A BRIEF HISTORY OF WILDLAND WATER QUALITY RESEARCH

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While wildland water studies are relatively uncommon, several pivotal studies do exist and give an interesting and insightful reflection on rangelands and bacterial water quality.

Wildlands may be defined as those remote areas which are not developed for agriculture, other than forestry, and are usually public lands in western states (Darling, 1973, p.14).

According to the Public Land Law Review Commission (1970) nearly one half of the 273 million acres of public rangeland in the eleven western states is grazed at one time or another by domestic livestock. Recreational use of many of these same lands is rapidly increasing as leisure time, increased affluence, greater mobility, and urban pressures grow (Outdoor Recreation Resources Review Commission, 1962). The Public Land Law Review Commission (1970) further notes that on the land areas which have been withdrawn for recreation, grazing is permitted on nearly one quarter of the area. Apparently, therefore, a potential for domestic animal fecal pollution and ensuing health hazards exists on high density recreational wildland which is grazed.

Diesch (1970) reported that numerous diseases can be transmitted from one warm blooded organism to another via water. Commonly observed diseases related to contamination of water supplies from cattle feedlots are salmonellosis and leptospirosis. A classic example was a leptospirosis outbreak among several young people in Iowa was traced to their swimming hole on the Cedar River. Leptospirosis infected cattle had access to the river upstream from the swimming hole (Willrich, 1967). Bryan (undated) has also reported a leptospirosis outbreak associated with a swimming hole near Columbus, Georgia. Cattle, swine and dogs found to have a *Leptospirosis canicola* infection all had access to the stream which fed the swimming hole.

Geldreich (1972) has concluded that the frequent occurrence of pathogens in domestic animals and wildlife supports concern about fecal contamination from all warm-blooded animal sources.

Kunkle (1970) related bacterial densities to patterns of land use in Vermont. He found an increase in fecal coliform counts when cattle were adjacent to the stream as opposed to further away. But he determined that only a minor fraction of the total available live bovine fecal material ever washed into the stream. He concluded, therefore, that only the area immediately adjacent to the stream, rather than the entire watershed, is of major importance in terms of introducing this sort of pollution into the stream.

Working with a wildland stream in Colorado, Morrison and Fair (1966) attempted to determine several environmental effects on microbial dynamics. They did note, as a peripheral observation, that cattle grazing adjacent to the stream caused an increase in coliform counts.

Kunkle and Meiman (1967) studied the Little South Fork of the Cache la Poudre River in Colorado in order to assess several water quality characteristics. They found that fecal coliforms proved to be a better indicator of watershed impact than turbidity and suspended sediment.

The same team also investigated the water quality impact of grazing on a mountain meadow. They found that the indicator bacteria produced evidence of more pollution in a grazed watershed than in a natural ungrazed catchment (Meiman and Kunkle, 1967).

Slawson and Everett (1973) found that the water quality of the main stream Colorado River was relatively constant in terms of chemical and biological parameters. However, the tributary streams showed extreme temporal variability in these parameters as a result of a summer rain and flood patterns. They concluded that the side streams pose a definite health hazard to unwary travelers.

Kunkle and Meiman (1968) also investigated the variation in bacterial numbers with time. They noted a daily variation with afternoon lows and evening highs. This cycle followed the cyclic diurnal streams stage, with the high bacterial counts correlating to high stream flow. They also noted an extreme bacterial die-off associated with 1-2 hours of exposure to sunlight. Perhaps this die-off contributed to the low bacterial counts observed during the late afternoons.

Mack (1974) demonstrated, however, that coliform bacteria, under specific environmental circumstances, can persist and even multiply in natural waters. He also noted that multiplication was great at 35°C compared to lower temperatures. Hendricks and Morrison (1967) have also reported the enteric bacteria's ability to multiply and grow in cold mountain streams. They suggested, however, that the river's self purification mechanism plays a role in suppressing the unrestrained growth of these organisms.

Walter and Bottman (1967) studied a pair of watersheds near Bozeman, Montana. They noted that one of the watersheds which had been protected from the public use for over forty years consistently showed higher bacterial counts than the adjacent watershed which was open to the public. Stuart et al. (1971) observed the same watershed and theorized that the higher bacterial counts could be attributed to higher wildlife numbers. Apparently the wildlife favored this watershed due to its protected or "refuge" status. Bissonnette et al. (1970) employing a serological technique attempted to isolate the source of bacterial contamination on the same closed or refuge watershed. They concluded that the sources of contamination were, indeed, wild animals.

Skinner et al. (1972) observing a mountain watershed in Wyoming noted a seasonal fluctuation in bacterial numbers. The authors found increasing concentrations of bacteria as the snowmelt hydrograph advanced toward its peak. They further speculated that increased bacterial numbers were correlated with grazing periods of domestic livestock and wildlife numbers.

In a wildland study in northern Utah, Darling and Coltharp (1973) found significant increases in bacterial counts during periods of cattle and sheep grazing at stream locations immediately downstream from the grazing activity. Bacterial counts in streams draining the grazed watersheds reached seasonal maximum values during the grazing period, while counts from a nearby ungrazed watershed remained relatively low and constant. In each case, grazed or ungrazed, bacteria levels were above the numbers permitted for drinking water standards (< 1 fecal coliform bacteria per 100 ml) and less than the number describing the limit of the next level, primary water quality [fishable and swimmable] which is 100 fecal coliform bacteria per 100 ml. In evaluating the health hazard implications of livestock grazing on public wildlands they recommended that direct access of livestock to important water supply streams be prevented (Coltharp and Darling, 1973). They concluded that fencing of stream channels would provide a buffer zone between the stream and the livestock and that livestock watering places should be developed away from the live stream. They further recommend that rather than suggesting a curtailment of livestock grazing on public lands, the recreating public be advised of the possible dangers involved in drinking untreated stream water.

Buckhouse (1975) in his PhD dissertation found that while cow "pats" will harbor fecal coliforms for up to several years, rain drop splash will only dislodge and disperse bacteria a distance of less than a meter from the pat. Therefore, unless a cow pat is deposited on the immediate streambank or directly into the water, its opportunity to infect flowing water is limited.

Meays, et al, 2005 in an attempt to refine the length of time fecal bacteria might remain viable in cow pats designed a study which exposed pats to differing levels of solar exposure. They discovered that after 45 days pats exposed to full solar exposure had lower counts than did those protected to the extent of 40, 80 and 100% cover using shade cloth with 0.018, 0.044, 0.11, and 0.44 x 10 to the sixth power colony-forming units per gram. They suggested that from a managerial point of view, the coliform bacterial counts were highest for the first 7 days following livestock removal.

Bohn and Buckhouse (1985) studied water quality in northeastern Oregon and found that the streams in this very rural area always contained measurable fecal bacteria. The study areas were home to a host of wildlife, both herbivores and avian, as well as to seasonal livestock. While coliform bacteria numbers were noted to increase during those periods when livestock were present, they did not exceed the EPA standards for primary (> 100 bacteria/100 ml) wildland water quality. Primary water quality standards are used to determine a “fishable/swimmable” designation. It should also be noted, that even when livestock were not present and had not been present for several months, the streams did not meet “drinking water standards” (<1 bacteria/100 ml), presumably due to presence of wildlife.

Larsen (1989) and Larsen, et al, (1994) following up on Buckhouse’s 1974 PhD observations sampled bacteria movement in a control laboratory experiment and found similar to even more conservative results. Bacteria remain confined in or near cow pats except in those circumstances where the pat has been deposited within 0.7 meters of the flowing water. Larsen also looked at animal distribution (and therefore manure distribution) and concluded that clearing juniper—followed by subsequent regrowth of herbaceous vegetation—seemed to have a positive impact on water quality….both from the standpoint of “luring” animals away from riparian zones by providing palatable forage in the uplands and by increasing infiltration of precipitation therefore reducing overland flows and the possibility of flushing bacteria toward the stream.

Miner, et al, (1992) investigated the possibility of a watering trough as a “lure” to attract animals away from flowing streams during periods of winter feeding. In this breakthrough study which has sparked discussion and research west-wide, they established a water trough in a field which was used as a winter, hay feeding location and which contained a flowing stream. Stunningly, the animals nearly completely abandoned the stream (90% reduction of use) as a watering source in favor of the trough. The avoidance of the flowing stream meant that the opportunity for fecal material to be deposited in the water or on the adjacent streambanks was decreased proportionally. Several reasons for this shift are likely: 1) The water in the trough was relatively warm, around 50 degrees F, whereas the stream water was at freezing, 32 degrees F. 2) the overflow from the trough was piped several feet away from the trough itself, resulting in dry, firm ground surrounding the trough as opposed to muddy banks next to the stream. 3) the trough was situated so that the surface of its water was 1 ½ feet above the ground’s surface whereas the stream was at, or below, the ground’s surface, forcing an animal to stoop in order to drink.

Encouraged by this development, Clawson, et al, (1994) conducted a similarly designed study to determine if an off-site watering trough would work to deter animal use from the riparian zone during plant growing seasons. They found that an approximate 26% reduction in animal use at the stream occurred over the course of the entire growing season….but that most of the riparian use reduction occurred after the riparian zone had been grazed down significantly and the animals’ grazing patterns had shifted more toward the uplands. From an animal behavioral point of view, this makes sense. The livestock found water, forage, and shade in the cooler riparian zones and were reticent to leave until much of the forage was consumed. Once their grazing patterns shifted, they would have to trail from their current grazing areas in the uplands back to the riparian zone daily for water. A trough located in between the water and the uplands was tempting enough to deter about a quarter of the potential use at the stream.

Larson, et al, 2007 studied livestock movements in the California annual grasslands using high tech tracking devices and found similar grazing patterns as noted by Larsen and Larsen, et al, (1989, 1994) and as reported by Clawson, et al (1994).

Sherer, B.M., J.R. Miner, J.A. Moore, and J.C. Buckhouse (1988) conducted a controlled attempt to determine distance travelled in-stream by bacteria if they were, indeed, successful in reaching a flowing stream. The researchers reported that under conditions of laminar flow, 90% of the fecal bacteria settled to the bottom within 100 meters where they associated themselves with sediments at the bottom of the creek. There they remained unless they were re-suspended by traffic crossing the stream or by the occurrence of turbulent flows associated with flooding. Once re-suspended, the bacteria remained in suspension for only another 100 meters or until the turbulent flow characteristics subsided. The researchers, in looking at stream flow records, found that many of the 3rd order streams of the intermountain west experienced turbulent flow flood conditions only 5 or 6 days per year on those occasions of rapid snow melt in the early spring or during late summer thunder storms.

This logically begged the question of how long bacteria might live in the sediments. In the wildland streams of the intermountain West, while it is theoretically possible for the bacteria to survive and even multiply once they are in the stream, it is unlikely since they do not have the protective substrate and environment of a warm-blooded animal's intestinal tract. Sherer, et al, (1992) found that fecal coliform and fecal streptococci bacteria revealed half-lives from 11-30 days after being deposited in the stream.

Within the past several years, concerns that livestock might be responsible for E. coli outbreaks prompted additional research using modern forensic methodologies. Meays, et al, (2006) developed a DNA/Ribotyping technique to determine bacterial sources. They found that the dominant sources of *E. Coli*, which shifted from one year to the next presumably due to weather and forage conditions, were wildlife. Wildlife accounted for >84% of the contribution in 2003 and > 73% in 2004. In both years avian species were the highest contributors. Tate and Atwill over a fifteen year period (1995-present) have concentrated on bacteria and cryptosporidium contamination of wildland streams and have developed a DNA approach to analyzing fecal bacteria which enabled them to determine the specific species of warm-blooded animal which deposited the fecal material. Perhaps to many people's surprise, the most common contributor of fecal contamination to the wildland waters they have investigate were resident rodent populations. Tate and Atwill (2010) published an excellent, yet succinct, review of their findings and suggestions in a rebuttal argument in the Sacramento Bee in response to a piece the Bee had published entitled "Bee exclusive: Livestock waste found to foul Sierra waters" Published Sunday, April 25, 2010, Page 1A. http://www.sacbee.com/2010/04/25/2703875/bee-exclusive-livestock-waste.html

Their response concluded with a statement that while there are risks associated with livestock grazing, there are management tools and opportunities available and research continues to explore even more.

CONCLUSIONS

If one looks at the larger picture of wildland water quality concerns associated with fecal contamination by warm-blooded animals, one can conclude:

1. All warm-blooded animals harbor fecal bacteria and are potentially capable of contaminating wildland waters.
2. Fecal contamination by livestock is greatly reduced if management practices which discourage the animals from defecating within a meter of the stream are employed (fencing, herding, salt and/or mineral supplements to lure animals to other locations, off-site watering, timing of livestock presence,).
3. If fecal matter is deposited into streams, it will generally precipitate to the bottom quickly where it will reside for only a relatively short period of time before it perishes.
4. Disturbance of bacteria-harboring bottom sediments should be kept to a minimum by using designated livestock fords and crossings and by being aware of turbulent flow conditions.
5. Animal sources of fecal contamination of wildland water supplies are commonly wildlife, with birds and rodents frequently being the most usual contributors.

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