



Current Condition of Standards from the Denali Park Road Vehicle Management Plan

2017 Summary Report

Natural Resource Report NPS/DENA/NRR-2018/1838



ON THE COVER

A lone grizzly bears walks in the morning light of Sable Pass on the Denali Park Road.
NPS Photo (T. Bracher)

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Abstract

Conditions on six Vehicle Management Plan (VMP) indicators from the Denali Park Road were documented for the 2017 regulatory year (May 27 – September 14, 2017). The six tier-1 indicators are: (1) Number of vehicles stopped at wildlife in the same place at one time (wildlife stops), (2) number of vehicles parked at rest stops at one time, (3) number of vehicles visible in specific viewscales at one time, (4) hourly 10-minute gaps in traffic at sheep crossing locations (sheep gaps), (5) nighttime (2200–0600) traffic rates, and (6) amount of time a hiker waits for a bus (hiker wait time). The method for monitoring standards for a seventh indicator, large vehicle traffic (> 80,000 pounds gross vehicle weight rating), has not been implemented but we include recommendations for future monitoring.

Here we (1) compare current conditions of the VMP indicators to the 1-year VMP standards, (2) use 2013–2017 data to assess 5-year VMP standards, and (3) assess the efficacy of the current monitoring techniques.

Assessment of the 1-year VMP standards:

- 1) Wildlife stop standards were met in all Wildlife Viewing Subzones. In fact, 32% of all wildlife stops ($n = 2,803$) were occupied by a single bus and 29% were occupied by two.
- 2) Rest stop standards for number of total vehicles were met at all sites. Rest stop standards for total number of buses failed at Toklat (>11 buses observed twice) and were met at Teklanika and Eielson.
- 3) Viewscape standards were met at all four sites. However, there is evidence that viewscales are becoming more crowded. The standard for the number of vehicles observable at one time was less frequently met at two of four viewscale sites.
- 4) Sheep gap standards were met at two of five sites (Tattler Creek and Grassy Pass).
- 5) Nighttime traffic standards were met Toklat, Stony, and Grassy. TekGate did not pass. Due to equipment failure, data was unavailable for Sable.
- 6) Hiker wait time standards were met. However, we question the quality of VTS driver data; for the last two years, the percentages reported are exactly the same between years, and for all categories of wait times (which is mathematically not possible).

One-year standards are less strict than 5-year standards to protect from aberrant years suggesting long-term failure trends. In 2017, 80% of 5-year standards were met. The wildlife stop indicator in Subzone 3 failed the 5-year standard for the percent time that two or fewer vehicles are present at wildlife stops. As predicted in 2016, sheep gap indicators at mile 21.6, 37.6, 52.8, and 60.6 did not meet the 5-year standard. The Tattler Creek sheep gap (mile 37.6) highlights how 1-year metrics can be met every year, while failing the stricter 5-year metric over the same period.

Sheep gap results are reported conservatively because they are only measured during the busiest times of day though the VMP defines sheep gaps as a 24-hour standard. Near-continuous data are collected at the mile 68.5 sheep gap using a battery-operated traffic counter. At mile 68.5, 10-minute

nighttime gaps in traffic are common. Data from traffic counters at other locations, away from sheep gap sites, suggest that 10-minute nighttime gaps in traffic are common along the road corridor. At the same time, 2016–2017 data suggest we may be under reporting the occurrence of day time sheep gap failures. Installing traffic counters at other sheep gap sites is planned for 2018/2019.

Additionally, we recommend the same counters to be installed at two sites (locations yet to be finalized) co-located with camera traps to monitor the seventh tier–1 indicator, large vehicle traffic.

Our field-based data collection effort slightly decreased (–3%) from 2016. Eighty percent (33 of 41¹ metrics) of all VMP standards were met in 2017, down 10% from 2016. Sheep gap success rate continues to be the biggest management challenge. Increasing sample size will be our first step to addressing this concern; 24-hour detection at all sheep gap sites will be implemented in 2019. A sustained effort to keep all road users aware of the unique management strategies of the road is imperative to avoid complacency. The integration of VMP-related Terms and Conditions into commercial use agreements, contracts, operating plans, road use permits, careful traffic scheduling (particularly nighttime projects), establishing park-approved parking places, and continued internal and external education and outreach all contribute to continued progress toward meeting all VMP standards.

¹ Beginning in 2016 data collected at the traffic counter located at mile 28.7 (Tek) is not being considered to measure the nighttime traffic standard because it is only 1.6 miles from the next counter, TekGate. While the two counters' proximity is necessary for determining traffic patterns (i.e. how many vehicles turn into Teklanika campground), it is redundant information for traffic disturbance. Each traffic counter location measures two nighttime traffic metrics: percentage of nights with <3 vehicle passes per hour and percentage of nights where no one hour had >6 vehicle passes. Thus, the number of metrics measured henceforth is 41 instead of 43.

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Introduction

For over eighty years the Denali Park Road has provided the primary access to Denali National Park and Preserve (Denali; Bryant 2011). Beginning at the park entrance, the road travels 92 miles west following the valley that separates the Alaska Range to the south from the Outer Range to the north. While traveling the park road, visitors have the opportunity to observe wildlife species in their natural habitats, view the continent's highest peak, Denali, and access trail-less wilderness hiking and camping.

Most of the park road is one lane and sections of it hang high above the valley, posing challenges for drivers and managers to ensure the safety of travelers. In 1958, the National Park Service (NPS) began a project that would have drastically altered the character of the road. The intent was to widen and pave the entire road and add guard rails and striping. Conservationists, including Adolph Murie, fought to protect the “wilderness atmosphere” of the road. Due to their efforts, the road is only paved to the Savage River Bridge (~ mile 15) and only widened to the Teklanika River (~ mile 31). Westbound visitors cross the Teklanika River Bridge and experience the rustic character of the road that has persisted since 1937 (NPS 1996).

The road improvement story is an example of one of the biggest challenges faced by national parks: balancing the need to protect park resources while making those resources accessible for people to enjoy. That challenge is particularly great in Denali, where demand for visitor opportunities to tour the park road is growing but still limited to a single 92-mile road (Figure 1).

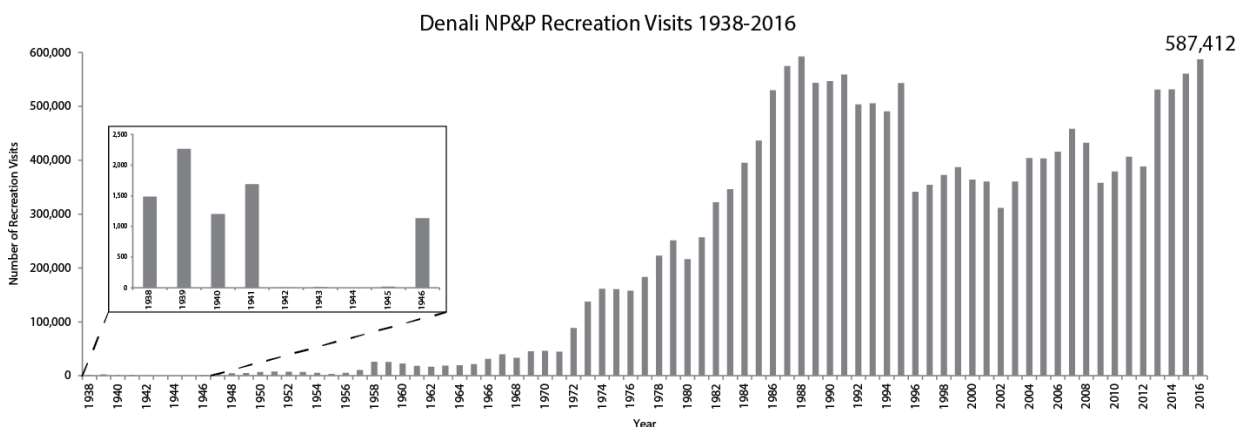


Figure 1. The number of recreation visits has steadily increased since the Alaska Road Commission finished construction of the Denali Park Road for 1938 (Denali National Park and Preserve, Alaska, USA).

To balance these sometimes conflicting responsibilities, in 1972 park managers began restricting private vehicle travel beyond the Savage River during the period from approximately Memorial Day through Labor Day (hereafter referred to as the regulatory season). In 1986, park managers instituted a vehicle limit of 10,512 round trips during the regulatory season (NPS 1986). Vehicle use was allocated among user groups, which include concessioner-operated buses, NPS and park partners,

and private vehicles including special permit holders, Teklanika campers, Kantishna property owners, and subsistence users.

The 1972 restrictions were implemented by park managers to address the anticipated increase in motor vehicle access to the park resulting from the opening of the George Parks Highway linking Anchorage and Fairbanks. The vehicle restrictions were further refined in the 1997 Entrance Area and Road Corridor Development Concept Plan (NPS 1997) and promulgated in special park regulation (36 CFR § 13.930 et seq.) in 2000. The 1997 plan also redefined the regulatory season to the Saturday before Memorial Day through the second Thursday after Labor Day or September 15, whichever came first.

Denali Park Road Capacity Study

Between 1986 and 2006, visitation to the park and demand to travel the park road steadily increased. In 2006, park managers, faced with increasing visitation and pressure to maintain or increase the annual vehicle limit, initiated a road capacity study to comprehensively evaluate strategies for transporting people on the park road. The road capacity study addressed concerns for protecting important park resources and values by evaluating the transportation systems and determining the carrying capacity of the road (Phillips et al. 2010a, Phillips et al. 2012). The study was conducted by an interdisciplinary team of NPS scientists and managers and academic scientists over several years. They assessed the effects of traffic volumes and patterns on the park's social, biological, and physical environment. The results of the study were used to inform development of the Denali Park Road Vehicle Management Plan and Environmental Impact Statement (VMP; NPS 2012), including establishing seven indicators (i.e. metrics) of desired resource and visitor experience conditions and developing quantitative standards (i.e. acceptable measureable levels of the metric) to ensure those conditions were maintained.

The study included three primary components: (1) an assessment of the relationship between vehicle traffic and wildlife movements and sightings (Phillips et al. 2010b), (2) visitor surveys to identify and quantify key indicators of a high-quality visitor experience on the park road (Manning and Hallo 2010), and (3) the development of a spatially explicit traffic model that integrated the results from the first two components with Global Positioning Systems (GPS) data collected from vehicles traveling the park road to predict the effects of changes in traffic volume and patterns on wildlife movements and visitor experience (Morris et al. 2010).

To identify possible links between vehicle traffic and wildlife behavior, 20 grizzly bears (*Ursus arctos*) and 20 Dall sheep (*Ovis dalli*) were radio collared and tracked using GPS. Data were also collected to determine the number and distribution of the “big five” large mammals: caribou (*Rangifer tarandus*), grizzly bears, Dall sheep, moose (*Alces alces*), and wolves (*Canis lupus*). Traffic data were collected using traffic counters placed at six locations along the park road and wildlife sightings along the park road were recorded by bus drivers using touch-panel interfaces installed in 20 buses (Phillips et al. 2010b, Phillips et al. 2012).

The results suggested that the volume and pattern of vehicle traffic affects the distribution and movements of wildlife, although the effects were not statistically significant, which is consistent with

other research (Yost and Wright 2001, Jaeger et al. 2005). The clearest indication of negative impacts from vehicle traffic on wildlife were that Dall sheep increased their rate of movement as they approached the road. Additionally, sheep were located further from the road during periods of higher traffic volumes. Some bands of sheep migrate between habitats in the Outer Range (primarily winter habitat) and the Alaska Range (primarily summer habitat) (Dalle-Molle and Van Horn 1991). Other bands may use habitats on both sides of the road throughout the summer. In both cases, these sheep must cross the road. Therefore, understanding and mitigating the impacts to sheep movement is important for maintaining the natural movement and habitat use patterns of the park's sheep populations. Results of the road capacity study suggested a reduction in the number of early morning sightings of the big five wildlife species followed higher levels of nighttime traffic (4–7 vehicles/hr). Park policy generally restricts large vehicle traffic (> 80,000 pounds gross vehicle weight rating, GVWR, whereas a typical concessionaire bus is 36,000 pounds GVWR) to nighttime hours only potentially confounding the effect of traffic during nighttime hours and large vehicle traffic.

The results of these wildlife studies helped park managers identify three indicators and define standards directly related to the volume and timing of vehicle traffic to protect wildlife and visitor experience: 1) the spacing of traffic at five sheep crossing locations; 2) the amount of nighttime (2200–0600) traffic; and 3) the hourly rate of large vehicle traffic.

Qualitative visitor surveys conducted in 2006 were used to identify the following indicators to capture the effects of vehicle crowding conditions on visitor experience: 4) the numbers of vehicles stopped at the same location and time to view wildlife, 5) the number of vehicles simultaneously visible in four iconic viewsapes, and 6) the number of vehicles parked at rest stops at one time. In 2007, researchers conducted quantitative visitor surveys to determine how varying levels of vehicle traffic affected visitor experience satisfaction. Survey participants were shown a series of simulated photographs depicting a range of vehicles at wildlife stops, rest stops, and within iconic viewsapes. The results were used to assess the reaction of visitors to increasing levels of crowding and provide management guidance for establishing standards (Manning and Hallo 2010). The goal for setting these standards was to maintain or improve current crowding conditions (i.e. numbers of vehicles).

The concessionaire operates a number of bus types, one of which is specifically for transit, rather than touring. Visitors using transit get on and off the bus to hike or backpack. The effectiveness of the transit system in serving this need is measured using two metrics. The first metric is the ability of visitors entering the park to purchase a seat on a bus, for which the concessionaire has a system in place to monitor and respond to demand fluctuations by holding and releasing seats or adding bus routes. The second metric is the wait time for hikers to re-board a bus once on the road system to get to a second location or to return to the entrance area. Therefore, a seventh indicator, the amount of time a hiker waits for a bus pick up, was developed to ensure that enough transit buses are adequately scheduled along the length of the park road ensuring available seats.

A Long-term Plan for Managing the Park Road

The VMP was approved in 2012 and was developed to improve management of vehicle traffic during the regulatory year for 15 to 20 years following the next concessionaire contract (NPS 2012). Approval of the VMP commits the park to amend a rule regarding the regulatory *yearly* vehicle limit

(10,512) with a *daily* limit of 160 vehicles, which applies only to the controlled section of Denali Park Road (west of the Savage River bridge at mile 14.9). this rule change requires an update to the U.S. Code of Federal Regulations (CFR) and has yet to take effect.²

The goals of the VMP are to ensure that visitors have the opportunity for a high-quality experience, wildlife and other park resources are protected, and the unique and historic character of the park road is maintained. The VMP uses an adaptive management approach to ensure that desired resource and visitor experience conditions are being met as traffic volumes and schedules are adjusted to optimize the transportation system. Adaptive management has been used since the 1970s and promotes flexible decision-making based on new knowledge; evidence-based adjustments are applied to management strategies as results of previous strategies are analyzed and better understood (Holling 1978). Many management plans use adaptive management as a tool due to the uncertainty in complex systems (Johnson 1999, Walters and Holling 1990). The complexity of the behaviors and regulations of Denali Park Road users and the long-term nature of the VMP make it an ideal system to use adaptive management techniques.

The adaptive management strategy in the VMP includes a four-tiered approach to monitor impacts to visitor satisfaction and natural resources resulting from changes in the transportation system, such as increases in traffic volume or modifications to scheduling (e.g., clustering vehicles). The four tiers include: (1) monitoring well-defined indicators and standards (from which this report is derived), (2) monitoring changes in wildlife observations, (3) monitoring changes in wildlife populations using data from other long-term monitoring programs, and (4) conducting Before-After Condition Change Assessment (BACCA) studies. The tier-1 indicators are monitored throughout the regulatory season. Some of the standards are based on absolute maximums (e.g., Toklat rest stop will not exceed 12 buses at one time) while other standards are based on both 1- and 5-year (yr) averages. The 1-year standard is less strict than the 5-year standard to allow for an aberrant year of increased activity without necessarily causing the 5-year standard to be exceeded. The results from the comprehensive monitoring program and the BACCA will enable park managers to make empirically-based decisions regarding the transportation system while protecting important park resources and maintaining a high quality visitor experience.

The VMP modifies the boundaries of Wildlife Viewing Subzones (Subzone) previously defined by the Park's 1997 Entrance Area and Road Corridor Development Concept Plan to clarify management objectives necessary for achieving the desired conditions within specific park road segments; three Subzones are defined (Figure 1). Crowding standards (number of vehicles at wildlife stops, number of vehicles at rest stops, and number of vehicles in viewsapes) are established at different levels for each Subzone. Generally, levels of accepted traffic volume decrease westward to preserve the character-defining qualities of the road segment's remoteness (i.e. wilderness character). Managers and visitors alike expect Subzone 1 to have the greatest volume of traffic and consequently, the most

² The change to the CFR change has to take place; however Denali is managing to the daily limit established by the VMP.

crowding. As visitors travel further into the park, the volume of traffic decreases and the standards become more stringent to reflect visitor's expectations for lower crowding conditions.

Park staff and volunteers have collected data to assess the current state of VMP indicators to refine monitoring techniques and protocols. The primary objective of this report is to compare the current conditions of the indicators to their defined standards. The results will help inform strategies to adaptively manage travel patterns on the park road through rescheduling, managing special use vehicle permits, or modifying driver behavior. This report summarizes data for six of the seven Denali Park Road VMP tier-1 indicators: (1) Number of vehicles stopped at wildlife at one time (i.e. wildlife stops), (2) number of vehicles at rest stops, (3) number of vehicles visible in viewsapes, (4) hourly 10-minute gaps in traffic at sheep crossing locations (i.e. sheep gap spacing), (5) average hourly nighttime vehicle traffic, and (6) hiker wait time. The methodology used to monitor the seventh standard, large vehicle traffic, has not been implemented. However, recommendations for measuring large vehicles are included at the end of the report.

Indicators and Standards

Indicators are defined at spatially explicit locations between mile 20 and 68 the Denali Park Road (Figure 2). Four indicators have 1- and 5-year average standards: (1) Number of vehicles at wildlife stops, (2) number of vehicles in a viewscape, (3) sheep gap spacing, and (4) hiker wait time. The remaining indicators have 1-year standards only (see Appendix A for tables of the tier-1 indicators and 1-year and 5-year standards).

Number of Vehicles at Wildlife Stops

Wildlife stops are stochastic events that can occur at any point along the park road. They are defined as one or more vehicles stopped to observe wildlife on the controlled section of road (Figure 3). One or more individual animals, representing one or more species may be present at a given wildlife stop. The most frequent stops are to view caribou, grizzly bears, Dall sheep, moose, and wolves, although vehicles will stop for other species (e.g. ptarmigan, fox, and others). The VMP manages for traffic volume at wildlife stops by establishing thresholds for the number of vehicles stopped to view wildlife in the same location at the same time. The maximum tolerable number of vehicles at wildlife stops varies by Subzone.

A wildlife event begins when the first vehicle stops and continues as long as at least one vehicle is present. The wildlife event ends when the last vehicle leaves the animal. For example, due to staggered bus schedules, it is possible that an animal (i.e. wildlife event) will experience 11 vehicles in a day while each vehicle may only experience one other vehicle at that animal. To capture visitor experience, the standard for the wildlife stop indicator is evaluated based on each vehicle's perspective. Monitoring the standard for wildlife stops captures the stop duration and traffic volume experienced by each vehicle present at wildlife events for as long as the observer's bus remains at the event. The total time or total number of vehicles at a wildlife event is not captured in monitoring. Each instance of a wildlife event may have several wildlife stops.

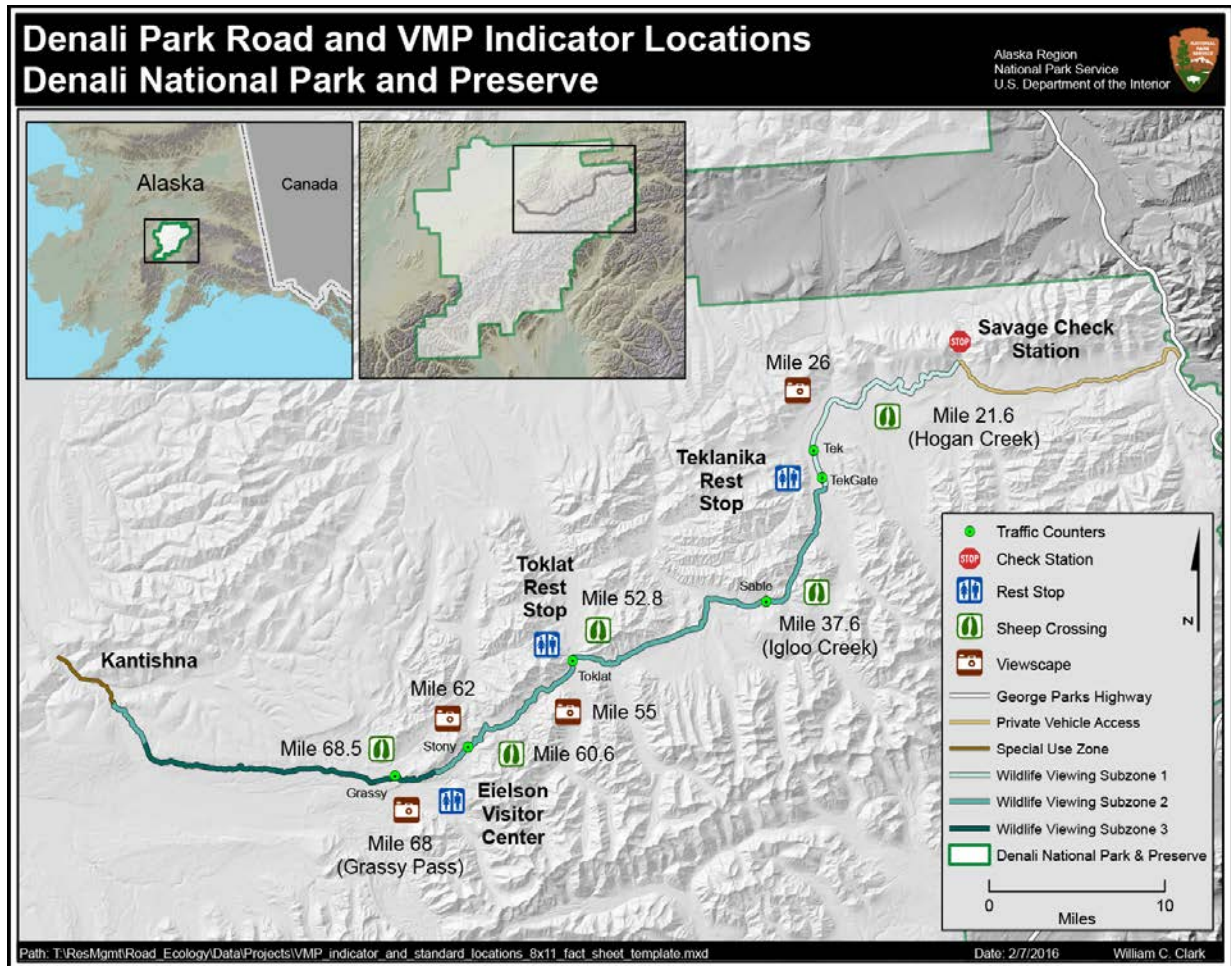


Figure 2. The Denali Park Road corridor traverses the northeast portion of Denali National Park and Preserve, Alaska, USA. There are 12 VMP indicator sites visited by field staff: five sheep gaps, four viewscales, and three rest stops. VMP standards for wildlife stops and viewscales vary by Subzone. Six remote, automated traffic counters are also distributed along the road and provide continuous data on traffic volume.



Figure 3. Two Lodge buses and one tour bus stop to view a grizzly bear near Stony Dome, Denali National Park, Alaska, USA. The number of vehicles stopped to view wildlife at one time is an indicator used to measure visitor experience quality and protect resources.

Number of Vehicles at Rest Stops

The VMP manages for traffic volumes at the Teklanika and Toklat rest areas and the Eielson Visitor Center (EVC; collectively called rest stops) by establishing standards for the maximum number of vehicles parked at any one time in these locations (Figure 4). The design standards and capacity for each facility's parking lot were used to inform the VMP standard.



Figure 4. The number of vehicles parked at one time at the Teklanika rest stop (A), the Toklat rest stop (B), and the Eielson Visitor Center (C) is used as an indicator to measure visitor experience quality in Denali National Park and Preserve, Alaska, USA. The standard varies by site and describes a maximum number of buses and a maximum number of total vehicles that can be parked at one time.

Number of Vehicles in Viewscapes

The VMP identified four viewscapes: mile 26, mile 55, mile 62 (Stony Overlook), and mile 68 (Grassy Pass; Figure 5). The standard for each viewscape is based on the social normative curves

developed from 2007 visitor surveys (Manning and Hallo 2010) and the desired conditions for visitor experience established for the Subzones where the viewscape is located (NPS 2012). The 1- and 5-year viewscape standards describe the percentage of time that a threshold number of vehicles are concurrently visible within the viewscape. The threshold changes with respect to both the standard level (i.e. 1- or 5-year) and Subzone. Viewscapes are small (~1.5–2.0 miles) and finite but are meant to be representative of the traffic volume and patterns of the larger landscape in which they are located; crowding conditions of the Subzone should be reflected within the viewscape metric. In most cases, viewscape metrics represent a conservative measure of visible traffic (i.e. a liberal measure of crowding) because the viewscape sites are in areas with large, broad views of the park landscape. In areas with greater road sinuosity the landscape will obstruct visibility and fewer vehicles are visible.



Figure 5. The number of vehicles visible in each of four viewscales is an indicator used to measure visitor experience quality in Denali National Park and Preserve, Alaska, USA. Arrows indicate the end points of the viewscape. The standard varies by Subzone and is described by a minimum percentage of time that fewer than a threshold number of vehicles are visible at one time.

Sheep Gap Spacing

The VMP identified five locations that are important for the movement of sheep and other wildlife: mile 21.6 (Hogan Creek), mile 37.6 (Tattler Creek), mile 52.8, mile 60.6, and mile 68.5 (Grassy Pass) (Figure 6). Although all points along the park road may be used during seasonal migrations

and/or for within–season movements between adjacent habitats, these monitoring locations represent key points along the road to monitor vehicle traffic patterns that may influence wildlife movement. Research suggests that movement patterns of sheep and other wildlife species between habitats bisected by roads may be affected by the volume and type of vehicle traffic (Dalle–Molle and Van Horn 1991). Sheep gaps have both 1- and 5-year standards. The 1-year standard requires at least one 10-minute gap in traffic per hour in 22 of 24 hours (90%); the 5-year standard requires a gap on average for 23 of every 24 hours (95%).

The indicator and its standard were established to balance the need to allow natural movement and seasonal migratory patterns to persist with the desire to minimize unnecessary restrictions on vehicle traffic, which could displace visitors. The sheep gap monitoring locations were established to encourage scheduling such that there are breaks in traffic along the entire length of the controlled section of the park road. Like viewscapes, sheep gaps are meant to be representative of the traffic volume and patterns of the larger landscape in which they are located; crowding conditions of the Subzone should be reflected within the sheep gap metric. Together, the sheep gap locations should provide a representative sample of the gaps in traffic along the controlled portion of the road corridor.



Figure 6. The spacing of traffic at five sheep crossing locations (i.e. sheep gaps) is used as an indicator to measure desired resource protection efforts along the Denali Park Road (Denali National Park and Preserve, Alaska, USA). Arrows indicate the monitoring reference point. The standard is a minimum percentage of hours that contain at least one 10-minute gap in traffic.

Nighttime Traffic

The VMP includes an indicator designed to reduce the impact of nighttime traffic on the following morning's wildlife sightings. The indicator evaluates nightly average and peak traffic rates and is defined as the number of vehicles traveling on the park road during nighttime hours (2200–0600). The standard is an average of three or fewer vehicles per hour (total west and eastbound) per night and a separate standard of no more than six vehicles in any one hour. The standards are mutually

inclusive and both are to be met at least 95% of the time. Nighttime traffic standards are measured using automated traffic counters. Traffic counters are installed at six locations, however only five sites are used for nighttime traffic analysis: TekGate, Sable, Toklat, Stony, and Grassy (Figure 2). Tek28 is used to monitor traffic pattern and not to infer impacts on wildlife in its section of roadway, which should be captured by TekGate, less than two miles west.

Hiker Wait Time

The amount of time a hiker waits to be picked up by a bus measures how well the transit service is meeting visitor demand in its primary function. A "hiker" is defined as a passenger that disembarks a transit bus and later attempts to re-embark a transit bus to continue traveling or return to the park entrance area. The VMP established 1- and 5-year standards for hiker wait time, representing the proportion of hikers waiting less than 30 minutes, less than 60 minutes, and less than 90 minutes to be picked up by a bus. The VMP prioritizes meeting the demand for transit services over concessionaire tour and charter services.

Large Vehicle Traffic

Work by park scientists show a general positive, direct relationship between GVWR and noise. Noise (i.e. non-natural sound) is well documented to cause negative effects on the health of animals and animal populations (Barber et al. 2010). The large vehicles (> 80,000 GVWR; e.g. semitrucks) VMP indicator is a measure to mitigate negative impacts from vehicle noise on wildlife. The standard is defined as < 5 large vehicles per hour. "Large vehicle" is defined by weight rather than dimension, requiring a weighing system to evaluate this standard. This is a practical challenge for a remote gravel road underlain with discontinuous permafrost and has not been fully implemented.

Methods

Study Area

Denali is 2.4 million hectares and located in interior Alaska between Anchorage and Fairbanks (Figure 2). Most visitors access the park via the 92-mile road that connects George Parks Highway to the former mining community of Kantishna. The Denali Park Road (henceforth, park road) follows a 1- to 10-km wide valley between the Alaska Range to the south and the foothills to the north commonly referred to as the Outer Range. Spruce (*Picea mariana*), scrub shrub dwarf birch (*Betula nana*), and willow (*Salix* spp.) dominate the habitat along the park road. Mountain avens (*Dryas integrifolia*), graminoids, and sedges dominate higher elevation tundra. Denali has a subarctic climate: Short, cool summers with an average minimum of 0°C and average maximum of 24°C (Western Regional Climate Center 2007). Annual precipitation averages 38 cm, over half of which occurs during the summer months. Snow cover is generally present from October through early May (Sousanes 2014). Due to the high latitude, daylight varies during the year from more than twenty hours in June to four hours in December. Visitation easily exceeds 500,000 annually.

Park Road User Groups

The park road has a diverse set of users and as such, a diverse set of permitting and access policies. The park concessionaire, Doyon/Aramark Joint Venture (JV), operates basic bus services (Visitor Transit System; VTS) and value-added tours (Tour). Together, VTS and Tours account for the majority of park road traffic. Three private lodge companies operate from Kantishna in-holdings and use buses to transport guest and supplies: Camp Denali, Denali Backcountry Lodge, and Kantishna Roadhouse (collectively, Lodge). In addition, employees drive the road in government-owned vehicles (GOV) for various purposes including road maintenance, visitor protection, interpretive programs, and resource management. All other travelers of the controlled segment of the road apply for, obtain, and display a purpose-specific permit for their personally owned vehicle (POV). POV permits include: private property right-of-ways, professional photographers/filmmakers, employee access to within-park duty stations, contractors, NPS-approved (includes researchers and special guests), and Teklanika Campground permits.

Data Collection

Overview

We collect vehicle data using: (1) a protocol conducted by NPS staff from a government vehicle (NPSO), (2) a protocol conducted by NPS staff and volunteers from a VTS bus, a program called Ride, Observe, and Record (ROAR), and (3) remote, battery-operated traffic counters. The regulatory year is divided into three monitoring subseasons to ensure stratification: early, peak, and late. Subseasons are defined by changes in the VTS bus schedule. For 2017 the subseasons were: early season: May 27–June 14, peak season: June 15–August 2, and late season: August 3–September 14. Peak season coincides with the highest level of park visitation and park road transit. We collected data at 18 sampling sites: six traffic counter locations, five sheep gaps, four viewsapes, and three rest stops.

NPS Observations (NPSO)

NPS staff collected data of viewscape and rest stop traffic volumes and sheep gap spacing at sites along the controlled portion of the park road using the NPSO Protocol. NPSO were conducted on one- or two-night stays in the park. We planned NPSO using a random number generator (RNG; www.random.org) to generate the observation start date based on a Julien Day calendar (e.g. a result of 202 created a July 21-22 observation period) and the location of the overnight stay.

We aim to have data to address both fine- (day of week) and coarse-scale (month of season) temporal trends and patterns. Thus, if a particular day of week went without sample we modified RNG results. Additionally, we modified RNG results to ensure observations during peak visitation periods because many VMP standards are based on maximum values: Memorial Day weekend (May 27-29), Independence Day (July 2-4), and Labor Day weekend (September 2-4).

Within subseason, NPS staff sampled during five hour blocks for each of the 12 non-traffic counter sites (traffic counters collect continuous data): 0600-0900, 0900-1200, 1200-1500, 1500-1800, and 1800-2200. These blocks cover the entirety of the concessionaire bus operating hours. We attempted to sample each site during each hour block ($n = 60$) at least twice during Early season and three times during Peak and Late season to ensure all indicators were sampled to capture patterns in daily variations of traffic. Geography (e.g. transit time between sites) and scheduling logistics (e.g. efficiency considerations) prevent truly randomized sampling within the daily sampling blocks.

Ride, Observe, and Record (ROAR)

ROAR observers recorded data at wildlife stops, rest stops, and hiker pickups during trips along the park road. We stratified observations proportionally to the VTS schedule using early- (before 0900), mid- (0900-1200), and late-day (after 1200) start times. Additionally, we collected overnight ROAR trips to sample eastbound camper buses that depart early mornings from Wonder Lake heading east. ROAR trip destinations were Toklat, the EVC, Wonder Lake, and Kantishna.

For simultaneous observations from a ROAR and NPSO observer at the same rest stop, one observations was discounted from analysis.

ROAR observations were recorded as features in a NPS application (app), Park Observer, using Apple iPads and iPad Minis (Apple Inc., Cupertino, CA USA). Observations were assigned a unique identifier and uploaded to ArcMap in a relational geodatabase format (FGDB) using in-house Python scripts. All features include geographic coordinates (WGS84), date, and local and UTC time. Additionally, at wildlife stops we recorded species, number of individuals, sex and age (when practicable), and distance from the road. Distance was determined using range finders (Nikon Aculon 6x20, Bushnell Elite 1500, or Legend 1200). At rest stops, we recorded rest stop name and the maximum number of vehicles parked, by vehicle type, upon the observer's arrival and departure. Four hiker wait time attributes were recorded for each feature: (1) if the bus had available seats, (2) if the bus picked up the hikers, (3) the number of hikers picked up, and (4) their wait time. Data were quality controlled in the ArcGIS environment using spatial and attribute queries then linearly referenced to the park road using the geoprocessing tool *Locate Features Along Routes*.

Traffic Counters

Six traffic counters are programmed to collect continuous data during the regulatory year. Five counters parsed data into 10-minute bins, the sixth counter, Grassy Pass, parsed data into 1-minute bins (finer resolution) to also monitor the nearby sheep gap (mile 68.5).

Supplemental Data

The Savage Check Station records all vehicles that enter the restricted portion of the roadway during their open hours, including vehicle type, permit type, destination, and number of passengers. The concessionaire provided hiker wait time data collected by VTS bus drivers and EVC dispatch staff. Additionally, the concessionaire provided data of daily bus manifests with route, driver, and departure information, passenger manifests from bus drivers including roadside pick-ups and drop-offs. These data are used for cross referencing and data quality control.

Indicators and Standards

Number of Vehicles at Wildlife Stops

The standard for the wildlife stop indicator was assessed using ROAR data. Observers recorded the maximum number of vehicles and classified the vehicles: Tour, VTS, Lodge, GOV, or POV. Observers on buses counted every vehicle present at the wildlife stop including the bus on which they were travelling. Observers driving a government vehicle counted all vehicles except their own to avoid artificially inflating the number of vehicles present.

Often, two ROAR observers were in the field on the same day and overlapping time. To reduce pseudo-replication, same-day observations of the same species occurring within a three minute window and less than ½ mile apart and collected by different observers were considered duplicate observations. Only one duplicate was chosen to include in analysis based on data quality (e.g. completeness). When data quality was equal the record considered duplicate was chosen at random and discounted.

Wildlife data were summarized in Excel (Microsoft, Redmond, WA, USA). Calculations for the proportion of observed instances when traffic volumes met the wildlife standards within a Subzone defined in the VMP were calculated as:

$$\frac{\text{number of wildlife stops with } < \text{threshold number of vehicles}}{\text{total wildlife stops}}.$$

The normalization calculation for the number of wildlife stop density by Subzone was calculated as:

$$\frac{\text{number of wildlife stops within a Subzone}}{\text{Subzone length (miles)}}.$$

The 5-year VMP standards were calculated using weighted averages to account for sample size variation among monitoring years:

$$\sum_{i=x-5}^5 X_i = \left(\frac{\text{sample size of individual year}}{\text{total sample size of all years}} \right) (\text{proportion of time an individual year met standard}),$$

Where: x is the current year.

This year, in the equation above, $i = x - 4$ because there were only four years of data to consider.

Additionally, we calculate a probability of sighting metric for each animal sighted during a year. Here, we report the probabilities of sighting one of: caribou, grizzly bear, moose, sheep, or wolf – the “big five” – while travelling at least as far west as the EVC.

Number of Vehicles at Rest Stops

We used NPSO and ROAR data to assess crowding conditions (maximum vehicles and maximum buses) at three rest stops (Figure 4). Based on NPSO, we recorded the maximum number of vehicles (by type) parked at the rest stop at the same time within 2-minute intervals for a period of 20 minutes (10 observations). This is distinct from recording a tally or count of all vehicles within the rest stop during each 2-minute interval. Vehicles must have been parked in the rest stop at the same time to count toward a maximum during a 2-minute interval. Composition of vehicles is recorded during the first instance of the vehicle maximum within a 2-minute interval and not changed if that maximum occurs another time within the same 2-minute interval. Thus, the composition of the maximum reflects that of the first instance of the maximum for that interval.

ROAR observers recorded numbers of vehicles upon their arrival and departure of the rest stop. For both ROAR and NPSO protocols, vehicles were classified using seven categories: Tour, VTS, Lodge bus, GOV, POV, heavy equipment, and maintenance. ROAR observers included the bus in which they were traveling in the vehicle count. NPSO protocols exclude the vehicle in which they were traveling because the vehicle is present only for monitoring. Thus, zero values are possible using the NPSO protocol. Zero values are not considered in analysis because this standard is based on visitors' experience and perception of acceptable levels of crowding. If there are no visitors there is no visitor experience to observe.

Rest stop data were summarized in Excel by site and vehicle category and maximum vehicle counts, averages, and standard deviations were calculated. Rest stop data were also analyzed by day-of-week, week-of-year, hour block, and subseason to examine temporal trends and patterns at each site. Temporal analyses were examined on a per-observation basis using the calculation:

$$\frac{\text{number of vehicle observations}}{\text{total number of observation periods}}.$$

Rest stop data are not continuous counts but maximums within 2-minute bins. Thus, temporal analyses only provide a relative sense of traffic pattern. Relative traffic at a rest stop is calculated by

$$\frac{\text{number of vehicles recorded}}{\text{total number of observations}}.$$

Appendix B of the report shows reported temporal analysis (several without pattern or trend are not published).

Number of Vehicles in Viewscapes

We assessed the viewscape standard using the NPSO protocol at four sites (Figure 5). Observers recorded the composition and maximum number of vehicles travelling within the viewscape at the same time during 2-minute intervals for a period of 20 minutes (10 observations). This is distinct from recording a tally or count of all vehicles that travelled through the viewscape during each 2-minute interval. Vehicles must have been visible within the viewscape at the same time to count toward a maximum during a 2-minute interval. Composition of vehicles is recorded during the first instance of the vehicle maximum within a 2-minute interval and not changed if that maximum occurs another time within the same 2-minute interval. Thus, the composition of the maximum reflects that of the first instance of the maximum for that interval.

Viewscape data were summarized in Excel by site. Tour, VTS, and Lodge bus categories were used to determine total bus count. Zero values are included in viewscape analyses because visitors may see no vehicles in the landscape. Calculations for the proportion of observed time when traffic volumes met the viewscape standards within a Subzone at a viewscape site were calculated as:

$$\frac{\text{total observed time with } < \text{threshold number of vehicles}}{\text{total observed time}}.$$

Viewscape data were examined by day-of-week, week-of-year, hour block, and subseason to analyze temporal trends and patterns at each site. Temporal analyses were examined on a per-observation basis. Viewscape data are not continuous counts but maximums within 2-minute bins. Thus, temporal analyses only provide a relative sense of traffic pattern. Results of viewscape temporal analyses are included in Appendix B of the report and calculated in two ways that reveal slightly different results:

1. (for a time period: $\frac{\text{number of vehicles recorded}}{\text{number of samples}}$) – i.e. average number of vehicles recorded by month.
2. (for a time period: $\frac{\text{maximum vehicles of observation}}{\text{number of observations for the time period}}$) – i.e. average maximum value recorded by month.

Sheep Gap Spacing

We assessed the standard for the sheep gap indicator using the NPSO protocol at five sites in addition to using the Grassy Pass traffic counter at one of those sites (Figure 6). Using the NPSO protocol, sheep gaps were monitored for between 10 and 60 minutes. The length of observation depended on traffic conditions. Once a 10-minute period passed with no vehicles, the observer recorded that a successful gap occurred. Observers remained at the site for an additional 10 minutes or until the next vehicle passed to get a better assess true gap length.

Observers record to the second when vehicles pass a reference point. For each site, the number of hours monitored that included a minimum of one 10-minute break in traffic at sheep gaps was tallied in Excel. The proportion of observed time when traffic volumes met sheep gap standards was calculated as:

$$\frac{\text{number of hours acheiving a 10-minute gap in traffic}}{\text{total number of hours observed}}.$$

The Grassy Pass traffic counter was programmed to collect data in 1-minute bins. This counter is located adjacent to a sheep gap location and was used to attain continuous, 24-hr monitoring. In this dataset, a gap was defined as at least ten 1-minute bins without traffic within the same hour block (e.g. during the 0900 or 1300 block). The percentage of hours meeting the standard was calculated using the same method as NPSO data.

NPSO sheep gap data were analyzed by day-of-week, week-of-year, hour block, and subseason to find temporal trends and patterns at each site. Temporal analyses were examined using graphs and contingency tables, where the rejection of the null hypothesis (H_0) indicated a temporal pattern other than random between maintenance of 10-minute gaps and the period examined.

Nighttime Traffic

Six International Road Dynamics Inc. Traffic Recording System (TRS; Saskatoon, Canada) 8-Loop inductive loop traffic counter assets were installed along the park road: Tek (mile 28.7), TekGate (mile 30.4), Sable (mile 39.6), Toklat (mile 53.6), Stony (mile 63.4), and Grassy (mile 68.8; Figure 2). TRS traffic counters detected a signal of magnetic interference from passing vehicles and records count and headway (direction of travel). Westbound and eastbound traffic were recorded in 10-minute bins; the Grassy counter recorded vehicle passes in 1-minute bins. The data collection period for Tek, TekGate, and Sable was May 23–September 15 inclusive and for Toklat, Stony, and Grassy was June 1–September 15 inclusive. Calculations for the proportion of nights when traffic rates at each traffic counter site met the nighttime traffic standards were calculated as:

$$\frac{\text{nights of } <3 \text{ vehicle passes per hour}}{\text{total nights sampled}} \text{ or } \frac{\text{nights with zero hours with } >6 \text{ vehicle passes}}{\text{total nights sampled}}.$$

All data were considered to analyze traffic volume and averages. Only periods of collection when all counters were functioning were considered when examining park-wide trends and patterns. The VMP considers this indicator only on a pass/fail basis along the whole length of road (i.e. not on a per data collection site basis – e.g. Toklat vs. Sable). However, we assert that failures at one location do not convict other locations to failure if the offending traffic volume does not propagate to other locations. The spatial context of nighttime traffic is important because sound disturbance is tied to its location.

Hiker Wait Time

We used data from the EVC dispatch, VTS manifests, and ROAR observations to evaluate hiker wait time standards. Visitors who altered the standard out-and-back schedule or hikers using the EVC as a transit hub were coordinated by an EVC dispatcher who tracks their wait time.

VTS bus drivers picked up hikers at any point along the road beyond mile 17. Drivers maintained a manifest and recorded the number of passengers that got on and off the bus, how long hikers estimated that they waited for a bus to pick them up (< 30 min, < 60 min, < 90 min, or $\geq$ 90 min), and where pick-ups and drop-offs occurred along the road. Pick-ups and drop-offs were recorded in 12 road segments (e.g. Teklanika rest stop to Tattler Creek) and two nodes (Toklat and EVC) each with separate westbound and eastbound records.

ROAR observers recorded hiker wait time while traveling the park road on VTS buses. The methods are described above. Calculations for the proportion of observed instances when hiker wait times met the standards defined in the VMP were calculated as:

$$\frac{\text{instances of wait time category (i.e. < 30 minutes)}}{\text{total number of wait times}}.$$

Beginning in 2015, ROAR observers recorded the instances when a bus was full and unable to pick up waiting hikers.

Capacity Limits

The Savage Check Station (SCS) database is queried to determine compliance with CFR 10,512 seasonal limits and VMP daily limits. CFR 10,512 includes all traffic traveling beyond the SCS except in-service emergency vehicles, the Denali Natural History Tour, and NPS contractor vehicles during the regulatory season (NPS 1986). The VMP daily limit includes all traffic travelling beyond the SCA except in-service emergency vehicles during the regulatory season (NPS 2012).

Wildlife Sighting Probability

Stops for wildlife and wildlife seen by ROAR observers for which there was no stop (i.e. wildlife for which there could have been a stop) on trips to either the EVC, Wonder Lake, or Kantishna are formatted and processed in R programming/statistical software. Given the number of samples and ROAR statistics, the script reports the probability of sighting specific animals for trips that travel at least as far as the EVC.

Results

Data Collection Effort

We sampled 241 VTS and 12 Tour trips using the ROAR protocol and 62 road regulatory days using the NPSO protocol. We completed 866 VMP condition observations in 2017 (Table 1). Observations closely matched the schedule for the early and peak subseasons, observations drifted further from target values in the late subseason (Appendix B: Table B1).

Table 1. VMP indicator observations were made throughout the Early, Peak, and Late subseasons of the summer on the Denali Park Road, Denali National Park and Preserve, Denali Park, Alaska. More observations occur during the Peak season because it the longest period.

Samples	Early (May 23–June 13; 19 days)	Peak (June 14–August 1; 48 days)	Late (August 2–September 13; 43 days)	Total
ROAR	36	118	87	241
NPSO	101	270	254	625
Total	137	388	341	866

During the Early subseason, each NPSO site was sampled an average of 1.7 times. During the Peak and Late subseason, each NPSO site was sampled at least 3 times, except Toklat Rest area from 9–12 Peak where we observed only twice (Appendix C: Table C1).

Number of Vehicles at Wildlife Stops

ROAR observers recorded 2,803 wildlife stops. Eighty-three percent of wildlife stops occurred in Subzone 2, 12% occurred in Subzone 1, and 5% occurred in Subzone 3. Subzone 2 was the most animal-rich road segment (Table 2).

Table 2. The number of ROAR observations recorded in three Subzones during the 2017 regulatory year on the Denali Park Road (Denali National Park and Preserve, Alaska, USA). The number of stops was normalized to Subzone lengths (miles) to report stops per mile. Subzone 2 is the most animal-rich Subzone in the park by this analysis.

Stop Type	Subzone 1	Subzone 2	Subzone 3
number of wildlife stops	330	2331	154
stops per mile	15.7	61.2	8.3

All wildlife stop measures met VMP 1-year standards (Table 3). However, wildlife stops were more crowded in 2017 compared to 2016. There were fewer instances of wildlife stops with one vehicle present (33% versus 55% from 2016) and more instances with two (up 1%), three (up 8%), and four (up 5%) vehicles present. A maximum of nine vehicles was observed two times in 2017 (all in WSV2) compared to zero instances of nine vehicles observed in 2016 (the maximum number of

vehicles observed in 2016 was seven, which was observed six times). The 5-year (2013–2017) standard for wildlife stops was met in two of the three wildlife viewing subzones (Table 4).

Table 3. Traffic volume conditions measured as a percentage of time x or fewer ($\leq$) vehicles were observed at a wildlife stop at Denali National Park and Preserve, Alaska, USA. All wildlife stop standards in each of the three Subzones were met in 2017.

Parameter	Wildlife Subzone 1			Wildlife Subzone 2			Wildlife Subzone 3		
	% $\leq$ 3 vehicles	% $\leq$ 4 vehicles	% $\leq$ 5 vehicles	% $\leq$ 2 vehicles	% $\leq$ 3 vehicles	% $\leq$ 4 vehicles	% $\leq$ 1 vehicles	% $\leq$ 2 vehicles	% $\leq$ 3 vehicles
Standard	70	85	90	70	85	90	70	85	90
ROAR result	97.0	99.1	100	80.1	91.7	96.6	74.0	95.5	100

Table 4. The 5–year VMP standards for number of vehicles at a wildlife stop was met for eight out of nine criteria on the Denali Park Road (Denali National Park and Preserve, Denali Park, Alaska, USA). One criteria, the most strict, failed in wildlife viewing subzone 3.

Parameter	Wildlife Subzone 1			Wildlife Subzone 2			Wildlife Subzone 3		
	% $\leq$ 3 vehicles	% $\leq$ 4 vehicles	% $\leq$ 5 vehicles	% $\leq$ 2 vehicles	% $\leq$ 3 vehicles	% $\leq$ 4 vehicles	% $\leq$ 1 vehicles	% $\leq$ 2 vehicles	% $\leq$ 3 vehicles
Standard	75	90	95	75	90	95	75	90	95
ROAR result	95.0	98.4	99.5	82.1	93.0	97.1	73.4*	93.7	98.5

* Failed criteria

Number of Vehicles at Rest Stops

We collected 2,294 traffic volume samples using the ROAR protocol and 156 20–minutes samples using the NPSO protocol at Teklanika, Toklat, and the EVC rest stops. Rest stops exceeded standards twice, at Toklat only, and during the 10:00 block only. The maximum number of buses was exceeded at Toklat on Thursday, July 13th (10:11) and Monday, August 14th (10:40) (Figure 7, Figure 8, Figure 9). The maximum allowable number of buses (11) was met once during observations at Toklat on Friday, July 7th (10:00) (Table 5). The EVC continued to have the highest average number of buses and total vehicles observed (Table 6, Table 7). There is a systematic increase from the NPSO to the ROAR protocol in the observed maximum number of buses, maximum total vehicles, and their averages at each rest stop. Analysis of day-of-week and week-of-year show few trends at any rest stops (Appendix B: Figures B1 and B2).

Table 5. Maximum number of buses and vehicles parked at one time at the Teklanika and Toklat rest stops and the Eielson Visitor Center (EVC) during the 2017 regulatory year on the Denali Park Road (Denali National Park and Preserve, Alaska, USA). Rest stop standards failed the maximum number of buses allowed at Toklat as observed using the ROAR protocol.

Parameter	Teklanika			Toklat			EVC		
	bus max	vehicle max	<i>n</i>	bus max	vehicle max	<i>n</i>	bus max	vehicle max	<i>n</i>
Standard	12	16	—	11	16	—	10	19	—
NPSO result	7	7	510	9	9	560	7	13	490
ROAR result	10	10	921	15*	15	816	9	13	557

* Rest stop standards failed the maximum number of buses allowed.

Table 6. Mean (and standard deviation, σ) number of total buses parked at one time at the Teklanika and Toklat rest stops and the Eielson Visitor Center (EVC) during the Denali Park Road (Alaska, USA) 2017 regulatory year. ROAR data were consistently greater than NPSO data; the most buses were observed at the EVC.

Parameter	Teklanika		Toklat		EVC	
	mean (σ)	<i>n</i>	mean (σ)	<i>n</i>	mean (σ)	<i>n</i>
NPSO result	1.7 (± 1.6)	510	2.0 (± 2.0)	560	2.1 (± 2.1)	490
ROAR result	2.9 (± 1.6)	921	3.6 (± 1.9)	816	3.7 (± 1.6)	557

Table 7. Mean (and standard deviation, σ) number of total vehicles parked at one time at the Teklanika and Toklat rest stops and the Eielson Visitor Center (EVC) during the 2017 regulatory year on the Denali Park Road (Denali National Park and Preserve, Alaska, USA). The margin of difference between EVC and Toklat grows considerably when we considered mean total vehicles compared to mean total buses. The EVC frequently has non-bus traffic because it is the duty station for several park employees. The standards for the number of total vehicles parked at rest stop were met in 2017.

Parameter	Teklanika		Toklat		EVC	
	mean (σ)	<i>n</i>	mean (σ)	<i>n</i>	mean (σ)	<i>n</i>
NPSO result	1.8 (± 1.7)	510	2.3 (± 2.9)	560	4.4 (± 2.9)	489
ROAR result	3.2 (± 1.8)	921	3.8 (± 1.9)	816	6.3 (± 2.2)	557

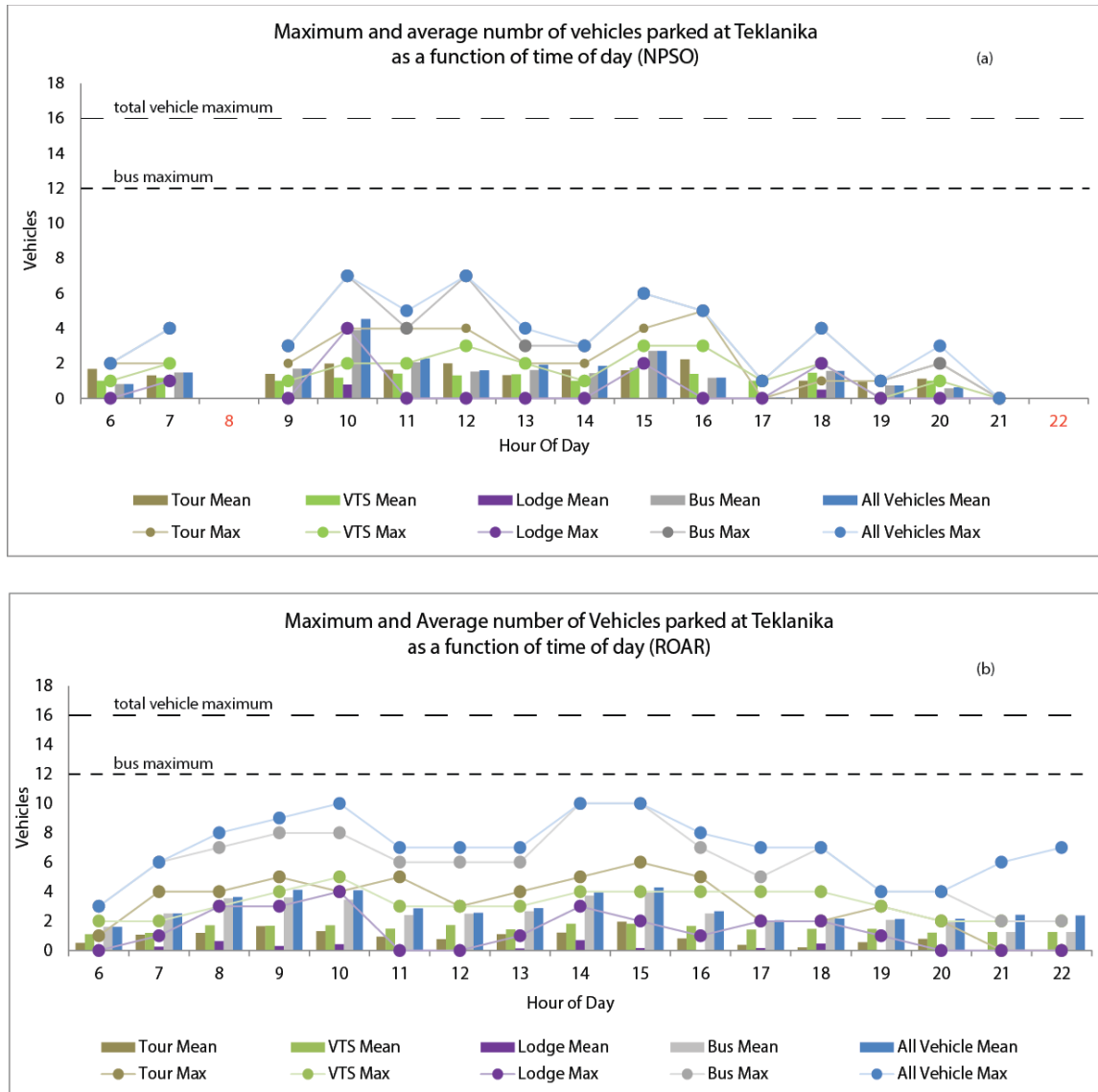


Figure 7. Maximum and average number of vehicles parked at the Teklanika rest stop based on the NPSO (a) and ROAR (b) protocols used at Denali National Park and Preserve, Alaska, USA. Both total bus and total vehicle maximums at the Teklanika rest stop met VMP standards for 2017. Red hour blocks on the x-axis indicate the time was not observed (i.e. no data available).

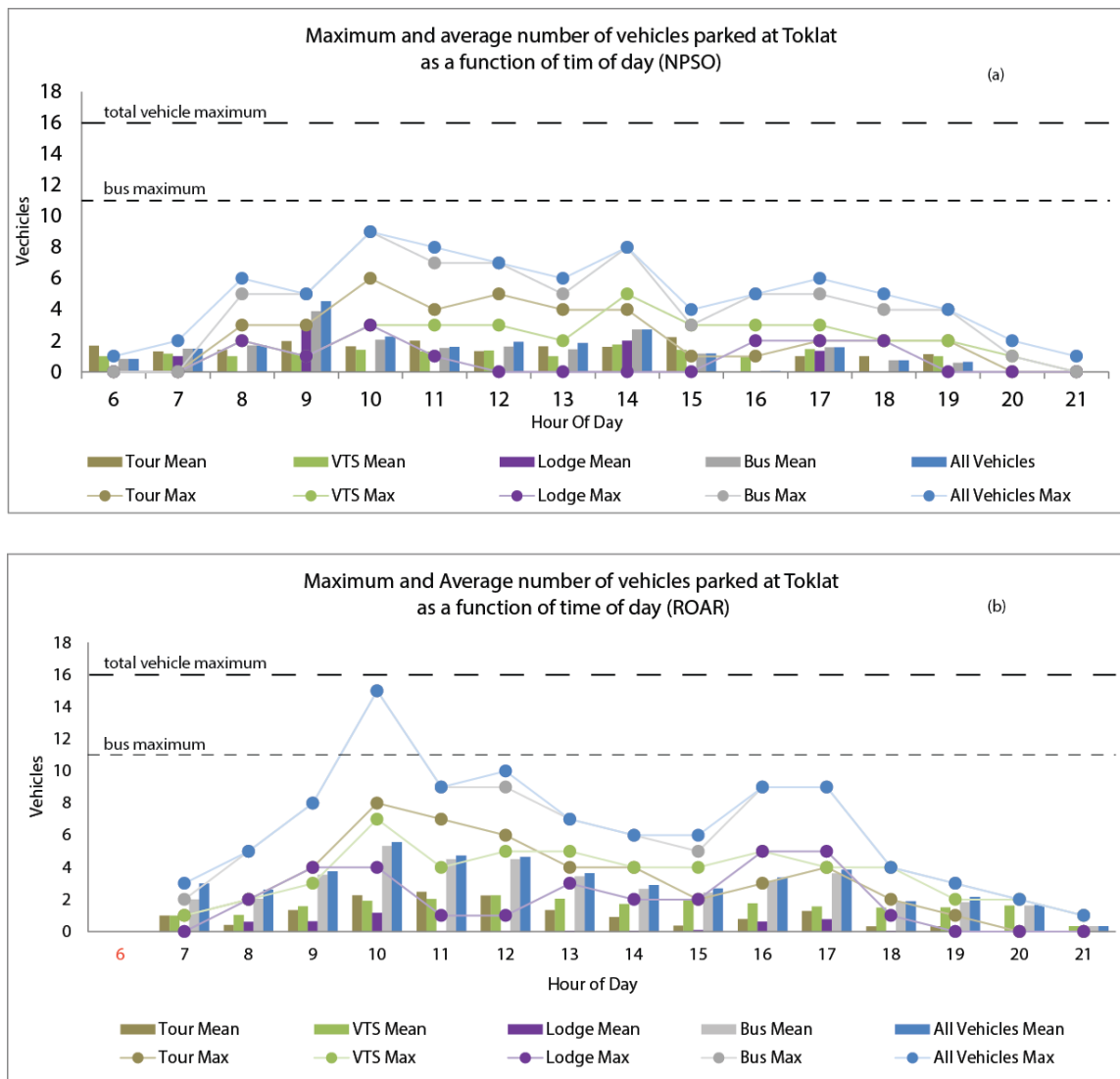


Figure 8. Maximum and average number of vehicles parked at the Toklat rest stop based on the NPSO (a) and ROAR (b) protocols used at Denali National Park and Preserve, Alaska, USA. The total bus and total vehicle maximums met VMP standards as measured by the NPSO protocol but the total bus maximum exceeded VMP standards as measured by the ROAR protocol at the Toklat rest stop. The total bus maximum was exceeded twice during observations: Thursday, July 13th at 10:11 and Friday, August 14 at 10:40. Red hour blocks on the x-axis indicate the time was not observed (i.e. no data available).

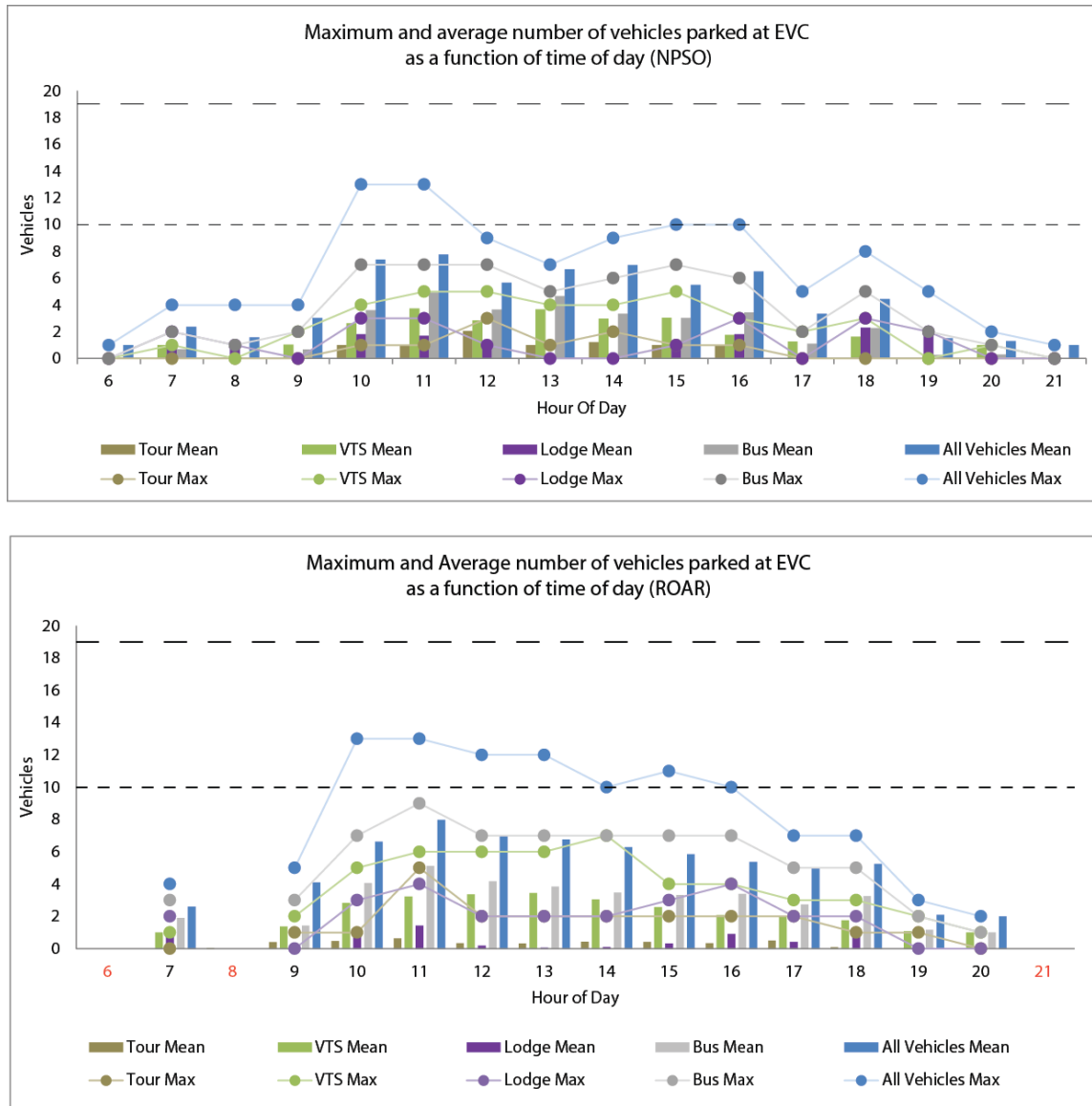


Figure 9. Maximum and average number of vehicles parked at the Eielson Visitor Center (EVC) based on the NPSO (a) and ROAR (b) protocols used at Denali National Park and Preserve, Alaska, USA. The total bus and total vehicle maximums met VMP standards. Red hour blocks on the x-axis indicate the time was not observed (i.e. no data available).

Number of Vehicles in Viewscapes

We collected 210 20-minutes viewscapes observations in 2017 at mile 26 ($n = 49$), mile 55 ($n = 54$), mile 62 ($n = 55$), and mile 68 ($n = 52$). Both the 1-year and 5-year VMP standards for vehicle visibility in each of the four viewscapes were met at all sites (Table 8, Table 9). The highest maximum number of vehicles observed (5 vehicles) occurred at mile 26 during the 1600 and 1700 hour blocks; mile 55 during the 1200 hour block; and mile 62 during the 1200, 1400, and 1500 hour blocks. This is the same maximum observed in 2016. The highest average maximum (1.6) for the season also occurred at mile 26 during the 1100 hour block and mile 62 during the 1500 hour block (Figure 10).

Table 1. Traffic conditions measured as a percent of time x or fewer ($\leq$) vehicles were observed within a viewscape in Denali National Park and Preserve, Alaska, USA. All of the VMP viewscape standards were met in 2017.

Parameter	Mile 26		Mile 55		Mile 62		Mile 68	
	% $\leq$ 3 vehicles	% $\leq$ 4 vehicles	% $\leq$ 2 vehicles	% $\leq$ 3 vehicles	% $\leq$ 2 vehicles	% $\leq$ 3 vehicles	% $\leq$ 1 vehicles	% $\leq$ 2 vehicles
Standard	80	90	80	90	80	90	80	90
2017 result	96.9	99.6	98.2	99	92.7	98	94	99.2

Table 2. The 5-year VMP standard at four defined viewscales along the Denali Park Road met standards in 2017 (Denali National Park and Preserve, Denali Park, Alaska, USA).

Parameter	Mile 26		Mile 55		Mile 62		Mile 68	
	% $\leq$ 3 vehicles	% $\leq$ 4 vehicles	% $\leq$ 2 vehicles	% $\leq$ 3 vehicles	% $\leq$ 2 vehicles	% $\leq$ 3 vehicles	% $\leq$ 1 vehicles	% $\leq$ 2 vehicles
Standard	85	95	85	95	85	95	85	95
2017 result	98.0	99.4	95.3	98.0	95.2	98.9	94.0	99.0

While viewscape standards were met and the percentage of time that a vehicle was visible in a viewscape decreased from 2016 (57% compared to 59%), there is evidence that viewscales are more crowded than in the past. Even with 220 fewer minutes observed (compared to 2016), the total time that a maximum of three, four, or five vehicles was observed increased 18% (Table 10). Thus, when vehicles are present, they appear to be more packed together rather than spread along the road.

Table 3. Viewscape statistics suggest that even though Denali is meeting VMP goals, viewscales are getting more crowded on the Denali Park Road (Denali National Park and Preserve, Alaska, USA).

Year	Minutes Sampled	Minutes w/ Vehicles	Minutes w/ 3, 4, or 5 Max
2017	4,200	57%	360
2016	4,420	59%	306

No significant temporal patterns were found in viewscape data by examining either hour of day (Figure 10) or week of year (Appendix B: Figure B3).

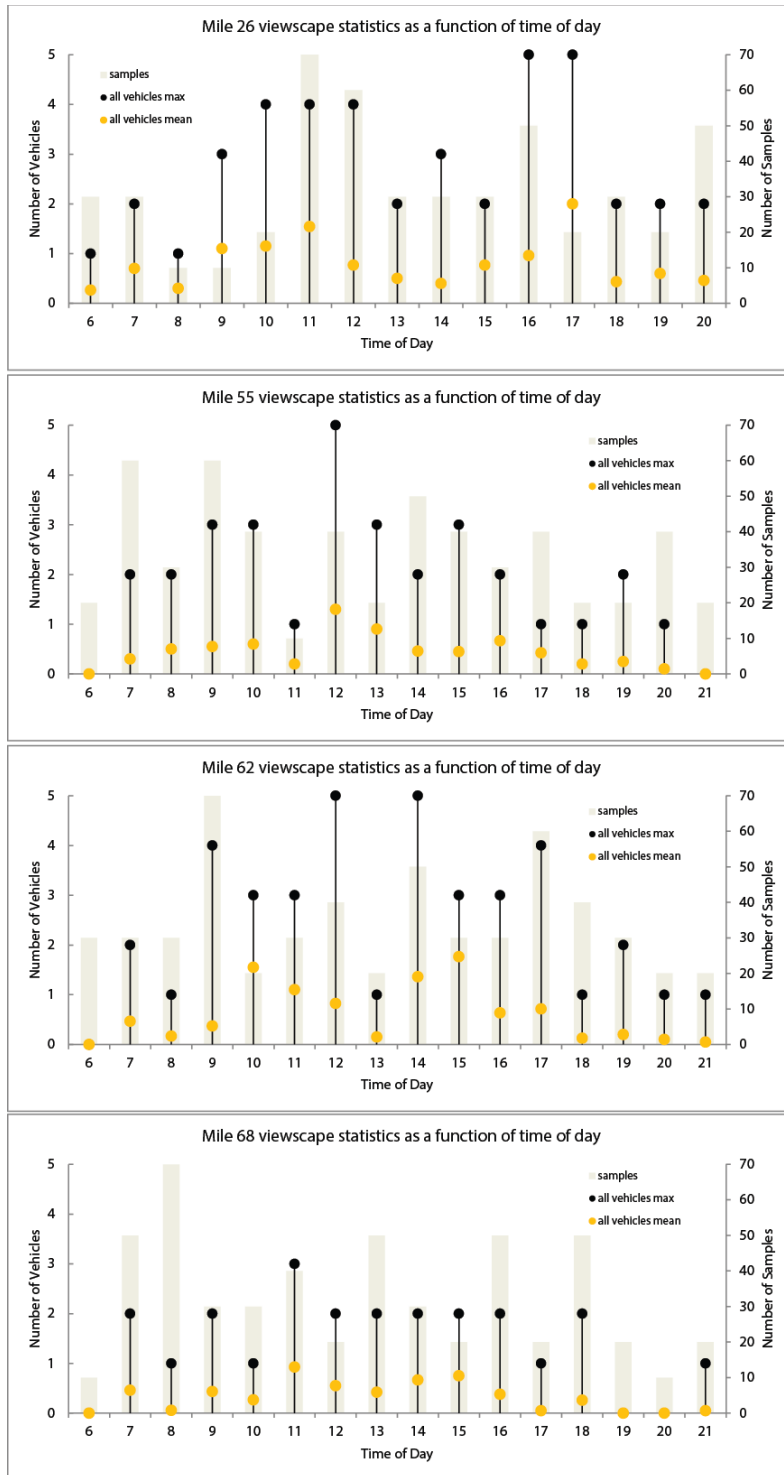


Figure 10. The maximum and mean (+1 σ) number of vehicles visible at one time at the mile 26 (a), 55 (b), 62 (c), and 68 (d) viewscape on the Denali Park Road (Denali National Park and Preserve, Alaska, USA). Bars show the number of observations for that site and hour block. The maximum number of vehicles seen at one time was five, which occurred during two-hour blocks at mile 26, once at mile 55, and three hour blocks at mile 62. All VMP viewscape standards were met.

Sheep Gap Spacing

Staff recorded 259 sheep gap observations in 2017. Additionally, we recorded 1,176 hours of sheep gap observations at mile 68.5 using the Grassy Pass traffic counter. VMP standards for the percentage of hours with at least one 10-minute gap in traffic were met at mile 37.6 (Tattler) and mile 68.5 (Grassy Pass, as measured by both NPSO and traffic counter). The VMP standard was not met at mile 21.6 (Hogan Creek), 52.8 (Sheep Hill), nor 60.6 (Stoney Hill, Table 11). The observed success rate dropped at Hogan, Tattler, and Sheep Hill but increased at Stony. The success rate at Grassy was unchanged.

Over the five year period from 2013–2017, we have collected 1,055 sheep gap samples. Four of the five sheep gap sites have failed the 5-year standard (Table 12). The Stony Hill site is the most frequent to fail never having met even the 1-year standard, while the Tattler Creek site has succeeded at the 1-year standard every year but failed to meet the 5-year standard.

Table 11. The percentage of hours with at least one 10-minute gap in traffic at each of the five sheep gaps established at Denali National Park and Preserve, Alaska, USA. Two of five sheep gaps met the standard during the 2017 regulatory season; mile 21.6, 52.8 and 60.6 did not meet the VMP standard (bolded text). The NPSO protocol was used to determine compliance at all five sheep gap sites. In addition, the Grassy Pass traffic counter was used to collect data at mile 68.5.

Parameter	Mile 21.6 % hours	Mile 37.6 % hours	Mile 52.8 % hours	Mile 60.6 % hours	Mile 68.5 % hours
Standard	90	90	90	90	90
NPSO	80.0 (n = 50)	92.6 (n = 54)	88.7 (n = 53)	88.2 (n = 51)	100 (n = 53)
Traffic Counter	—	—	—	—	99.3 (n = 1,176)

Table 12. The 5-year sheep gap standards were not achieved at four of five sites on the Denali Park Road (Denali National Park and Preserve, Denali Park, Alaska, USA).

Parameter	Mile 21.6 % hours	Mile 37.6 % hours	Mile 52.8 % hours	Mile 60.6 % hours	Mile 68.5 % hours
Standard	95	95	95	95	95
NPSO	87.0 (n = 201)	93.9 (n = 213)	90.8 (n = 218)	88.2 (n = 218)	99.0 (n = 205)

More failures were observed on Saturdays than other days of the week, but not statistically significantly. There is a possible effect of sample size on the observance of sheep gap failure – we may be underestimating the failure rate during the day (Appendix B: Figure B4).

Nighttime Traffic

The park road was open for 110 nights from the Savage Check Station to the Toklat rest stop and 101 nights to points west of Toklat. All counters experienced interruptions in data collection due to battery failure, heavy rain, USB failure, or other unknown causes (Figure 11). These interruptions were more severe than in previous years, likely because a USB drive used to download data broke

midway through the season. This caused an apparent data loss and lingering compatibility issues with other USB devices. The Sable counter lost the most data (Table 13).

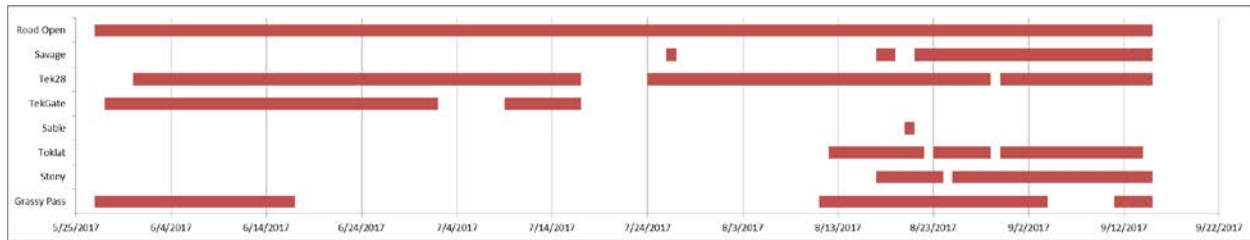


Figure 11. Gantt chart of traffic counter operation periods compared to the Denali Park Road (Alaska, USA) regulatory year for 2017. None of the counters functioned fully throughout the whole season.

From the data collected, Toklat, Stony, and Grassy counter locations met the VMP standards for both percentage of nights that averaged three or fewer vehicles per hour and the percentage of nights with six or fewer vehicles passing in any one hour. TekGate failed these metrics. This dataset may under-represent nights of high traffic use.

Table 13. Summary of nighttime (hours of 2200–0600) traffic rates on the Denali Park Road (Alaska, USA). Toklat, Stony, and Grassy traffic counter locations passed the fine-scale (≤ 6 vehicles in any hour) and coarse-scale (≤ 3 vehicles/hour over the night time period) VMP standards in 2017, while TekGate did not.

Location	Number of nights sampled	% nights ≤ 3 vehicle per hour	Number of nights with >3 vehicles per hour	% nights ≤ 6 vehicles per any nighttime hour	Number of nights with >6 vehicles in any hour
Standard	—	95%	—	95%	—
TekGate	43	86%	6	62.8%	16
Sable	1	—	—	—	—
Toklat	31	100%	0	100%	0
Stony	28	100%	0	100%	0
Grassy	49	100%	0	95.9%	2

There is a spike in traffic at the TekGate counter (about mile 32) during the end of August and the first two days of September (Figure 12). Interruptions in the dataset disallow further analysis.

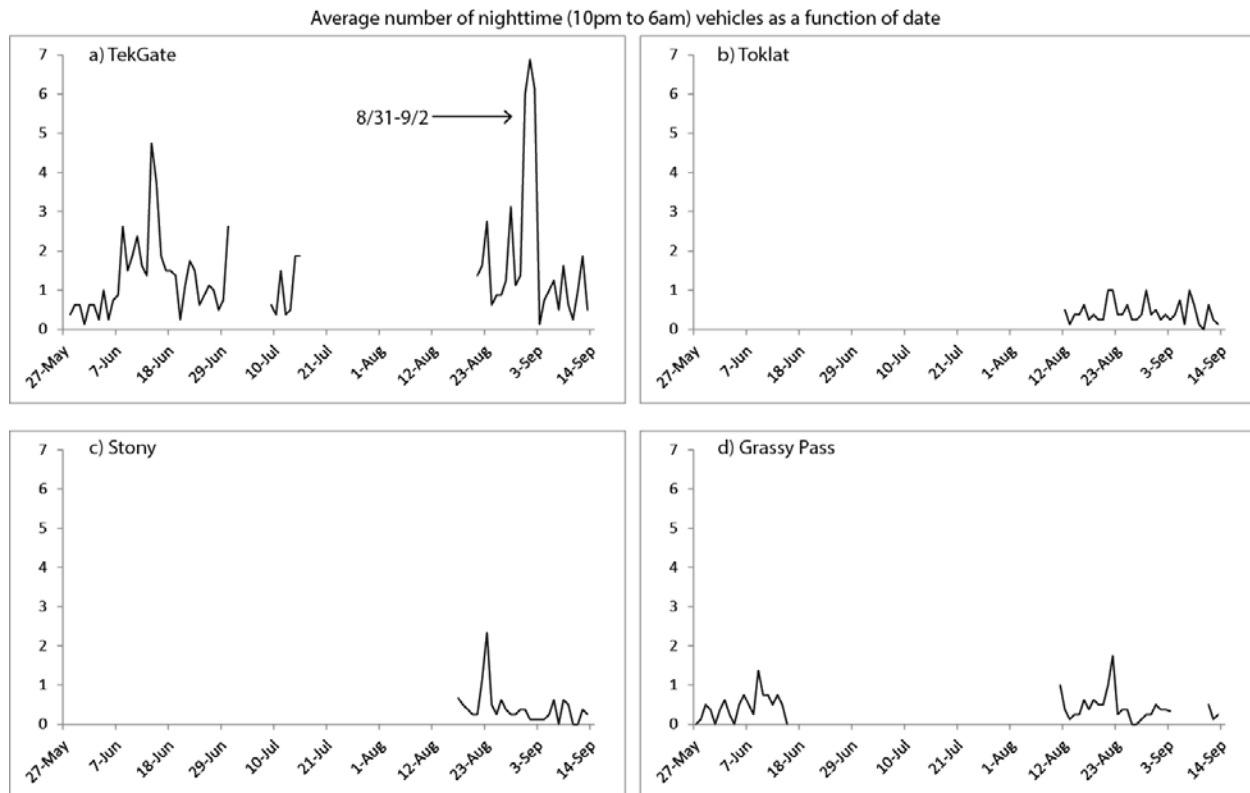


Figure 12. Average nighttime (2200–0600) traffic rates (west– and eastbound combined) for (a) TekGate, (b) Toklat, (c) Stony, and (d) Grassy Pass at Denali National Park and Preserve, Alaska, USA. A fifth counter at Sable Pass did not record enough data. A spike in traffic from August 31 to September 2 (TekGate) does not propagate to Toklat, but exceeds VMP standards. Breaks in the dataset indicate nighttime hours when the counter was not operating and data were not collected (also observable in Figure 11).

Hiker Wait Time

We collected data on 494 hiker pickups using the ROAR protocol. However, we collected wait time data on only 401 pickups. Both the 1-yr and 5-yr standards for hiker wait time were met during the 2017 regulatory season (Table 14, Table 15). Data collected using the ROAR protocol had the lowest percentage of hikers waiting less than 30 minutes for a bus. Additionally, we recorded 164 (11.8%) instances when the bus was too full to transport waiting hikers, a 5.8% increase over 2016.

Table 14. Hiker wait times as reported by concessioner dispatch at the Eielson Visitor Center (EVC), concessioner VTS drivers, and ROAR observers on the Denali Park Road (Alaska, USA). Sample size is consistent with data of previous years. All hiker wait time VMP standards were met in 2017.

Method	% Time <30 min	n	% Time <60 min	n	% Time <90 min	n
Standard	70%	—	93%	—	98%	—
EVC Dispatch	87.1	13,199	99.5	15,075	99.9	15,121
VTS Driver	98.9	21,280	98.9	21,280	98.9	21,294
ROAR	82.5	331	97.3	390	99.0	397

Table 15. The 5-year standard for hiker wait time was met for all categories between 2013–2017 on the Denali Park Road (Denali National Park and Preserve, Denali Park, Alaska, USA).

Parameter	% Time <30 min	% Time <60 min	% Time <90 min	<i>n</i>
Standard	75%	95%	99%	–
2013–2017 result	91.0	98.4	99.2	181,388

We plotted 2014–2017 hiker wait time results (proportion of time meeting standard as a function of sample size) based on sampling method to assess the efficacy of each method (Figure 13). Sample size is dependent on sampling method but percentage of time meeting VMP standards is independent of sample size. Thus, detecting compliance to VMP standards is independent of sampling method.

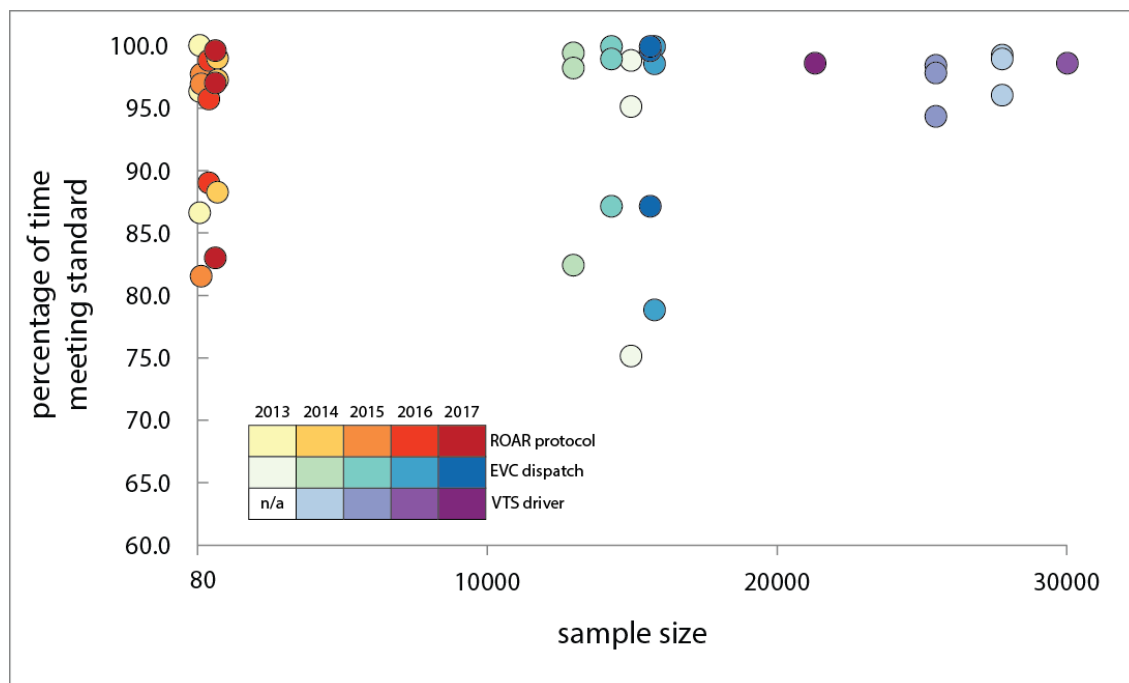


Figure 13. Percentage of time that hiker wait time standards were met as a function of sample size for the three methods used to collect hiker wait time data, 2014–2017, in Denali National Park and Preserve, Alaska, USA. Sample size does not affect the percentage of time that hiker wait time standards are met.

Capacity Limits

In 2017, 10,455 vehicles were counted against the CFR 10,512 capacity limit. No day had greater than 160 vehicles (maximum = 122) (Figure 14).

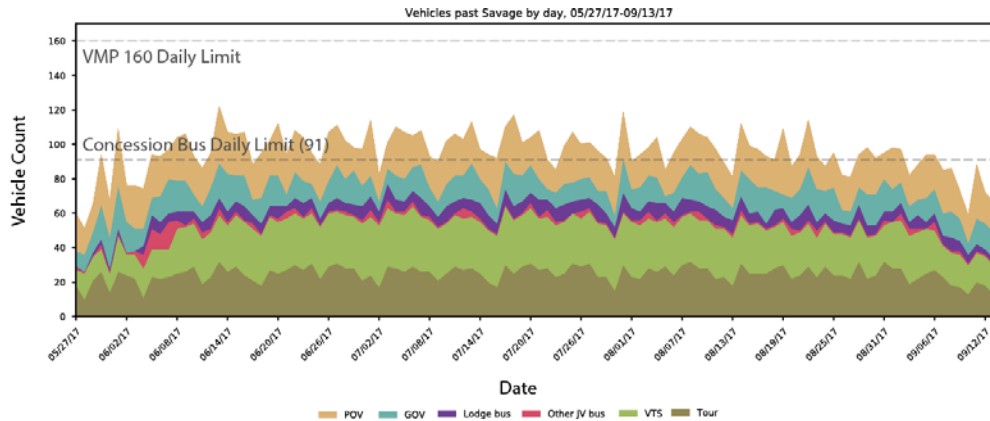


Figure 14. The VMP daily capacity limit was never exceeded in 2017 – the most number of vehicles on the Denali Park road was 122 (June 13; Denali National Park and Preserve, Denali Park, Alaska). No real use pattern appears from concessionaire buses. However, there is a consistent rise–fall pattern controlled by the GOV use of the road (most GOV employees have a regular pattern to their days off).

Wildlife Sighting Probability

The probability of sighting grizzly bears, Dall sheep, and wolves increased in 2017 compared to 2016 (Figure 15).

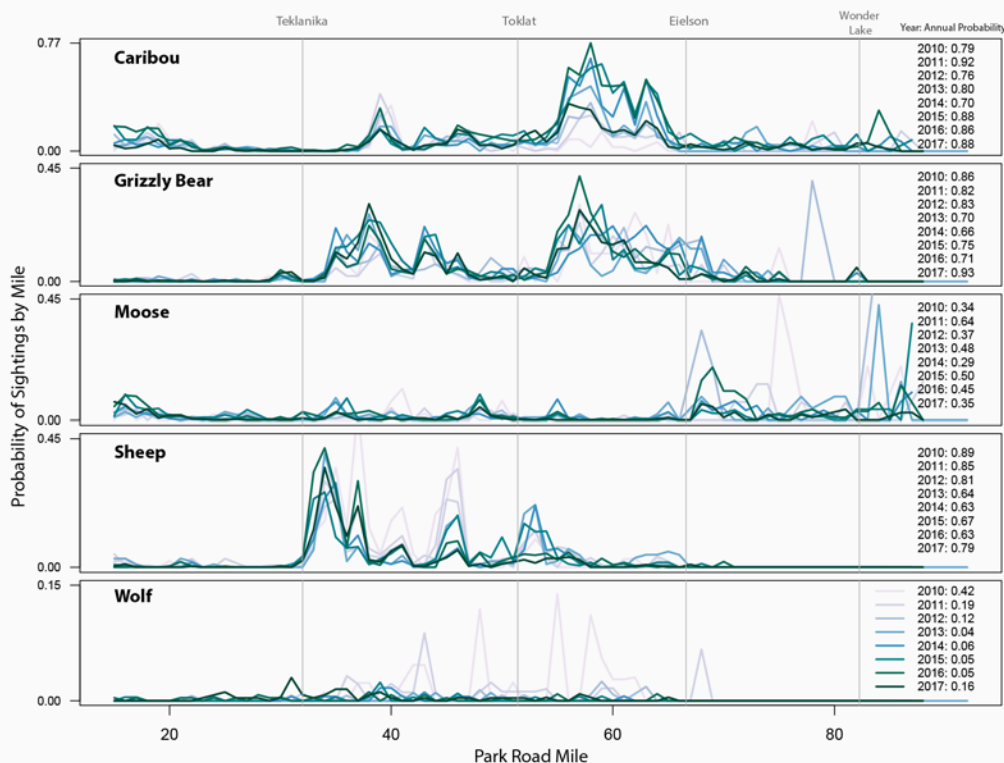


Figure 15. The probability of sighting a caribou, grizzly bear, moose, Dall sheep, and wolf on the Denali Park Road, Denali National Park and Preserve, Denali Park, Alaska. Compared to 2016, the probability of sighting a grizzly bear, Dall sheep, or wolf increased, while moose sighting probability decreased.

Discussion

The Road Ecology Program (REP) measured 41 individual metrics related to the Vehicle Management Plan (VMP) indicators in 2017 and 33 (80.5%) met standard. Collection effort was similar to 2016.

Number of Vehicles at Wildlife Stops

The number of vehicles at wildlife stops is the only VMP indicator that directly measures conditions related to both park natural resources and the quality of visitor experience. Thus, the number of vehicles at a wildlife stop is a particularly important indicator of park system dynamics.

In 2017, the transportation system met all 1-yr and most 5-yr wildlife stop standards. The large majority (82%) of observed wildlife stops ($n = 2,803$) were occupied by either one or two vehicles – most visitors are accessing high quality, intimate wildlife sightings on their bus trip. Only 3% of all wildlife stops had greater than four vehicles present at one time. One 5-yr standard was not met – the percent time of ≤ 1 vehicle in Subzone 3, where at least three out of every four wildlife stops must only be occupied by one bus. This criteria was only met 73.4% of the time.

Overall, the vast majority of visitors are afforded the opportunity to experience wildlife in an intimate setting. Additionally, very few wildlife experience more than three vehicles at one time.

Number of Vehicles at Rest Stops

Rest stop standards were exceeded on two occasions for the maximum number of buses parked at Toklat. Despite this, the data show that morning and late afternoon hours at Teklanika, late afternoon at Toklat, and early morning and late afternoon hours at EVC have further capacity within VMP standards. Meaning, with respect to rest stops, there is remaining capacity as defined by VMP standards when we hypothetically smooth traffic volume peaks and lulls. That there remains overall capacity yet VMP standards were exceeded illustrates the difficulty of keeping vehicles spaced in a manner to meet VMP in a stochastic environment.

The maximum number of vehicles at rest stops observed using the ROAR protocol is consistently greater than that observed using the NPSO maximum (Table 3). Since 2013, ROAR maximums have been greater than NPSO 25 times, less than NPSO three times, and equal twice (McKenny et al. 2015, McKenny et al. 2014a, Clark 2016, Clark 2018). This may be caused by the difference in sampling behavior between the two protocols. The ROAR protocol is inherently tied to the bus network because the observer is travelling within the network. Network behavior is imposed on the ROAR observer's sampling schedule. The NPSO observer travels both west and eastbound sampling sites in a nonlinear fashion – the NPSO observer imposes their behavior on the sampling schedule. We believe the ROAR protocol better captures visitor experience at rest stops than NPSO.

For an "even" (e.g. smoothed) schedule we expect about 14% of all traffic to occur each day ($100/7 = 14.3$). Here we focus on bus traffic: at all three sites, 16–17% of all bus traffic occurs on Sundays. Furthermore, nearly 18% of all bus traffic at Teklanika occurs on Mondays. The concessionaire continues to under consume most days of the week and over consumes on Sundays and Mondays.

This use pattern could put increasing pressure on other VMP indicators in the future (e.g. sheep gaps, whose metric is more closely tied to daily traffic patterns rather than volume).

Number of Vehicles within Viewscapes

The viewscape standard was met at all four sites for the fifth year in a row – the only VMP indicator to do so. Viewscope results have been the most consistent of any VMP indicator. Every viewscape site also met the 5-yr VMP standard.

Though viewscape standards have been easily met to date, they remain a particularly vulnerable indicator because they tend to be locations that tempt drivers to linger or park to obtain scenic views unique to Denali. Parking within a viewscape for extended periods would have outsized negative effects on the standard. Moreover, our data show that two of four sites were more crowded than they were in 2016.

Sheep Gap Spacing

The 1-year sheep gap standard was met at two of five sheep gap sites but the 5-year standard was met at only one. The mile 60.6 sheep gap site has never achieved 10-minute gaps in 90% of observed hours in the five years since monitoring began (2013).

We believe that the site's proximity to a popular scenic view, Stony Overlook, makes it difficult to meet VMP standards. The mile 60.6 sheep gap is located at the base of a hill 1.4 miles east of Stony where an iconic view of Denali awaits. The Stony overlook is also the turn-around point for the majority of the popular Tundra Wilderness Tours (TWT). TWT buses stop at Stony for approximately 10-15 minutes. The proximity of this turn-around to the mile 60.6 sheep gap increases traffic return rates. Combined with other traffic, the achieving a 10-minute gap in this location is difficult.

The 5-year sheep gap VMP standards failed at four sites, miles 21.6, 37.6, 52.8, and 60.6. The mile 37.6 sheep gap needed a 98% 10-minute gap success rate in 2017 to pass the 5-year standard, but only passed with 92.6%. The sheep gap at mile 68.5 has passed the 1-year standard every year and passed the 5-year standard in 2017. A larger sample size of high-success results will help increase overall averages for future years because the 5-year standard is a moving window.

The sheep gap indicator is defined as a 24-hour standard. Currently, it is only sampled during bus operating hours. However, as the mile 68.5 grassy pass site highlights, we have the ability to automate sheep gap data collection and achieve a continuous dataset. At the mile 68.5 sheep gap, all nighttime hours achieved a 10-minute gap in traffic. To replicate this data collection technique four additional traffic counters will need to be installed under the road surface in close proximity to the other sheep gap sites, Hogan Creek, Tattler Creek, Toklat River, and Stony Creek. It is our hypothesis that the vast majority of nighttime hours achieve a 10-minute gap in traffic at each of these locations.

Installing automated traffic counters at each sheep gap site would achieve four goals:

- 1) Sheep gap sites would be monitored 24 hours daily as intended by the VMP.

- 2) The likelihood of meeting all sheep gap standards would increase.
- 3) Field operations would be more predictable. Sheep gap observations last between ten and 60 minutes depending on traffic levels. Thus, five sheep gap sites take between 50 and 300 minutes, which is a lot of variability for which to plan.
- 4) With a more continuous dataset, the distribution of maximum sheep gap length can inform management about the system's flexibility with respect to maintaining sheep gaps. Average sheep gap lengths of 15 minutes indicate much different traffic conditions than 30- or 40-minute averages. Currently, this level of detail is not possible other than the site at mile 68.5.

Sheep gap sites would still require dedicated time to ground-truth and validate results. Additionally, as we have seen in the last several years and especially at the Sable traffic counter in 2017, traffic counters do occasionally experience temporary failures due to heavy rain, low battery, user error, and other unknown, unpredictable factors. However, the amount of data lost is insignificant when compared to the amount of data we are not currently collecting by not employing this methodology.

An in-depth analysis of sheep gap data is needed to determine the appropriate adaptive management track. That analysis is underway.

Nighttime Traffic

Due to significant data loss, lengthy analysis of nighttime traffic rates in 2017 is not possible.

The effect of nighttime traffic on next-day wildlife sightings is still under analysis. The park plans to continue working with researchers to better describe and categorize these effects on wildlife, wildlife sightings, and visitor experience.

Hiker Wait Time

The hiker wait time indicator is the most direct performance measure of the transportation system's primary purpose: public transit service. All measures of hiker wait time were within VMP standard in 2017. Data from the EVC dispatch and bus driver datasets recorded the lowest percentage of hikers waiting less than 30 minutes for a bus (78.9%). In previous years, the EVC dispatch dataset stood alone in marking the longest wait times. While the overall data suggest park management is meeting its goals, the number of instances of full bus not able to pick up hikers has increased.

Evidence from 2013-2017 hiker wait time data supports that collection method is independent of meeting VMP standard (Figure 13). If collecting hiker wait time continues to be in the VTS driver job description, hiker wait times collected by the ROAR could set as a lower priority making field staff more available to conduct other duties such as day hiker surveys. However, this is the second year in a row that VTS drivers have reported 98.9% values for all three wait time categories. The chances of this identical value for all three categories for two years running are very small. The quality of these data are questionable. Nonetheless, data collected by ROAR and EVC dispatch show hiker wait times are within VMP standards.

Large Vehicle Traffic

The VMP defines large vehicles as vehicles > 80,000 pounds GVWR. To assess weight, park management could employ Weigh-In-Motion (WIM) technology, which does not require a vehicle to stop to be measured. However, the technology is expensive to install (~ \$45,000) and maintain (yearly calibrations) and research suggests it is fastidious. Extreme cold, frost heaves, and the gravel sections of the road complicate the use of WIM technology in Denali. Additionally, many WIM solutions would require infrastructure counter to the historic and rustic character of the park road. Park management determined that WIM technology was inappropriate for the Denali setting and has decided to monitor large vehicle traffic using remote, motion-triggered cameras co-located with traffic counters. This solution is analysis-heavy and more subjective than WIM technology since weight will not be directly measured. Thus, this standard will continue to be refined during the first years of implementation of the VMP.

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Appendix A. Denali Park Road Final Vehicle Management Plan: Tier–1 Indicators and Standards

Table A1. Number of vehicles stopped at the same location to view wildlife at one time.

Wildlife Stops	Standards
Wildlife Viewing Subzone 1	75% of wildlife stops will have 3 or fewer vehicles (5–yr average) No one year will have less than 70% of wildlife stops with 3 or fewer vehicles
	90% of wildlife stops will have 4 or fewer vehicles (5–yr average) No one year will have less than 85% of wildlife stops with 4 or fewer vehicles
	95% of wildlife stops will have 5 or fewer vehicles (5–yr average) No one year will have less than 90% of wildlife stops with 5 or fewer vehicles
Wildlife Viewing Subzone 2	75% of wildlife stops will have 2 or fewer vehicles (5–yr average) No one year will have less than 70% of wildlife stops with 2 or fewer vehicles
	90% of wildlife stops will have 3 or fewer vehicles (5–yr average) No one year will have less than 85% of wildlife stops with 3 or fewer vehicles
	95% of wildlife stops will have 4 or fewer vehicles (5–yr average) No one year will have less than 90% of wildlife stops with 4 or fewer vehicles
Wildlife Viewing Subzone 3	75% of wildlife stops will have 1 or fewer vehicles (5–yr average) No one year will have less than 70% of wildlife stops with 1 or fewer vehicles
	90% of wildlife stops will have 2 or fewer vehicles (5–yr average) No one year will have less than 85% of wildlife stops with 2 or fewer vehicles
	95% of wildlife stops will have 3 or fewer vehicles (5–yr average) No one year will have less than 90% of wildlife stops with 3 or fewer vehicles

Table A2. Number of vehicles parked at one time at the Teklanika, Toklat, and Eielson rest stops.

Rest Stops	Standards
Teklanika	No more than 12 buses at one time with a total of no more than 16 vehicles
Toklat	No more than 11 buses at one time with a total of no more than 16 vehicles
Eielson Visitor Center	No more than 10 buses at one time with a total of no more than 19 vehicles

Table A3. Number of vehicles visible at one time in four scenic viewscales during bus operating hours.

Viewscales:

Viewscales	Standards
Mile 26 Wildlife Viewing Subzone 1	85% of the time there will be 3 or fewer vehicles visible in the viewscape (5-yr average) No one year will have less than 80% of the time with 3 or fewer vehicles visible in the viewscape
	95% of the time there will be 4 or fewer vehicles visible in the viewscape (5-yr average) No one year will have less than 90% of the time with 4 or fewer vehicles visible in the viewscape
Miles 55 and 62 Wildlife Viewing Subzone 2	85% of the time there will be 2 or fewer vehicles visible in the viewscape (5-yr average) No one year will have less than 80% of the time with 2 or fewer vehicles visible in the viewscape
	95% of the time there will be 3 or fewer vehicles visible in the viewscape (5-yr average) No one year will have less than 90% of the time with 3 or fewer vehicles visible in the viewscape
Mile 68 Wildlife Viewing Subzone 3	85% of the time there will be 1 or fewer vehicles visible in the viewscape (5-yr average) No one year will have less than 80% of the time with 1 or fewer vehicles visible in the viewscape
	95% of the time there will be 2 or fewer vehicles visible in the viewscape (5-yr average) No one year will have less than 90% of the time with 2 or fewer vehicles visible in the viewscape

Table A4. Maintenance of at least one 10-minute gap in traffic per hour at designated sheep crossing locations.

Sheep Gaps	Standards
Mile 21.6, 37.6, 52.8, 60.6, and 68.5	There will be at least one 10-minute gap in traffic every hour with a 95% success rate (23 of 24 hours with gaps at each crossing) averaged over 5 years
	No one year will have less than 90% success rate (22 of 24 hours with gaps at each crossing)

Table A5. Average number of vehicles per hour per night passing any of the traffic counters west of Savage between 10 p.m. and 6 a.m. (2200–0600).

Location	Standards
West of Savage	There will be an average of 3 or fewer vehicles per hour per night (total westbound and eastbound) passing any of the traffic counters with never more than six vehicles in any one hour. Both standards must be achieved at least 95% of the time. This standard will undergo further analysis and development.

Table A6. The amount of time a hiker spends waiting to be picked up by a bus.

Hiker Wait Time	Standards
Less than 30 minutes	At least 75% of hikers will have wait times of less than 30 minutes for pick-up by a bus, averaged over 5 yrs. No one year will have less than 70% of hikers with wait times of less than 30 minutes.
Less than 60 minutes	At least 95% of hikers will have wait times of less than 60 minutes for pick-up by a bus, averaged over 5 yrs. No one year will have less than 93% of hikers with wait times of less than 60 minutes.
Less than 90 minutes	At least 99% of hikers will have wait times of less than 90 minutes for pick-up by a bus, averaged over 5 yrs. No one year will have less than 98% of hikers with wait times of less than 90 minutes.

Table A7. Total number of large (> 80,000 pounds gross vehicle weight rating) vehicles crossing any of the traffic counters west of Savage in any one hour.

Location	Standards
West of Savage	There will never be more than 4 large vehicles in any one hour crossing any of the traffic counters west of Savage. This standard will undergo further analysis and development.

Appendix B. Temporal Analysis Graphs of Denali Park Road Indicators

Table B1. The distribution of VTS ROAR observations compared to the 2017 VTS schedule on the Denali Park Road (Alaska, USA). The target proportion of observations was in Early and Peak subseasons; variance increased in Late subseason. The bus concessionaire offers several different VTS schedules as demand fluctuates through the summer season.

Time Period	Location	Proportion of Trips		n
		VTS schedule (target)	ROAR observations (actual)	
Early	Toklat	35.2	44.4	16
	EVC	44.4	41.7	15
	Wonder Lake	13.0	8.3	3
	Kantishna	7.4	5.6	2
Peak	Toklat	13.8	12.7	15
	EVC	44.8	44.9	53
	Wonder Lake	24.1	23.7	28
	Kantishna	17.2	18.6	22
Late	Toklat	11.9	10.3	9
	EVC	46.3	48.3	42
	Wonder Lake	28.4	28.7	25
	Kantishna	13.4	12.6	11

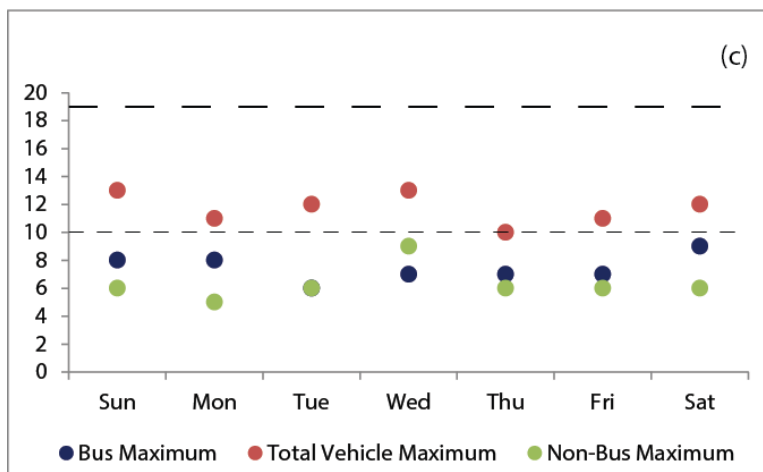
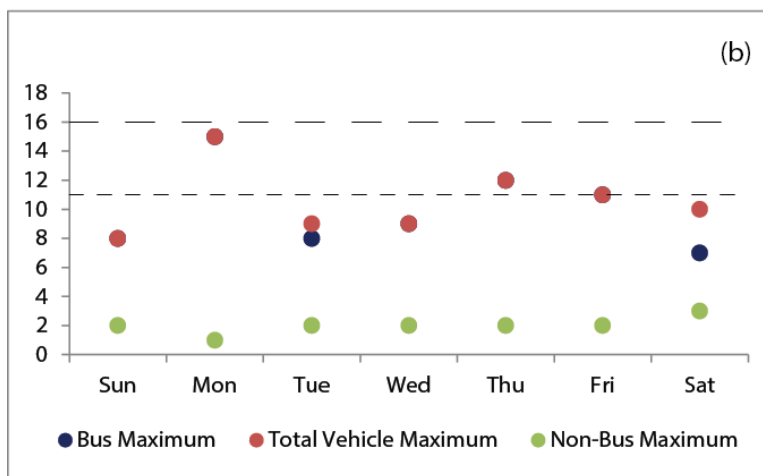
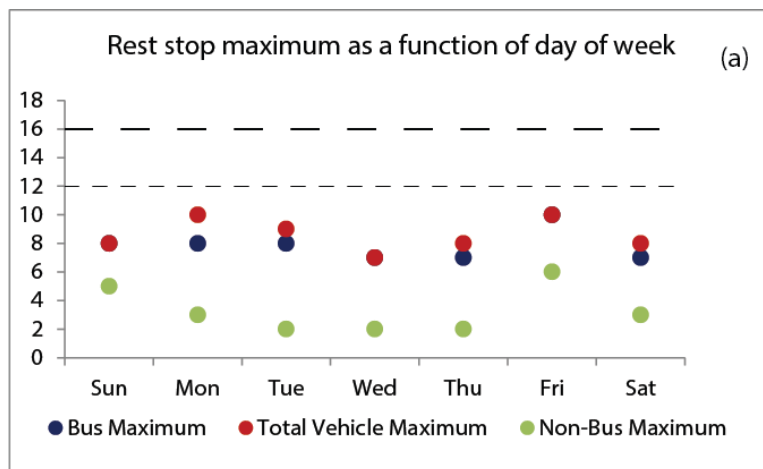


Figure B1. Traffic volumes at the Teklanika (a), Toklat (b), and EVC (c) rest stops in Denali National Park and Preserve (Alaska, USA). No consistent temporal patterns carry through all three of the rest stop areas observed.

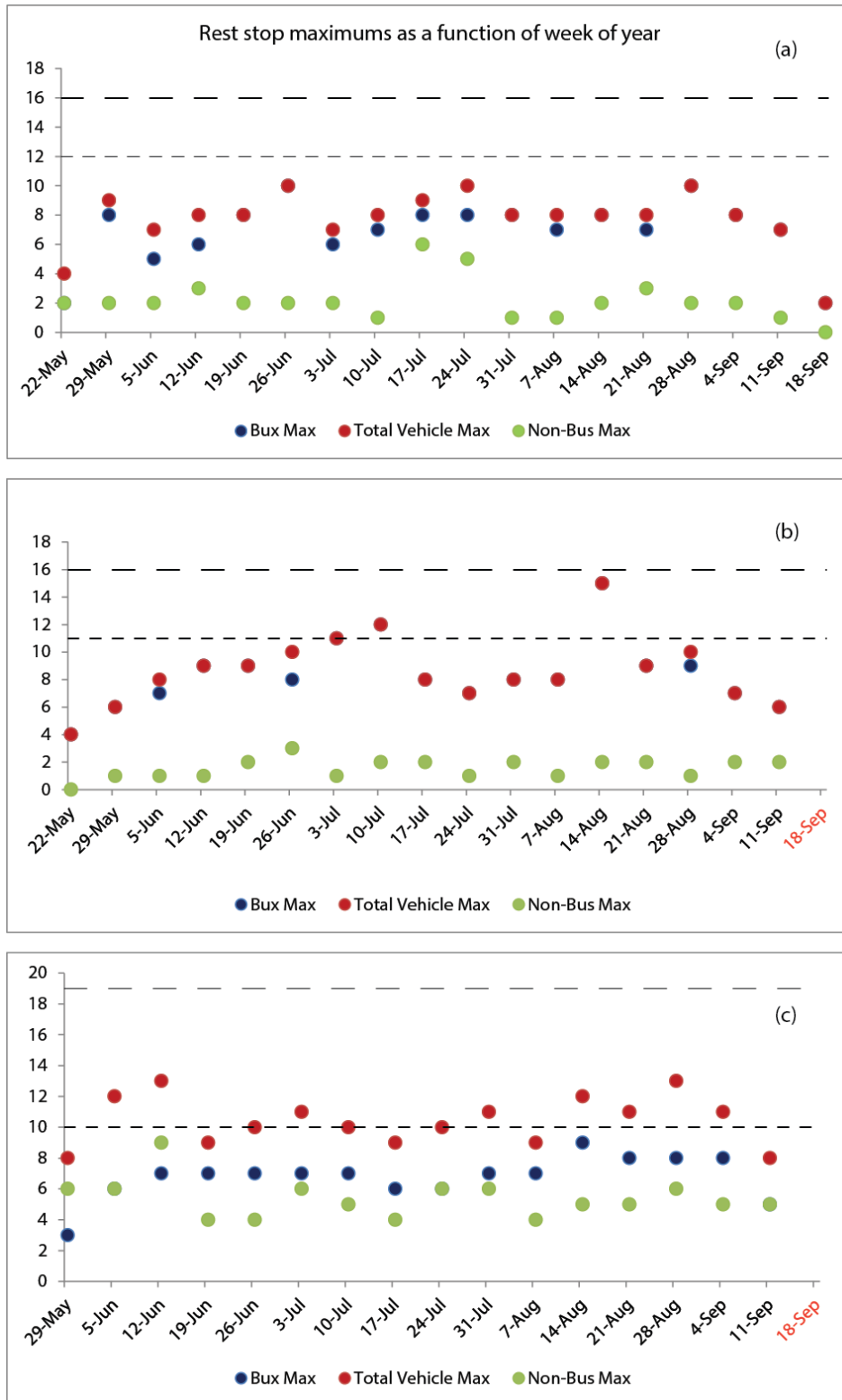


Figure B2. There were few significant trends in traffic volumes, as a function of week-of-year, at the Teklanika (a), Toklat (b), and EVC (c) rest stops in Denali National Park and Preserve (Alaska, USA) were detected in 2017. Traffic maximums at Toklat increased steadily until after the 4th of July holiday and then dropped significantly. Maximums at the EVC were steady all year.

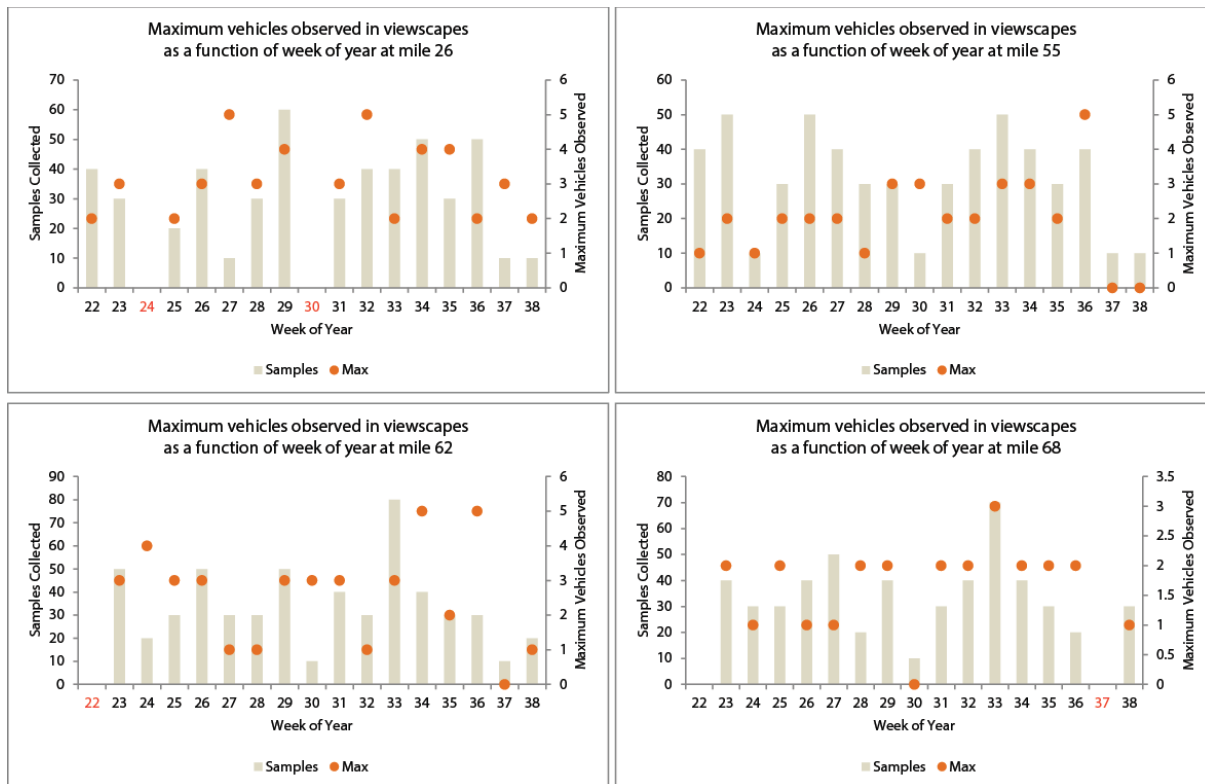


Figure B3. Viewscope results were not correlated to the week of the year in 2017 (Denali National Park and Preserve, Denali Park, Alaska, USA).

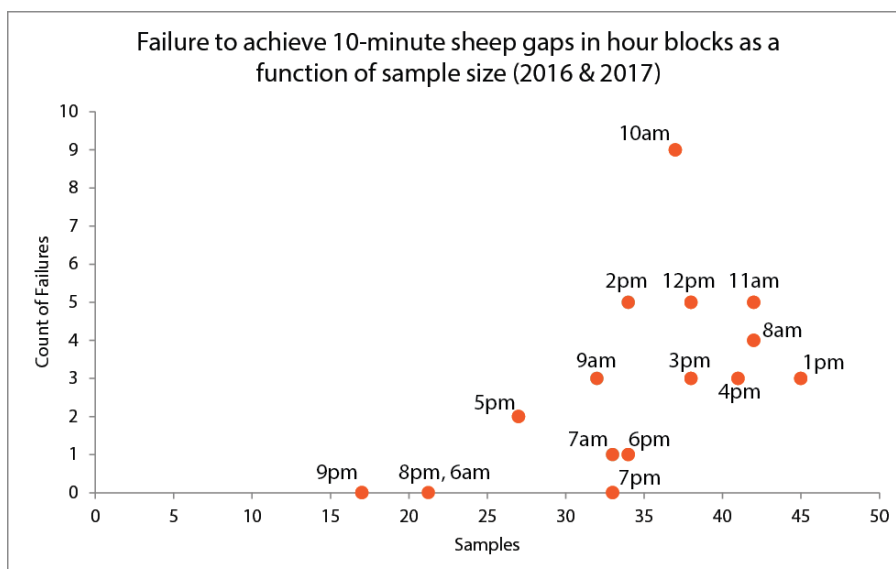


Figure B4. Sheep gap sample size from the last two years suggest we may be under reporting the occurrence of sheep gap failures on the Denali Park Road, Denali National Park and Preserve, Denali Park, Alaska. However, nighttime hours frequently achieve sheep gap standards but we do not count them currently.

Appendix C. 2018 Sampling

Table C1. The 2017 sampling was stratified through times of day throughout the season (Denali National Park and Preserve, Denali Park, Alaska, USA).

Mile	Indicator	Time Block					Total
		6–9	9–12	12–15	15–18	18–22	
21.6	Sheep Gap	7	11	11	11	10	50
26	Viewscape	7	10	12	10	10	49
30	Tek Rest	7	11	13	11	9	51
37.6	Sheep Gap	10	9	13	11	11	54
53.5	Toklat Rest	10	10	14	10	12	56
52.8	Sheep Gap	11	11	11	10	10	53
55	Viewscape	11	11	11	11	10	54
60.6	Sheep Gap	9	12	11	10	9	51
62	Viewscape	9	12	11	12	11	55
66	Eielson Rest	11	10	10	9	9	49
68	Viewscape	13	10	10	9	10	52
68.5	Sheep Gap	13	10	8	10	10	51

The Department of the Interior protects and manages the nation's natural resources and cultural heritage; provides scientific and other information about those resources; and honors its special responsibilities to American Indians, Alaska Natives, and affiliated Island Communities.

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