

Standard Operating Procedure (SOP) 12: Data Analysis, Version 1.0

Dall's Sheep Monitoring Protocol

Arctic (ARCN) and Central Alaska (CAKN) Inventory and Monitoring Networks

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March 2017

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Please cite this Standard Operating Procedure as:

Rattenbury, K. L. and J. H. Schmidt. 2017. Standard Operating Procedure (SOP) 12: Data Analysis, Version 1.0. Dall's Sheep Monitoring Protocol, Arctic (ARCN) and Central Alaska (CAKN) Inventory and Monitoring Networks. National Park Service, Fairbanks, Alaska. Available online at <https://irma.nps.gov/DataStore/Reference/Profile/2238933>.

The main Narrative for the Protocol for Monitoring Dall's Sheep, Arctic (ARCN) and Central Alaska (CAKN) Inventory and Monitoring Networks is available from the NPS Inventory and Monitoring Arctic Network website (<http://science.nature.nps.gov/im/units/arcn/>), the NPS I&M Central Alaska Network website (<http://science.nature.nps.gov/im/units/cakn/>) and the Natural Resource Publications Management website (<http://www.nature.nps.gov/publications/nrpm/>).

SOP 12 – Data Analysis

Standard Operating Procedure #12
Version 1.0 (03/01/2017)

Revision History Log:

Previous Version #	Revision Date	Author	Changes Made	Reason for Change	New Version #
Add rows as needed for each change or set of changes associated with each version.					

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SOP 12.0 – Introduction

This SOP describes the assumptions required under the distance sampling framework to insure proper inference. The general processes for analysis are also described.

SOP 12.1 – Methodological assumptions

Historical Dall's sheep surveys in ARCN and CAKN were largely based on minimum count methods (e.g., Singer 1984, Shults 2004, but see Udevitz et al. 2006). When using a minimum count approach, one must assume that detection probability is constant across time and space. This is unlikely to be true in a majority of cases. Also, because detection is assumed to be a fixed rate, there is no way to assign uncertainty to the resulting counts. Because of this, population change and variation in detection probability are confounded, decreasing statistical power to detect trends. In addition, minimum counts are much more logistically challenging to complete at large spatial scales, leading to more incomplete surveys. Because these methods are based on simple comparisons of raw counts, incomplete counts are largely incomparable with past values. The distance sampling approach solves these problems through survey design and estimation.

The success of the distance sampling approach is dependent on several assumptions, the most important being that detection probability is ≈ 1.0 on or near the transect line. Although this assumption could not be directly tested, the data collected between 2009-2016 had the characteristic 'shoulder' expected for distance sampling data, suggesting observers were not systematically failing to observe sheep at short distances. Sheep are also white and occupy predominantly open habitats, making them highly visible, further suggesting that detection probability should approach 1.0 at close distances. It is possible that some individuals may be unavailable for sampling (e.g., in a cave, under a rock overhang), however, the proportion of the population that could be expected to be unavailable to sampling is quite small (i.e., <10%), suggesting bias should be minimal. In circumstances where incomplete availability is more common, distance sampling may not be an appropriate tool for monitoring. The remaining assumptions associated with distance sampling approaches (i.e., accurate distance measurements, lack of animal movement in response to survey aircraft prior to detection, independence of detections) are generally addressed through strict adherence to the survey protocol. The implicit reliance on survey procedures highlights the importance of thorough training of pilots and observers to ensure data collection procedures are followed precisely (SOP 5, SOP 7). A comprehensive overview of the assumptions associated with distance sampling in general can be found in Buckland et al. (2001, 2004). Details specific to Dall's sheep are covered by Schmidt et al. (2012) and Schmidt and Rattenbury (2013).

SOP 12.2 – Analysis of distance sampling data

Prior to analysis, the observation data are left-truncated at <22m and right truncated at >685m (see Schmidt et al. 2012, Schmidt and Rattenbury 2013 for detailed explanation). After doing so, the area within a 663m buffer along the transect is then calculated in GIS to determine the area that was sampled by each transect. Bayesian hierarchical distance sampling models (Royle et al. 2004, Royle and Dorazio 2008, Johnson et al. 2010, Schmidt et al. 2012, Schmidt and Rattenbury 2013) are used to estimate total abundance and abundance by composition class (i.e., lambs, ewe-like, small rams, full-curl rams). A hazard-rate detection function is fit to the observed distance data to estimate detection probability. Group size is included as a covariate on the detection process to account for the fact that larger groups are more easily detected. Group

size is assumed to be the sum of the number of individuals in each composition class within that group. This allows composition data to be directly included in the model while acknowledging that the group is the unit related to the detection process. Overdispersion terms are added to the sub-model for each composition class to account for extra-Poisson variation. Because the same field protocol is used for each survey, detection information may be borrowed across surveys to improve information (Schmidt and Rattenbury 2013). This is done through the use of informed priors on the parameters of the hazard-rate detection model. These priors are updated each year based on the posteriors of the prior years' analyses and can be considered to be analogous to analyzing all datasets together with a common detection function. Models are fit using OpenBUGS 3.2.3 (Thomas et al. 2006). Full details regarding model development, structure, and fitting (including example code) are comprehensively covered by Schmidt et al. (2012) and Schmidt and Rattenbury (2013).

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