Psoroptic mange in California bighorn sheep in southern British Columbia: A preliminary review of occurrence, risk and management options.

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March 19, 2013

SECTION 1 EXECUTIVE SUMMARY

Over the past three years there have been several reports of California bighorn sheep (*Ovis canadensis*) with "strange" looking ears in the Ashnola River Valley, British Columbia (BC), but due to the anecdotal nature and assumed benign nature of the reports the issue could not be investigated until recently. In February 2011, an emaciated ram with a generalized skin disease was euthanized by government staff near Olalla, BC. Samples were collected and the condition was diagnosed as psoroptic mange caused by the ectoparasitic mite *Psoroptes ovis.* Although this mite has persisted in several wild sheep populations in the western United States, this is the first reported case in bighorn sheep in Canada and the first since eradication from domestic sheep herds in 1924.

Surveillance of infested bighorn sheep has since relied on reports from the public as well as through aerial surveillance of the Ashnola and Similkameen bighorn sheep subpopulations, which are part of the greater Similkameen-Okanagan metapopulation. It is apparent that *P. ovis* is widespread throughout these subpopulations, with an estimated prevalence of 54% in sheep that were observed and photographed during aerial inventories in 2011. To date there are no reports of infestation in other south Okanagan subpopulations. Further knowledge of this newly recognized condition is important to understand its impact on bighorn population dynamics. Several recommendations are proposed:

- Develop a public/interest group outreach program about the disease, highlighting the importance of reporting bighorn or domestic sheep exhibiting clinical signs consistent with mite infestation.

- Aerial surveillance of the Ashnola and Similkameen subpopulations every three to four years for detailed inventory and visual surveillance to estimate prevalence and distribution of *P. ovis* and sheep populations.

- Collect diagnostic samples opportunistically from rams harvested in the limited entry hunt in Management Units 8-01, 8-02, 8-03A, 8-03B 8-07 and 8-09 during compulsory inspection exams.

- Survey the area that received transplanted bighorn sheep originating from the Ashnola and Similkameen subpopulations for evidence of psoroptic mange.

- Monitor the south Okanagan subpopulation and adjacent herds for evidence of psoroptic mange.

- Develop a collaborative research program to identify the mite and assess exposure to mites through serological testing of banked blood samples.

The risk of *P. ovis* spreading to additional BC bighorn sheep metapopulations (Fraser River, Thompson River, and Kettle-Granby River) is relatively low given that Ashnola and Similkameen sheep are fairly well isolated. However, these sheep may be linked, both spatially and temporally, with the south Okanagan subpopulation on the east side of the valley and with populations in Washington, United States, which further emphasizes the importance of future aerial surveillance. Of these populations, some Washington state herds are known to be positive for *P. ovis*. At this time, the most significant risk factor for transmission of *Psoroptes* to additional bighorn sheep populations is by dispersal of free-ranging bighorns and through transplantation of infested sheep into unaffected populations. For this reason future translocations will not occur from populations in which there is evidence, or a high index of suspicion, of psoroptic mange:

- Bighorn sheep in areas that are known to have infested sheep, such as the Ashnola and Similkameen subpopulations, will not be used in translocations.

- Bighorns to be used in translocations should be assessed for lesions compatible with *Psoroptes* infestation and have diagnostic samples collected by a wildlife veterinarian or an experienced wildlife biologist. Evidence of disease should preclude the use of the herd from which these sheep originate. During processing at capture, all source sheep, regardless of location, are routinely given an injectable anthelmintic (doramectin) that is claimed to be effective to control mite infestations on cattle.

- Following translocations, all recipient populations should be monitored for evidence of mite infestation.

The BC Domestic/Wild Sheep Separation Program has identified several domestic sheep farms along the Similkameen River located within bighorn sheep range. Close contact between *P. ovis* positive bighorns and domestic sheep is possible and does put the domestic sheep at risk of developing infestations. The BC Sheep Federation and individual producers will be contacted and updated on the status of psoroptic mange in bighorn sheep and educated on the clinical signs associated with infestation. This will ensure early recognition of mite infestations, so that producers can implement appropriate mitigation tactics to prevent/control/treat mites from spreading to the rest of the herd. Effective treatments are available to treat *P. ovis* in domestic sheep, while none currently exist for wild sheep.

Based on an extensive literature review and contact with wildlife biologists in the United States familiar with managing bighorn herds with endemic *P. ovis* infestations, it appears that this condition is not a significant threat to bighorn populations and should not require immediate human intervention. It does not appear to be the cause of population declines, and, to date, treatment in field settings is unsuccessful. However, it is a management concern and does present a threat to the quality of other bighorn populations. In addition, nothing is known about the source of the mite, its effects in newly affected sheep herds and many other research questions.

SECTION 2 LITERATURE REVIEW – *Psoroptes ovis*

2.1 Background

Psoroptes ovis is a non-burrowing ectoparasitic mite belonging to the family Psorptidae (Order: Acarina). It is the etiologic agent of psoroptic mange or "sheep scab", a highly contagious and devastating condition that can affect domestic and wild sheep. Psoroptic mange has been the cause of significant economic loss in domestic sheep farms due to loss of condition and damage to the fleece in infested animals (Nieuwhof *et al*., 2005), and accordingly has been listed as an annually notifiable disease by the Canadian Food Inspection Agency (CFIA) under the Health of Animals Act.

Psoroptic mange was eradicated from domestic sheep herds in Canada and the United States in 1924 and 1970, respectively, through the effective use of macrocyclic lactone drugs however, it has been an ongoing problem in the United Kingdom (UK) for the past two decades. Prior to 1991, under the national dipping program in the UK, it was compulsory for farmers to treat sheep annually with insecticidal plunge-dips containing organophosphates and pyrethroids. Deregulation of psoroptic mange occurred in 1992 due to concerns regarding operator and environmental exposure to insecticides and parasite resistance (Kirkwood, 1986), and since then prevalence has dramatically increased and is estimated to cause the United Kingdom approximately 8 £ million per year (Nieuwhof e*t al.*, 2005).

Although psoroptic mange is considered eradicated from domestic herds in North America, it has continued to persist in many wild bighorn sheep populations in the western United States, including New Mexico, Arizona, Wyoming, Idaho, California, Colorado, Oregon, and Washington (Muschenheim *et al.*, 1990; Clark *et al.*, 1992; Foreyt *et al.*, 1985; Jessup, 1985; unpublished reports). Despite its widespread distribution, the condition appears to be more of an animal welfare concern rather than a significant threat to population numbers. The single exception to this was an outbreak in the San Andres Mountains, New Mexico; psoroptic mange was believed to have played a role, along with harsh weather and cougar predation, in the near extirpation of desert bighorn sheep (Boyce *et al.*, 2005).

2.2 Taxonomy and Host Range

There are currently five recognized species within the genus *Psoroptes* including *P. cervinus*, *P. cuniculi*, *P. equi*, *P. ovis*, and *P. natalensis*, all of which are identified based on morphological characteristics of mites, the location of lesions, and host species (Zahler *et al.*, 1998). At one time mites were considered host-specific, however several studies have since shown that this may not be the case. Mites collected from different host species have shown similarities in morphological characteristics, and populations of mites collected from a single host species have shown varying phenotypical traits. Additionally, molecular characterization shows very little host related differences between mite populations (Pegler *et al.*, 2005; Orchs *et al.*, 1999). Further in-depth molecular studies are needed to elucidate the taxonomy of the genus *Psoroptes* to understand the true host range of these mites; however, for the purpose of this report, and as it is considered in most papers, *P. ovis* is a disease of domestic and wild sheep and each species should be treated as a potential source of infection for one another. To our knowledge there have been no reported outbreaks of psoroptic mange in other species that are housed in close proximity to infested domestic sheep.

2.3 Clinical Signs

Clinical signs associated with mite infestation vary, ranging from inapparent, mild to severe abnormal ear conformation with accumulations of crusted skin and debris (Figure 1) to a more generalized skin disease that is characterized by intense pruritus with secondary lesions such as marked crusting of the skin and alopecia (Figure 2). Early infestations are typically limited to the ears and shoulders and may only be recognizable as yellow staining of the wool/hair and inflamed skin, while more severe cases have lesions distributed along the dorsum, flank, and shoulders (Center for Food Security and Health, 2009). Severely affected animals are often in poor body condition due to reduced feed intake and are predisposed to secondary bacterial infections, a combination that can result in mortality. In some cases, infested sheep do not develop clinical signs, but are still a potential source of infection for unaffected animals.

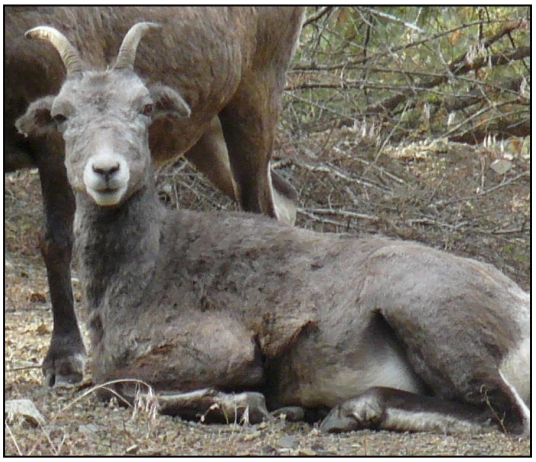

Figure 1. Bighorn ewe with crusts and wrinkled and droopy ears, characteristic of *Psoroptes ovis* infestation.

Figure 2. Bighorn ram with severe generalized psoroptic mange, characterized by locally extensive areas of alopecia and crusted skin covering approximately 50% of the body surface.

2.4 Life Cycle

Psoroptes ovis is an obligate ectoparasite, with its entire life cycle occurring on a single host. As mites abrade the skin and incite a potent inflammatory response, the subsequent exudate and crust that forms provides a perfect environment for mites to thrive and reproduce in. A single female mite can deposit anywhere between 35-100 eggs in her adult lifetime, which is approximately 30-60 days (Kirkwood, 1986). Once hatched, mites proceed through one larval stage and two nymph stages (protonymph and tritonymph) before finally molting into its adult form (Sanders *et al.*, 2000). This entire lifecycle from egg to egg takes approximately two weeks, but may vary with environmental conditions (Center for Food Security & Public Health, 2009).

Transmission is typically through direct contact with infested individuals making psoroptic mange a herd disease; it only takes a single gravid female mite to establish an infestation in an individual, and hence the entire herd. Fomites, such as contaminated fence posts, feeders, or chutes are sources of infection in domestic animals, and similar contaminated objects in nature may play a role in transmission and maintenance of the mite amongst and within bighorn sheep populations.

2.5 Diagnosis

2.5.1 Identification of the mite

The gold standard for diagnosing *Psoroptes* infestations is collecting skin scrapings at the margins of lesions and identifying the agent (Center for Food Security and Public Health, 2009). Cotton swabs are useful for obtaining samples from severely affected ear canals. *Psoroptes* are distinguished from other mites by the presence of joint pretarsi bearing a pulvilli, while most other mites have unjointed pretarsi. Sanders *et al.* (2000 (Sanders et al., 2000)) published a key to distinguishing morphological characteristics amongst the five different life stages.

2.5.2 Serology

The detection of serum antibodies for *Sarcoptes scabei* by enzyme-linked immunosorbent assay (ELISA) is commonly utilized to test the success of sarcoptic mange eradication programs in swine farms (Jacobson *et al.*, 1999). It should not come as a surprise that many have tried to replicate this success and design an ELISA for the detection of *P. ovis;* unfortunately, the sensitivity and specificity of most of these tests needs to be improved upon before they can be considered a reliable diagnostic tool. Recently a laboratory in the UK developed an ELISA test measuring antibody levels in response to a recombinant mite allergen (Pso o 2), which shows great promise in that it has already been used to detect disease in the face of a natural outbreak and is capable of identifying subclinical infections (Nunn *et al.,* 2011).

2.5.3 Polymerase Chain Reaction (PCR)

Pairs of primers (Rib-3 and Rib-4, Huo-3 and Huo-4) are commercially available to amplify sections of the internal transcribed spacer 2 (ITS-2) region, a section of ribosomal RNA that is commonly used in studies of taxonomy and molecular phylogeny due to its highly conserved nature in species (Orchs *et al.*, 1999; Zahler et al. 1998). Two ITS-2 sequences for *P. ovis* have been published on BLASTN (accession numbers AF123079 and AF123080).

2.5.4 Microsatellite Analysis

Evans et al. (2003) isolated nine microsatellite markers from *P. ovis* that can be used in furthers studies investigating host specificity of the mite and possibly determining the origin of infection in new recorded cases.

Table 1: EMBL accession numbers and clone names for microsatellite markers for *Psoroptes ovis.*

Locus	EMBL Accession Number & Clone Name
Psor01	AJ507616 and SCAB001E07
Psor02	AJ507617 and SCAB005A09
Psor04	AJ507619 and SCAB034E01
Psor05	AJ507622 and SCAB038S08
Psor07	AJ507622 and SCAB045A05
Psor11	AJ507626 and SCAB100C09
Psor13	AJ507628 and SCAB129G04
Psor14	AJ507629 and SCAB130D03
Psor16	AJ507631 and SCAB150B03

2.6 Treatment

2.6.1 Domestic Sheep

Historically, prophylactic and therapeutic treatment of psoroptic mange in domestic sheep flocks was achieved by using insecticidal plunge-dips containing organophosphates (propetamphos and diazinon) and pyrethroids (high *cis*-cpermethrin and flumethrin); however, their use has greatly diminished since the 1990s due to health concerns regarding operator exposure, environmental contamination, and resistance of parasites (Bisdorff, 2008). As the popularity of plunge-dips began to fade over the next two decades, the use of macrocyclic lactones, such as doramectin and ivermectin (0.2-1.0mg/kg, SQ or IM, repeated 10 days after first injection), and milbemycins, such as moxidectin (O'Brien *et al.*, 1996), became increasingly popular amoungst farmers. The macrocyclic lactones are currently the therapeutic treatment of choice, despite their poor prophylactic properties. Therapeutic efficacy is maximized by administering two doses 10-days apart to all animals in a herd/population in order to ensure that all animals and all life-stages on each animal will be exposed to therapeutic levels of the drugs; under-dosing may suppress infection and associated clinical signs, creating "carriers" that are a source of infection for unaffected sheep.

To avoid issues associated with multiple dosing and under-dosing, O'Brien et al. (1999) designed a controlled-release formulation of ivermectin that was effective in treating and preventing disease; unfortunately, this bolus has not been studied since this original study. Several other treatment options have been studied including the use of natural products, such as lavender oil and linalool, and insect growth regulators, but as of recently there is little evidence supporting their use in controlling mange in a clinical setting (O'Brien *et al.*, 1996)

2.6.2 Captive Wildlife

Supplementing feed with medication(s) has been common practice in veterinary medicine, and is often one of the few options for treatment of captive wildlife and exotic species. It has the benefit of being non-labour intensive, animals are not subjected to repeated bouts of capture and restraint, and it is less invasive compared to other routes of administration (ie. darting).

In-feed formulation of ivermectin has proven to be a potentially useful way of treating psoroptic mange in several studies. Foreyt (1993) effectively eradicated mites from two bighorn sheep in captivity by feeding a 6% in-feed formulation of ivermectin, mixed and formed into pellets with a ration of alfalfa over the course of ten days (dosage of 1mg/kg body weight). Similarly, Garris *et al.* (1991) effectively eliminated all life-stages of mites in 91% of captive white-tailed deer with ivermectin treated corn (0.2 mg/kg body weight per day).

There are several drawbacks of medicating with in-feed formulations. The biggest pit-fall is that it is impossible to ensure that each animal will receive the

therapeutic dose required due to the natural dominance hierarchy of sheep. In this scenario, some sheep will not receive the appropriate amount of medication and continue to be a source of mites for treated individuals. Also, if used in a field setting it may be difficult to prevent non-target species from gaining access to the feed.

2.6.3 Free-ranging Wildlife

Literature regarding active management of psoroptic mange in free-ranging bighorn sheep is limited to a single report by Sandoval (1980), published over thirty years ago, on desert bighorn sheep in the San Andreas Mountains. The New Mexico Department of Fish and Game attempted to utilize dust bags containing coumaphos, suspended over salt blocks placed along known travel routes, water sources, and bedding sites. Unfortunately, San Andreas bighorns are shy to both human presence and artificial structures and failed to use these man-made stations. Following this failed attempt, as many sheep possible were trapped, dipped in a toxaphene solution, placed into holding for 14 days, recaptured and dipped a second time. Although this method of treatment was effective in eliminating mites it was considerably more expensive (~$2000/sheep), which limits its use to small or highly valued populations, and resulted in significant mortality (59% of treated animals survived). Treatment of nineteen sheep with ballistic implants of ivermectin were attempted and anecdotal reports suggest that this method was effective for clearing mites, however follow-up procedures were vague at best and the true efficacy is not clear.

Muschenheim (1988) failed to successfully treat radio-collared *Psoroptes* infested elk and rocky mountain bighorn sheep with injectable ivermectin, although some did appear to be clear of infestation upon recapture.

The only other field attempt at treating this disease, to our knowledge, was in Washington State (unpublished information). Kristen Mansfield, veterinarian with the Department of Fish and Wildlife in Washington, reported that a small isolated herd was identified and administered injectable doramectin, 1.0% synergized permethrin pour-on for domestic livestock, and over the counter topical ear mite medication (0.6% permethrin) for dogs; unfortunately two lambs were not successfully captured and treated. This herd is still infested with mites, which may highlight the importance of treating all animals in a herd.

SECTION 3 *Psoroptes Ovis* IN BRITISH COLUMBIA

3.1 Background

There have been several reports in Olalla and the Similkameen valley, dating back to 2009, of bighorn sheep with “strange looking” ears; however, this was anecdotal, not confirmed with photographs or investigated until recently. In February 2011, a ram with a

severe generalized skin disease was reported outside of Olalla, observed and assessed by government staff and euthanized due to the severity of the lesions and the poor condition of the animal. Samples of crusts were collected from this ram, submitted and later identified as *P. ovis* by Dr. Walter Boyce at the University of California (Davis).

3.2 Purpose

This document aims to provide an overview of the current surveillance program, status of *Psoroptes* infestations, and management options for *P. ovis* in bighorn sheep in British Columbia, with particular reference to the Ashnola and Similkameen subpopulations. Specific goals of this project include the following:

- Summarize and evaluate the current surveillance program implemented by the BC Ministry of Forest, Lands and Natural Resource Operations and identify areas that can be improved upon and obstacles that may potentially undermine the success of the program

- Summarize the current status of the Ashnola and Similkameen subpopulations in regards to population dynamics and estimate the prevalence of infection in the Okanagan region

- Estimate the risk of transmission to additional populations, including domestic animals, and what precautions can be taken to prevent introduction of the disease into unaffected areas

- Determine whether or not management of this new newly documented pathogen requires human intervention and if so, what management strategies are available for controlling or eradicating the disease from the bighorn sheep population

SECTION 4 SURVEILLANCE

4.1 Reporting of Affected Sheep by the Public

Following the identification of *P. ovis* in bighorn sheep in the Ashnola area, news of the condition spread quickly amongst local bighorn sheep enthusiasts. Since then, local residents, outfitters, hunters, and First Nations members were contacted and are enthusiastically contributing to surveillance by reporting sheep with lesions suggestive of mite infestation. Information regarding the location of animals, the number of animals with and without *Psoroptes*-associated lesions, and any additional comments (ie. description of lesions, herd composition) are recorded during each interaction.

In an attempt to raise awareness of psoroptic mange, and increase the likelihood that cases will be reported, the Ministry of Lands, Forests, and Natural Resources developed a Fact Sheet, posted in a number of venues and mailed to applicants who were successful in

the limited entry draw for Management Units 8-02, 8-03A, 8-03B, and 8-07. This documents describes the nature of the disease, clinical signs to be aware of, and provides contact information for reporting affected animals.

4.1.1 Results

In 2011, there were five documented sightings of bighorn sheep with ear lesions and one report of a bighorn sheep with generalized mange. Interestingly, four of these reports were received in February, three of which were in the Olalla area. In 2012, a second ram with generalized mange was reported, and subsequently euthanized, in the same area as the previous year.

Unfortunately, hunters did not submit reports regarding sheep observed when hunting; it is unclear if failure to respond was because affected animals were not seen, or because of poor compliance by hunters.

4.1.2 Recommendations

Members of the public are still strongly encouraged to report potentially affected sheep to regional wildlife biologists or the provincial wildlife veterinarian. It is critical that efforts to educate the public on psoroptic mange and the importance of reporting cases and providing digital images are continued, until we have a better understanding of the epidemiology of the disease and its impact on bighorn sheep populations. An outreach program may include any of the following: presentations at local meetings or symposiums (ie. Wild Sheep Society of BC), providing updates in local newsletters; posting signs in areas where diseased-sheep were observed in the past.

In future limited entry hunts, it is recommended that hunters report whether or not suspect mange cases were observed; this information could be collected at the time of compulsory inspection of rams harvested or followed up with phone calls.

4.2 Aerial Surveillance

After the identification of the index case, on March 28, 2011, aerial surveillance of bighorn sheep was conducted in Management Units 8-02, 8-03A, 8-03B and 8-07 by helicopter inventory. On the east side of the Similkameen River, the flight path extended from Paul Creek to Crater Mountain, the South Slopes, and southwest along the river. West of the Similkameen river the flight surveyed from Hedley to Keremeos and north along Highway 3A (Figure 3). Although the main goal of this survey was to assess and record population dynamics within the Ashnola and Similkameen subpopulations and to attempt to identify infested sheep, it did serve as an excellent opportunity to retrieve baseline data on parameters such as geographic distribution and was very useful in estimating the prevalence of *Psoroptes* infested sheep in this region by a unique method. Numerous high quality photographs were taken of each sheep group or herd encountered and the following information was recorded: GPS coordinates, herd composition (number

of animals, age classification), description of lesions, and what proportion of the herd was affected.

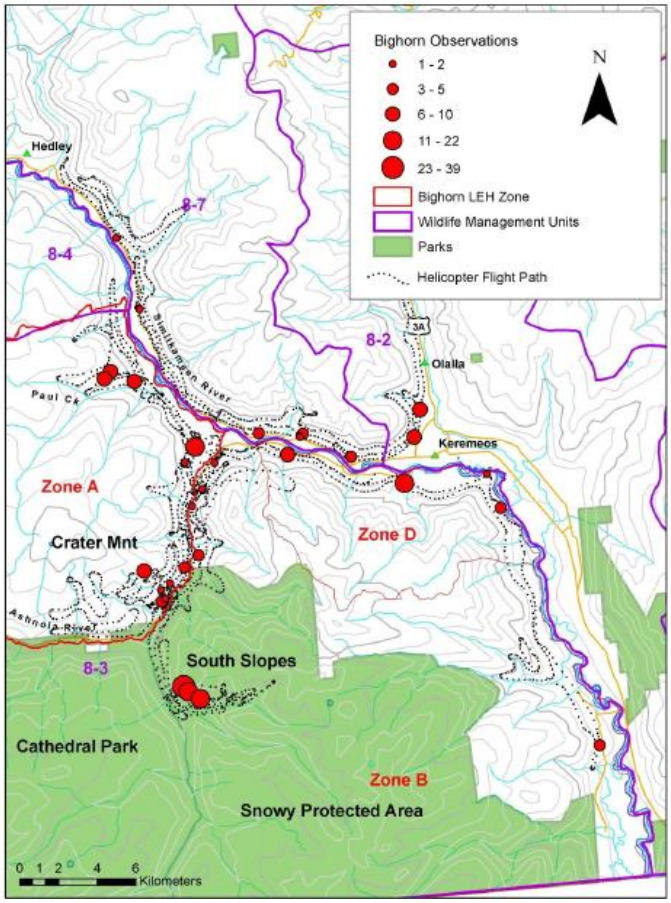

Figure 3. Inventory flight path for the Similkameen and Ashnola bighorn sheep populations in March, 2011.

4.2.1 Results

During the March 2011 Ashnola/Similkameen bighorn sheep inventory a total of 265 sheep were observed and approximately 44 sheep had ear lesions suggestive of psoroptes infestation. Due to poor sightability, especially in the South Slopes, approximately 178 sheep could not be visualized well enough to make a visual diagnosis (Reid, 2011). Based on results from sheep in which there were high quality photographs available, a conservative estimate of prevalence of infestation is in the Similkameen/Ashnola metapopulation is 54% (44 sheep with ear lesions out of the 82 sheep that were visualized well enough to make a diagnosis).

There was evidence of infestation in all age classes and affected sheep were widely distributed along the flight path (Figure 4); however, most were focused along the Similkameen River and around Crater Mountain. No lesions were observed in the South Slopes area or east of the Ashnola River confluence on south of the Similkameen River; however, the lack of infested sheep in the South

Slopes may be attributed to poor sightability and to the observation that sheep are much more likely to flee in this area.

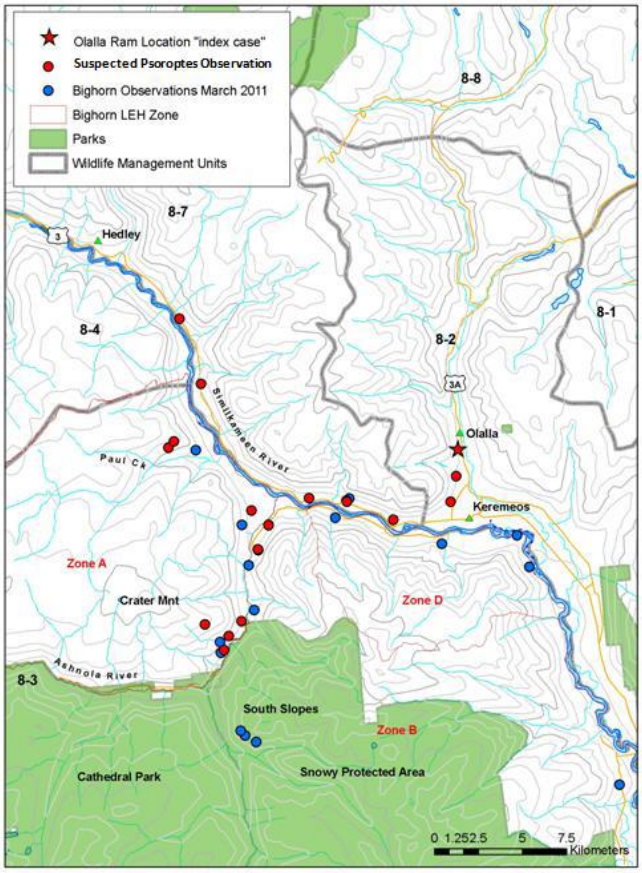

Figure 4. Map of the Similkameen Valley with locations of psoroptes-infested sheep (red dots).

4.2.2 Recommendations

The 2011 Ashnola/Similkameen bighorn inventory provided valuable baseline data on population dynamics as well as gross clinical signs of parasitic distribution. Depending on the availability of funding, aerial surveillance should be continued every three to four years to determine if prevalence of psoroptic mange and geographic distribution of the mite is progressing and whether or not it is impacting population numbers.

4.3 Compulsory Inspection Exam (2012)

Rams harvested during the limited entry hunting for mountain sheep are required by law to be brought to any one of the province's compulsory inspection contractors. Beginning in 2012, inspectors were provided with supplies to take appropriate diagnostic samples from the ears of all rams harvested.

4.3.1 Results

Pending

4.3.2 Recommendations

Collect diagnostic samples from ears of rams harvested and inspected.

4.4 Additional Recommendations for Future Surveillance

4.4.1 Bighorn sheep surveillance

The current surveillance program was developed based on the assumption that bighorn sheep with abnormal-looking ears are infested with *P. ovis*. Although this is most likely the case, there have been no samples collected from sheep with lesions that are restricted to the ears; the only definitive diagnoses are from two rams with severe generalized psoroptic mange. Additional bighorn ectoparasites have been observed in the Ashnola population by Blood (1963) and provincial wildlife veterinarian Dr. Helen Schwantje (unpublished report) including the spinose ear tick (*Otobius megnini*), which caused marked accumulation of debris in the ear of one infested sheep. Incorrectly diagnosing *P. ovis* based on ear conformation alone would over-estimate the prevalence of this mite, emphasizing the need for diagnostic samples from more animals. Ear samples should be collected during compulsory inspection exams and whenever bighorn sheep are captured for other purposes, such as radio collaring and translocation. In addition to ear swabs, blood samples should be collected and banked with previously collected samples, for future serological testing to identify sheep or groups of sheep that have been exposed to the mite in the past.

There are anecdotal reports of bighorn sheep with ear lesions in an isolated herd west of Penticton, and another herd approximately 15-km south of the border at Palmer Lake, Washington. This suggests that the south Okanagan subpopulation is at high risk of being exposed to the mite in the future, unless they are the original source that introduced the mite to the Ashnola and Similkameen region. It is important that those who are likely to observe bighorn sheep on a regular basis in this area (ie. ranchers, outfitters, bighorn enthusiasts) be aware of the clinical signs associated with mange and be prepared to report any sightings of affected sheep. Aerial surveillance would be justified in this region and if sheep are captured and handled then diagnostic samples, as previously described, should be taken. Fortunately, the Similkameen-Okanagan metapopulation is relatively isolated and may pose little risk to additional bighorn sheep metapopulations in BC, unless they have been used as a source for translocations in the past. For this reason, areas that have received sheep from the south Okanagan should be surveyed for evidence of the mite.

4.4.2 Domestic livestock

Local domestic sheep producers were contacted and informed about the status of psoroptic mange in bighorn sheep in BC. This should continue and producers should be educated on clinical signs associated with disease so that outbreaks can be reported immediately, and the importance of reporting instances where there is contact between domestic and wild sheep.

4.4.3 Additional wildlife

It remains unclear what role additional wildlife species play in the epidemiology of *P. ovis*. It is possible that other species may become infested or act as carriers for the mite, particularly elk (Muschenheim, 1988). If there are reports of mange in species in which it has not been previously documented, then this would warrant further investigation.

SECTION 5 PREVENTION

5.1 Prevention of Spread to Additional Wild Sheep Populations

5.1.1 Translocation

Arguably one of the most important risk factors for the introduction of *Psoroptes* into naïve populations is through translocation of infested bighorn sheep. The significance of this was demonstrated when clinically unaffected sheep were transplanted from Idaho to Oregon, which led to the introduction of *Psoroptes* into a state where it was not previously documented (unpublished reports). To help prevent these unfortunate scenarios, the Western Association of Fish and Wildlife Agencies (2009) has since developed several recommendations to help mitigate the risk of disease transmission and should be referred to prior to any translocation.

The Ashnola/Similkameen population was most recently used in 2007 when 34 sheep were transplanted to Okanagan Mountain Park. Unfortunately, now that psoroptic mange is widely distributed throughout the Ashnola and Similkameen river valleys, transmission of mites to additional bighorn sheep populations is likely if these animals are to be used in future translocations.

The following are recommendations to help prevent *Psoroptes* mites from being introduced into unaffected populations during all future translocations:

- The Ashnola/Similkameen population should no longer be used as a source for translocations. Of particular interest, in regards to the transmission of *Psoroptes* mites, is the frequency of contact between sheep from separate herds. Radio telemetry of the south Okanagan bighorn population revealed that there was significant overlap in home range of rams, and ewes were observed

interacting with sheep from different herds (Chapman, 1999). This information is not available for the Ashnola/Similkameen population, and hence it is difficult to estimate the risk of transmission between herds. This is an area that could be investigated in the future to identify isolated herds that have no contact with infested sheep, and which would make suitable candidates for future translocation purposes.

- Any bighorn sheep considered as sources for translocations must be assessed for lesions compatible with mite infestation by a wildlife veterinarian or an experienced wildlife biologist. This health assessment should be carried out prior to translocation so that appropriate diagnostic samples can be collected and processed before sheep are transplanted into new habitats. If any sheep shows evidence of infestation, then the entire herd should be considered infested and not suitable for translocation.

- Ears should be swabbed for identification of mites, and blood should be collected and banked for future serological testing. If mites are isolated from ear swabs, or serological tests reveal exposure to mites, then this should preclude the use of the herd from which positive animals originate.

- Regardless of whether or not sheep are exhibiting clinical signs of mite infestation, ivermectin or doramectin (0.2 – 1.0mg/kg, SQ or IM) should be administered to all sheep in the source herd when health assessments are carried out.

- Following translocation, this population should be monitored closely for evidence of psoroptic mange. If identified, animals should be euthanized to prevent the mite from being spread in this new population.

5.1.2 Migration of Infested Sheep

Fortunately, the Similkameen-Okanagan metapopulation is isolated from other metapopulations in British Columbia, being separated by large areas (Figure 5). Therefore, the risk of *Psoroptes* being introduced into those new populations through natural movement of sheep is considered relatively low. However, there are anecdotal reports of bighorns extending their northerly range, north of the Similkameen River and questions about connectivity with the South Okanagan bighorns. Distribution/linkages of bighorn sheep should be closely monitored during future aerial surveys.

There is a natural corridor west of Penticton that could potentially serve as a route for infested sheep to gain access to the South Okanagan metapopulation (if not present already, and therefore, monitoring and surveillance of sheep in this area would be justified.

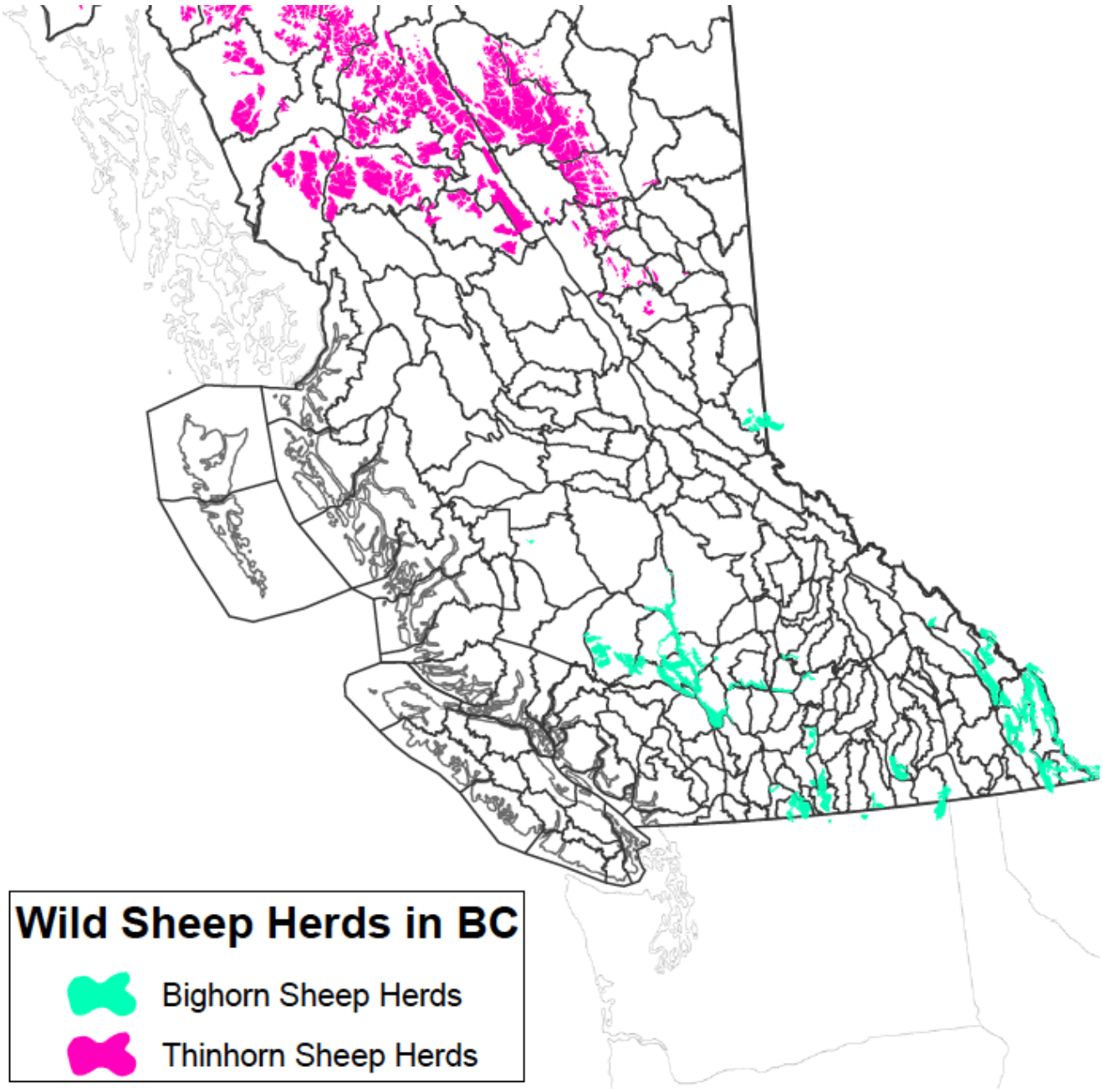

Figure 5. Map demonstrating the distribution of bighorn sheep and thinhorn sheep herds in British Columbia. The Similkameen-Okanagan bighorn sheep population is isolated from other wild sheep populations in the province.

5.2 Prevention of Spread to Domestic Sheep Flocks

Following the 1999-2000 die-off of the south Okanagan bighorn sheep population, the BC Domestic/Wild Sheep Separation Project was developed to provide outreach, prevent contact between domestic and wild sheep and to reduce the risk of transmission of pathogens, especially those that cause respiratory diseases. This project involves identifying domestic sheep producers and their properties and determining the risk of contact with wild sheep, educating producers on disease transmission and risks, and the development of management options to ensure effective separation. Currently over seventy-nine domestic sheep farms have been identified near bighorn sheep range in BC, and of these there are seven located near Ashnola and Similkameen bighorn sheep range and twelve located near south Okanagan bighorn sheep range (Tables 2 and 3). Domestic sheep on these farms are at high risk of being exposed to bighorn sheep and inadvertently becoming infested with *Psoroptes* mites.

The following recommendations are made to enhance the current BC Domestic/Wild Sheep Separation Program and prevent *Psoroptes* from crossing over into domestic sheep farms:

- Continue to identify domestic sheep farms, determine their proximity to bighorn sheep range, and keep an updated spreadsheet on the location of farms.

- Domestic sheep producers near bighorn sheep range, which are known or suspected of being infested with *Psoroptes* mites, should be contacted and updated on the status of psoroptic mange in bighorn sheep in BC and educated on the clinical signs associated with infestation. Early recognition of clinical signs is critical for preventing mites from spreading throughout a herd.

- Domestic sheep producers should be provided with management options in face of a psoroptic mange outbreak.

Table 2. Location and number of sheep farms that are near or in Similkameen-Okanagan bighorn sheep range in 2012.

Location of Domestic Sheep Farms	Number of Farms
Keremeos	5
Olalla	2

Table 3. Location and number of sheep farms that are near or in south Okanagan bighorn sheep range in 2012.

Location of Domestic Sheep Farms	Number of Farms
Okanagan Falls	3
Penticton	3
Oliver	3
Kelowna	1
Anarchist Mountain	1
MacLean Creek Road	1

SECTION 6 MANAGEMENT OF *Psoroptes ovis*

Based on the extensive literature review and contact with wildlife biologists throughout the western United States familiar with psoroptic mange in bighorns, immediate human intervention is not recommended. Reports of *Psoroptes* infested wild sheep date back into the 1800s, mostly in the United States, and there is no conclusive evidence that it is associated with population declines. Most of these reports attribute bighorn declines to inclimate weather, restricted winter habitat, overhunting, and predation, with infestation by *Psoroptes* as a complicating factor (Packard, 1946; Lange, 1980). Additionally, management of psoroptic mange in field settings has largely been unsuccessful (Lange, 1980), likely due to the low population threshold of the mite and the difficulty of access to all animals for treatment (Wobeser, 2002).

Several management options were discussed in SECTION 2, and any of these could be attempted on known isolated herds to gauge the success of different management options. At this time managing this condition at the population level is not realistic, as we still know very little on movement patterns of bighorn sheep in the Ashnola and Similkameen river valleys. Frequent contact between sheep of different herds would undermine any attempt at treatment since sheep would likely be re-exposed and infected.

Although not viewed as a threat to populations, severe psoroptic mange is a welfare concern. Due to the extreme discomfort associated with these lesions, and since these severely affected sheep will likely to succumb to secondary events (predation, malnutrition, secondary bacterial infections), euthanasia of these sheep is justified. Euthanasia of the two severely affected sheep was performed by gunshot by government staff or their designate.

SECTION 7 FUTURE GOALS

- Determine the origin of *Psoroptes* mites through genetics, molecular analysis, and gene sequencing. This would be a fairly intensive project, and hence may be suitable for a future graduate student.

- Further study the Ashnola/Similkameen population structure, through radio telemetry, and determine the risk of transmission of *Psoroptes* between herds.

- Serological testing of banked blood samples collected from sheep in the Ashnola and Similkameen subpopulations, and neighbouring populations, in collaboration with researchers in the United Kingdom and the US.

ACKNOWLEDGMENTS

The authors would like to thank Aaron Reid, Andrew Walker and Brian Harris for their comments on this paper and ongoing involvement with aerial surveillance of bighorn sheep in the Ashnola/Similkameen River Valley, and maintaining an inventory of this subpopulation. We would also like to thank Dr.s Kristen Mansfield, Peregrine Wolff and Eric Rominger for providing insight on the current status of psoroptic mange in Washington, Nevada and New Mexico, respectively, and Diana Demarchi for creating the map of wild BC bighorn sheep populations used in this document.

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