Observed Changes in Populations of Thinhorn Sheep in Western Canada and Alaska

Wild Sheep Initiative

Western Association of Fish and Wildlife Agencies

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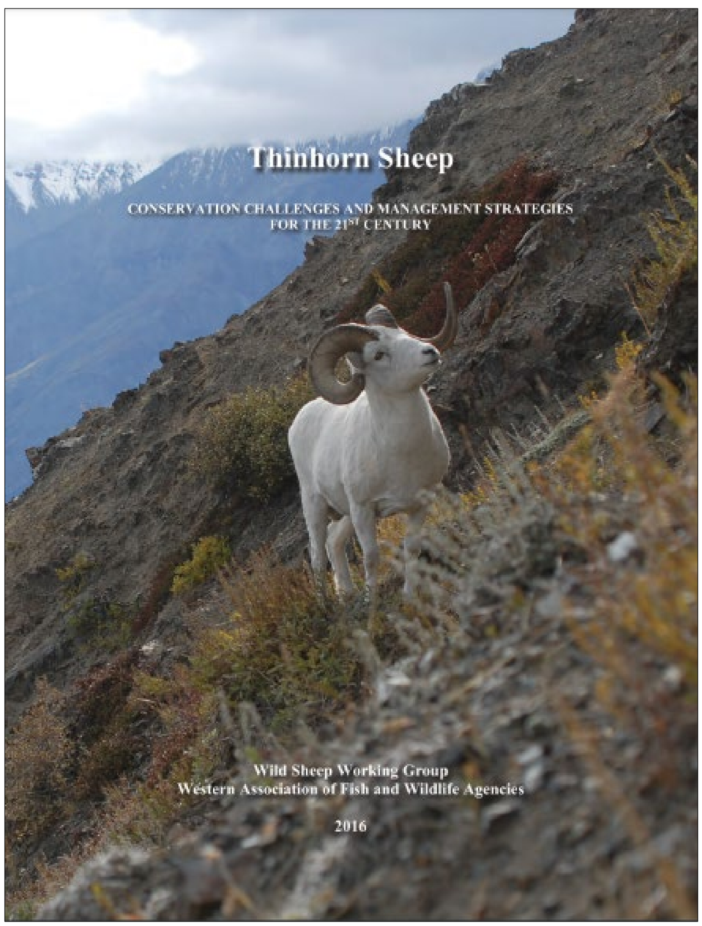
Western Association of Fish and Wildlife Agencies – Wild Sheep Initiative

White Paper: Observed Changes in Populations of Thinhorn Sheep in Western Canada and Alaska

Overview:

Over the past year, media outlets have been reporting on observed changes to thinhorn sheep populations (Dall's sheep and Stone's sheep) across their range in North America. This White Paper provides a summary of up-to-date information on the recent population trends of thinhorn sheep in the regions of British Columbia, Alaska, Yukon, and Northwest Territories.

In 2016, the WAFWA-Wild Sheep Initiative (then the Wild Sheep Working Group) published *Thinhorn Sheep: Conservation Challenges & Management Strategies for the 21st Century* (https://wafwa.org/wpdm-package/Thinhorn-sheep-conservation-challenges-management-strategies-for-the-21st-century/). This *White Paper* provides additional information and an update of jurisdictional information.



Cover photo: Lance Goodwin – Yukon Dall's sheep

Population Trends:

Since the early 2000's, significant population declines have been observed across thinhorn sheep ranges in North America. Most jurisdictions report gradual, long-term declining trends in populations but more recently, many are also experiencing losses associated with specific weather/climate events followed by minimal recovery.

1. Dall's Sheep (*Ovis dalli dalli*):
   - Alaska: Dall's sheep populations are found throughout eight mountain ranges in Alaska. The Alaska Department of Fish and Game has established minimum count areas within these ranges. The traditional count areas are small, relative to the geographic area of the range and is a function of their remoteness. Data are not corrected for snow cover, shadows, sun angle, observer experience, or other factors affecting animal counts. Therefore, minimum counts are a crude population index and are not a measure of absolute abundance. However, most areas counted have experienced a 50-70% decline when compared against higher counts between approximately 2007-2011 (consistent survey methods were used). The US National Park Service developed a distance sampling technique to estimate sheep abundance in their managed lands, including Denali, Wrangell St. Elias, Gates of the Arctic and Lake Clark National Parks. Results from those abundance surveys also suggest a population decline of 50-70% from the most recent highs[1]. The similar sheep population trends on both hunted and nonhunted lands in all 8 mountain ranges provides evidence that current harvest strategies are not the driver of population dynamics. Population declines may be partially explained by poor lamb recruitment in 2012, 2013, and 2014. Low survival of lambs in those years was observed and considered to be most likely weather related; the winter of 2011-2012 brought record snow depths to much of the state, and the 2012-2013 winter was also characterized by extreme snow depths. The impact of high snowfall on lamb production was exacerbated by low adult survival during the winters of 2019-2020, 2020-2021, and 2021-2022. The adult survival rate was based on data from GPS radio collared adult ewes (n=20) and rams (n=20) in the Talkeetna Mountains. Those results provided rates of 66%, 81% and 71% adult survival from 2019-2022. For reference, data from sheep in the Chugach, Wrangell, and Talkeetna mountains radio collared between 2008-2018 estimated overall adult survival rates between 88-92%, similar to the Brooks Range (77-88%)[2] and Alaska Range (72-91%)[3].

     Concern for declining Dall's sheep numbers are valid, especially in the face of uncertainty with the increasing temperatures in Arctic and sub-Arctic ecosystems, however, it is important to keep in perspective that population cycles have occurred before. For example, in Murie's book "*Wolves of Mount Mckinley*", he speaks of robust sheep numbers in the park until a drastic die-off associated with heavy snowfalls in the late 1920's early 1930's. And again, in the 1940's,

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[1] https://www.nps.gov/articles/000/dalls-sheep-resource-brief.htm?utm_source=article&utm_medium=website&utm_campaign=experience_more&utm_content=large

[2] Arthur, S. M. 2014. Demographics and spatial ecology of Dall sheep in the central Brooks Range. Federal Aid Final Research Performance Report 1July2007–30June2014, Federal Aid in Wildlife Restoration Project 6.15. Alaska Department of Fish and Game, Division of Wildlife Conservation, , Juneau, Alaska, USA.

[3] Arthur, S.M. and Prugh, L.R., 2010. Predator-mediated indirect effects of snowshoe hares on Dall's sheep in Alaska. *The Journal of Wildlife Management*, *74*(8), pp.1709-1721

wildlife managers had substantial concerns about declining sheep numbers in the Talkeetna and Chugach Mountains. A more contemporary example was observed in the Alaska Range where sheep populations and harvest rates were high until a weather-related population decline occurred during the winter of 1992-1993. Sheep populations and harvest rates in the Alaska Range returned to pre-decline levels over a long period, estimated at 15-20 years, peaking in 2016 until the recent population decline.

Photo: Bill Jex

- Yukon: Game Management Zones 5 and 7 have some of the highest densities of Dall's sheep in the Yukon and are very accessible to resident hunters (the zones are situated between Whitehorse and the Alaska border). Broad-scale sheep total-minimum-count and classification surveys were conducted across these two Game Management Zones in the 1970s and in 2015/2016. Although trends varied by sheep management units between the two survey years, sheep numbers were similar in zone 5 and increased by roughly 22% in zone 7. Since 2015, sheep populations in zone 5 west of the Alaska Highway (Kluane Range of St. Elias Mountains from southern Kluane Lake to White River, and the Nutzotin Mountains, including areas in which licensed harvest is not permitted), have all declined by roughly 50 to 60%. Anecdotal observations suggest similar declines in other regions of the Yukon.

- Northwest Territories (NWT): Population declines were observed in the Mackenzie and Richardson mountains (some areas are shared by the Yukon) beginning in about 2000, although consistent short- and long-term monitoring is only conducted in small, isolated study areas within the NWT sheep range (Palmer Lake and Katherine Creek). These populations currently appear to be stable at somewhat lower levels. The Palmer Lake population has declined approximately 60% from a peak in 2004, whereas the Katherine Creek study area has declined approximately 85% from a peak in 1998.

- British Columbia: As with thinhorns in general, Dall's sheep in British Columbia are in remote and logistically difficult areas to access. Population inventory is rarely prioritized on a regular basis, predominantly due to the area's remoteness and the conservative harvest regulations. Although considered relatively stable range-wide as recently as 2023, the perception may be due, at least in part, to the paucity of population inventory data. At very localized geographic scales where multiple surveys have been conducted, declines of 15-50% were observed from 2000 to 2020. The declines were considered attributable to successive years of poor lamb survival (2010-2014) and more recently, recurrent winter weather related losses in the juvenile and adult cohorts (2019-2022) similar to observations made in Alaska. As with all jurisdictions described, infrequent population inventories prevent the generation of reliable trends; for example, the most frequently surveyed area near Atlin had 5 total-minimum-count surveys completed in 40 years, with the number of observed sheep ranging from 145 in 1982, to 81 in 2013, and 94 in 2023. Its unknown if some local populations may have shown some levels of recovery during the time between surveys. There are however, currently no areas in the province where Dall's sheep populations are assessed as increasing or above numbers observed in the late 1990's to early 2000's.

2. Stone's Sheep (*Ovis dalli stonei*):
    - British Columbia: Stone's sheep ranges in some areas of BC have been more frequently inventoried than Dall's sheep ranges. Results from total-minimum-count surveys are showing similar declines as observed in Dall's sheep ranges. The declines in Stone's sheep populations range from 13-50%, whereas other localized populations appear relatively stable highlighting concerns for population variability, viability and resiliency. Interpretation of data will be less reliable without regular inventory or when methods vary. In some areas, range contraction, most likely as a result of shifting climatic patterns and resultant changes in habitat quantity and quality, has been observed at regional scales. Several isolated sub-populations are now considered extirpated (e.g., Mount Frank Roy, Mount Monteith) or no longer present (e.g., Sikanni Chief Canyons).


Photo: Bill Jex

Population Trends – Threats and Issues:

1. Habitat Loss and Fragmentation:
    - The decades old effects of human activity and disturbances from development, resource extraction, and infrastructure projects have compounded over time, leading to habitat loss, fragmentation and alienation/abandonment in some sheep ranges (e.g., some Stone's sheep ranges in British Columbia). In other areas the magnitude of effect is smaller due to less access/landscape permeability, so anthropogenic effects do not yet appear to have created significant change in sheep distributions or populations (e.g., Northwest Territories).

    - Changes in land management interests and governance, as well as habitat interventions and manipulations (e.g., prescribed fire) at varying scales, can result in changes in sheep distribution and lead to exploitative, interference and apparent competition with other ungulate species[4]. Until recently these effects in and of themselves, do not appear to have posed significant risk to thinhorn sheep. However, the sum of cumulative impacts to sheep habitat and seasonal range may lead to reduced fitness and reproductive potential, ultimately impacting sheep population resilience and trend. Long term comprehensive strategies for managing habitat and mitigating

[4] https://wafwa.org/wpdm-package/thinhorn-sheep-conservation-challenges-management-strategies-for-the-21st-century/

human effects should be delivered alongside, and be responsive to, the results of long-term monitoring of sheep herd health and demographics.

2. Changing Climate:
    - Temperatures in northern North America and the Arctic are increasing at significantly faster rates than southern environments and the global average temperature predictions[5,6]. Two considerable drivers of climate that can affect population outcomes for thinhorn sheep in North America are the Pacific Decadal Oscillation (PDO) and global climate patterns that affect precipitation, snow levels and temperature extremes on seasonal and annual cycles[7], with these occurring at approximately 10-20-year intervals[8][9]. Pacific Decal Oscillation (and to a lesser degree, Arctic Decal Oscillation) has positive and negative phases, and depending on which phase and the strength of that phase, PDO can dramatically affect climate cycling, influencing precipitation, temperature and wind patterns. Within this 10-year PDO cycle, events such as El Niño and La Niña also occur in somewhat regular weather cycles, typically affecting weather patterns on 6–12-month timelines; these are primarily driven by winds and ocean surface temperatures. Where PDO and El Niño or La Niña phenomena are in the same phase (i.e., positive or negative) the associated effects on weather patterns can be amplified. Very localized events such as temperature inversions and chinook winds happen infrequently, more affected by the El Niño and La Niña pattern, with these lasting only hours, to a day and up to a week. These events are often unpredictable in their effect on habitat suitability and mountain sheep. Rain on snow events in particular may occur more frequently, creating icing/crusting conditions that can significantly restrict access to forage, or create hardened snow that improves predator access. Such conditions can result in population level impacts by direct mortality (e.g., western Brooks Range 2014).

      Climate patterns specifically affect the availability (i.e., seasonality and quantity) and quality of forage for thinhorn sheep. An increase in the irregularity of climate and weather patterns from climate change may delay the arrival of spring green-up, affect summer growing conditions, autumn forage quality, and reduce winter forage availability, ultimately manifesting in poorer individual nutrition and impacts to lamb survival and recruitment[10]. Recently published literature suggests that adult sheep survival is negatively associated with increased winter freeze-thaw events. Further, there is evidence for increased shrubification[11] in the alpine and sub-alpine plant communities due to warmer and moister climate, decreasing the amount of suitable habitat for thinhorn sheep and leading to decreased carrying capacity on many ranges. Changing conditions in seasonal ranges may also affect the suitability and function of those

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[5] https://arctic-council.org/explore/topics/climate/

[6] https://www.climatehubs.usda.gov/hubs/northwest/topic/climate-change-impacts-northwest

[7] https://www.climatehubs.usda.gov/hubs/northwest/topic/alaska-and-changing-climate

[8] https://sealevel.jpl.nasa.gov/data/el-nino-la-nina-watch-and-pdo/pacific-decadal-oscillation-pdo/#:~:text=The%20Pacific%20Decadal%20Oscillation%20(PDO,or%20a%20'warm'%20phase.

[9] Hik, D.S. and J. Carey. 2000. Cohort variation in horn growth of Dall sheep rams in the southwest Yukon, 1969–99. Biennial Symposium Northern Wild Sheep and Goat Council 12:88-100.

[10] Cosgrove C. L., J. Wells, A. W. Nolin, J. Putera, and L. R. Prugh. 2021. Seasonal influence of snow conditions on Dall's sheep productivity in Wrangell-St Elias National Park and Preserve. PLoS ONE 16: e0244787.

[11] Myers-Smith I. H., and D. S. Hik. 2018. Climate warming as a driver of tundra shrubline advance. Journal of Ecology 106:547–560.

ranges. In summary, climatic drivers directly and indirectly affect habitat use in thinhorn sheep, which can then affect fitness and body condition, reproductive success, and lamb condition that influences survival[12] and population trajectories[13].

Collectively, severe winter and spring events may result in lower populations of thinhorn sheep, particularly when they occur through consecutive years. For example, as described above, between autumn 2010 and spring 2014, most areas with thinhorn sheep range observed population declines, predominantly linked to reduced winter survival and poor lamb recruitment. This occurred during a period of stronger positive PDO effect, amplified by a moderate to strong positive La Niña effect seen in North America's Pacific Northwest. More recently, the three winters (2019-20, 2020-21 and 2021-22) described above had similar outcomes with an unusual La Niña effect that lasted 3 consecutive years, to again result in higher than expected adult and juvenile winter mortality (i.e., similar to 2010-2014). This outcome was widespread, affecting sheep populations in Alaska, Yukon, Northwest Territories and British Columbia. When such cohort losses occur, they also indirectly impact lamb numbers and recruitment through the reduction in the number of breeding adults and recruiting juveniles. These more recent weather events appear to fall outside traditional PDO patterns[14]. The strength of the La Niña pattern, through recent consecutive winters and despite being classified as 'moderate' in strength, still appear to have created more stochastic local and severe weather effects.

3. Predation:
   - Thinhorn sheep share their ranges with a wide range of terrestrial and aerial predators. Predation is not a new challenge for sheep, except where range expansions for predators has occurred (e.g., cougar range expanding into north-western British Columbia; coyote and wolverine populations benefit from targeted wolf reductions), or where predator populations have increased. Observed increases in predation, particularly by eagles, wolves, coyotes and bears, has been noted as a significant factor in declining sheep populations, and these effects can be exacerbated where sheep predation is associated with apparent competition[15]. Historical predator removal programs undertaken in some jurisdictions in the late 1940's to 1960's by land

[12] Lohuis, T., K. Smith, L. Metherell and D. Roman. 2018. Dall's sheep population declines in Alaska's Chugach Range may be related to climate and weather patterns. Proceeding of the 21st Biennial North Wild Sheep and Goat Council Symposium 21:76.

[13] Aycrigg J.L., A. G. Wells, E. O. Garton, B. Magipane, G. E. Liston, L. R. Prugh, et al. 2021. Habitat selection by Dall's sheep is influenced by multiple factors including direct and indirect climate effects. PLoS ONE 16: e0248763.

[14] https://www.worldclimateservice.com/2021/09/01/pacific-decadal-oscillation/

[15] https://wafwa.org/wpdm-package/thinhorn-sheep-conservation-challenges-management-strategies-for-the-21st-century/?wpdmdl=11704&refresh=66205a8633bb61713396358

management agencies (i.e., poisoning[16]) and aerial removals that occurred into the 1990's, dramatically reduced predator numbers. The success of control programs appears to have had mixed results with respect to their effect on thinhorn populations. Since the cessation of historic large-scale predator reduction programs, widespread recovery of those large carnivore predator populations has occurred, undoubtedly contributing to at least some impact to small and isolated sheep populations. More generally, predation effect can negatively influence thinhorn sheep population resilience and trajectory in years when winter and snow conditions are more conducive to predator success.


Photo: Clint Walker

- Other efforts to target specific large predators for removal have shown conflicting outcomes and, in some instances, there were increased predation effects to sheep populations where mesocarnivore populations were no longer limited by the presence of larger predator species[17]. While this was suggested in Alaska[18], past predator removal programs implemented in the Yukon, did not appear to significantly influence sheep populations[19]. The Yukon research suggested that predation rates by wolves appeared to be pack and condition specific, with wolves exhibiting a functional prey shift to sheep when conditions in high elevation areas were favourable compared to those at lower elevation, with the degree of predation being variable based on terrain conditions. Some of the variability in observed outcomes may also be due to localized predator prey selection, large carnivore seasonal range overlap with prey species, and mesocarnivore niche partitioning in response to the reduced large carnivore population (i.e., mesocarnivore suppression).

4. Health:

- Historically, few diseases and parasites of thinhorn sheep have been described. *Protostrongylus stilesi* and *rushi* (lungworms), secondary bacterial pneumonia, gastrointestinal nematodes and other internal parasites, *Dermacentor albipictus* (winter tick) infestation and associated hair loss, necrobacillosis or bacterial osteomyelitis (lumpy jaw) and orf (soremouth or contagious ecthyma[20]), trauma, exposure to various viruses such as Malignant Catarrhal Fever and other

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[16] Hatler, D.F. 1981. An analysis of livestock predation and predator control effectiveness in northwestern British Columbia. Unpublished Report. Ministry of Environment, Fish and Wildlife Branch, Victoria, British Columbia, Canada.

[17] Prugh, L., and S. Arthur. 2015. Optimal predator management for mountain sheep conservation depends on the strength of mesopredator release. Oikos 124.

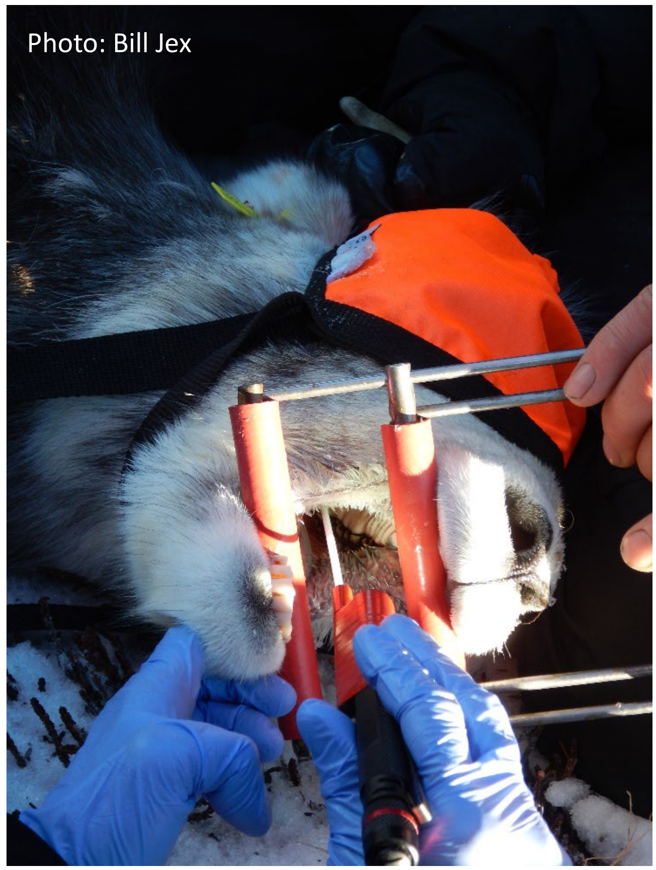
[18] Scotton, B.D. 1998. Timing and causes of neonatal Dall sheep mortality in the Central Alaska Range. M.Sc. Thesis, University of Alaska, Fairbanks, Alaska, USA.

[19] Barichello, N., J. Carey, R. Sumanik, R. Hayes, and A. Baer. 1989. The effects of wolf predation on Dall sheep populations in the southwest Yukon. Yukon Department of Renewal Resources, Whitehorse, Yukon, Canada.

[20]Tryland, M., K. B. Beckmen, K. A. Burek-Huntington, *et al.* .2018. Orf virus infection in Alaskan mountain goats, Dall's sheep, muskoxen, caribou and Sitka black-tailed deer. Acta Veterinaria Scandinavica 60:12.

diseases and parasite findings have been reported in thinhorns. However, there is no strong association of any of the conditions or exposures with herd level health effects. As with any individual health challenge, there is the potential for health challenges to be cumulative with other stressors (e.g., weather and predation) or disproportionately impact young or old individuals. In immunologically naïve populations of thinhorn sheep, exposure to new or uncommonly encountered pathogens may create a more severe situation, affecting a higher proportion of individuals with more serious effects but at this time it is only speculative as this is not recorded. Recently, more data from specific studies on thinhorn sheep health has provided a baseline of mostly endemic diseases and parasites. Establishing long term community- or harvest-based monitoring programs is strongly recommended to help predict further changes in thinhorn health. Such changes are expected due to climate models predicting emerging infectious diseases and climate-driven adaptations in endemic and novel parasite reproductive cycles[21]. Jurisdictional management focus on long-term change must include the consideration of the potential introduction of novel pathogens as an essential part of species management programs.

- Potential risk to thinhorn sheep exists from some human agricultural or recreational activities with the potential for transmission of domestic livestock diseases and parasites to thinhorn sheep[22,23]. This risk may also be presented by contact with sympatric species such as mountain goats and caribou, which can share the same domestic pathogens[24,25,26].



[21] Aleuy O. A., K. Ruckstuhl, E. P. Hoberg, A. Veitch, N. Simmons, and S. J. Kutz. 2018. Diversity of gastrointestinal helminths in Dall's sheep and the negative association of the abomasal nematode, Marshallagia marshalli, with fitness indicators. PLoS ONE 13: e0192825.
[22]https://open.yukon.ca/sites/default/files/thinhorn_sheep_risk_assessment_cwhc_2016_0.pdf.
[23] https://www2.gov.bc.ca/assets/gov/environment/plants-animals-and-ecosystems/wildlife-wildlife-habitat/wildlife-health/wildlife-health-documents/risk_assessment_use_of_camelids_for_backcountry_trekking_bc.pdf
[24]Wolff P.L , J. A. Blanchong, D. D. Nelson, P. J. Plummer, C. McAdoo, M. Cox, T. E. Besser, J. Muñoz-Gutiérrez, and C. A. Anderson. 2019. Detection of Mycoplasma ovipneumoniae in pneumonic mountain goat (Oreamnos americanus) kids. Journal of Wildlife Diseases 55:206-212.
[25]http://media.nwsgc.org/proceedings/NWSGC-2016/Wolff_NWSGC20_79.pdf
[26]Blanchong, J., C. Anderson, N. Clark, R. Klaver, P. Plummer, M. Cox, C. McAdoo, and P. Wolff. 2017. Respiratory disease, behavior, and survival of mountain goat kids. Journal of Wildlife Management 82:1243-1251.

- Understanding of the implications of newly recognized parasites in thinhorn sheep such as *Toxoplasma gondii*, *Marshallagia marshalli*, and improvements in our ability to detect and interpret the significance of pathogens, such as *Mycoplasma ovipneumoniae* (M.ovi), may lead to better knowledge of the baseline health of thinhorn sheep and allow more effective population monitoring in the future. Interdisciplinary collaborations using One Health principles will inform governments, agencies and public awareness of the challenges to wildlife and implications of all emerging infectious diseases[27].
- Thinhorn sheep are considered immunologically naïve to pathogens carried by domestic livestock, however, there are no recorded exposures to the M. ovi bacterium in British Columbia, Yukon or the Northwest Territories. There is an example in a zoo setting, of Dall's sheep exposure to M.ovi that resulted in 100% mortality; infected sheep either died as a result of the infection, or from having to be humanly euthanized due to the severity of illness[28]. Research in Alaska has reported a novel, apparently stable strain of M.ovi present in Dall's sheep in that state[29], however there are no previously documented effects on historical Dall's sheep populations in Alaska, associated with this strain of M. ovi. This strain found in Alaska differs from M.ovi strains detected in bighorn sheep populations further south, that have been associated with respiratory disease, all-age die-offs and population declines.

5. Human Disturbance:
   - Disturbance as a result of industrial activities (e.g., resource exploration and extraction, winter drilling programs on winter range), and recreational activities (e.g., hiking/skiing, hunting, use of off-road vehicles and motorized recreation) during critical seasons (i.e., rut, winter, and lambing/natal periods), can affect habitat use and induce stress responses in thinhorn sheep, disrupting their natural behaviors[30].
   - Ongoing research, monitoring and implementation of policy and regulations protecting habitat values and directing consumptive activities is common across all jurisdictions.


Photo: Bill Jex

[27] Buttke, D. E., D. J. Decker, and M. A. Wild. 2015. The role of One Health in wildlife conservation: a challenge and opportunity. Journal of Wildlife Diseases 51:1–8.
[28] Black S.R., I. K. Barker, K. G. Mehren, G. J. Crawshaw, S. Rosendal, L. Ruhnke, J. Thorsen, and P. S. Carman. 1988. An epizootic of Mycoplasma ovipneumoniae infection in captive Dall's sheep (Ovis dalli dalli). Journal of Wildlife Diseases 24:627-35.
[29] Lieske, C. L., R. Gerlach, M. Francis, and K. B. Beckman. 2022. Multilocus sequence typing of Mycoplasma ovipneumoniae detected in Dall's sheep (Ovis dalli dalli) and caribou (Rangifer tarandus grantii) in Alaska, USA. Journal of Wildlife Diseases 58:625-630.
[30] https://wafwa.org/wpdm-package/thinhorn-sheep-conservation-challenges-management-strategies-for-the-21st-century/

Consumptive use is closely monitored through compulsory inspection of harvested sheep by licensed hunters.
- The nature of cumulative effect(s) presents a more likely scenario for widespread population decline, where the localized effect depends on the specific disturbance parameters or type of stimulus and the population size, resiliency and composition[31,32].

Conservation Efforts:

1. Habitat Protection and Restoration:
    - Initiatives are underway in some jurisdictions that are focused on protection and restoration of important seasonal habitats. This can include a range of activities from habitat interventions using prescribed fire, to regulatory prohibitions related to types of access and land use. While these can be effective, actions such as these can take many years to implement; and may have varied success since their efficacy is vulnerable to weather and climate, they depend on public support of funding and compliance with the management strategies, and implementation of effectiveness monitoring that informs adaptive management processes.

2. Predator Management:
    - In recent years, changes in jurisdictional management of sympatric species and climate moderated range expansions have resulted in a changed predator landscapes when compared to those in thinhorn sheep ranges in the 1970's. These specific changes, to which thinhorn sheep will have to respond to, require additional focused research in order to properly understand their implications to thinhorn sheep populations and jurisdictional management.
    - Predator management, whether a control program or targeted species reductions, can be a polarizing topic in every jurisdiction, and particularly where regionally specific research has yet to be undertaken that inform understanding of wildlife responses to those efforts. Collaboration across sectors will be required where predators are known to be main factors limiting population resiliency and recovery. In some very small populations that could be at risk of extirpation, reducing the impact of predation on thinhorn sheep at least in the short-term, may be necessary if those populations are to increase or persist. In areas where range overlaps with endangered species and predator control program areas is occurring, opportunities for focused study of coincidental outcomes associated with removals on other species, as well as sheep population responses.
    - Different predator species may affect sheep at different rates and their prevalence can vary across different mountain ranges. For example, lamb mortality studies in Alaska demonstrated that golden eagles were the primary predator in the Brooks Range, coyotes in the Alaska Range and a suite of predators in the Chugach Mountains. Researchers have suggested that state sponsored wolf removal in the Alaska Range may have resulted in an increase in coyote abundance. Decision-makers are encouraged to support policy decisions related to predator mitigation efforts, to be informed by cause-specific mortality data (collected as it is generated

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[31] Stewardship Framework for Thinhorn Sheep (*Ovis dalli*) in British Columbia (draft). Thinhorn Sheep Indigenous Perspectives and Thinhorn Sheep Management Teams. Unpublished Report. Prepared for the Wildlife Branch, British Columbia Ministry of Water, Land and Resource Stewardship, Victoria, British Columbia, Canada.

[32] https://www.wildsheepfoundation.org/cache/DOC195_DallSheepNews.pdf?20171204035910

through mitigation actions), within an effectiveness monitoring framework that assesses the outcomes of initiated actions.

- Most jurisdictions have licensed seasons to harvest predator and/or fur-bearing (mesocarnivore) species, however, it is not clear whether hunter and trapper harvesting provides an effective solution to high predator densities. Recent literature suggests that human-caused mortality, for example at low rates of harvesting wolves (<22%), can result in additive mortality effects reducing overall wolf population numbers and affecting population growth rate[33].   Where harvest of pack leaders occurs, wolf pack destabilization and fragmentation has been suggested[34], however this was not the findings of work conducted in the Rocky Mountains[35] where pack abundance and distribution appeared to remain stable despite frequent turnover of individuals within packs. It is likely that numerous local and environmental factors[36] affect the outcomes from hunter and trapper off-take of predators, and the corresponding responses by predator populations, making generalized statements incorrect if applied at a non-corresponding geographic scale.

3. Climate Adaptation Strategies:

- As funding options diversify and increase, researchers and managers are realizing more opportunities to understand how climate change specifically affects sheep habitat and populations[37]. Results will inform adaptation strategies to reduce risks posed by environmental change, to sheep populations and increase population resilience. Improved weather station infrastructure may serve as tools to assist the understanding rates of habitat change associated with climate pattern shifts, or create improvements in forecasting habitat and anticipated vegetative change that can then inform habitat intervention and enhancement proposals.
- There is significant value in establishing long-term studies[38] that facilitate opportunities to examine archived ecological research and expand that into new projects that improve our collective understanding of past and potential future effects on thinhorn sheep, changes in their environment[39] as well as from anthropogenic pressures[40]. In the case of bighorn sheep, knowledge from four long-term programs monitoring individually marked bighorn sheep have significantly improved our understanding of the ecology, behavior, evolution, disease impacts

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[33] Creel, S., and J. J. Rotella. 2010. Meta-analysis of relationships between human offtake, total mortality and population dynamics of gray wolves (Canis lupus). PLoS ONE 5: e12918.
[34] Cassidy, K. A. B. L. Borg, K. J. Klauder et al. 2023. Human-caused mortality triggers pack instability in gray wolves. Frontiers in Ecology and the Environment 21:353-400.
[35] Bassing, S. B. 2017. Harvest and persistence of wolf populations: variable effects of harvest on wolf packs in the rocky mountains. MSc Thesis. University of Montana, Missoula, Montana, USA.
[36] Bassing, S. B., D. Ausband, M. Mitchell, P. Lukacs, A. Keever, G. Hale, and L. Waits. 2018. Stable pack abundance and distribution in a harvested wolf population. Journal of Wildlife Management 83:577-590.
[37] van de Kerk, M., D. Verbyla, A. W. Nolin, K. J. Sivy, and L. R. Prugh. 2018. ABoVE: Dall sheep lamb recruitment and climate data, Alaska and northwest Canada, 2000-2015. ORNL DAAC, Oak Ridge, Tennessee, USA.
[38] Davidson, S. C., et al. 2020. Ecological insights from three decades of animal movement tracking across a changing Arctic. Science 370:712-715.
[39] Hueffer, K., A. J. Parkinson, R. Gerlach, and J. Berner. 2013. Zoonotic infections in Alaska: disease prevalence, potential impact of climate change and recommended actions for earlier disease detection, research, prevention and control. International Journal of Circumpolar Health 72.
[40] Brown, C. L., S. F. Trainor, C. N. Knapp, and N. P. Kettle. 2021. Alaskan wild food harvester information needs and climate adaptation strategies. Ecology and Society 26(2):44.

Photo: Alicia Woods

and conservation of the species; specifically at Ram Mountain and Sheep River, Alberta, the National Bison Range, Montana, and Hell's Canyon, Idaho.

4. Public Education and Outreach:
    - Several jurisdictions are undertaking or have completed jurisdictional thinhorn sheep management or stewardship plans. These plans inform stakeholders of positive and negative pressures on populations, but also outline regulatory and management decision-making processes associated with the conservation of thinhorn sheep resources.
    - Educational programs and outreach campaigns to raise awareness about the potential effects humans can have on wild sheep and their habitats, the importance of conserving thinhorn sheep, and promoting responsible outdoor recreation are being developed by wild sheep and environmental conservation organizations.
    - Research and information efforts to better explain the linkages, risks and effects posed by domestic livestock disease[41] exist in most jurisdictions[42], with some areas (e.g., Alaska, Yukon, Northwest Territories) also implementing regulatory and policy directives that specifically guide domestic livestock production, or health testing outcomes[43].
    - The importance of timely, regular, and accurate population inventory of thinhorn sheep is of critical importance. Once considered to be of low conservation risk due to the ruggedness and remoteness of their habitats and the inherent conservative nature of harvest regulations, thinhorn sheep managers and conservation advocates have come to understand just how vulnerable Dall's and Stone's sheep are to environmental and human influences. This has resulted in increased financial investment across most jurisdictions aimed at ensuring a reliable suite of population and trend data exists, that land and wildlife managers can base resource development and species management decisions.


Photo: Province of British Columbia

5. Hunting and Human Activities:

[41] https://www2.gov.bc.ca/gov/content/industry/agriculture-seafood/animals-and-crops/animal-production/sheep-and-goats/mycoplasma-ovipneumoniae
[42] https://hctf.ca/bc-s-wild-domestic-sheep-separation-program/
[43] https://wafwa.org/wp-content/uploads/2020/09/2018-11-19-KPH-mark-up-to-Fact-Sheet-for-YT-Control-Order.pdf

- Thinhorn sheep are used by humans in both non-consumptive and consumptive ways. Non-consumptive use of thinhorn sheep or their habitats[44,45], specifically commercial and recreational photography and wildlife viewing[46,47] is increasingly including the use of drone or unmanned aerial vehicle technologies. These activities are largely unregulated in most jurisdictions unless they are commercial in nature. Research on effect(s) is informing new agency and organizational policies and regulations related to these activities[48,49,50]. Preliminary analyses suggest that these activities are not benign in their effect on wildlife or other species of wild sheep[29,51], and it would be reasonable to conclude that similar effects on thinhorn sheep would be likely. Collaboration across sectors will be required to acknowledge and better understand the implications of existing unregulated pressures, levels of activity(ies) and local-direct effects on thinhorn sheep populations, fitness, ecology and habitat use.
- Consumptive uses such as subsistence and recreational hunting generally have geographically bound, directed or regulated restrictions that are based on some form of population inventory or harvest allocation process; from this, recreational licensed harvest of thinhorn sheep is predominantly restricted to conservative approaches limiting harvest (e.g., mature males that have either reached a minimum age or have specific horn-curl morphology). While conservative in nature, cumulative annual harvest can affect demographic structure of the population depending on harvest intensity (i.e., the percent of males taken annually from within mature ram and recruiting ram cohorts). The goal of harvest management often is for harvest to align with compensatory mortality outcomes by limiting overall harvest and harvest from within specific demographic groups. However high rates of illegal harvest (e.g., recruiting rams) potentially introduces elements of additive mortality effect in subsequent years through altered recruitment, ram age structures and ram:ewe-like ratios. This can be particularly problematic if that occurs in a small population, or in a population with a longer declining trend and an already lower proportion of mature males. Collaboration across sectors could be required to better

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[44] Lowrey, C. and K. M. Longshore. 2017. Tolerance to disturbance regulated by attractiveness of resources: a case study of desert bighorn sheep within the River Mountains, Nevada. Western North American Naturalist 77(1):82-98.
[45] Kuwaczka, L. F., V. Mitterwallner, V. Audorff, and M. J. Steinbauer. 2023. Ecological impacts of (electrically assisted) mountain biking. Global Ecology and Conservation 44: e02475.
[46] Wiedmann, B.P., and V.C. Bleich. 2014. Demographic responses of bighorn sheep to recreational activities: a trial of a trail. Wildlife Society Bulletin 38:773-782.
[47] Papouchis, C. M., F. J. Singer, and W. B. Sloan. 2001. Responses of desert bighorn sheep to increased human recreation. Journal Wildlife Management 65:573–582.
[48] https://www.nps.gov/zion/learn/news/droneharassesbhs.htm
[49] https://www.wildsheepfoundation.org/cache/DOC391_DronePolicy_1.pdf?20211027020139
[50] Courtemanch, A. B. 2014. Seasonal habitat selection and impacts of backcountry recreation on a formerly migratory bighorn sheep population in northwest Wyoming. Thesis, Department of Zoology and Physiology, University of Wyoming.
[51] MacArthur, R.A., V. Geist, and R. H. Johnston. 1982. Cardiac and behavioural responses of mountain sheep to human disturbance. Journal of Wildlife Management 46:351-358.

understand the implications of existing regulations and levels of harvest pressure[52,53,54], or where uncertainty about the actual population size exists, particularly when population monitoring shows a long-term declining trend.

- Research identifies both a biological and management benefit through application of the full curl harvest strategy, considered a conservative approach since it predominantly restricts the harvest to older male classes, generally ensuring that those individuals have at least one opportunity to contribute genetically to a population through participation in breeding activities. Similarly, there is agreement that environmental influences can also dramatically influence horn growth[55,56,57] and where the combined effect of genetics and environment increase an individual's rate of horn growth (i.e., they become full curl at a younger age) their risk of harvest by hunters increases[58]. Additionally, the influence of male cohort age compositions can affect ram abundance at localized scales and increase foray movements, particularly for younger recruiting males seeking opportunities to participate in rutting/breeding activities. Recent Alaskan data from radio-collared 3-7 year old rams in both heavily hunted (i.e., under harvest ticket and full curl regulation) or lightly hunted (i.e., under State drawing hunts or Federal subsistence regulations) in the Wrangells, Chugach, and Talkeetna mountain ranges indicated that younger, presumably non-dominant rams experience overwinter mortality rates between 8-12%, similar to other segments of the population, even during winters when icing and/or heavy snowfall events do not occur[59].

Photo: Province of British Columbia

[52] Douhard, M., M. Festa-Bianchet, F. Pelletier, J-M. Gaillard and C. Bonenfant. 2016. Changes in horn size of Stone's Sheep over four decades correlate with trophy hunting pressure. Ecological Applications 26(1):309–321.
[53] Karabatsos, S., N. C. Larter, D. G. Allaire, K. Eykelboom, C. Estevo, M. Iravani, I. C. Barrio, and D. S. Hik. 2024. Dall's sheep horn growth and harvest management in the Mackenzie Mountains, Northwest Territories, Canada. Journal of Wildlife Management 88: e22536.
[54] Brown, C. L., S. F. Trainor, C. N. Knapp, and N. P. Kettle. 2021. Alaskan wild food harvester information needs and climate adaptation strategies. Ecology and Society 26(2):44.
[55] Hedrick, W.P. 2011. Rapid decrease in horn size of bighorn sheep: environmental decline, inbreeding depression, or evolutionary response to trophy hunting? Journal of Heredity 102(6):770-781.
[56] Sim, Z., and D. W. Coltman. 2019. Heritability of horn size in thinhorn sheep. Frontiers in Genetics 10:959.
[57] Hik, D.S. and J. Carey. 2000. Cohort variation in horn growth of Dall sheep rams in the southwest Yukon, 1969–99. Biennial Symposium Northern Wild Sheep and Goat Council 12.
[58] Bonenfant, C., F. Pelletier, M. Garel, and P. Bergeron. 2009. Age-dependent relationship between horn growth and survival in wild sheep. The Journal of animal ecology 78:161-171.
[59] Alaska Department of Fish & Game, unpublished data.

Photo: Province of British Columbia

Call to Action:

Conservation advocates, stakeholders, First Nations, government agencies, wildlife professionals, hunters, recreationalists, and the public are encouraged to support conservation efforts through responsible outdoor practices, reporting wildlife observations or unlawful activities, and staying informed about supporting local initiatives. While there are similarities in the challenges each jurisdictions' thinhorn sheep populations currently face, there is no one-size fits all solutions for most environmental challenges, meaning that most wild sheep managers must implement an adaptive learning and management philosophy to understanding the viability of wild sheep resources. There are common tools we can use to reduce the effects on habitats and risks associated with pathogen and disease transmission, but perhaps most important is the need to expand education and knowledge across the industrial and domestic livestock sectors. By working together, we can ensure that shared knowledge enables population resilience and the continued well-being and sustainability of thinhorn sheep populations for future generations.

For more information, please see: https://wafwa.org/initiatives/wsi/

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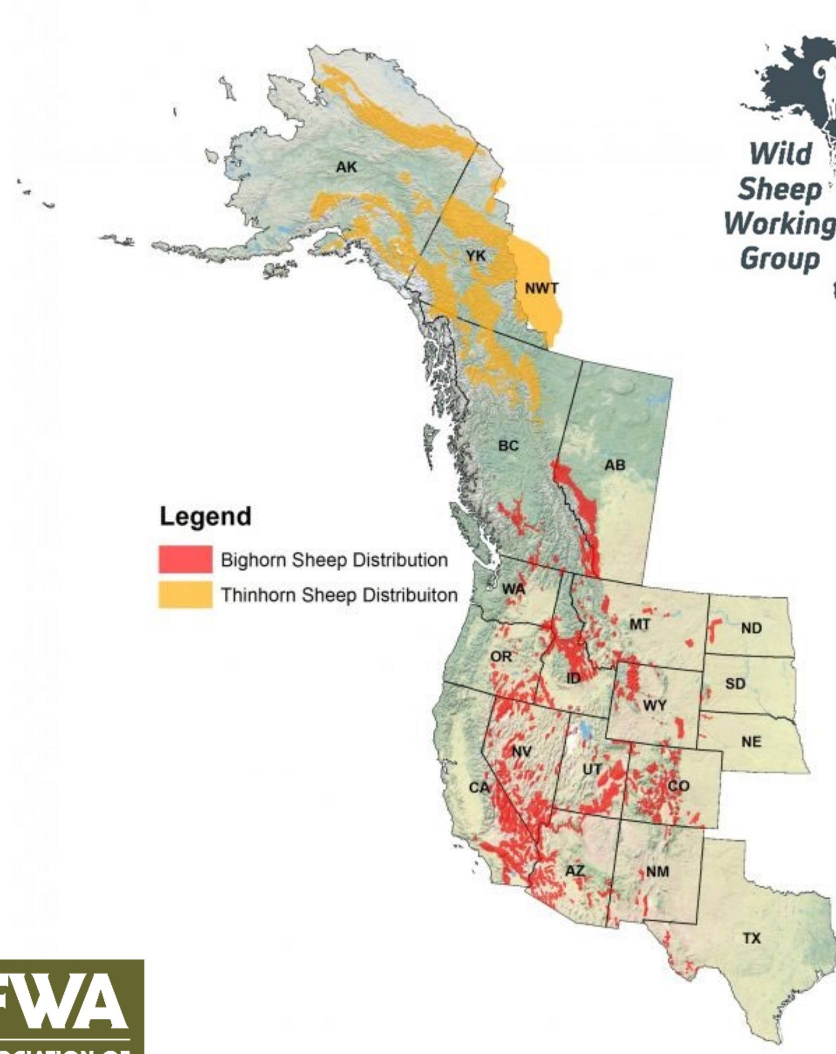

Wild Sheep Working Group

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