Agricultural Risk Management: The Case of Wildlife Risks

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When agriculture, wildlife, and risk are mentioned in the same sentence, thoughts often turn to risks agricultural production imposes on wildlife (e.g., habitat degradation and pesticide exposure).

The imposition of risk can, however, work in the other direction as well. Wildlife populations on agricultural land create a unique set of risks for producers, few of which are considered in traditional risk management discussions.

The purpose of this bulletin is to:

1. increase awareness of wildlife-related risks in agricultural production,
2. describe common wildlife-related risks in Wyoming and potential management strategies, and
3. outline a systematic framework for managing wildlife risk.

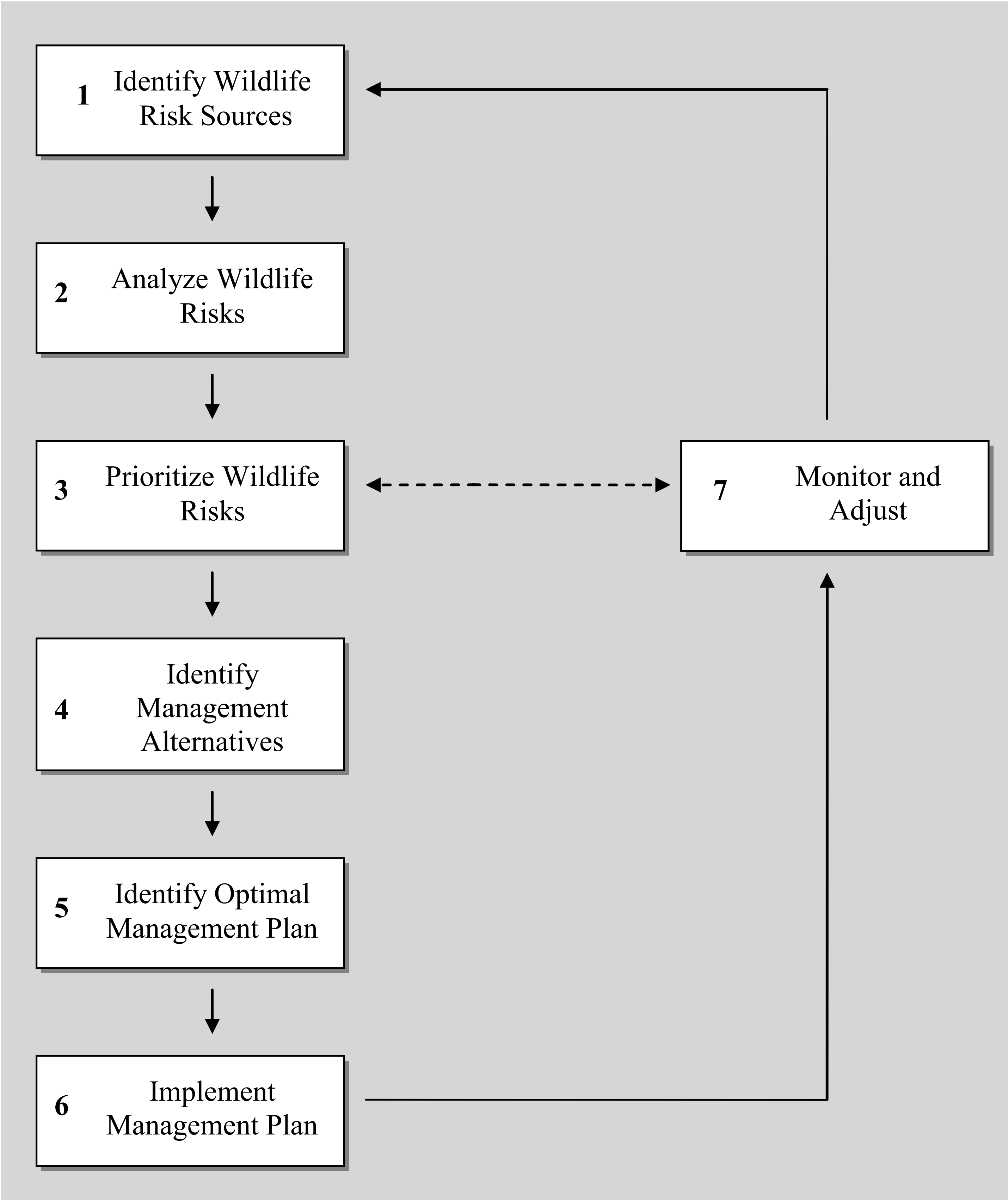
As human populations expand into rural areas, viable wildlife habitat becomes more scarce, and wildlife increasingly depend on remaining private agricultural land to offset habitat loss. Additionally, land that is productive for agricultural development is often productive for wildlife. Wildlife and agriculture are therefore inextricably linked. Many wildlife species in Wyoming depend on private land for all or some portion of their lifecycle. Antelope, deer, elk, and moose, for example, depend on private land for more than 50 percent of their annual habitat needs (Coupal, 2004). Conflicts between wildlife and agricultural production are inevitable.

Numerous articles have been written about wildlife damage management (see e.g., Brockmann, 1992). This bulletin differs because it makes a distinction between wildlife damage management and wildlife risk management. Agricultural producers experience damage as a result of wildlife activities on private lands, and tools exist to manage wildlife damage once it has occurred (e.g., depredation claims). Risk management, in contrast, refers to managing potential damage: taking steps and actions before damage actually occurs. Risk management is an inherently difficult process because it requires that decisions be made under uncertainty. Management of wildlife risk is intuitively similar to the management of any other source of agricultural risk; however, wildlife risks may be more subtle, and the likelihood of their occurrence is often difficult to estimate (e.g., wildlife-livestock disease outbreaks). Carefully and systematically considering the risks wildlife generate for their operation may therefore be worthwhile for producers.

Strategic Risk Management in the Context of Wildlife

Because wildlife risks are intuitively similar to other agricultural risks, there is no need to reinvent the proverbial risk management wheel. The Strategic Risk Management Process (SRMP), developed by The RightRisk Education team to help producers manage all types of agricultural risk (see Hewlett, 2002), is readily applicable to wildlife risk. Using the SRMP as a guidline, we propose seven steps to managing wildlife risks.

Steps to Manage Wildlife Risks



Step 1. Identify Wildlife Risk Sources

The first step in managing wildlife risk is to identify potential risk sources using a systematic approach to ensure no source is overlooked. Many wildlife risk sources may seem marginally important (e.g., crop damage from rodents); however, taken collectively, related risk sources may have important cumulative impacts (e.g., crop damage from rodents, birds, and deer). Because many wildlife risk sources are subtle, categorizing them into different types can be helpful. Agricultural risks can be divided into five general categories: 1) production, 2) market/price, 3) institutional, 4) human resource and 5) financial (Hardaker, 1997; Sprague, 2008). It is important to acknowlege that many risk sources cut across several of these general categories. The threat that brucellosis will be spread from wildlife to cattle, for example, creates an obvious production risk, but the ramifications of an outbreak will likely present institutional and price risks as well. Mitigating such a risk requires that producers simultaneously consider multiple, interrelated risk categories. Thus, while categorizing risk can help frame the risk management process, we should not forget wildlife risks are complex problems that often cannot be easily categorized and individually managed. With that caveat, wildlife risk intuitively fits into the first four general categories:

1. **Production risk** – uncertain agricultural yields due to risk sources such as weather or pests. In the context of wildlife, common production risks include:

    a. Damage to crop and rangeland

    Many wildlife species feed on the viable parts of cash crops, thereby reducing yields (Johnson, 1987). Wildlife can also damage cash crops by trampling them. Plants like corn and wheat are especially susceptible to trampling because mature kernels and ears may be shaken from the plant and lost from harvest (Demaree, 1994). Partially consumed and damaged crops can also reduce the quality of remaining crops. After crops have been harvested, mice and other small rodents may contaminate stockpiles and destroy packaging material, making the final product unfit for consumption (eXtension, 2008). During winter months, deer, elk, and antelope eat hay that has been stockpiled for cattle forcing the producer to replace hay eaten by wildlife (Demaree, 1994).

    In the context of rangelands, gophers, prairie dogs, and ground squirrels damage the land in ways that can harm livestock. Burrows present a hazard to livestock, which can lead to crippled animals. Large networks of rodent burrows can also cause erosion, which potentially affects water runoff patterns and the productivity of the landscape. Beavers can also affect rangeland and cropland by diverting water, flooding lowland areas, plugging canals, and damaging irrigation systems.

    b. Disease

    Wildlife are capable of transmitting a variety of diseases to both livestock and humans, including hantavirus, Lyme disease, rabies, encephalitis, brucellosis, leptospirosis, bluetongue, psittacosis, and plague.

    Brucellosis is of particular concern to livestock ranchers because elk and bison can spread the disease to cattle. Elk winter feed grounds in northwest Wyoming have allowed the elk population to grow artificially large, which may increase the threat of brucellosis by up to 10 times the natural rate (Robbins, 2006). A brucellosis outbreak in a Wyoming cattle herd in 2003 was attributed to transmission from elk. Wyoming cattle producers lost their disease-free status and were required to test all cattle leaving the state. Losses from the outbreak include not only the infected cattle herd, which was quarantined and culled, but also the time, productivity, and sales Wyoming producers lost because of the outbreak.

    Bluetongue virus is also of concern because of its potential to devastate sheep herds. Sheep producers in the Big Horn Basin of Wyoming experienced significant losses from bluetongue in 2007. The outbreak was attributed to infected pronghorn and deer. Bluetongue is spread by midges that cannot cover large distances (WSVL & WGFD, 2007). Thus, an infected midge is likely to transmit bluetongue only to other sheep (and wildlife) in the vicinity. This leads to an epidemic in one flock and potentially disastrous losses to an individual producer.

    c. Predation

    Livestock depredation by bears, wolves, coyotes, and mountain lions is a topic of concern for livestock ranchers. Certain regions of Wyoming are more prone to predation than others. The Big Horn Basin, for example, is home to the Washakie, Owl Creek, Greybull River, Carter Mountain, Absaroka, Sunlight Basin, Beartooth, and Red Lodge wolf packs (NPS, 2004). Cattle ranchers in these areas face greater risk from predation than producers elsewhere in the state.

    Wyoming predators depredate wildlife as well, which poses two risks to agricultural producers and private landowners. First, as wildlife migrate onto private land, predators may follow, thereby increasing the risk of livestock depredation. Second, many private landowners derive utility (and in some cases income) from wildlife hunting and viewing opportunities. Predation can decrease wildlife populations and with them hunting and viewing opportunities.

    Overall, the threat of depredation creates uncertainty and risk for livestock producers. Livestock losses to predation are relatively small industry-wide, but individual ranchers may suffer significant losses.

2. **Market/price risk** – uncertain input and output prices. In the context of wildlife, common market/price risks include:
   a. Increasing control costs
      Fences, noisemakers, pesticides, and other deterrent devices are used to guard against wildlife damage. Unexpected increases in the cost of deterrent devices pose a price risk. Vaccinations against diseases transmitted by wildlife are also susceptible to price shocks. Drastic changes to vaccine prices may affect the number of animals that can be vaccinated or the type (and therefore efficacy) of vaccination. Both responses to a higher vaccine price could increase the risk of a disease.

3. **Institutional risk** – uncertainty about regulations and policies due to changes in the social, political, or legal environment. Typical examples include policies restricting pesticide use, subsidy and tax policies, and waste disposal laws. In the context of wildlife, examples of institutional risk include the following:

   a. Threatened and endangered species
      The Endangered Species Act of 1973 provides protection for listed animals on both public and private land. Protection of listed animals and their habitat on private lands can put landowners at odds with wildlife. Relocation and protection programs are supported by tax dollars, but agricultural producers sometimes incur additional costs in the form of reduced agricultural productivity or foregone development opportunities. Additionally, if land near a farm supports a protected species, the legal status of pesticides or other chemicals may change.

   b. Chemical controls and vaccines
      Many chemicals once commonly used are now prohibited by the EPA due to their negative environmental impacts (EPA, 1988). Producers who use chemicals to deter wildlife, or enhance crops or livestock production, face institutional risk because the use of these chemicals might be prohibited in the future. Additionally, vaccines to protect livestock from wildlife-borne diseases are governed by regulatory processes. Changes in the status of vaccines can present a significant institutional risk to producers.

   c. Liability
      Wildlife on private land creates opportunities to supplement agricultural income with income from commercial recreation, such as hunting and fishing. A landowner is liable for the well-being of the people on their land, even if they are uninvited. The degree of legal liability in Wyoming depends on the types of activities occurring on the land and precautions the landowner takes (Schroeder, 2002). Schroeder and Olsen (2002) provide additional information about minimizing landholder liability from recreational use of private lands as well as state statutes that dictate legal responsibilities. Landowners need to determine the degree to which they are liable for various types of guests to understand their exposure to legal risk.

4. **Human resource risk** – unforeseen personnel changes. Typical examples include injury, prolonged illness, or death of farm operators or personnel. Specific wildlife-related examples of human resource risk include the following:

   a. Predation
      On rare occasions, predators attack ranch employees creating health risks for which the producer may be liable. Attacks on humans are relatively rare and hardly ever fatal, but healthcare expenses associated with such attacks, including treatment for potential exposure to diseases like rabies or plague, can be costly.

   b. Zoonotic diseases[1]
      Encephalitis, hantavirus, Lyme disease, psittacosis, and rabies are examples of zoonotic diseases. The first three are especially noteworthy in the context of wildlife risk management. They are all carried by rodents, either directly or indirectly through ticks and fleas. Agricultural producers who spend significant time on range and forestlands are more likely to be exposed to zoonotic diseases.

Step 2. Analyze Wildlife Risks

People face risk in nearly every aspect of their lives. If a person strived to minimize risk in their life, they would never leave the safety of their home (and even then would still face some risk). In contrast, most of us are willing to take some risks because the benefits of doing so outweigh the expected costs. The critical decision in risk management is to choose the degree to which each source of risk is managed, from ignoring the risk entirely to going to extreme lengths to eliminate it. To make such decisions, however, it helps to understand the probability and consequence of each risk. This is the objective of the risk analysis step.

There are two components in the process of analyzing wildlife risk:
1. determining the likelihood of the risk occurring, and
2. assessing the consequence if the peril does occur.

For some sources of risks, such as price risk, probabilities of alternative price levels can be objectively determined using publicly available price data. This approach may be difficult for wildlife risks because relevant public data is often limited. Some data are available, such as county-level predation rates; however, for many wildlife risks, personal experience and anecdotal evidence must be used to form subjective probabilities. The process of forming subjective probabilities can be simplified by dividing risky outcomes into classes, such as low damage, medium damage, and high damage.

[1] Zoonotic diseases are those that can be transmitted from wildlife to humans, such as rabies, Lyme disease and brucellosis.

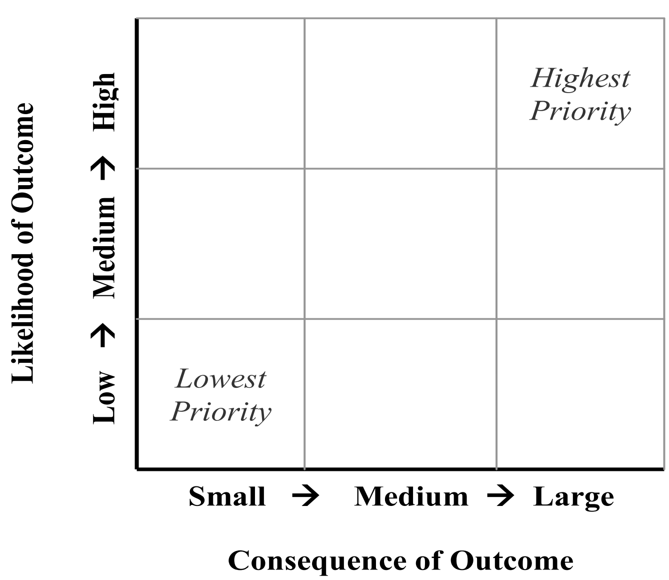
The second component of analyzing wildlife risk is to determine consequences if the risky event were to occur, i.e., to quantify monetary gains or losses associated with alternative states of the world that could occur. This can be relatively straightforward or complex depending on the wildlife risk. For wildlife-related production risks (e.g., crop damage and predation) output prices can be used to quantify alternative possible outcomes. Suppose, for example, there is a risk of coyotes killing 20 sheep per year; the market value of those sheep can be used to calculate the consequence. For other risk sources, such as disease transmission, quantifying the consequences will require an understanding of disease-response policies that may be imposed on the operation (e.g., quarantine protocols and government compensation programs).

Step 3. Prioritize Wildlife Risks

The next step in wildlife risk management is to decide which wildlife risks to manage further (if any) and which to ignore (hence the dashed line connecting this step to the final step). The criterion that should be used to prioritize risk is relatively complex and requires consideration of expected benefits gained if the risk is managed (keeping in mind there is some probability an adverse outcome will not occur), and the cost of managing the risk (recognizing that time spent learning about the risk and identifying the cheapest way to manage it should be included in the cost). Risks with negative expected net benefit (expected benefits minus costs) from management should not be managed; the costs of management in this case are larger than the expected gains. Risks with positive expected net benefit from management should be prioritized from highest expected net benefit to lowest, where risks with highest expected net benefit from management are given highest priority.

Among the sources of risk that can be managed, it is not always obvious which will generate the highest expected net benefit. An intuitive way to prioritize the risks is to combine the likelihood of outcomes and the consequences of outcomes (determined in the previous step) into a priority matrix.

Priority Matrix for Wildlife Risks



Wildlife risks that have a low probability of occurring and a small consequence are the lowest priority. Management of risk sources with small consequences has the potential to generate small benefits; however, it may also be very inexpensive to manage, in which case the expected net benefit of management might be about the same as for other sources of risk. Risks that have a high probability of occurring and a large consequence should be examined further to determine how costly the risk is to manage. The thresholds of likelihood and consequence that determine which risk sources to consider further ultimately depends on individual risk preferences and the relative magnitude of expected consequences.

Step 4. Identify Management Alternatives

With the highest priority wildlife risks identified, now is the time to consider the relevant risk management alternatives. The Strategic Risk Management Process (see Hewlett, 2002) identifies four ways to manage agricultural risk that are equally relevant in the context of wildlife risks. They are to avoid, reduce, trasfer, or to assume:

1. **Avoid** – In some instances, simply avoiding the risk might be best. Agricultural producers can avoid wildlife risks in several ways. Livestock injuries and losses can be avoided by grazing in areas that are less rodent-infested or in areas where predators are less prevalent or effective (due perhaps to a lack of cover in which to hide).

2. **Transfer** – Risk can also be managed by transferring the risk to someone else. The most common method for transferring risk is to purchase insurance. In the context of wildlife, examples include:

    a. Insurance

    Federally subsidized insurance has been offered in some since the Dust Bowl. Once enrolled, the provider covers all loses due to 'unavoidable perils beyond the farmer's control.' Like all insurance, premiums are higher for higher levels of coverage (where levels of coverage are chosen for both yield and price) and lower deductibles (USDA Risk Management Agency, 2008). A major limitation of crop insurance in the context of wildlife damage is that many insurance policies only pay indemnities if yield is reduced below the chosen yield coverage level. If crop damage from wildlife is minimal, insurance may cover little, if any, of the lost revenue.

    Producers who suffer livestock losses due to high-profile diseases, such as brucellosis and foot-and-mouth disease, currently receive indemnification payments for the culling of diseased and exposed animals. These payments do not require enrollment in any insurance or government program (Koontz, 2006).

    Insurance can also be used to divert liability risk associated with the use of private property by guests. Homeowners insurance and insurance for recreational operations are available to transfer the risk of liability for guests involved in wildlife recreation on private land.

b. Cost-Share Programs

Because society is interested in conserving predators (wolves and grizzly bears especially), a handful of conservation groups compensate agricultural producers for predation losses. Defenders of Wildlife maintain the Bailey Wildlife Foundation Wolf Compensation Trust to compensate ranchers for confirmed wolf predation on livestock. To date, the compensation trust has made 738 payments totaling $1,047,738 (Defenders of Wildlife, 2008). The Wyoming Legislature also allocates money for the Wyoming Game and Fish Department (WGFD) and the Wyoming Animal Damage Management Board to operate temporary cost-share programs for wildlife predation on livestock (ADMB, 2006).

If a predator is classified as a trophy animal, WGFD is obligated to compensate ranchers for livestock depredation. The grey wolf, which was recently removed from the endangered species list, is now classified as a trophy animal in parts of Wyoming. WGFD must compensate for depredations by wolves within the trophy zone but not within the predator zone (Wyoming Game and Fish Commission, 2007). Depredations outside of the trophy zone may also be ineligible for compensation through non-profit organizations' programs[2].

Compensation trusts and cost-share programs for livestock depredation provide an opportunity to transfer wildlife risk; however, these programs have limitations of which producers should be aware. The Bailey trust fund only compensates ranchers for depredations that can be confirmed by WGFD, Wildlife Services, or the Animal Damage Management Board. Legitimate cases of livestock depredation may go unconfirmed if the carcass cannot be found or if the evidence is inconclusive. Additionally, cost-share programs might not compensate for the full value of lost animals.

Lastly, a producer may have to invest a significant amount of time to prove depredation and file a successful claim, thereby increasing the cost of transferring the risk.

c. Liability Waivers

When providing wildlife-related recreational opportunities on private land, landowners can use waivers and contracts (rather than, or in addition to, insurance) to divert liability risk. Waivers or contracts disclose potential dangers to guests who wish to engage in recreational activities on private property. By signing a waiver or contract, the guest assumes liability for the risks (see the Cooperative Extension Bulletin by Schroeder and Olsen, 2002 for a comprehensive discussion of risk management in recreational land uses).

3. **Reduce** – Risks are reduced by either decreasing the likelihood of risky outcomes or their associated consequences. Means to reduce risk in the context of wildlife include the following:

a. Fences and dispersal devices

Fences can be used in many situations to reduce crop damage, disease, trespassing, and predation. For example, 39- or 48-inch woven wire fencing adequately exclude antelope. Adequate fences, in some cases, may cost more than the value of the damage they prevent. Fences to exclude deer, elk and moose, for example, are significantly more expensive than antelope fences (Demaree, 1994).

Dispersal devices are an alternative to fencing. Dispersal devices include noisemakers (firearms, zon guns, fuse ropes, etc), chemical repellants, flags, and scarecrows. Each dispersal device works better for some wildlife species than others, and the cost of dispersal device can differ substantially (Oneale, 1999).

b. Guard animals

Dogs, llamas, and donkeys are commonly used to protect livestock (usually sheep and goats) from predators (Andelt, 2004). Guard dogs are particularly beneficial because they are effective in open range settings; llamas and donkeys, in contrast, are only effective in enclosed areas (Andelt, 2004). A survey of Colorado ranchers who use guard dogs reports that 392 dogs on 125 ranches reduced livestock depredation losses by $891,440 in 1993 . Most of those surveyed believed the benefits of owning a guard dog far outweighed the cost of purchasing, feeding, and caring for it.

Guard animals reduce the risk of livestock depredation and reduce the time producers spend watching their herds. Guard animals may also reduce the need for other forms of predator risk management.

c. Vaccinations

Vaccinations against diseases that can be transmitted from wildlife to livestock represent a means for reducing wildlife-related risk; however, vaccines do not exist for many diseases and vaccine development may be prohibitively expensive (e.g., bluetongue virus) if the efficacy of available vaccines is low (e.g., brucellosis), or the use of a vaccine disqualifies the producer from participating in some markets (e.g., foot-and-mouth disease vaccines). Increases in the availability and effectiveness of vaccines will improve this risk-reduction tool.

[2] The current staus of the grey wolf is uncertain. On July 18, 2008, a Montana Federal District Judge offered a preliminary injunction that relisted the wolf under the endagered species act thereby stopping planned hunts of the animal for the fall of 2008. As of September 4, 2009 wolf hunting in Idaho and Montana is proceeding; however, litigation on the status of wolves in Wyoming is still pending.

d. Trespassing

Risk of liability for trespasser injury can be reduced by locking gates and other access points to the land thereby deterring potential trespassers and limiting landowner liability. Clearly marking land boundaries and posting signs to indicate that trespassing is prohibited also reduces landowner liability. Wyoming statutes provide less protection for trespassers than do other state's statutes, but taking precautions shows that the landowner is attempting to both protect their land and potential trespassers' rights as well.

4. **Assume** – If the cost of reducing a risk is higher than the expected benefit, it may be worth living with – or assuming – the risk. The old adage 'the greater the risk the greater the reward' suggests an alternative view of the problem: taking risks that others are not willing to assume may create the potential for higher revenue outcomes. Taking risks for the chance of enjoying higher revenue often comes at the cost of potentially suffering much lower revenue if the realized outcome is adverse rather than favorable. Again, a risk is only worth assuming if the expected benefit of assuming it outweighs the expected cost.

The examples above suggest there are many ways risk can be mitigated. Before implementing any risk management strategy, producers should understand that some alternatives may be more cost-effective than others. Using dispersal devices may be more effective than fences. Or, ultimately, it may be some combination of management alternatives that yields the best outcome. Identifying the full suite of available activites before moving forward with a management strategy is important.

It is important in this stage to not only identify available risk management options/tools, but also to evaluate their efficacy and cost of implementation. Efficacy is particularly relevant in the wildlife risk context because many management alternatives are not 100-percent effective. Consider, for example, the standard risk management problem of weather uncertainty. In this case, the random weather outcome is completely outside of the manger's control. Furthermore, the impact on yields of alternative weather scenarios and management practices can be predicted with relative confidence using years of production data. Thus, if the management option considered was whether to install a sprinkler system to reduce the risky outcome of drought, yields with the sprinkler system (outcomes under alternative weather scenarios) could be predicted with a fair degree of confidence.

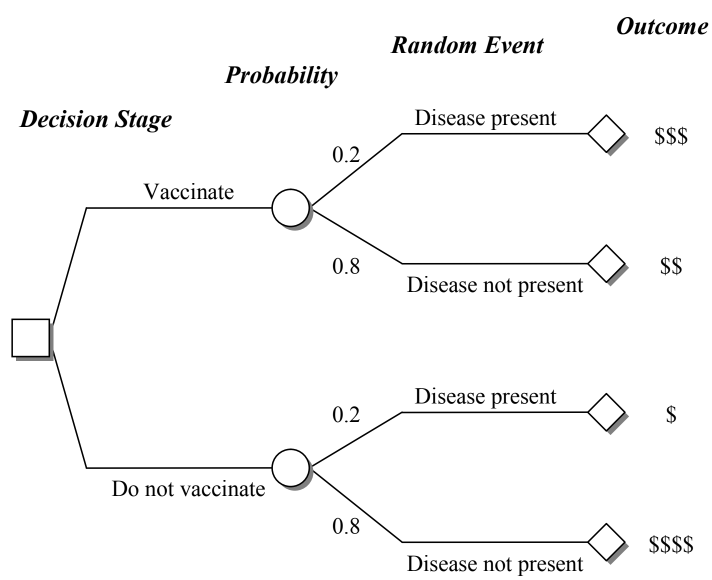
The ability to predict the outcome of management is often less straightforward in the case of wildlife risks. Consider, for example, vaccination for a disease that livestock can contract from wildlife. Most vaccines are not 100-percent effective or may only work on certain disease strains. When deciding whether to vaccinate, producers must consider not only uncertainty about the presence of infected wildlife but also uncertainty about a vaccines' effectiveness.

This uncertainty over management efficacy arises in many wildlife risk contexts; examples include the amount of livestock predation guard animals are able to reduce, the number of depredation claims that will be honored, the amount of crop damage avoided with deterrent devices, and the number of rodents traps will capture. In each of these examples, efficacy of the management tool is likely to vary between producers, locations, and years.

5. *Identify Optimal Management Plan*

The first four steps have set the stage for the fifth step, which is to identify an optimal management plan for risks you intend to reduce or avoid. It is important to note there is an optimal level of wildlife associated risk that may not equal to zero. It is rarely profitable and sometimes impossible to eliminate all risk. Doing so is too costly and the incremental benefits of more mitigation are usually decreasing. Realizing that information has likely been imperfect or unavailable in the previous steps, the objective in step 5 is to make the best decision possible given the available information. The "best" decision depends, of course, on individual risk preferences and management goals. Once these are determined, a decision tree diagram can be used to summarize the information collected in steps 1-4 and guide the selection of an optimal management plan. A decision tree diagram succinctly displays the decision stages, probabilities, random events, and consequences of a risk management problem in chronological order.

Decision tree for a hypothetical wildlife-livestock disease problem

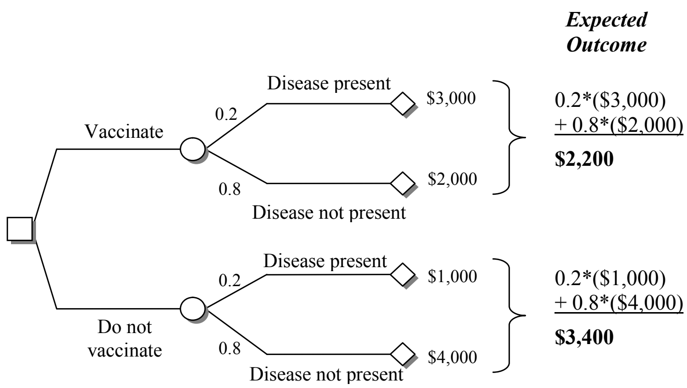


In the hypothetical wildlife-livestock disease problem above, there is one decision – whether or not to vaccinate. The probability of the disease being present and its associated financial consequences were determined in Step 2, and the cost of vaccination was determined in Step 4. The net return associated with each outcome (i.e., return less vaccination cost with and without disease) is then quantified ($ = $1,000, $$ = $2,000, etc.).

Once a decision tree has been constructed, it remains to select the optimal management decision (i.e., the optimal "arm" of the decision tree) based on individual preferences and goals. The decision tree diagram accommodates several alternative decision criteria, four of which are described below.

1. **Expected maximization** – individuals who are not overly concerned about the variability in net returns that risk generates may choose the management option that maximizes expected net return (or equivalently minimizes expected damages). The expected net return for a given management decision is calculated by first multiplying each outcome possible under that management decision by its probability, and then summing this across the set of possible outcomes.

Maximization of expected net return



In the wildlife-livestock disease example, the expected net return from vaccinating is $2,200 and the expected net return from not vaccinating is $3,400. Thus, under the expected maximization criteria, not vaccinating would be the optimal management decision.

2. **Mini-max** – individuals that are extremely averse to risk (i.e., strongly dislike variation in net return, and are willing to accept a lower average return to avoid variation) may use the mini-max criterion. With this criterion individuals choose the management option that minimizes the largest possible loss (or equivalently maxi-min – which maximizes the minimum gain). In the wildlife-livestock disease example, the worst outcome possible if they choose not to vaccinate is $1,000 (when the disease is present). In contrast, the worst outcome possible if they choose to vaccinate is $2,000 (when the disease is present). Thus, the mini-max criterion would identify vaccination as optimal because the value of its worst outcome is larger than that for not vaccinating.

3. **Safety-first** – when the risky event poses significant threats to an operation, such as bankruptcy, an individual may want to choose the management option most likely to prevent such an event. There are multiple ways to specify the safety-first criterion; the simplest is to choose the management option that minimizes the probability of the bad event occurring. Assume in the wildlife-livestock disease example a return less than $2,000 could bankrupt the operation. The safety-first criterion would identify vaccination as optimal because it minimizes the probability (actually makes it zero)of getting a return less than $2,000[3].

   If many discrete options are available, a producer can first apply the safety-first approach to minimize the probability of the worst outcomes, and then apply a different criterion to choose among the remaining options (e.g., prevent bancruptcy first, then maximize the expected benefits of the remaining options).

4. **Mean-variance efficiency** – when individuals care about both expected net return and variation in net return (risk), the mean-variance efficiency or E-V criterion may be appropriate. According to the E-V criterion, a management option is efficient if it generates the highest expected outcome (net return in this example) for a given level of variance, or the lowest variance for a given level of expected outcome. Application of this criterion requires an estimate of both the expected outcome and the variance of outcomes for each decision option. The expected outcome calculation was discussed in the expectation maximization criterion above. The variance of outcomes can be estimated in the discrete case as:

   (probability event occurs) times (outcome – expected outcome)^2
   \+ (probability event does not occur) times (out come – expected outcome)^2
   ____
   = variance of outcomes

   Thus, in the wildlife-livestock disease example, the variance of the vaccinate option is given by:

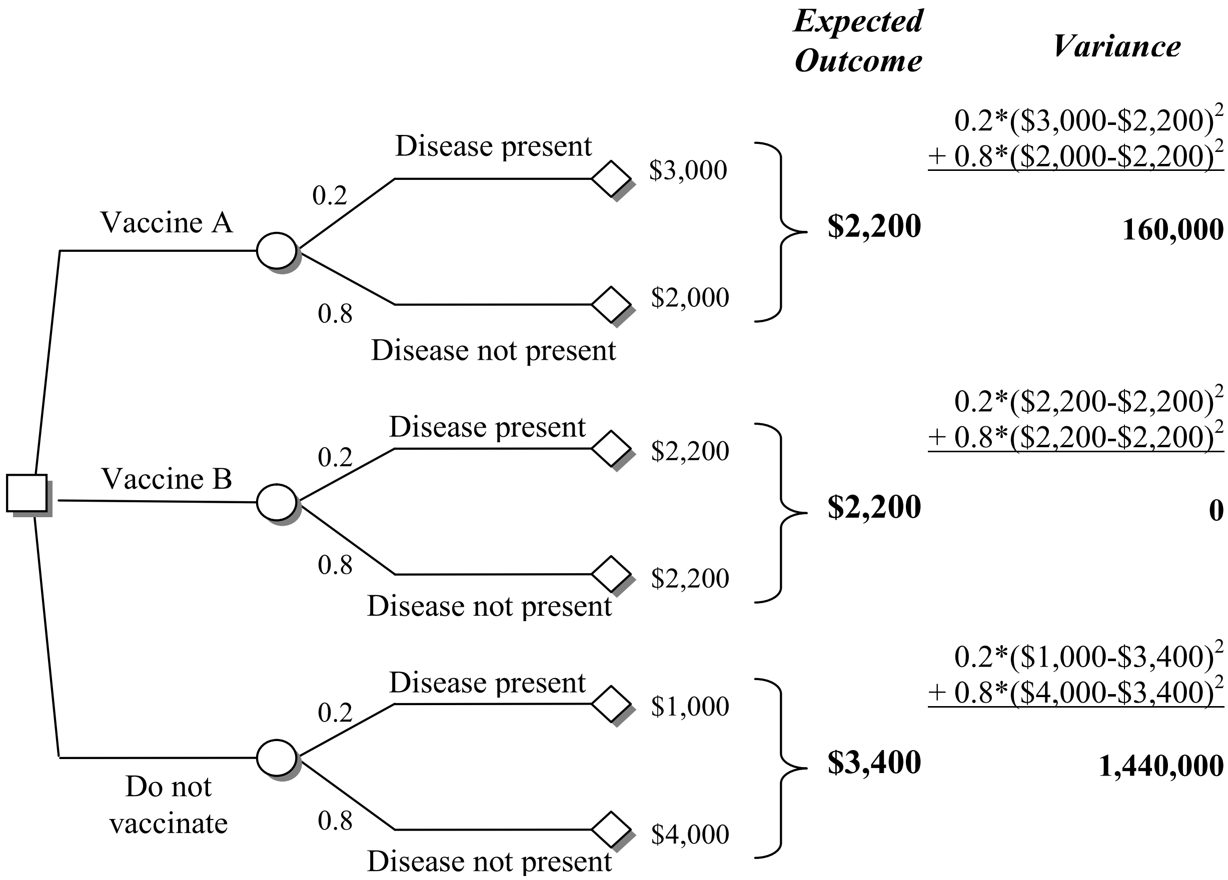
   $$0.2*(\$3,000 - \$2,200)^2 + 0.8*(\$2,000 - \$2,200)^2 = 160,000$$

The variance captures the dispersion of likely outcomes around the expected outcome. Larger variances therefore imply a greater likely of observing an outcome far from what is expected.

The E-V criterion is most useful when there are many options. To better demonstrate the approach, consider a more complex wildlife-livestock disease problem in which there are two different vaccines (A and B) to choose between. In this case, the probability of the disease being present is unchanged, but the outcomes may be different because the vaccines have different costs or effectiveness.

[3] This example oversimplifies the safety-first approach by assuming the probabilities and events are discrete – i.e. there is not a continuum of possible events (e.g. 1 percent of the herd is infected, 2 percent,…,100 percent) and an associated continuous probability distribution. If events are continuous, rather than discrete, application of the safety-first criterion becomes more mathematically challenging.

Mean-variance (E-V) efficiency in a wildlife-livestock disease example



In this example, the E-V criterion indicates the option 'vaccine A' is inefficient; for the same level of expected return ($2,200) there is less variability (risk) with vaccine B (0) than with vaccine A (160,000). Therefore, it would never be efficient to use vaccine A, regardless of your individual risk preference. A decision between three choices has now been narrowed to two. One of the earlier criteria could now be used to choose between using vaccine B and not vaccinating.

Whether using expected maximization, mini-max, safety-first, or mean-variance efficiency criteria, identifying an optimal management plan can be challenging. Even when historic data is available to aid in decision making, and the probabilities of alternative outcomes are known, the decision making process can still be overwhelming. Hopefully, the criteria given in this section are helpful when organizing a risk management decision process and choosing options that are consistent with individual management objectives.

6 – 7. Implement, Monitor and Adjust

Because risk management involves a great deal of uncertainty, achieving a perfect management plan is unlikely. Certain risk management activities may prove less productive or more expensive than initially thought or additional experience might reveal new information about the probability of alternative outcomes. It is important to follow-through with steps 6 and 7, which involve monitoring and adjusting the overall management plan in a constant search for the optimal plan. The circumstances of an individual agricultural producer change from year to year and even day to day. A risk management plan must therefore be adaptive.

Summary

Wildlife generate tremendous social benefits, as evidenced by the large number of people (including agricultural producers) who participate in wildlife-related activities and contribute to wildlife conservation funds. Agricultural producers, however, often bear a larger portion of costs associated with wildlife populations through a wide range of wildlife-related risks. Therefore, there is likely an optimal level of wildlife associated damage, which is not equal to zero. Eliminating all risk is rarely optimal; doing so is usually too costly. Risk management is inherently difficult because it involves uncertainty about the type, intensity, and frequency of losses attributable to wildlife. The benefits of risk management activities are also uncertain, depending on whether an adverse outcome, such as disease transmission, occurs. Wildlife-related risks are also especially challenging due to limited data describing the probability and consequence of various wildlife risks, as well as the cost and effectiveness of alternative management options. This bulletin attempts to break the wildlife risk management process into more manageable steps by adapting the Strategic Risk Management Process (SRMP) framework for application to common wildlife risks. Critical steps in applying the SRMP to wildlife, include 1) identifying risks that wildlife generate; 2) understanding and analyzing each risk; 3) prioritizing risks based on their probability of occurrence, magnitude of consequence, and net benefit of management; 4) identifying management alternatives for priority risk sources; 5) choosing the best alternative based on individual risk preference and management objectives; and 6) monitoring the plan after implementation and making adjustments as additional information and experience becomes available.

Risk management is a challenging task whose complexities may leave producers feeling overwhelmed, particularly in the case of wildlife risk. We hope this guide provides concrete steps and insights to help producers begin managing wildlife risks or improve upon existing efforts.

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