persist for decades despite human population growth and modification of habitat.

24. TREVES ET AL 2004 (USA‐MN, WI). Many carnivore populations escaped extinction during the twentieth century as a result of legal protections, habitat restoration, and changes in public attitudes. However, encounters between carnivores, livestock, and humans are increasing in some areas, raising concerns about the costs of carnivore conservation. This study presents a regional model that predicts future sites of human‐carnivore conflict in relation to landscape features such as human land use and vegetation types. The model is based on the sites of past wolf attacks on livestock in Wisconsin and Minnesota (U.S.A.). Researchers used a matched‐pair analysis of 17 landscape variables in a GIS to discriminate affected areas from unaffected areas at two spatial scales (townships and farms). They believe this approach can be applied wherever spatial data are available on sites of conflict between wildlife and humans.

25. BRECK & MEIER 2004 (USA). With the successful recolonization and reintroduction of wolves in parts of the western United States and the natural expansion of wolves in the upper Midwest, managing conflicts between wolves and livestock is a growing issue for livestock producers, resource professionals, and the general public. Unlike the coyote, where a great deal is known regarding the biology and ecology of depredation and methods for managing it, very little is known regarding patterns and processes of wolves preying on livestock and effective ways to mitigate this conflict. Understanding the ramifications of growing wolf populations for livestock production and successfully managing these problems will require knowledge of depredation patterns, wolf ecology, livestock husbandry, and the effectiveness of different tools and techniques to manage wolves. As wolf populations expand into more agricultural areas such knowledge will become increasingly important. Here historic records were compared to current data on wolf depredation rates and wolf management techniques relative to the wolf's status on the endangered species list. The objectives were to synthesize the history of wolf depredation and management, present current data of wolf impacts on livestock, and speculate on the future management of wolves so that producers can consider the ramifications of a growing wolf population and possible mechanisms for decreasing the threat.

26. BANGS ET AL 2005 (USA-NRM). Wolf restoration in the western U.S. began in 1986 when a 'Canadian' pack denned in Glacier National Park, Montana. Management in northwestern Montana emphasized legal protection and building local public tolerance of non-depredating wolves. Wolves from Canada were reintroduced to central Idaho and Yellowstone National Park in 1995 and 1996 to accelerate restoration. The wolf population grew to an estimated 800–850 wolves in the Northern Rocky Mountains (NRM) of Montana, Idaho, and Wyoming by late 2004. Since 1987, wolves have killed a minimum of 410 cattle, 1,044 sheep, 70 dogs [18 of which were being used to guard livestock], 12 goats, 9 llamas, and 3 horses. To minimize conflicts, we moved wolves 117 times and killed over 275. Researchers for this study encourage sheep producers to use livestock guarding dogs (LGDs) and other methods to reduce the risk of wolf depredation. LGDs are working well against a diverse carnivore guild but this paper is intended to show some novel aspects of their use against wolves. This report discuss some interactions that have been observed between LGDs and wolves and speculations are made about increasing the effectiveness of LGDs to protect livestock from wolf depredation.

27. BRADLEY ET AL 2005 (USA-MT & ID). Successful nonlethal management of livestock predation is important for conserving rare or endangered carnivores. In the northwestern United States, gray wolves have been translocated away from livestock to mitigate conflicts while promoting wolf restoration. We assessed predation on livestock, pack establishment, survival, and homing behavior of 88 translocated wolves with radio telemetry to determine the effectiveness of translocation in our region and consider how it may be improved.

28. BRECK ET AL 2005 (USA-CA). Wildlife managers developed and tested a system that alerts personnel when a radio collared animal enters an area designated as off-limits. The remote alarm combines the monitoring capabilities of data loggers with a message transmitter that sends a voice message via two-way radios when an animal enters a monitored area. The remote alarm system was tested with food-conditioned American black bears *(Ursus americanus*) in Yosemite National Park by setting up six remote alarms in areas designated off-limits to bears (i.e., campgrounds and parking lots). Researchers recorded the number of times a radio tagged bear entered an off-limits area, the number of times bear management detected a bear in areas off-limits, and the number of hazing events.

29. MUSIANI ET AL 2005 (CAN & USA). Due primarily to gray wolf predation on livestock (depredation), some livestock producers and other interest groups oppose wolf conservation, which is an important objective for large sectors of the public. Predicting depredation occurrence is difficult, yet necessary to prevent it. Better prediction of wolf depredation also would facilitate application of sound depredation management actions. In this paper researchers analyze temporal trends in wolf depredation occurrence and wolf control, which is employed as a depredation management action. Data were gathered from wolf depredation investigations for Alberta, Canada, from 1982-1996 and for Idaho, Montana, and Wyoming, USA, from 1987-2003.

30. BRADLEY & PLETSCHER 2005 (USA-ID, MT). Managing wolf depredation on livestock is expensive and controversial; therefore, managers seek to improve and develop new methods to mitigate conflicts. Determining which factors put ranches at higher risk to wolf depredation may provide ideas for ways to reduce livestock and wolf losses. Researchers sampled cattle pastures in Montana and Idaho that experienced confirmed wolf depredations from 1994–2002 and compared landscape and selected animal husbandry factors with cattle pastures on nearby ranches where depredations did not occur.

31. SCHULTZ ET AL 2005 (USA-WI). Researchers evaluated the use of a dog-training shock collar fitted to wild, free-ranging gray wolves to prevent livestock depredation. The study was conducted on 536/ha farm that included mixtures of oak-pine-aspen forest, brushy grasslands, and open pastures dominated by cool-season grasses. Lowlands adjacent to a small (5m-wide) stream comprised about 10% of the farm. County forest lands, used extensively by wolves since the early 1990s, surrounded much of the farm to the west, north, and south. Approximately 300-560 calves were born on the farm each year during April-May in outside pastures. Calves were rotated among 2-3 fenced pastures during the course of the summer. Cattle were contained with a four-strand 1.4m tall barbed wire fence with an additional one strand of electric wire in the center. A pair of wolves established a territory (Chase Brook Pack) near the farm during the winter of 1994-1995. During the study period, the pack occupied a 156-km^2 territory encompassing the farm. It was assumed this pack was responsible for the majority of wolf depredation on the farm from 1998-2001...Black bears and coyotes occurred frequently on the farm, but neither was determined to be responsible for any livestock losses. White-tailed deer densities in the area ranged from 12-16 per km^2 (Wisconsin Department of Natural Resources, unpublished data). Other wolf prey species included snowshoe hare, beaver, and cottontail rabbit.

32. BANGS ET AL 2006 (USA-NRM). Gray wolf populations were eliminated from the NRM of the western United States by 1930, largely because of conflicts with livestock. The wolf population is now biologically recovered and over 1,020 wolves are being managed in Montana, Idaho, and Wyoming under the federal Endangered Species Act (ESA). From 1987 to December 2005, 528 cattle, 1,318 sheep, 83 dogs, 12 goats, 9 llamas, and 6 horses were confirmed killed by wolves, and over $550,000 was paid from a private damage compensation fund. To help restore the wolf population, managers employed 22 variations of nonlethal control tools, relocated wolves 117 times, and killed 396 wolves to reduce conflict between wolves and livestock. A variety of tools, including regulations that empower the local public to protect their private property, reduced the probability of wolf-caused damage. This wolf population was restored, the risk of livestock damage reduced, and public tolerance of wolves improved through an integrated program of proactive and reactive nonlethal and lethal control tools. Reduced conflict increases the potential to restore wolf populations.

33. SHIVIK 2006 (USA). The loss of large carnivores at the edges of parks, preserves, and human habitations threatens the conservation of many species. Thus, effective predation management is a conservation issue, and tools to mitigate conflicts between humans and predators are required. Both disruptive-stimulus (e.g., fladry, Electronic Guards, radio-activated guards) and aversive-stimulus (e.g., electronic training collars, less-than-lethal ammunition) approaches are useful, and technological advances have led to many new, commercially available methods. Evaluating the biological and economic efficiency of these methods is important. However, social and psychological effects should also be considered. The management of animal damage to human property is necessary, and methods that allow the coexistence of livestock and large predators must be employed. With further research and development that includes interdisciplinary approaches to management methods, biologists may be better able to conserve large carnivore species by ameliorating human conflicts with them.

34. TREVES ET AL 2006 (WORLD WIDE). Conservationists recognize the need to work beyond protected areas if they are to sustain viable populations of wildlife. But ambitious plans to extend wildlife corridors beyond protected areas must consider the economic and political implications when wildlife forage on crops, attack livestock, or otherwise threaten human security. Traditionally, humans respond by killing "problem" wildlife and transforming wild habitats to prevent further losses. This traditional response, however, is now illegal or socially unacceptable in many areas, changing a simple competitive relationship between people and wildlife into a political conflict. As a result of experiences in Bolivia, Uganda, and Wisconsin researchers outline a strategy for mitigating human–wildlife conflict based on participatory methods and co-management with twin objectives of wildlife conservation and safeguarding human security. Incorporating local stakeholders as partners in planning and implementation can help to win space for wildlife beyond protected area boundaries. We also show why systematic study of local people's perceptions of risk and participant planning of interventions are irreplaceable components of such projects.

35. SIME ET AL 2007 (USA-MT). The Montana gray wolf population grew from two wolves in 1979 to a minimum of 316 by late 2006. Resolving conflicts, both perceived and real, between wolves and livestock became a dominant social issue for the federal recovery program, and it remains so today. The United States Fish and Wildlife Service and now Montana Fish, Wildlife & Parks work with United States Department of Agriculture, Animal Plant Health Inspection Service, Wildlife Services (WS) to reduce depredation risks and address wolf-related conflicts through a combination of non-lethal and lethal management tools. The number of wolf complaints investigated from 1987-2006 increased as the population increased and expanded its distribution into Montana after reintroduction into Yellowstone National Park and central Idaho during 1995 and 1996. Montana wolf packs routinely encountered livestock, though wolf depredation was a relatively rare cause of livestock death and difficult to predict or prevent. Conflicts are addressed on a case by case basis and lethal control is implemented incrementally after predation is verified. Resolving wolf and livestock conflicts at a local scale is but one component of a larger state wolf conservation and management program.

36. STONE ET AL 2008 (USA-GYA). In 1999, Defenders of Wildlife and The Bailey Wildlife Foundation worked together to create The Bailey Wildlife Foundation Proactive Carnivore

Conservation Fund. One of the main purposes of this fund is to support research and on-the-ground use of tools, methods and strategies to reduce livestock deaths and therefore reduce lethal control of wolves. Five years later, Defenders established the Livestock Producer Advisory Council to provide advice from a producer's viewpoint. In 2006, Defenders brought together wildlife conservationists, university researchers, agency staff who work on wolf-livestock conflicts, biologists and members of the Livestock Producer Advisory Council for a Yellowstone-area workshop to evaluate proactive livestock protection tools and nonlethal methods and strategies that are helping to reduce livestock losses to wolves. This manual incorporates the experiences, insights and recommendations of the workshop participants and from ongoing discussions and interactions with livestock producers and researchers.

37. HARPER ET AL 2008 (USA-MN). Gray wolf depredations on livestock in Minnesota, USA, are an economic problem for many livestock producers, and depredating wolves are lethally controlled. Researchers sought to determine the effectiveness of lethal control through the analysis of data from 923 government-verified wolf depredations from 1979 to 1998. Data was analyzed by 1) assessing the correlations between the number of wolves killed in response to depredations with number of depredations the following year at state and local levels, and 2) the time to the next depredation.

38. TREVES 2009 (WORLD WIDE). A literature review was combined with researcher's experiences of working with affected communities in order to list and describe distinct types of methods used to mitigate human–wildlife conflicts (interventions). These methods were then classified as *direct interventions* that aim to reduce the severity or frequency of encounters between wildlife and property or people or *indirect interventions* that aim to raise people's tolerances for such encounters. The study summarizes the recommendations about the interventions with three complementary criteria: cost effective design, selectivity and specificity for the problematic wildlife, and sociopolitical acceptability. These three criteria are not prescriptions. Rather they capture experiences of strengths and weaknesses of each method under different conditions, so users can assess whether the interventions are feasible in their particular sociopolitical and biophysical situations. Finally this framework dovetails with recent standards for conservation planning.

39. RUID ET AL 2009 (USA-MN, WI, MI). Recovery of gray wolves in the Great Lakes region has been accompanied by an increase in wolf—human conflicts. The interface between owners of domestic animals and wolf recovery presents unique challenges for wildlife management. Investigating wolf complaints, explaining wolf ecology, conservation goals, and litigation that has impacted wolf management to people who have had domestic animals killed by wolves are challenges faced by those involved with managing wolf—human conflicts. In this chapter, wolf—human conflicts and management are described, focusing on the period 1974-2006, when wolves were protected under the ESA.

40. HAWLEY ET AL 2009 (USA-WI). Lethal control alone has not proven entirely effective in reducing gray wolf depredation in chronic problem areas. Opponents of lethal control argue that more emphasis should be placed on integrating nonlethal strategies into current management. However, few evaluations have tested the effectiveness of nonlethal options. Researchers compared behavior patterns in terms of frequency and duration of bait station visits for five wolves fitted with shock collars to five control animals inhabiting wolf pack territories in Northern Wisconsin during the summers of 2003 and 2004. Prior to this research, shock collars had not been tested on free-ranging wolves in a controlled experiment. The study's objective was to determine if current shock collar technology could effectively deter free ranging wolf movements from using a desirable site. The study area comprised 9,000-km^2 of beef and dairy cattle operations at 1280 head per 100-km^2 in Northern Wisconsin, bordering the Upper Peninsula of Michigan. The topography was 64-percent forested encompassing federal, state, county, timber company, and private land with a wolf population of around 140 individuals comprising 40 packs and averaging 3.5 individuals per pack, or 1.5 wolves per 100 square kilometers. White-tailed deer were present at 1800 per 100-square kilometers. To avoid variation in wolf behavior and movement patterns, all research was conducted during the rendezvous season, when adult wolves leave pups in a designated area between hunting and territorial excursions.

41. MUHLY & MUSIANI 2009 (USA-MT, WY). Due primarily to wolf predation on livestock (depredation), some groups oppose gray wolf conservation in the Northwestern U.S., which is an objective for large sectors of the public. Livestock depredation by wolves is a cost of wolf conservation borne by livestock producers, which creates conflict between producers, wolves and organizations involved in wolf conservation and management. Compensation is the main tool used to mitigate the costs of depredation, but this tool may be limited at improving tolerance for wolves. Furthermore, livestock production may in fact provide indirectly an important benefit for wolf conservation – i.e. a positive externality, by maintaining relatively intact habitat on private lands. Researchers analyzed some of the costs of livestock depredation by wolves to livestock producers relative to recent economic trends in the livestock production industry, specifically income generated from livestock production and trends in land and livestock value. Data were gathered from depredation investigations, from the livestock compensation program and on land and livestock prices in Idaho, Montana and Wyoming, U.S.A. from 1987 to 2003 – a period during which wolves had endangered species status.

42. GEHRING ET AL 2010 (EU & USA). Europe and North America share a similar history in the extirpation and subsequent recovery of large carnivore and ungulate species. Both continents face challenges and opportunities for managing human-wildlife conflict at the junction of livestock production and wildlife conservation. Predation of livestock and disease transmission between wildlife and livestock is an ongoing and escalating worldwide issue. In order to manage this conflict, producers need effective tools, and they have used livestock protection dogs LPDs for reducing predation for well over 2000 years. This study reviews the history of the use of LPDs, including the loss of information on their use and the paucity of scientific research on their effectiveness. Researchers then discuss the potential for LPDs to be integral components in modern-day livestock husbandry and outline future directions to pursue.

43. LANCE ET AL 2010 (USA). Wolf predation on livestock can cause economic hardship for livestock producers as well as reduce tolerance for wolves. Lethal control of wolves is often controversial thus development of effective non-lethal methods for reducing wolf–livestock conflict is important. Electrified fladry is a new tool that is similar to fladry (i.e. a barrier system that scares wolves), but electrified fladry also incorporates an electric shock designed to decrease the potential for wolves to habituate to the barriers. Evaluation of electrified fladry requires understanding of its effectiveness relative to fladry and the costs and benefits of applying it in the field. By using captive wolves, researchers compared the effectiveness of electrified fladry v. fladry for protecting a food resource during two-week trials. They then performed a field trial with electrified fladry for managing wolves in Montana, USA. Researchers measured livestock depredation and wolf activity on six treatment and six control pastures, calculated the cost of installation and maintenance, and surveyed all study participants about application of electrified fladry.

44. DAVIDSON-NELSON & GEHRING 2010 (USA-MI). Several forms of nonlethal management exist, but field testing is problematic, and few such techniques have been tested on free-ranging gray wolves or other predators. Researchers tested fladry in the eastern Upper Peninsula of Michigan during the summers of 2004 and 2005 on treatment farms and control farms.

45. RIGG ET AL 2011 (EU-SLOVAKIA). Conflicts with human interests have reappeared following recovery of large carnivores in Europe. Public acceptance is higher than historically but there is a need to identify effective, acceptable techniques to facilitate coexistence. We present a case study of predation on livestock in Slovakia. Livestock and large carnivores are largely confined to ranges in the Carpathian Mountains which are interspersed with lower-lying areas of higher human use and permanent settlement. Commercial forestry, game management, gathering of forest fruits and recreation (hiking and skiing) are common. The area studied was 793 km^2 and contained 95-97 percent of Slovakia's large carnivores, including Gray Wolves, Brown Bear & Eurasian Lynx. Native red deer, roe deer, and wild boar occurred at medium to high densities. Livestock comprised 164 flocks at 147 farms totaling around 79,000 sheep, primarily grazed in unfenced pastures and attended by one to five shepherds and a herding dog. In 2004 reported losses averaged 3.1 sheep per flock to wolves and 0.7 to bears, representing 0.8 and 0.2 percent of sheep losses respectively. Damage, mitigation measures and public opinion were assessed using compensation records, analysis of farm conditions, questionnaire surveys, semi-structured interviews, diet analysis and on-farm trials of LGDs. The study was conducted spring to autumn during the lambing season.

46. DIETSCH ET AL 2011 (USA-WA): This report documents the results of a study assessing the attitudes and beliefs of residents living in the state of Washington toward the following: the place where they live and wildlife, including the wildlife near their homes; lethal control of coyotes and black bears; management actions addressing problem deer/elk and the recolonization of Washington by wolves; salmon recovery; and the importance of and willingness to pay for wildlife-related services. Levels of participation in outdoor and wildlife-related recreation as well as beliefs about access to land areas for recreational opportunities were also explored. Findings are part of the larger research program entitled *Understanding People in Places*, a multi-state study designed to demonstrate the utility of geographically-tied human dimensions information for fish and wildlife management and to introduce and test a spatially-explicit approach to depicting such data.

47. FONTURBEL & SIMONETTI 2011 (WORLD WIDE). Translocation is a nonlethal practice used to manage carnivore-livestock conflicts. Nevertheless, its use has been questioned due to its low success rate and high cost. Researchers performed a literature review to assess the effectiveness of translocation, human-related mortality and cost.

48. JACKSON ET AL 2012 (AFRICA-BOTSWANA). Researchers studied the effectiveness of targeted scent-mark deployments around the boundaries of the Northern Tuli Game Reserve to keep the ranging behavior of the endangered African wild dog (*Lycaon pictus*) within the safety of the protected area.

49. VERCAUTEREN ET AL 2012 (USA & EU). Dogs have been employed to protect an array of resources from various species of offending wildlife. Historically, LPDs protected domestic sheep and goats from predators based on development of a strong bond between protected and protector. Within reason, developing that bond between a LPD and other species of livestock should be achievable. Researchers conducted several studies in which they raised and bonded LPDs with bovine calves and evaluated them for protecting cattle in a variety of settings. Though successful strategies in developing LPDs to protect cattle were similar to those established for sheep, this study found differences that were important for optimizing the process. Strategies are outlined for developing LPDs for maintaining separation between cattle and wild ungulates that are reservoirs of disease that cattle are susceptible to, as well as wild carnivores that are predators of cattle.

50. AUSBUND ET AL 2013 (USA-ID). Conserving large carnivores can be challenging due to conflicts with human land use and competition with humans for resources. Predation on domestic stock can have negative economic impacts, particularly for owners of small herds, and tools for minimizing carnivore depredation of livestock are needed. Canids use scent-marking to establish territories and avoid intraspecific conflict. Researchers for this study hypothesized that human-deployed scent-marks (i.e., 'biofence') could be used to manipulate the movements of gray wolves in Idaho, USA. They deployed 65 km of biofence within three wolf pack territories during summer 2010 and 2011 and used location data from satellite collared wolves and sign surveys to assess the effectiveness of biofencing.

51. FOX 2013 (USA-CA). The Marin County Board of Supervisors approved a community-based program to assist ranchers with livestock-predator conflicts known as the Marin County Livestock and Wildlife Protection Program (hereafter MCLWPP). The MCLWPP is a collaborative effort involving multiple stakeholders from local wildlife protection organizations to ranchers, scientists, and county government officials. Five years after implementation of the MCLWPP, a research assessment was conducted (Fox 2008) that compared the former Wildlife Services program to the MCLWPP, with regard to rancher satisfaction and preferences, lethality to predators, livestock losses, use of nonlethal predator deterrent techniques, and costs.

52. VAN LIERE ET AL 2013 (EU–SLOVENIA). Researchers aimed to characterize differences between sheep farms in wolf habitat in Slovenia that either suffered from wolf attacks or not during the main pasture seasons of 2008–2010. Sustainable animal production is mainly limited to sheep and goat breeding in mountainous and hilly perennial grasslands with shallow soils of poor quality. This Natura2000 area is an EU protected natural corridor with high biodiversity maintained by grazing small ruminants. It links the Alps in the northwest with mountainous Gorski Kotar in the southeast border with Croatia. It is also the main Slovene habitat for wolves. The total area of Slovene wolf territories is around 4700 km^2, implying a density of 1 wolf/100 sq km. The estimated total biomass of ungulates in these wolf territories is 245 kg/sq km. Sheep density was 23.3 per ha with goat mixed into the flocks on nine farms.

53. BECKER ET AL 2014 (USA-WA). In 1973, gray wolves were classified as an endangered species in Washington under the provisions of the ESA. In December 2011, the Washington Fish and Wildlife Commission formally adopted the Wolf Conservation and Management Plan to guide recovery and management of gray wolves as they naturally recolonize the State of Washington. At present, wolves are classified as an endangered species under state law (WAC 232-12-014) throughout Washington regardless of federal status. Washington is composed of three recovery areas which include Eastern Washington, the Northern Cascades, and the Southern Cascades and Northwest Coast. The WDFW is the primary agency responsible for managing wolves in the Eastern Washington recovery area while WDFW works as an agent of the USFWS in the remaining areas of the state. Wolves that inhabit tribal lands in the Eastern Washington recovery area are managed by those specific tribal entities.

54. JACHOWSKI ET AL 2014 (WORLD WIDE). Fences can both enhance and detract from the conservation of wildlife, and many detrimental impacts are associated with creating physical barriers. By contrast, virtual fences can restrict, control or minimize animal movement without the creation of physical barriers, and present key benefits over traditional fences, including: (1) no need for construction, maintenance or removal of traditional fences; (2) rapid modification of boundaries both temporally and spatially based on specific conservation concerns; (3) application of novel conservation approaches for wildlife that integrate monitoring, research and management; and (4) social-psychological benefits that may increase support for conservation. Researchers review the various types of sensory, biological and mechanical virtual fences, and the potential benefits and costs associated with fully integrating virtual fences into protected area management and wildlife conservation. The recent development of real-time virtual fences represents the potential for a new 'virtual management' era in wildlife conservation, where it is possible to initiate management actions promptly in response to real-time data. Wide-scale application of virtual fences faces considerable technological and logistical constraints; however, virtual fences are increasingly popular and soon will offer realistic management strategies for both terrestrial and avian wildlife conservation.

SUMMARIES OF STUDY FINDINGS

The findings from these studies are categorized into three focus areas: Husbandry Practices, Nonlethal Predator Control Methods, and Wildlife Management Strategies. Studies are referenced according to their numbering in the "Research Studies" section. Due to the complexities inherent in addressing multi-dimensional conflicts between livestock and predators, human applied strategies will also be multi-faceted. Therefore, certain studies will have findings reported across multiple categories. Additional context to the topics contained in these studies can be found in Appendix B.

SUMMARIES OF STUDY FINDINGS

I. HUSBANDRY PRACTICES

General Practices

STUDY 1. It is highly unlikely that any single factor is completely independent of other factors. Attempts to measure the data for the interaction of management practices was not possible. *Correlations between pasture characteristics and losses of sheep to predators do not necessarily imply cause-and-effect relationships.*

STUDY 8. On the basis of data and observations from 1975 to 80, the development and perpetuation of depredation problems in Minnesota was found to be related to three animal husbandry or farm management practices: 1) *Leaving livestock carcasses near farmyards or in pastures during winter and spring centered wolf activity there at calving time*. 2) *Allowing calving on pastureland also drew wolves to easy prey; and, 3) allowing livestock access to large wooded areas prevented them from being easily monitored.*

STUDY 29. Researchers for this study see *the greatest promise for reducing wolf depredation by improving animal husbandry, especially in high-risk seasons.*

STUDY 25. *Producers experienced less predation loss when they hauled away sheep carcasses, lambed during particular seasons, confined flocks of sheep to corrals, and maintained large flock sizes.*

STUDY 30. Depredation problems represent unique situations requiring consideration on a case-by-case basis to determine the best course of action. *Ranches should be individually assessed to determine which methods are most applicable given the time of year and sites where depredations are occurring.*

STUDY 32. Some people mistakenly believe that changes in livestock husbandry will prevent wolf depredation and that wolf depredations are often the producer's "fault." *Some conditions (sick cattle, carcass removal) are difficult to detect and resolve in remote areas.* Most wolf depredations occur on private land (70% of cattle and 48% of sheep).

STUDY 39. Wolf depredations occur in all habitat types including edges of densely populated urban areas. Population growth and range expansion of wolves has resulted in wolves occupying agricultural areas and increasing wolf-livestock conflicts. During expansion of wolf range in the Great Lakes Region, wolves have proven adaptable at occupying or colonizing human-disturbed areas.

STUDY 52. Within a year, repeated attacks by wolves usually occurred within 5 days of each other.

Facility Design & Location

STUDY 1. *Slightly more than 80% of all predator-caused losses were on 22% of the farms in the study. Sheep losses to coyotes were less on farms <1.6km from a town or human settlement than those located >8km.* On the other hand, sheep losses to dogs on farms <1.6km from a town or settlement were greater, likely being a reflection of predator density (more dogs than coyotes in human settlements). *As pasture size increased, rate of sheep loss to coyotes increased*. Rate of loss of sheep to dogs relative to pasture size was not as clear as for coyotes. Distance from a residence to the center of a pasture was not related to rates of losses of sheep to coyotes. Woven wire was the fencing material most commonly used. Fencing was designed to confine sheep, not exclude predators. Construction and maintenance of fences capable of deterring predators is expensive and the benefit would have to outweigh the cost. *Only a small portion of the sheep and lamb losses were in corrals. Losses of sheep to coyotes were higher in corrals without lights than with lights* but the reverse was true for dogs.

STUDY 4. Only *2% of 41 ranchers had experienced predation while flocks were corralled.* The average distance between corrals and hogan (homestead) was less than 200m.

STUDY 8. Aside from totally wooded pastures, areas with *a mosaic of fields and forests seemed to present the greatest opportunity for depredations*. *Wolves were reluctant to cross large open spaces. In areas with a sharp transition between expanses of forest and expanses of open pastureland, wolves generally remained in the forest.* The same finding was reported in the vicinity of Riding Mountain National Park, Manitoba.

STUDY 24. *Wolves preyed on livestock in townships sharing a consistent set of landscape features* across both states (Wisconsin & Minnesota) despite dramatic differences in the two states' wolf population sizes, wolf control policies and farm sizes. Pasture area and townships with high deer density was strongly and positively correlated with risk to livestock. Perhaps wolves select areas with many head of livestock. Alternately, deer prefer a mixture of forests and pastures so that wolves following the deer encounter cattle incidentally. *The roles of pasture and deer in wolf predation deserve further scrutiny.*

STUDY 29. Researchers detected a 3-season pattern to wolf depredations in Alberta, Canada and a 2-season pattern in depredation occurrence in the United States*. However, the greatest number of depredations occurred in August for both locations.* In Alberta and in the northwestern United States, there was a clear relationship between number of depredation occurrences in a particular season and occurrences during the same season in following years. *These findings indicated annual reoccurrence of depredation events.* [TABLE 1, p 880: Quantitative data tying control methods to depredations in western US and Canada.]

STUDY 30. The data from this study demonstrates that in the GYA, NWMT, and ID recovery regions that pastures with depredations compared to pastures without depredations were larger, had more cattle and were located further from human residences. These three ranch-size related factors were correlated. The data from this study found no differences between pastures with depredations and without depredations in regard to distance from forest edge, percent vegetation cover, cattle breed, cattle type and carcass disposal method.

The data from this study found no differences between pastures with depredations and without depredations for calving locations, calving duration and the date calving begins. Data from this study found that 5 of 7 pastures where depredations occurred during the wolf denning season were closer to wolf dens than grazed pastures on ranches without depredations. *Based on the above data, pastures predicted to experience depredations had elk present, had >310 head of cattle, and were far (>1,487.5,) from human residences. Elk presence was the variable most related to pastures with depredations and was the best predictive variable in classification tree analysis of pastures with depredations in combination with other variables.* Distance from human residence variable is still in question as this and other studies have experienced wolf depredations near residences.

STUDY 35. At a course spatial scale, the data suggest that most wolf-livestock conflicts in Montana occurred on private land and that some areas are more prone to conflict than others. *However, this could simply reflect that depredations are easier to discover on smaller, private pastures compared to losses on remote, rugged grazing allotments.*

STUDY 36. What type of livestock is being protected and where they are grazing are important considerations for creating a predation management strategy. *Permanent fencing has proven to be a very effective deterrent for smaller operations where livestock use night corrals or small pastures. For open range conditions, portable fencing and pens are more easily used and affordable*, but stress to livestock and native plants, and the conditions and restrictions of grazing permits must be considered.

STUDY 39. *The reoccurrence rate for wolf depredations on all species of livestock was estimated to be 23% at the farm level, 29% within 4 km of the farm, and 37% within 8 km of the farm. I*n Minnesota, the re-depredation rates were higher for sheep and turkey than for cattle. Wolves may live near livestock without causing depredations and proportionally few wolf packs cause depredations. *Generally, wolves kill livestock opportunistically when they find livestock in close association with wild prey.*

STUDY 52. There was no statistical difference between farmers with or without problems with wolves in the size of fenced area, herd size or density. *Number of sheep killed per attack tended to correlate positively with herd size and density. Farms with wolf attacks more often used open night barns or no night enclosure at all than farmers without attacks.*

Herd Management

STUDY 1. Kansas' primary lambing season is October-December during a time when predator demand for food is low. *Rate of sheep loss to coyotes and dogs was greater in flocks that lambed during January-March than in flocks that lambed in October-December or year-round. The highest monthly rate of sheep loss to coyotes and dogs occurred in flocks pastured day and night with no access to a corral, and the lowest rate of loss was in flocks confined to corrals day and night. Most predator losses occur at night so a pasturing-confinement scheme that takes this into account is a major option to reduce losses.* Lambing in confinement, although less convenient for large range operations, may be an economically feasible alternative if large losses of lambs are being incurred by individual producers in certain geographic areas. The data for this study indicate that sheep confined near human residences suffered less loss to predators than those far from residences, but the evidence was not strong.

STUDY 4. Eighty-eight percent of 51 ranchers herded mixed sheep-goat flocks for several hours in the morning and night. Twelve percent said they herded flocks throughout the day. Flocks were returned to corrals or kept near the homestead between foraging periods, which took place on open rangeland with no fencing*. A combination of walking and riding horses were used. LPD's were present at all times. Few ranchers had lost LPD's to coyotes.*

STUDY 21. The data indicates that for each day older a calf is when turned out onto an allotment, the calf's risk for wolf predation drops by five percent (5*%). On average, the surviving cohort of calves from our study were 24 days older than that of the wolf-killed cohort*. *Maternal age and experience level, as well as birthdate of calves, should be evaluated more fully as potentially predisposing livestock to wolf predation. Core area overlap between wolves and cattle appear to result in a higher predation rate for that herd. Cattle likely constitute a secondary prey item, one killed opportunistically by wolves. On several occasions wolves were observed in close proximity to cattle (<500m) without resulting in either predatory attempts or clear avoidance behavior by either species.* Wolf predation risk did not influence cattle movement patterns or group size, suggesting *that wolf-caused mortalities were not frequent enough to influence cattle behavior*. *Managers may be able to minimize the spatial overlap of wolves and cattle by implementing a system to move cattle away from wolf core areas during periods of intensive activity.*

STUDY 29. Grazing practices and *seasonality of calving* might explain the 2-season pattern of wolf depredation documented for the United States, *with more attacks occurring March-October* than from November-February. Unlike wild ungulates, domestic prey species are not allowed to move to new areas or to select suboptimal habitat to reduce depredation risk. This further explains adherence of temporal patterns in wolf depredation to patterns in grazing and calving practices. The data on seasonality of wolf depredation and on reoccurrence of seasonal patterns across years suggest wolf attacks on livestock are predictable across time. Ranchers and managers can use this data for predicting wolf depredation risk and for planning in advance investment of resources to prevent depredation increases.

STUDY 25. *Wolves predate on sheep 2-30x more than cattle and the phenomenon of surplus killing is only associated with sheep*.

STUDY 36. *Keeping records of wolf-livestock interactions and related observations can help producers identify trends, problem areas and vulnerable times of year, which can help improve the effectiveness of targeted, preventative measures. Count livestock on a regular basis. This is especially true in large pastures or areas with dense vegetation and/or rugged terrain where livestock could go undetected for weeks or months. When options are limited, moving livestock to an alternative grazing location temporarily to avoid wolf conflicts can be a win-win situation.*

STUDY 41. Findings on food waste and on killing in excess of food requirements demonstrate that wolves conduct 'excessive killing' on sheep (1.07 cattle/per attack, 14.48

sheep per attack) demonstrating their vulnerability as a prey species. Researchers were unable to assess if wolves would return to carcasses to consume more meat if human disturbance of the carcass had not occurred. *The number of cattle and calf losses due to the category called "other predators" (including wolf, grizzly, black bear) was no more than 3% of all mortality In Idaho, Montana & Wyoming during 2005.*

STUDY 45. *Losses reported from 93 flocks kept in pastures at night averaged 3.6 sheep per flock compared to 0.4 for 47 flocks always or sometimes returned to a barn. Losses dropped to zero when flocks were confined to barns in winter.* This study found no correlations between predation and flock size, number of dogs or shepherds' experience.

STUDY 52. The start or ending month of the pasture season did not differ between farmers with attacks and those without.

Human Presence

STUDY 1. The personal contact with all cooperating producers coupled with a monthly reporting system, which reduced reliance on the producer's memory, greatly increased the accuracy and reliability of the livestock loss data gathered.

STUDY 4. All family members participated in herding duties. The herder did not devote constant attention to the animals but intervened as necessary to change direction of the herd toward a desired grazing location, a water hole, or toward the homestead.

STUDY 5. The essential difference between management of dogs in the U.S. (mainly farm operations) and in Europe (mainly range operations) tends to be *the amount of time owner-operators spend with their stock.*

STUDY 13. *Important additive factors to the LGD effectiveness were the attentiveness of the herder, disposing of carcasses (burned,) and regularly moving the herd.*

STUDY 20. Guard dogs are used effectively in Europe and northern Asia where shepherds and ranchers work direct with the dogs. North American ranchers use guard dogs less frequently. In addition, dogs are often left alone to guard livestock, and some evidence suggests that this makes guard dogs less effective.

STUDY 32. *It is uncertain if more human presence (range riders) among widely distributed livestock like cattle reduces the risk of wolf depredation.*

STUDY 36. *Range Riders can monitor cattle while looking for signs of wolves and other predators, scaring any away. Sheep herders can work in shifts, with the herder on night duty focusing on spotting and scaring away predators while sheep are on bedding grounds.*

Livestock Guardians

STUDY 1. *Lower losses of sheep to coyotes were incurred by those with dogs compared to those without*. However, higher losses of sheep to dogs were suffered in this category.

Additionally, farm dogs may attract free-running (feral) dogs and may be enticed into killing sheep. Three producers reported their dogs killed sheep while six producers reported catching neighbor's dogs killing sheep and lambs.

STUDY 4. *LPD's were associated with herds throughout the year and were not excluded from any husbandry practices such as shearing, dipping and lambing*. Most ranchers said their dogs could not catch coyotes but mostly kept them away by chasing and barking. Most believed depredations would increase without the protection of dogs. *Ranchers said the simplest method of training pups to guard sheep was to raise them with an experienced sheepdog, preferably their mother.*

STUDY 5. Prevailing beliefs that guarding dogs would be more successful in fenced pastures than on range operations were not sustained, either in the national data or in the Oregon Pilot Project. In the United States, the only places where dogs were judged not effective were those where sheep scattered widely over a great area and never flocked, or where producers did not spend more than a minimal amount of time with the flock. *Dogs that protect livestock have to display a set of behaviors appropriate to their work. The natural variation in guarding dogs can be capitalized on by matching its behavior with the type of livestock operation and/or the style of the producer. Problems arose on farms with mixed stock where experienced dogs that were socially bonded to one species displayed predatory or protective displays against other species.* Disadvantages arose when a few dogs, trustworthy with sheep or goats, drove deer from the range where a producer earned part of his income from hunting leases. Producers for the most part were willing to accept the "mistakes" of young dogs, or an occasional loss of new lambs or odd sheep, due to the overall reduction of predation on the flock. *Guarding dogs enter into social interactions with predators, rendering their predatory behavior contextually inappropriate at best and inefficient at least.* This means that the predator may totally avoid a dog-guarded flock, or else enter into greetings, scent-marking, dominance displays, play, exploratory behavior or ritualized aggression, any one of which diverts the predator from attacking the stock. Thus the mere presence of the dog has the effect of disrupting a predator's behavior and thereby reducing predation on farms and ranches by 60-70% or more. This management system has attracted increasing attention and use not only because of its effectiveness but because producers feel they can take charge of what happens on their farms or ranches.

STUDY 6. Ratings of dogs from small pasture operations (<50 head) were better than for dogs on large pasture or range operations (m=1000 head). However, range operators only made up 10% of the study sample (39 operators) and of those, 66% rated their dogs very effective, 19% somewhat effective, and 15% not effective. All but one range operator recommended use of LGDs. *The top two common breeds for guarding from this study were the Great Pyrenees and Komondor. Dogs were more successful when they were reared with livestock from the time they were ≤2 months old.* Despite the indication that mixed-breed dogs of non-typical guarding stock may be effective guardians, few were identified in this survey.

STUDY 8. Effectiveness of dogs seems to be reduced in wooded or brushy pastures where livestock are dispersed, and in situations close to neighboring residences or other farm operations.

STUDY 10. Before producers obtained their guard llamas, they had been losing an average of 26 head (11%) annually to predation. After obtaining llamas, producer's losses dropped to 8 head (1%) annually. All producers reported continuing to use other preventive and control methods in addition to the llamas. Llamas averaged 2 years of age when introduced to sheep, with the most common age being 6-11 months. For the 201 flock introductions reported, the initial adjustment period lasted anywhere from a few hours to a week. Introductions were most effectively made in a corral. Llamas are canid aggressive and can be aggressive towards herding dogs and family dogs. Predation was higher in flocks guarded by multiple llamas then flocks guarded with a single llama. There appeared to be no differences in losses on open rangeland versus rangeland with cover (forested, shrubby, gullies, etc) but this needs further study. It appears that llamas do not reach their full protective potential until 1 to 2 years old. 80% of producers said that daily care for the llama is the same as the sheep, and no special feeds are given. 25% of 61 intact males and 5% of 135 gelded llamas attempted to breed ewes. In one instance a single male killed 100 ewes before the problem was determined. Five percent of producers reported their llamas were overprotective, so much so that they couldn't work with the sheep. *How guard llamas respond to group hunting canids is unknown. One rancher reported a 7-month old llama was killed by a group of coyotes.* [TABLE 1, TABLE 3, p9: Comparison of characteristics of guard llamas and guard dogs]

STUDY 11*. Further experiments should document how llamas react to canid predators in larger, fenced pastures, in open-range situations, and with flocks of different sizes.* More research is needed to determine how guard llamas react to the approach of more than one predator, such as group hunting canids.

STUDY 13. This study demonstrated that the top three rated livestock guardian dogs were Akbash, Great Pyranees and Komondor. It also showed that lambs have a statistically greater survival rate with guard dog presence while ewe survival rate did not vary. Open range producers experience higher mortality rates overall when compared with fenced pasture and feedlot operations. Producers who did not have guard dogs lost 5.9 and 2.1 times greater proportions of lambs to predators than producers who had dogs in 1986 and 1993 respectively. *Producer ratings of guard dog effectiveness at deterring predators did not differ between fenced pasture and open range operations. The data for this study indicates that guard dogs are more effective against mountain lions and black bears as predators on open range systems. Ewe and lamb mortalities decreased with the number of years producers used dogs*. Mortalities in this study did not vary with the number ewes or lambs/guard dog nor with the number of dogs/herd. This relationship may reflect producers adjusting numbers of ewes or lambs/dog or numbers of dogs/herd for each operation until mortalities are reduced to a certain level. Producers estimated that their guard dogs saved $891,440 of sheep from predation during 1993. This savings has an economic "multiplier effect" of about 2.7 which suggests the use of guard dogs added about $2.4 million of value to Colorado's economy during 1993.

STUDY 15. LGD are different from herding dogs. Herding dogs behave more like a predator with livestock threatening flocks and herds to move with clear predatory mannerisms. Guarding dogs are genetically adapted to retain some adolescent traits into adulthood, thus encouraging behaviors that bond them to their flock or herd. *To be effective LGD are required to be more strongly bonded to livestock than to humans. It is critical to remember that the dog* *is a working dog and not a pet. Because LGD are often used in conjunction with other predator control methods, it is difficult to attribute such reductions to LGD alone; however, many ranchers have been able to reduce other control measures after incorporating LGD into their management system*. *A crucial factor is early bonding to the flock, accomplished by placing 6-8 week old pups with the sheep. Pups older than ten weeks have passed the primary socialization stage where bonding is most successful, although some individuals have been bonded as late as twelve weeks (but with less positive results). It is recommended that LGDs be established with livestock in possible conflict zones before wolves arrival, giving the LGD time to establish a territory.* Data collected in the Absorka Mountains in Montana from 1990-1993 documented 40 bear-sheep encounters. Of these encounters, 29 sheep were killed in the 2 years before employing LGD's and 7 sheep were killed in the 2 years after employing dogs. *The use of donkeys and llamas as guardian animals isn't as promising as LGD's because most livestock are grazed on the open range and these animals need enclosed pastures to work best.* In addition European depredations are usually from large predators on open range systems where these guardian animals are likely to become prey themselves. 81% (91 total) of open range producers rate their dogs "effective" or "very effective" compared to 79% (671) of fenced pasture producers.

STUDY 20. *Guardian animals besides dogs remain largely untested against wolves, but a few anecdotes suggest little benefit.*

STUDY 26. *Wolves infrequently kill dogs and usually do not eat them. Only a few dogs killed in the NRM were fed upon and most conflicts appear territorial and competitive. At least 18 LGDs have been killed by wolves between 1995 and 2004 in the NWMT and GYA recovery zones.* The data from this study suggests that dogs are more likely to be killed by wolf packs. *Conflicts peak in summer when wolves are rearing pups and LGDs are in remote areas and most likely to encounter wolves.* Some conflicts occur in winter when wolf breeding behavior seems to make them more territorial and wolves seemed to seek out dogs. *All dog conflicts including LGDs suggest attacks by wolves are more likely when people are not present and the dogs are outnumbered or out-weighed.* Researchers of this study have never documented wild wolves and dogs breeding in the wild. LGDs have been an attractant to wolves and in some cases have befriended them, allowing the wolf to depredate on the livestock (sheep in the case cited) and in some cases joining them. Wildlife professionals speculate that multiple LGDs can repel lone wolves if the wolf does attempt to challenge them, and behaviorally, multiple LGDs might be less likely to 'accept' a strange wolf as a companion. *The case studies in this paper show a pattern where wolf packs with established territories and pups perceive dogs as trespassing 'wolves' and will, in some cases actively, seek out and attempt to attack and kill them. The authors speculate that defense of territory and pups is "considered a life and death matter by wolves."* Almost all of the dogs, including LGDs, were killed in areas within resident pack territories and were not being directly protected by people. LGDs can help reduce losses and are most likely to be successful when used in combination with other techniques to reduce the potential for depredations on livestock by wolves.

STUDY 32. Wolf packs search out, attack, and kill guard dogs so multiple dogs are often needed and herders must be nearby to protect dogs. Interest to try spiked collars to protect the guard dog was very limited, and they were rarely used in the field because the sharp spikes were perceived as a nuisance to the guard dog, other dogs, equipment, and herders.

STUDY 33. Dogs and other guard animals can be thought of as behavior-contingent, multi-sensory disruptive stimulus producers, and continued understanding of their training and use may result in what amounts to the ultimate disruptive stimulus device.

STUDY 36. Breeds that make good LGDs are not the ones that make good livestock herders. The ability of LGDs to protect cows from wolves has been tested (MN, MI) and some dogs demonstrated that, if managed correctly, they could be effective. *LGDs defend livestock from wolves most effectively by alerting people to the presence of wolves, not by fighting off wolves. Once they sound the alert they need human support, such as a herder who can use other methods to deter wolves by scaring them away. Keep LGDs away from active wolf den sites to avoid increasing conflicts with wolves' protective of their pups. For LGDs to work successfully, a thorough understanding of guard dog training and management and how this approach will work into a producer's management system is vital.*

STUDY 39. Wolf attacks on dogs in Michigan usually occurred during hunting and training for hunting and generally occurred on lands open to public hunting while hunters were ≥200 m away. Wolves use rendezvous sites during July through early October and will aggressively defend these sites, especially from other canids.

STUDY 42. The integration of LPDs gives producers an opportunity to become active managers in protecting their livestock, helping them become integrated and active stakeholders in the wider management process. Preliminary studies suggest that LPDs are effective for excluding mesopredators (e.g. foxes, raccoons, skunks) from pastures, reducing predation on ground nesting birds. Consideration of diseases that LPDs might introduce or perpetuate must also be considered and preventive actions taken. The researchers for this study support the opinion that LPDs are excellent disruptive-stimulus tools, and would further suggest that LPDs may be an aversive-stimulus tool that can cause predators and ungulates to modify their behavior (e.g. shift spatial use or time spent in an area due to the presence of a perceived threat). Several interactions between wolves and LPDs (recorded using a thermal camera, France) strongly suggested that wolves were not frightened by the presence of LPDs. Researchers observed two wolves remaining on the same alpine pasture for 10 hours and interacting with LPDs a minimum of 15 times. This suggests one role of LPDs is to disrupt the predatory behavior of wolves. *Additional research is needed to gain a better understanding of why LPDs are sometimes killed by wolves, how the number of dogs in use might relate to this, and whether LPDs attract wolves.* More rigorous research is needed to definitively assess the effectiveness of LPDs in preventing livestock depredations from wolves or reducing the risk of livestock contracting zoonotic diseases. *Research is needed to develop guidelines for use of LPDs with livestock on open ranges or on small alpine pastures in cases when a shepherd is not present.* Additionally, direct study of the economics of using LPDs might include more refined cost-benefit modeling to assess producer risk as well as the conservation value of LPDs. Information exchanges between those producers who already use LPDs and those who do not in Europe and North America could lead to the development of a program for research, education, and outreach that would further address the modern conservation challenges of protecting livestock and conserving valued wildlife.

STUDY 45. Of 34 LGD pups that were placed at farms in Slovakia during 2000–2004, 17 were successfully integrated into flocks during their first full grazing season, five were partially integrated, ten were separated from livestock by shepherds and two died. *Total known mortality by two years of age was ≥7 of 68 dogs, none by predation activities. Three more disappeared.* The presence of LGDs was associated with lower levels of predation and an absence of surplus killing. The mean loss reported at 13 trial flocks in 2002 was 1.1 sheep compared to 3.3 for 45 control flocks in the same regions.

STUDY 49. This study provides a general strategic plan from which others can derive their own tactics for developing LPDs to protect cattle from a variety of wildlife–related risks, such as disease and predation. Too much interaction has potential to render LPDs less effective in protecting livestock due to lack of motivation to remain with cattle and desire to be with humans. It is important, however, that pups are familiarized enough with producers that they can be caught and handled for training, transport, and routine health care. On two occasions LPDs abandoned their herds and began to chase and kill livestock nearby and had to be euthanized. This situation emphasizes the importance of routine monitoring and maintenance of LPDs by producers to ensure success. *Breed selection and number of LPDs to employ should be based on likely adversaries and characteristics of the surrounding environment.* Researchers observed that cattle can respond aggressively to predators in response to particular dog vocalizations. This study suggests that it is easier and safer to introduce a LPD to calves or heifers than with adult cows, and especially cows with calves. The specific calves researchers started their pups with remained with them throughout the research (2–4 years) which was believed to help later transition into larger herds. Naive cattle were quick to accept the LPDs presence along with its associated calves. The larger a given fenced pasture or the higher the local density of deer the less likely LPDs could be expected to keep deer from entering areas occupied by cattle. Researcher observations and producer accounts noted occasional cases of LPD killed mesopredators in protected pastures. Researchers found most producers using LPDs deemed them an asset and cost–effective supplement to their management regime. In these studies, LPDs demonstrated the ability to effectively protect livestock when raised with attention to details such as building strong bonds with cattle, minimizing potential to roam, and providing a suitable level of protection for the level of threat. [TABLE 1, p. 130: Common problem behaviors encountered with employing livestock protection dogs and methods for correction (with references) as observed during research directed at protecting cattle from wildlife–related risks in USA and Europe.]

STUDY 52. There was no difference between wolf attacks for farms with or without guarding dogs. Of the 30 farmers with wolf attacks, there was no difference between those with and those without guarding dogs in the number of sheep killed per attack. Four farmers with wolf attacks and 3 farmers without had guarding donkeys. Guarding donkey presence did not affect the number of sheep killed per attack.

STUDY 53. During 2013 in Washington, two wolf packs were responsible for 3 confirmed dog injuries and 1 dog mortality.

Reducing Attractants

STUDY 1. *Producers who buried carcasses or had them hauled away had lower losses to coyotes than producers using other disposal methods.* [TABLE 3, p. 901: Variables within management practices with differences in losses of sheep to canine predators.]

STUDY 8. Losses near buildings were usually in early spring when wolves were visiting livestock carrion that had been disposed of outside the farmyard during winter.

STUDY 18. *One Canadian study found that on farms that promptly removed dead livestock, predator losses were lower than on farms where dead livestock were not removed.*

STUDY 30. This study found no evidence that carcass disposal method was related to depredation problems. Researchers believe that the question of carcass disposal would best be addressed with information on carcass presence or absence near the time of depredation, and, more specifically, whether wolves had fed on the carcasses.

STUDY 36. *Hauling away, burying or burning livestock carcasses rather than leaving them in the field to rot reduces the chances of attracting predators.*

STUDY 39. *Fritts et al (1992) reported improper disposal of livestock carcasses may condition wolves to prey on livestock. Bradley and Pletscher (2005) found no relationship between livestock carcasses and depredations in Montana and Idaho, and Mech et al (2000) reported this relationship was inconclusive.*

II. Nonlethal Predator Control Methods

General Practices

STUDY 8. During this study flashing highway lights were installed at farms in response to 36 depredation complaints, surveyor's flagging was placed on farms in at least 8 instances, and a combination strobe light-siren device was placed at the problem site in 6 instances. These devices were used along with trapping in 17 instances. *Whether these nonlethal devices were successful in frightening away wolves is not certain. The public must be educated to realize that nonlethal methods will work only in certain circumstances and have realistic expectations of them.*

STUDY 9. *Penning sheep at night or fencing them was the most commonly used technique by CFA respondents to reduce coyote predation. Some respondents also reported using guard animals (dogs and donkeys).*

STUDY 23. It is suggested that solutions to human-carnivore conflict can be classified as those that modify behavior (of human, livestock or carnivore) and those that prevent the activities of humans and carnivores from intersecting in space.

STUDY 32. *The effectiveness of nonlethal tools seemed to be enhanced when several types were used in combination.*

STUDY 33. There are two conceptual approaches to repelling carnivores. Disruptive stimulus approaches act by disrupting appetitive behaviors and frightening predators away from resources. Aversive-stimulus approaches seek to modify behavior through aversive conditioning of the predator.

STUDY 35. The effectiveness of nonlethal tools seemed to be enhanced when several types were used in combination with each other. Wolf specific nonlethal deterrents have all worked and they have all failed at one time or another. Circumstances are different for each livestock operation, and the key is to select nonlethal tools that are economically feasible and have the greatest potential to decrease conflict in each unique situation.

STUDY 53. In Washington state wildlife managers have employed the following nonlethal and preventative control measures to minimize wolf-livestock conflict: fladry, electrified fladry, RAG boxes, hazing, increased operator presence around range livestock, range riders, providing wolf location data to livestock producers and range riders, and removal of injured and/or dead livestock from grazing sites.

Disruptive Stimuli

STUDY 22. The effectiveness of disruptive stimuli can be prolonged by randomizing stimuli and location and by using behavior-contingent technologies that selectively activate dependent upon behavior of the predator being repelled. *Effectiveness of disruptive stimuli is possibly influenced by availability of alternative food resources and if unprotected food resources are not available, the effectiveness of any nonlethal technique is limited.*

STUDY 33. *Predators will rarely form a conditioned response to disruptive stimuli; rather, they normally habituate to the stimuli, which eventually renders the approach ineffective.*

Fladry / Electrified "Turbo" Fladry

STUDY 20. In captivity, wolves appear willing to risk crossing fladry only after an extended period of food deprivation (>28 hrs). Results with captive wolves suggest that wolf avoidance of fladry decreases when food attraction is coupled with the stress associated with social separation. *The limited duration of fladry's effectiveness in captivity suggests that it would also be only temporarily effective for the management of wolves in nature. Results with baited sites and cattle pastures in Alberta suggest that wild wolves can be effectively excluded for at least 60 days from food sources and smaller areas (≤25 ha) by fladry barriers. The presence of available prey outside the fladry boundary is critical for enhancing its effectiveness. Fladry increases time and energy invested in testing prey vulnerability. Therefore, theoretically, wild wolves should leave the area to seek alternative prey and not risk crossing fladry.* Field experiments should be conducted without researchers monitoring the structures on foot in order to distinguish between avoidance of people and avoidance of fladry.

STUDY 22. Fladry has limited effectiveness for wolves and it does not appear to be as effective for other predatory species.

STUDY 32. *Fladry is more portable and less expensive to purchase and install than wire fencing. Fladry does not appear to inhibit the movements of wildlife other than wolves. Turbo-fladry incorporates a shock and is much more effective. Fladry must be constantly maintained due to wind and livestock caused damage.* Wolves habituate to fladry barriers in a few weeks or may walk adjacent to the line until they can find a place to cross.

STUDY 33. Fladry's effectiveness on less wary species (e.g. ursid and avian predators) is limited and initial estimates indicate a 60-day period of effectiveness for wolves. "Turbofladry" incorporates electrically charged wires with a fladry barrier. Using electrified wires paired with novel signals may promote an aversion to a barrier such as fladry.

STUDY 36. *Fladry can be used alone or as an addition to permanent or portable fencing. It is relatively inexpensive, but must be properly installed and maintained.* Turbofladry, fladry hung on electrified fencing, can increase the length of time that fladry is an effective barrier against wolves.

STUDY 37. *Human activity may be at least partly responsible for the effectiveness of fladry. Waning of the aversive response to the fladry could have been caused by habituation to the fladry or to the human scent.*

STUDY 39. From 2004-2006, WS installed fladry on nine farms in Wisconsin after wolves depredated (four farms) or harassed livestock (five farms). After 60-180 days on each property, anecdotal evidence suggested that wolves only crossed this visual barrier once and never depredated livestock within an enclosed pasture.

STUDY 43. Electrified fladry is similar to fladry in that it consists of flagging, however the nylon tine that supports flagging is replaced with an electrified wire. Electrified fladry relies on this additional aversive conditioning technique to increase its effectiveness after habituation has begun. Fladry kept captive wolves from crossing to food resources for up to 7 days. Electrified Fladry kept them from crossing for up to 14 days, but this was limited by the observation time of the study and needs further research. Wolves are adapted to feast and famine cycles and can survive for up to 17 days between feedings. The data from this study suggests that the duration of habituation to fladry is less when coupled with an increase in food motivation. *Duration of success and rate of habituation is dependent on individual behavioral variations. Thus failure of non-lethal tools such as fladry may partly depend upon persistent and bold individuals within a population.* Maintenance and installation has the potential to be a limiting factor in the applicability of electrified fladry. A change in the design to an integrated approach with existing fencing would decrease the number of people, supplies, installation time, transportation and handling.

STUDY 44. Researchers observed two wolf visits inside fladry-protected pastures when the fladry barrier was not properly installed or maintained. The first fladry (+21 days in place) failure was due to calves pulling down a 200 m section as they escaped. The second failure (+26 days in place) occurred when the producer failed to re-attach a fladry gate to the fence line after leaving the pasture. *Wolf visitations inside pastures compared to those outside pastures were less on fladry-protected farms, whereas, we found no difference in wolf visitations both inside and outside pastures on control farms.* The study found no difference in coyote visitations inside and outside pastures on treatment and control farms. Coyotes first crossed the fladry an average of 47 days after fladry establishment. During the 2004 field season, there were no wolf or coyote depredations on either fladry or control farms. During the 2005 field season, there were no wolf depredations on either fladry or control farms, but we did document 8 verified coyote depredations on 1 sheep farm with fladry. *The total costs to establish and maintain fladry on a 150-ha farm would be $4,392 [2010 figures] per year. It takes 40.8 labor hours to install a fladry line on a 150-ha farm. Annual depredation losses would have to exceed 37 lambs or 11 calves to equal the approximate costs of using fladry on a 150-ha farm.* It is important for farmers to gauge the risk of depredation with the cost and time commitments of using fladry on their farms. This study suggests that fladry, if it is maintained, can exclude wolves from livestock pastures for up to 75 days. Additional research should focus on the relationship between the frequency of visitation to fladry-protected farms and the time it takes for wolves to become acclimated to it. There was no long term exclusion for coyotes from fladry protected pastures discovered in this study. Researchers speculate that the gap on the standard fladry used in this study may have been too great relative to the size of the coyote and did not prevent them from accessing pastures. Future research should attempt to determine if modifications to standard fladry can effectively exclude coyotes from sites. *Researchers from this study suggest that it is important to install fladry independent and outside of existing livestock fencing.*

Visual & Acoustic Scare Devices

STUDY 8. *The combination strobe light-siren device reduced coyote depredations on pastured sheep when three to six devices were used, and thus may deserve systematic research trials with wolves in the future.*

STUDY 16. *No systematic research has been conducted to test the effect of frightening devices on livestock depredations by wolves.*

STUDY 19. *Visual and acoustic repellants act as disruptive stimuli to reduce a predator's desire to enter or stay in the area where livestock is located.* Rapid habituation can occur when the stimuli are not linked to any particular behavior of the predator. *Preliminary results indicate that RAG boxes are effective at deterring wolves from depredating cattle in small pastures.* An important limitation to the RAG device is that wolves or other predators need to be wearing a radio collar to activate it. Despite this limitation, RAG boxes may still prove cost effective in many management situations because of the high costs of other strategies (translocation, lethal removal). RAG boxes are not designed for open range situations but this drawback can be overcome by altering husbandry practices to incorporate night penning or pasturing of cattle or young calves. Continued monitoring in a variety of management situations and over a longer period of time will provide better understanding of RAG devices and their effectiveness for managing wolves.

STUDY 22. The MAG technology repelled all vertebrate consumers until the conclusion of the study. We did not evaluate the duration of effectiveness for the MAG device but such research is necessary, especially because different responses are likely from different predators.

STUDY 32. Wolves are afraid of novel stimuli and strange noises and light can temporarily displace them. *RAG can detect and record approaches of radioed wolves, allowing for more targeted control.* Wolves habituate to strange stimuli, especially when they go off regardless of wolf proximity. Scare devices can frighten and annoy livestock or people if close to dwellings [or on recreational lands]. *RAG devices require training and radio-collared wolves to work, and they are too bulky to use in remote areas. Individual devices cover a relatively small area and require livestock be confined.*

STUDY 33. The RAG is complicated because it requires radio-tagging predators, a significant effort. *The MAG uses passive infrared sensors to detect approaching predators. In a multi-predator system it has been determined that electronic devices (MAG) were more effective than passive disruptive stimuli (fladry) or electronic training collars.* More sophisticated sensor designs using radar and other technologies may result in sensors that are useful in a wide array of predation management situations. *Many aspects of electronic disruptive stimulus devices require more thorough research. The optimum area and duration of effective protection* *are not known.*

STUDY 36. RAG boxes are most effective for small pastures (<25 hectares). With a range of up to 300 meters, the RAG device is not designed to protect cattle on large, open range operations except when cattle are bunched during calving time or corralled at night. *The RAG box's internal computer can record the number of times the box has been activated and which radio‐collared wolf triggered the device, which can provide valuable information to managers on local wolf activity.*

Real Time Virtual Fence (RTVF) / Remote Alarm Aid

STUDY 28. The Remote Alarm Aid is a system designed to alert management personnel to the presence of individual radio‐tagged black bears in off limits areas of Yosemite National Park. Bear managers were able to detect four times the number of bears entering off limits areas with the message transmitter active than when it was inactive. *The alarm system helped park personnel focus search efforts to areas known to contain bears. The alarm system increased awareness and alertness of personnel, increasing their detection rate and improving their bear‐human conflict avoidance hazing program.* Inherent variation in radio‐transmitter signal strength made a zone of uncertainty around each monitoring system where an animal could have been detected. Furthermore, as the radius of the detection distance increased the size of the uncertainty zone increased logarithmically.

STUDY 54. Elephants in south and central Africa are managed to stay within the boundaries of game preserves with cellular phone based transmission of real‐time GPS location data from collars that trigger when the animal leaves an area. A task force is then dispatched to haze the animal back into game reserve boundaries. Alarm messages can be modified and restricted to certain animals, certain areas or certain times of the day or night. *The RTVF system allows for the management of risk across a wide geographic area without having to fence off areas physically, which causes impacts to a whole host of species other than the one being managed for.* Managers could establish virtual fence polygons surrounding key refuge and corridor areas that alert them to when human access to those areas should be limited. The organization "Save the Elephants" is developing an alert network that extends beyond wildlife managers to include private landowners outside of protected areas who can register their lands so as to be warned when elephants (in this case) have crossed or are approaching a virtual barrier near their land, (elephants raid agricultural crops). *There are at least 18 companies that produce satellite or cellular phone‐based GPS collars for wildlife, at least four of which have the capacity to be integrated into a RTVF system.* Through RTVFs managers can gain detailed monitoring records of animal movement that are well suited to adaptive management programs, and that can enable improved protected area management. For RTVF systems, the availability of real‐time locations can facilitate human‐wildlife interactions, providing managed viewing opportunities as well as helping to mitigate potentially dangerous interactions

Aversive Stimuli

STUDY 12. This study suggests that prey-killing aversion can be most readily established by applying response-contingent aversive stimuli during the chase and attack phase of the predatory sequence.

STUDY 16. Aversive conditioning refers to the elimination of an established, undesired behavior, by associating that behavior with some negative conditioning stimulus. The retention time of the conditioned response and the number of treatments necessary to achieve it are important measures of the success and practicality of a particular conditioning stimulus.

Electric Fencing

STUDY 7. *Livestock management workloads decreased after electric fence installation for 32 of 51 (67%) producers. A reduction in the need for lethal control after installation of electric fences was reported by 38 of 51 (75%) producers. About 95% of producers in this study said that electrical malfunction was a chronic maintenance problem. Potential for electrical malfunctions, physical damage, additional gates, more washouts, and predator ingress increase as fenced areas increase in size.* Most producers were satisfied with their fences even though expenses of construction and maintenance were cited as important liabilities. Most producers agreed that electric fencing decreased the need for intense lethal control; however, they indicated that lethal control was still needed to prevent predators from entering fenced areas and to protect sheep that were grazing outside of protected pastures. Reported sheep losses to predators were significantly reduced after installation of electric fencing for 46 producers with 2 or more years of electric fence experience.

STUDY 18. Fencing is more effective if it is strung before the predator has established a pattern of movement. Snow and frozen ground can greatly reduce the effectiveness of an electric fence.

STUDY 30. *Protecting hay supplies with electric fences or other means, especially during spring when cattle are calving, may minimize attractiveness to elk and thus wolves.*

STUDY 32. *Livestock confined for long periods can have husbandry issues with diseases, birthing, cleanliness, and foraging.* Wolves can easily go through barbed wire fence or jump over short fences, while woven wire and taller fences can be barriers to other wildlife. Wolf depredation is so uncommon that if fences become burdens to producers they stop using them.

STUDY 52. Two farmers witnessed wolves jumping electric fences up to 145 cm in height. Farmers with wolf attacks strongly preferred wire-mesh fencing compared to farmers with wolf attacks who used single horizontal wires or no fencing at all. *This study did not find that electric fences provided a noteworthy physical barrier to wolves as they did not reduce attack rates when wolves were persistently depredating a particular farm.* Researchers for this study would like to see more detailed research into how wolves move under, over and around barriers like electric fences.

Bio‑Boundary

STUDY 48. Scent mark trials with a reintroduced African wild dog pack habituated to human proximity consistently resulted in the pack moving in the direction of their familiar territory inside the protected area in the following 24 hours. The packs lengthy movements in the direction of the geometric center of their range are consistent with territorial avoidance of another wild dog pack. *The option to signal wild dogs to return to the relative familiarity of a protected area using translocated foreign scent marks represents a significant advance in management techniques.* Researchers for this study believe that the use of species‑specific semiochemistry for management of free‑ranging wildlife merits further investigation with other territorial species.

STUDY 50. *Biofencing effectively manipulated the movements of most radio‑marked wolves in this study although some exceptions occurred that may have reflected behavioral differences among individuals. Trespass of the biofence occurred 1‑14 days after refreshing, so researchers conclude that refreshing the line every 5‑7 days may be desirable if total exclusion is the goal.* Given that trespass between adjacent wolf packs is expected and common researchers suggest placing biofences between 2 and 3 km from an attempted exclusion area based on the average trespass distances (163 m to 4 km) they observed. Wolves seldom overmarked the secondary line of fencing so one line may be enough to control movements, thereby greatly decreasing deployment and refreshment time. The study sample size (three packs, 8‑14 individuals, over two seasons, 1 pack failed to breed & is disbanding) limits generalization and further evaluation to determine efficacy for wolves. A study sampling several animals per wolf pack and employing a treatment/control design would be beneficial, albeit expensive and logistically difficult. *Exploring the effectiveness of using more easily obtainable scats from captive wolves would be worthwhile. Use of automated howling devices might help fortify biofencing and increase its effectiveness.*

STUDY 54. By avoiding physical boundaries, virtual fencing provides a number of distinct benefits compared to traditional fencing such as few fence related edge effects, ease of use in multiple predator systems and low installation cost compared to traditional fencing. In contrast to traditional fences, all virtual fence techniques present key benefits associated with integrating monitoring, research and management action that could enhance wildlife population and protected area management. Future research is needed to identify optimal strategies for implementing virtual fencing for conservation programs that use either individual cues or multiple cues specific to a particular site or suite of species.

Electronic / Shock Collar

STUDY 12. Most shocks administered [to captive coyotes] during active pursuit resulted in an immediate interruption of the attack. Electronic training collars will have limited application for resolving conflicts with predators and the effectiveness of any application will need to be tested in the field. Primary applications will be where the extent of depredations or the conservation value of the predator can justify the costs of the method.

STUDY 22. *In this and other studies researchers reported that electronic training collars were difficult to use with wolves.*

STUDY 31. This study, using an adaptive management approach, found that the use of shock collars activated by a command center may have potential to help reduce wolf depredation on domestic animals in some situations. It appeared the shock collar by itself could drive wolves from farms, but unless wolves were able to relate the negative stimulus to some aversive signal, such as beepers associated with the shock, long-term avoidance was not possible. The command centers, which were located in the middle of calving pastures, were set up to emit a shock signal to the collar 2-3 seconds immediately before the shock command was sent. Researchers could hear the beeper from 200 m and because wolves can hear other wolves howl about 3 times as far as humans can, we assumed that wolves heard the beep >600m away. Repeated shocking of the wolves in our study did not affect the size or location of home range or den- and rendezvous-site attendance. *Nine calves were confirmed killed by wolves on the farm in 1998 but only 1 was killed after the shock collar was placed on wolf 724F (the lactating alpha female for the Chase Brook Pack.)* No calf kills were detected on the farm in 1999 and wolf 724F was not detected on the farm in 2000 when only 2 depredations occurred. In 2001 6 calves were killed and researchers captured wolf 367F who was lactating and appeared to have displaced wolf 724F as alpha female. Both collared wolves stayed off the farm while 5 command centers were operational. *It appears from this study that when an alpha female was caught prior to depredations that all depredations were prevented. When shock collars were placed on wolves after depredations had begun, it seemed less likely to affect other wolves.*

STUDY 32. The USFWS in the NRM region unsuccessfully attempted penned experiments with electric shock collars on 2 different groups of wolves that would have been killed for attacking cattle. These wolves were then released back into their territory where they depredated again. All were lethally removed. This experiment resulted in a large public outpouring of complaints for being inhumane.

STUDY 36. *Shock collars have had limited experimental use but have demonstrated effectiveness in causing wolves to avoid specific sites in the few studies conducted so far.*

STUDY 40. *Results of this study demonstrated that shock collars altered free-ranging, wild wolf behavior in and around a specific site. Shock-collared wolves shifted 0.7 km further away from the center of the zone during and after treatment occurred.* Similar to Shivik et al (2003) this study found variability in wolf response to shock units during captive trials. The researchers for this study believe that much of the variability was attributable to technological variation within shock collars rather than behavioral differences of the wolves. If a shock collar with a higher degree of consistency is developed and tested, results could show a long term conditioning effect and a greater reduction in or complete elimination of both wolf visits and time spent in an area. The shock collar design used in this study could be further developed and tested to extend battery life, consistent shock probe contact with the neck, and audible shock warnings. *Future research should attempt to quantify effects shock-collared wolves may have on other pack members.*

STUDY 54. The use of electric shock raises significant animal welfare issues, and such collars are illegal in parts of the United Kingdom and Australia.

Less-Than-Lethal Ammunition

STUDY 16. Projectiles [rubber bullets, soft slugs] give a generally positive result for use with bears, but the scope of their use is rather limited as they will kill or injure smaller predators or even bears if improperly used. Only trained wildlife management personnel should be allowed to shoot an animal with these types of slugs. *Projectile repellants will be difficult to employ against livestock-killing wildlife as they must be used while in the act of killing livestock and are unlikely to provide much help against depredation.*

STUDY 32. USFWS developed a program of agency-issued permits and training, and provided 12-gauge shotgun cracker shells, bean bag shells, and rubber bullets to shoot at wolves. These munitions fire up to 100m and can hurt a wolf or explode near them. USFWS issued 200 permits and wolves were fired at numerous times. Only 3 wolves were reportedly hit and none were permanently injured. The permit, training and monitoring processes were time intensive although it allowed for a positive interaction between landowners and agency personnel prior to serious conflicts. *Munitions require a wolf be seen and at close range, and the landowner have a shotgun handy right at that time. Close encounters with wolves are relatively rare, and interest in obtaining the permits waned after a few years.*

STUDY 33. Nonlethal projectiles can be combined with harassing dogs as an aversive stimuli. Many predators are likely to develop a conditioned aversion to the person or vehicle applying the conditioning stimuli, rather than generalizing to an area or behavior. The duration of effectiveness for less than lethal ammunition strategies for black bears is about 1 month.

Conditioned Taste / Food Aversion

STUDY 2. One herd suffered very high identified domestic dog losses during 1978 before alternative elimination could be initiated, and finally, this manager and one other refused to maintain continued baiting or carcass lacing through each season, even though baits were placed yearly.

STUDY 3. The change in the numbers of lambs lost between 1978 and the preceding 2 years was not different between farms baited with LiCl and placebos. Thus, the LiCl treatment did not measurably reduce predation losses. Control was initiated when predation occurred, and was required on 5 of 8 farms baited with placebos and on all 9 farms baited with LiCl.

STUDY 8. An experiment with taste aversion on wolves was conducted in 1979 and 1980 (Gustavson 1982).

STUDY 9. *Sixteen percent of program participants rated CFA as very successful, 38% as somewhat successful, 36% as unsuccessful, and 10% indicated no opinion. However only 1 person in the program was still using CFA. Results of our study, when combined with the negative findings from a large-scale study in Alberta [Bourne & Dorrance 1982] and several* *studies on captive coyotes suggest that the proposed CFA technique may not be sufficiently effective to warrant its use.* Other attempts to get animals to generalize an aversion from a treated to an untreated food source have succeeded. However in those cases the treated food closely mimicked the untreated food. The lack of close mimicry between a treated bait package and alive sheep or lamb may be a fundamental factor that diminishes the effectiveness of CFA as a predator control method.

STUDY 12. Various applications of aversive chemicals to the necks or bodies of sheep have been unsuccessful in establishing aversion to live prey in coyotes. *CTA has not led to rejection of live prey under practical field applications because coyotes apparently rely primarily on visual stimuli rather than taste and odor stimuli when capturing prey.*

STUDY 16. There continues to be controversy over this technique, with inconsistent results leading to questions as to whether an aversion to eating a particular animal will deter killing of that animal. Gustavson in 1982 reported no change in wolf predation in Minnesota with LiCl baiting. The concept of CTA/CFA still has merit, but perhaps further research should concentrate in another direction.

STUDY 33. *CTA may be useful in many situations and should continue to be examined, especially for limiting consumptive behaviors, if not predation behaviors.*

III. Wildlife Management Strategies

General Practices

STUDY 32. Intensive and intrusive management enforces unrealistic public perceptions about wolves and the resources needed to manage them, compared to other wildlife management and damage control programs in the western U.S. *USFWS loans radio telemetry systems to ranches that have had depredations so they can locate radio-collared wolves in their area. Although this provides ranchers with an increased sense of security, detection is limited to line of sight and a few miles on the ground and it does little to affect wolf-livestock hunting behavior.*

Contraception / Sterilization

STUDY 17. Among coyote packs that killed sheep intact coyote packs killed 6 times more sheep than sterile packs. The data for this study indicates that coyotes change their predatory tendencies when pups are present and that sterilization could be an effective method of reducing coyote predation on domestic sheep in the Intermountain West. For this technique to be successful, the breeding pair must be sterilized. In some areas where pups were present, no lambs were killed by some coyote packs even after 3 years of exposure to sheep. A more efficient method of fertility control would likely be needed for application as a viable management tool on a larger scale. Sterile coyotes maintained territories and pair bonds in a manner similar to non-sterile coyotes.

STUDY 31. It might be possible to use the shock-collar system in conjunction with sterilization to create "conditioned" wolf packs that do not produce pups but continue to occupy regular territories. Conditioned packs maintaining territories may prevent dispersing wolves from establishing territories and reduce local coyote abundance, which may further reduce depredation losses.

STUDY 33. *Contraception/sterilization may be counterproductive as a conservation tool but there is room for more investigation, because sterilization may help to stabilize local populations of predators and have longer-lasting effectiveness than lethal methods, at least for territorial predators.* Appropriate chemical contraceptives and delivery systems have not yet been developed and additional research is required.

STUDY 39. Surgical sterilization of wolves has been assessed for its feasibility for preventing wolf depredations. Breeding wolves die or can be displaced by other wolves and territories shift: this would require additional wolves be sterilized and if a wolf harvest was implemented it would require protection of sterilized individuals.

Translocation / Lethal Removal

STUDY 23. *In Wisconsin translocated adult and yearling wolves had significantly higher mortality than other radio-collared adults or yearlings.* Translocation can work if the individual is transported sufficiently far that it cannot return home and is placed in suitable habitat with territorial vacancies. *A survey of systematic studies of lethal control suggests that 11-71% of the carnivores killed to prevent conflict showed no evidence of having been involved in recent conflicts.*

STUDY 27. This study examined 63 individuals and 9 cohesive groups of translocated wolves (moved because of livestock conflict) to determine whether they preyed on livestock or established or joined a pack after release. Overall most mortality of translocated wolves was caused by humans, with government control and illegal killing as the first and second leading cause of mortality respectively. Soft-released wolves were less likely to return to capture sites than hard-released wolves. Soft-released wolves travel shorter distances after release than hard-released wolves. *Translocated wolves showed a strong homing tendency. Most wolves, whether attempting to return home or not, moved away from the release site. Wolves that were translocated shorter distances were more likely to return home*. Wolf translocation was not always effective at reducing predation on livestock. *Translocations helped further wolf recovery by establishing eight new packs. However, most translocated wolves (67%) died or disappeared without ever establishing new territory. Release site selection is important and the extent of available habitat should be given the highest consideration when translocating wide-ranging animals such as wolves.*

STUDY 29. In Canada and the United States there was a strong relationship between wolf depredation and wolf removal, which was consistent with other studies that employed regression analysis. In either country, the absence of negative correlations indicated that wolf removal was corrective, not preventive. *This analysis, which was conducted on a regional scale, does not support the notion that removal of wolves at current intensity reduced depredation, immediately or in the following years.* Further research is needed to evaluate the cost-effectiveness and socio-economic benefits of wolf control. For example, it would be helpful to gather information on specific properties receiving lethal control and the fate of the livestock on the properties where wolves were lethally removed in future years.

STUDY 32. Just as removal is not a replacement for nonlethal tools, nonlethal tools are not replacements for targeted removal. Both appear useful and to enhance each other's effectiveness. *Removal addresses immediate conflicts but does not prevent conflicts from reoccurring in that area the following grazing season. Removal results in a cycle of wolf colonization, depredation, and wolf removal that repeats itself. Local producers supported wolf relocation, but producers where the wolves were released did not. Relocated wolves caused additional depredations.*

STUDY 33. Lethal removal may be an important long-term practice for selecting against depredation behaviors in predator populations and is ultimately useful for conserving predators.

STUDY 35. As an initial response to confirmed depredation, we believe full pack removal has limited utility, although it can provide immediate relief, albeit short-term until the "vacancy" is filled by the next pack. Researchers for this study believe the combination of proactive nonlethal deterrents combined with strategic incremental lethal control of problem wolves is the best way to resolve wolf-livestock conflicts.

STUDY 37. With the possible exception of removing an adult male, age and sex of wolves killed had no effect on re-depredation rates. Total number of animals removed did not appear to affect re-depredation rates. *None of the correlations from this study supported the hypothesis that killing a high number of wolves reduced the following year's depredations at state or local levels. Researcher's analyses of localized farm clusters showed that as more wolves were killed one year, the depredations increased the following year.* For all analyses, trapping but catching no wolves led to lower recurrence than not trapping at all, which suggests that the mere increase in human activity and the introduction of foreign odor and objects at a depredation site might have been enough to reduce further depredations. For depredations on sheep, killing wolves was more effective than unsuccessful trapping or not trapping similar to Fritts et al 1992. *Experimenting with a regimen of daily visits simulating trapping activities might show that such an approach is more cost-effective than trapping and killing wolves, especially at farms that require long travel by controllers.*

STUDY 39. Lethal removals are appropriate when wolves are actively harassing or hunting livestock and consideration for stakeholders who are negatively impacted by wolves must accompany wolf recovery. Removal of human-habituated wolves will become more important as wolves continue to colonize unsuitable areas.

STUDY 47. Except for the black bear and the brown bear, the number of lost livestock that could be compensated with the money spent on one translocation was greater than the number of individuals that a given carnivore could have killed in one year. Despite many possible mortality causes in translocated animals, human-related mortality accounted for 83% of the death causes. Homing behavior appears to be common in all carnivore groups and soft-release procedures may help to reduce it. Critical release distances to avoid homing on large carnivores usually range between 100 and 300 km, but could >500 km for some species. *From a conservation perspective, translocation appears equivalent to lethal removal for 6 out of 10 individuals.* The evidence presented in this study shows that in the vast majority of cases, a well implemented compensation scheme, associated with best herding practices, would be a more cost-effective alternative rather than translocating endangered carnivores.

STUDY 53. The WDFW has full management authority of wolves in the Eastern Washington recovery area and, under state law RCW 77.12.240, can implement lethal measures to control depredating wolves to detour chronic livestock depredations. However, in the western two-thirds of Washington, where wolves remain classified as an endangered species under the federal ESA, WDFW must consult with USFWS to ensure that any management actions being considered are consistent with federal law. Under state law (WAC 232-36-051), and the provisions of the Plan, WDFW may issue "Caught-in-the-Act" permits in the Eastern Washington recovery area to livestock producers and their authorized employees for wolves attacking livestock on private land and public grazing allotments they own or lease after a documented depredation. These permits are not available in the western two-thirds of Washington.

Planning, Conservation, Mitigation, Education

STUDY 8. Researchers believe that perception of the depredation problem in Minnesota exceeded the actual problem, because the term "wolf" was often used for both coyotes (*Canis latrans*) and wolves in Minnesota. Distinguishing wolf from coyote depredation was a common problem, stemming in part from the public's failure or inability to distinguish between the two canids. Thirty-nine percent of the 570 cattle claimed killed by wolves were missing cattle. Actual loss of cattle and other livestock to wolves lies between the verified and claimed loss figures. Often a few wolves have a disproportionate effect on the state's compensation program. We consider the Minnesota compensation program successful and well worth its cost, but suggest that payment be reduced or withheld when correctable husbandry practices seem responsible for depredations.

STUDY 20. *It has been suggested that compensation programs should be designed in combination with incentives to encourage preventative management.*

STUDY 21. The carcass detection data suggest that current compensation procedures in the western United States might be compensating for one-eighth the actual losses incurred by cattle producers from wolf predation.

STUDY 24. Policymakers can use data derived from this spatial model to more precisely define management zones regarding human-wildlife-livestock conflicts. Being able to anticipate sites and conflict can focus outreach, deterrence, and mitigation efforts where they are needed. Locally, wildlife managers, researchers and farmers could use this spatial model to tailor research and interventions according to local conditions.

STUDY 25. *Because large populations of native ungulates and abundant livestock have never been studied in relationship to wolves, there is little known about the impacts that wolves might have on these simultaneously present native game and livestock populations.* Often it is found that kills are relegated to a few ranches (i.e. hot spots) and that wolves can have a significant economic impact on these individual operations. *The data indicate that the size of the wolf population did not affect the rate at which they killed livestock.*

STUDY 30. Of 31 ranches with confirmed wolf depredations, 15 (48%) claimed to have additional unconfirmed depredations.

STUDY 32. Twice wolves were documented around livestock without conflict, but within days they attacked and injured livestock placed in the same pastures. Both instances involved young calves, one killed after being treated for severe cuts by a fence, and another after being treated for frostbite. Compensation programs have several challenges. First, they only mitigate for damage and do not provide an incentive to allow wolves to be present. Second, they do not reimburse producers for the full costs of wolf damage which may include unconfirmed or missing livestock losses. Still, compensation programs may help reduce negative attitudes towards wolves and attempts to illegally kill them. *Personally-conducted outreach by agency personnel reduces misinformation and rhetoric, and it lets wildlife professionals hear first-hand the concerns of livestock producers/landowners and wolf advocates.*

STUDY 33. There are three means to gauge the effectiveness and use of management tools. New tools should be applied in an adaptive management system during the limited periods of use indicated, and with a focus on understanding why they worked or failed to be effective. *While technological advances may well lead to further improvement in predator management, ultimately some of the tools that are most desperately needed are social ones.*

STUDY 34. Researchers present a step-by-step procedure for navigating the political, social, and strategic aspects of human-wildlife conflict management. When local stakeholders identify human-wildlife conflict as a priority, participatory planning may improve perceptions of projects, partners and outcomes. Joint objectives should include both protecting human welfare and abating threats to wildlife.

STUDY 36. *Agencies, Ranchers and NGO's may be able to pool resources to establish range-rider or herder programs.*

STUDY 38. The goals of participatory intervention planning (PIP) workshops were to help participants consider all possible types of interventions and weigh the relative merits of the alternatives with standard criteria. PIP workshop brainstorming was structured and preceded by a critical first step that defined the cause-and-effect relationships underlying a given human-wildlife conflict. This step exposed multiple possible focal points of intervention. Researchers identified eight distinct types of direct interventions to reduce the severity or frequency between wildlife and people or their property and five distinct types of indirect interventions intended to raise people's tolerance for wildlife encounters. Researchers for this study expect that additional methods will be added as researchers and practitioners around the world report on their observations and experiments. *Three common problems in planning in interventions are: 1) the assumption that only one or a few solutions exist for a given threat; 2) related to the first, the selection of the first solution that comes to mind to the exclusion of others; 3) the selection of interventions in any field should be based on feasibility, not just effectiveness, which includes cost-effective design, wildlife specificity, and sociopolitical acceptability.*

STUDY 39. From the years 2002-2006 WS verified 277 depredations of livestock animals by wolves, coyotes, bears, and domestic dogs. Of these, 69% were depredated by wolves, 28% by coyotes and 3% by dogs or bears. In Wisconsin, livestock producers have an incentive to report wolf and bear depredation because of compensation whereas coyote depredation is not compensated. *Conflict management needs to be flexible because depredation scenarios are multifaceted.*

STUDY 41. *Results suggest that difference in morphology, behavior and husbandry between sheep and cattle induce different predatory behaviors in wolves, represented as excessive killing of sheep in relation to wolf food needs.* Compensation providers should be aware of excessive killing of sheep by wolves. Compensation providers should identify and regularly communicate with sheep producers within wolf range to ensure that depredation events are identified and compensation is delivered promptly. *Managers from this study suggest that if wolf conservation is a recognized societal objective then public funds destined to wolves may be used to contribute to habitat conservation more directly. For example, wolf conservation programs could contribute funds to support ecologically-friendly livestock* *production on rangelands thus conserving habitat for large ranging wildlife species, such as wolves.*

STUDY 46. In Washington, residents were less accepting of landowner compensation schemes for wolf-related livestock losses, but were slightly more accepting of these strategies if the funds for compensation came from the sale of hunting and fishing licenses rather than from state tax dollars.

STUDY 51. *The Marin County Livestock & Wildlife Protection Program (MCLWPP) initiated cost sharing to help ranchers install or upgrade fencing and other livestock protection infrastructure, install predator-deterrents and detectors, and purchase and sustain guarding animals, coupled with indemnification for any ensuing verified livestock losses to predators.* MCLWPP participants do not give up their rights to kill predators consistent with state and federal laws. MCLWPP provides a cost-effective, ecologically beneficial model to address carnivore-livestock conflicts and guide the development of other non-lethal programs across differing landscapes.

STUDY 53. In Washington, livestock producers can work actively to minimize conflict with wolves by receiving technical assistance from WDFW staff under a Damage Prevention Cooperative Agreement which enables producers to receive cost-sharing for deploying prescribed nonlethal conflict prevention measures. In cases of depredations considered "confirmed" or "probable" by WDFW personnel, producers can receive compensation from damage caused by wolves under RCW 77.36 and WAC 232-36.

STUDY 54. The implementation of RTVFs and remote monitoring of permeable barriers in particular, represents the potential for a new 'virtual management' era in wildlife conservation, where it is possible to initiate management actions promptly in response to real-time data.

APPENDICES: LITERATURE REVIEWED

APPENDIX A: STUDIES CITED

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