



Adaptive Wild Sheep Disease Management Venture (DMV) Strategy

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Western Association of Fish and Wildlife Agencies, Wild Sheep Working Group

Background

Respiratory disease remains the biggest impediment to restoring and sustaining bighorn sheep populations with a west-wide survey documenting 175 die-off incidents from the 1970s through 2014. These disease events involved 17 of the 20 jurisdictions and the loss of over 14,000 adult bighorn. Over 75 herds experienced 3 or more years of poor lamb recruitment post disease event with over 20 herds having 10 or more years. In 2015, the Wild Sheep Disease Management Venture (DMV) was established by the Western Association of Fish & Wildlife Agencies (WAFWA) Wild Sheep Working Group (WSWG) to identify management challenges associated with these respiratory disease events and collaboratively develop solutions to these challenges.

The DMV accepts that *Mycoplasma ovipneumoniae* (*M. ovi*) is a primary causative agent driving epidemic respiratory disease (i.e. pneumonia) in bighorn sheep. Additional bacteria including *Pasteurellaceae*, viruses, and other emerging factors (e.g., paranasal sinus tumors), likely contribute to the severity of disease in individuals or herds. Initial spillover of *M. ovi* occurs via contact with domestic sheep or goats (which commonly carry *M. ovi* without experiencing signs of disease), and can subsequently be circulated within and between populations by wild sheep or mountain goats. Following spillover into a bighorn herd several different outcomes have been documented, ranging from little to no impact on health and recruitment to epizootic pneumonia, followed by years of lamb deaths caused by pneumonia. This variable pattern has defined the key question for the DMV: ***What contributes to this variation in herd response to respiratory disease and how can management actions improve herd performance?***

Mission and Objectives

To aid jurisdictions in addressing this key question the mission of the DMV is to work collaboratively to:

- **Improve and speed collective learning on respiratory disease and herd response**
- **Be a source of guidance and expertise**
- **Be a clearinghouse for information sharing among jurisdictions and researchers**
- **Facilitate the evaluation of adaptive management actions**
- **Encourage jurisdictions to explore new management actions**
- **Seek funding to support enhanced monitoring and adaptive management trials**
- **Summarize outcomes of management actions and identify those that have the most promise of improving herd performance**

The DMV seeks to use the collective resources from all jurisdictions to strengthen the power of inference to find solutions to wild sheep disease challenges. The efforts of the DMV are similar to models used in emerging disease management where actions are developed to “reduce the harm” to herds already exposed to disease agents and promote herd health and productivity. The current vision is for the DMV to have an initial 5-year life (see Appendix A). The hope is that

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through strong participation, successes, and funding opportunities, the DMV will continue beyond 5 years in providing support and promoting communication in its continued mission.

Process and Methods

The DMV will assist jurisdictions in assessing candidate herds for monitoring and possible adaptive management actions. A flowchart was developed (see Appendix B) to help visualize the interaction/relationships of herd history, disease risk, herd size and performance, and pathogen testing/exposure. This can be used in assigning “candidate” herds to categories to assess variables for standard monitoring or for consideration in adaptive management trials.

The DMV will provide guidance for conducting enhanced herd monitoring (see Appendix C) and to identify variables that may contribute to a herd’s initial and long term response to pathogens and associated disease factors. It will also provide information and assistance to implement and evaluate adaptive management actions that potentially improve population performance in herds negatively impacted by respiratory disease.

The DMV will develop publications such as a web-based newsletter, fact sheets, email blasts, literature reviews or white papers to synthesize findings from monitoring and adaptive management trials, and pertinent research related to respiratory disease and herd response.

Enhanced Monitoring

In support of the DMV mission, jurisdictions are encouraged to conduct an enhanced level of monitoring of demographics, pathogens, and other associated factors on selected candidate herds (see Appendix C). This will greatly assist in information sharing and collective learning. Due to staff, funding, and access limitations, it is understood that not every candidate herd will undergo enhanced monitoring. In these situations, the DMV encourages continuing baseline monitoring and will seek funding to assist these efforts. General trends and highlights from monitoring efforts west wide will be summarized and shared annually. After 5 years of monitoring, the DMV proposes to analyze all jurisdictional data and information using generalized linear mixed models to identify correlations between performance variables (e.g., population growth rate, lamb recruitment, etc.) and predictive variables (e.g., *M. ovi* strain type, time since outbreak, secondary pathogens, herd substructure, etc.). Finally, the DMV proposes to model the probability of *M. ovi* elimination and herd recovery using the above predictive variables.

Adaptive Management Actions

Jurisdictions are encouraged to identify appropriate candidate herds for adaptive management actions that: 1) hasten elimination of pathogens from the herd, 2) prevent the spread of the pathogen to adjacent uninfected herds, 3) improve herd performance despite continued evidence of primary respiratory pathogen infections, or 4) evaluate risk of translocating animals from herds which are infected with identical strains of pathogens. Enhanced monitoring (see Appendix C) will be used to evaluate the cost/benefit, logistics, practicality and success of each action. The exploration of other adaptive management actions is encouraged.

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APPENDIX A - DMV Strategy Timeline

Time period	What to Ask Jurisdictions for	What to Give back to Jurisdictions
Year 1	<ul style="list-style-type: none"> • List of herds by revised list of categories • Data for Frances' JWM manuscript 	<ul style="list-style-type: none"> • General Summary - Assessment of herd information gathered through Google Survey • Suggested additional suite of tools/management actions • Updated Health Guidelines; include justification of archiving samples • Frances et al. JWM Bighorn Pneumonia Manuscript will be finalized and submitted
Year 2 - 5	<ul style="list-style-type: none"> • Agency participation in enhanced monitoring • Agency participation in management actions 	<ul style="list-style-type: none"> • Assessment of the suite of actions and summarize/distribute • Develop Best Mgmt Practices, web-based communications, specific reviews, white papers, training videos, and workshops • Management Actions Guidelines

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APPENDIX B – Herd Categories and Flowchart

Herd categories are identified based on disease event history, herd size, and performance:

1. Disease event with an initial population decline, followed by persistent or variable annual lamb mortality, resulting in below expected lamb recruitment and a stagnant/declining population.
2. Disease event with little or no initial population decline and herd recovery to pre-disease event levels or higher
3. Disease event with little or no initial population decline, followed by persistent or variable annual lamb mortality, resulting in below expected lamb recruitment and a stagnant/declining population.
4. Healthy herd with low risk of disease transmission
5. Healthy herd with high risk of disease transmission
6. No known disease event but stagnant/declining population.

Display a conceptual flowchart on herd history, size, performance, disease risk, pathogens sampled, and pathogen detection.

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APPENDIX C - Suggested Enhanced Monitoring Guidelines

Parameter	Examples of Methods	Desired Frequency	Rationale
Population Estimate	Reconstructive, Integrated Population, Mark-Resight or Sightability, or Minimum Count using helicopter and/or ground surveys	Annual	Needed to document and detect changes in population trends.
Lamb Recruitment	Lamb to Ewe ratios at least 4 months post-parturition based on composition surveys from helicopter and/or ground	Annual	Most consistent long-term metric collected by jurisdictions
Lamb Survival	Observe lambs born to marked (e.g., radio-collared) ewes after birth and again no later than 4 months from ground, camera, or fixed wing HR imagery surveys. Radio mark new-born lambs and monitor cause-specific mortality.	Annual to document timing of lamb loss	Lamb pneumonia mortality peaks within 4 months of birth; lamb mortality ≥ 6 months post parturition may be more reflective of predation or weather.
Adult Survival	Monitor radio-collared (VHF or GPS) animals or derive from population estimate	Annual ; minimum of 10 animals per gender	Detect large changes in adult survival due to pneumonia events.
Movements and Herd substructure	GPS collared adults, widely distributed throughout herd so as to capture substructure. Alternatively, VHF collars may give sense of substructure.	Daily -GPS collars; suggest minimum of 10 ewes and 5 rams	Pathogen transmission is sensitive to sub-structuring and contact patterns within a herd.
Pathogen Surveillance	At a minimum, collect samples recommended in 2014 WAFWA Herd Health Monitoring Document. Nasal and tonsil swabs; blood; feces. Attempt to sample across herd substructure groups. Passive sampling of skulls for sinus tumors.	Every other year , 10% of herd or 10-15 animals. Annual opportunistic sampling of mortalities and hunter harvest.	Targeted sampling provides detection, and in some cases estimates of prevalence, for key pathogens as well as estimates for how these change over time.
Nutritional Status	Body condition through BCS Palpation, body weight, or ultrasound body fat	During all captures.	Gives point estimate of nutritional condition.
Genetic structure	Fecal, tissue, horn-shavings, or blood collection	Bank a minimum of 15 samples per herd	Genetic diversity, connectivity, MHC, disease-specific loci
Habitat or abiotic factors	Habitat or related indices/metrics, stressors, deficiencies, climate/weather events	Annually or other appropriate timing	May be tied to herd resiliency, resistance, or susceptibility to disease

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APPENDIX D- Adaptive Management Actions

Proposed Actions

1. Selective Test and Cull - Test (nasal swab PCR) and cull *M. ovi*-shedders to reduce the number or eliminate all *M. ovi* shedders from the herd, to prevent *M. ovi* infection of lambs and improve lamb survival. Jurisdictions may choose to use a different pathogen metric other than *M. ovi* detected through PCR
 - a. Test and identify 75% or more of ewes 2 years or older at least once.
 - b. Resample all animals that test positive.
 - c. Cull or remove ewes that test positive twice.
 - d. Test and monitor at least 25 or 50%, whichever is less, of ewes in a separate control population.
 - e. Assess productivity and lamb survival in treatment and control herd in a manner that will allow detection of pneumonia related mortality.
 - f. If pneumonia in lambs is detected following culling, retest ewes and cull positive animals.
 - g. Schedule: Years 1 and 2: Test, treat and monitor herds; Year 3 and 4: Monitor; Year 5: Monitor and retest herds.
2. Depopulation - Remove all animals from a poor performing herd. Repopulate after the original source of disease transmission is removed.
 - a. To ensure complete depopulation; consider using “Judas” animals (radio collared) and monitor for association with remaining sheep.
 - b. Conduct thorough aerial and ground surveys to ensure no sheep remain; consider thermal imaging infrared and/or high definition camera surveys to locate any remaining sheep.
 - c. Reintroduced sheep should all have visible markings, and all adults should be radio-collared.
 - d. Conduct enhanced monitoring for minimum of 3 and ideally-5 years post-reintroduction to document herd performance and to confirm that no original animals remain or other unmarked immigrants are present.
 - e. Any original animals or immigrants that are located within the repopulated herd area should be removed and tested for disease.
3. Translocation of animals with identical strains of *M. ovi* or other primary pathogen: With greater risk of disease transmission among wild sheep herds, translocations must now involve a more critical evaluation to ensure they do not extend the current distribution of *M. ovi* or unknowingly spread a *M. ovi* strain that may cause a different herd response in the recipient herd area compared to the source herd.
 - a. Both source and recipient animals should have identical strains (defined as an exact match on 4 gene locus sequencing as performed at the Washington Animal Disease Diagnostic Lab.) for all PCR positive animals.

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- b. Herd performance and pathogen profiles must be known for both source and recipient populations within 1 year of the translocation and all handled animals will be marked.
- c. Neither the source nor recipient herd areas should have a domestic sheep, goat, or wild sheep herd nearby or within 32 km that poses a risk of *M. ovi* transmission that possesses a different strain type.
- d. All translocated adult animals should be collared.
- e. Enhanced monitoring should continue for a minimum of 3 and ideally 5 years post-translocation

Consider Additional Management Actions:

Nonselective culls – ewe hunts

“Breakup” herds – actions to disperse/distribute/hazing

Fertility Control to reduce herd densities