The Silence of the Lambs

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Year after year on bighorn sheep ranges across western North America, pneumonia kills thousands of bighorn lambs, usually between one and three months after birth. While dramatic all-ages pneumonia die-offs receive far more media attention, lamb pneumonia outbreaks probably have a bigger overall impact limiting growth of bighorn sheep populations. In affected populations, most ewes will lamb normally, and for the first three weeks or longer the lambs show no signs of disease, only to develop pneumonia and die before the end of summer. Research shows that whenever lamb survival to weaning drops below 50%, it's very likely that pneumonia was the culprit.

Photos: Dr. Frances Cassirer, IDFC

The source of infection that triggers lamb pneumonia

Pneumonia outbreaks striking previously healthy bighorn sheep populations often result in 'all-age die-offs' that may kill many dozens of animals. The most severe outbreaks may result in losses of up to 90% of the population, but more commonly, 20% to 80% of the animals survive. Some of these survivors will have scarred lungs that makes them unthrifty, or will have pockets of persistent infection that may later re-emerge and cause pneumonia. Overall though, ewes that survive the pneumonia outbreak appear to develop immunity and have been shown to have a pretty normal life span. For example, after the northern Hells Canyon all-age outbreak in 1995/1996, annual ewe survival exceeded 90% over at least the subsequent 7-year period. We now know, though, that some of these surviving ewes, while apparently healthy, chronically carry *Mycoplasma ovipneumoniae* in their upper respiratory tract, providing a source of infection to trigger lamb pneumonia outbreaks. Because ewes and their lambs often congregate during lamb-rearing, we suspect it may only require a single carrier ewe to trigger an epidemic of infection that can devastate an entire lamb group.

The importance of lamb pneumonia

Lamb pneumonia outbreaks are not as dramatically visible as many all-age die-offs, and pneumonic lambs often die in remote terrain where they may be rapidly removed by predators or scavengers.

Therefore, considerable efforts are required to document occurrence of lamb pneumonia. For any bighorn sheep population where there appears to be poor survival of lambs through the first several months of life, lamb pneumonia should be considered a possible or even the most likely explanation for it, unless proven otherwise.

There is nearly always a lamb pneumonia outbreak the year following an all-age die-off. After that, occurrence of lamb pneumonia is much more variable. Some populations may experience only a year or two of lamb losses, after which the disease fades out and the population returns to apparent health. Some populations will experience lamb die-offs year-after-year for decades, until the lack of recruitment causes the population to slowly decline, and in some cases, disappear. However, it seems the more common outcome is for lamb pneumonia to vary from year to year, with some good years augmenting the population of survivors, and some bad years in which most or all the lambs die. Overall, it is now clear that the presence or absence of lamb pneumonia is one of the most important factors determining the eventual decline or recovery of a bighorn population struck by an all-age pneumonia die-off.

What accounts for differing patterns of lamb pneumonia in different populations and different years? This question is a subject of active research in my WSU program. Some possibilities we are evaluating with our collaborators include: 1) variation in the disease-causing ability (virulence) of the particular strain of *Mycoplasma ovipneumoniae* involved in the outbreak, or variation in the ability of the strain to persist in bighorn sheep; 2) variation in the numbers of chronic carrier ewes in the population preceding the lambing season; 3) variation in the number and recent health status of adjacent populations; 4) variation in animal contact patterns within and between populations; and 5) variation in the identity and virulence of the secondary bacterial infections that follow M. *ovipneumoniae* infection.

The relationship between all-age pneumonia die-offs and lamb pneumonia die-offs

All-age die-offs, and the lamb pneumonia outbreaks that can follow for years afterwards, are strongly linked by their association in time: the lamb disease nearly always follows an all-age die-off. This association is also strongly supported by detection of the same strain 'fingerprint' of the triggering respiratory bacterial pathogen *Mycoplasma ovipneumoniae*: each all-age die-off has been associated with a single strain of M. *ovipneumoniae* detected in the lungs of most or all of the affected animals, and that same outbreak strain of M. *ovipneumoniae* is then detected in the lungs of most or all lambs dying of pneumonia in subsequent years.

Examination of lambs of known ages collected from populations experiencing recurrent severe lamb pneumonia reveals a consistent sequence of events: 1) early invasion of *Movi* into the lung tissues (often in the first week of life); 2) progressive development of pneumonia with microscopic evidence of 'chronic' inflammation typical of Mycoplasma infection (as early as the second week of life and onwards); and 3) waves of lung invasion by other bacteria that soon greatly out-number M. *ovipneumoniae* and trigger 'acute' inflammatory lesions in the lungs (around a month of age and after). The role of M. *ovipneumoniae* in bighorn sheep pneumonia is analogous to the role of the virus HIV in acquired immunodeficiency syndrome (AIDS) in humans: M. *ovipneumoniae* doesn't directly kill the affected animals, but by impairing the immune defenses, indirectly results in multiple, diverse and often fatal bacterial lung infections.

Many of these features of lamb pneumonia outbreaks (early predominance of M. *ovipneumoniae* followed by poly-microbial infections, inflammatory lesions, slow insidious time course, etc.) appear to apply equally well to all-age pneumonia die-offs; this will be the subject of a future article in this *Wild Sheep*™ series.

The puzzle of lamb susceptibility in the face of ewe immunity

For most infectious diseases of sheep and other hooved mammals, immune dams pass their immunity on to their offspring through antibodies secreted in colostrum and absorbed by the newborns. However, this does not seem to be the case for bighorn sheep and M. *ovipneumoniae* infection. Research in Dr. Srikumaran's lab has previously demonstrated that antibodies produced by bighorn ewes are efficiently transferred to the lambs through colostrum, in the same way other hooved mammals transfer immunity to their offspring. It's an intriguing puzzle, therefore, why lambs of bighorn ewes in M. *ovipneumoniae* infected populations aren't protected, since their dams appear to be immune to the infection and usually have high levels of anti-M. *ovipneumoniae* antibodies available for secretion into colostrum. Nevertheless, lambs clearly are highly susceptible to infection shortly after birth, and develop pneumonia during their first month of life. This puzzle is another subject of active research in my WSU program. Some of the possibilities we're evaluating include: 1) whether ewe immunity results from immune system cells rather than antibodies (since immune system cells are not effectively transferred to neonates); 2) whether ewe immunity results from a class of antibodies (IgG2) that, unlike IgG1 antibodies, aren't effectively secreted into colostrum; and 3) whether bighorn sheep immune systems over-react to M. *ovipneumoniae*, producing antibody reactions that are so strong that the antibodies themselves contribute to lung damage and pneumonia.

Going forward

Bighorn sheep pneumonia remains an enigma at many levels. However, discovery of the underlying role of M. *ovipneumoniae* has answered many previously perplexing questions (What is the relationship between all-age and lamb pneumonia outbreaks? Why has it been so difficult to find a common predominant bacterial agent in pneumonic lungs within an outbreak?) while suggesting new research directions that offer more potential for eventually ending 'the silence of the lambs'. WS