



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

A Summary Report 2015

Natural Resource Report NPS/DENA/NRR—2016/1338



ON THE COVER

Passengers of a Tundra Wilderness Tour (TWT) enjoy the view of Denali from Stony Overlook – an iconic vantage point.
NPS Photo (W. Clark)

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Abstract

This report summarizes data collected to document conditions on six of seven Denali Park Road Vehicle Management Plan (VMP) indicators from the Denali Park Road 2015 regulatory year (May 23 - September 15, 2015). These six tier-1 indicators are: (1) Number of vehicles stopped at wildlife in the same place at one time (i.e. 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 (i.e. sheep gaps), (5) nighttime (2200-0600) traffic rates, and (6) amount of time a hiker waits for a bus (i.e. hiker wait time). The methodology for monitoring standards for the 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 2013-2015 data to begin assessment of the 5-year VMP standards, (3) assess the efficacy of the current monitoring techniques and make recommendations for improvement, and (4) make recommendations for improving the condition of the resource as measured by the indicators.

Prior to the 2015 monitoring season, a decision was made to discontinue the use of fleet-based, on-board GPS data due to both systematic and random errors. In response, we amplified on-the-ground monitoring resulting in 22-53% increases in field-based samples providing adequate sample size to estimate traffic conditions and compare them to VMP standards.

Assessment of the 1-year VMP standards:

- 1) Wildlife stop standards were met in all Wildlife Viewing Subzones. A single bus was stopped at 57% and two buses were stopped at another 27% of the total 2,542 wildlife stops.
- 2) Rest stop standards were met at all three sites.
- 3) Viewscape standards were met at all four sites.
- 4) Sheep gap standards were met at four of five sites. Mile 60.6 maintained a 10-minute gap in traffic 87.2% of the time, short of the 90% standard. Sheep gap results are a two-fold improvement over 2014 when only two sites met standard.
- 5) Nighttime traffic standards were met at five of six sites for the nightly average traffic standard and at only three sites for the nightly peak traffic standard. The traffic counter at mile 30.3 (TekGate) failed to meet either standard and mile 28.7 (Tek) and 39.6 (Sable) failed to meet the nightly peak traffic standard.
- 6) Hiker wait time standards were met.

We used 2013-2015 data to begin assessment of 5-year VMP standards and assumed the use of the current sampling scheme for 2016-2017. The wildlife stop indicator in Subzone 3 may or may not meet the 5-yr standard for the percent time that one or fewer vehicles are present at wildlife stops; the standard is 75%, while its 2013-2015 weighted average is 74.80%. Subzone 3 will fail the 5-year standard if its results in 2016-2017 are similar to 2015 when it met this standard 73.6%. All other

wildlife stop standards have at least three percentage-point margins to meet the 5-year standard. Viewscapes have a minimum margin of 8.8 percentage points to meet the 5-year standard. The 5-year standard for vehicle spacing at sheep gaps presents a clear challenge for park management. Sheep gap sites at mile 21.6, 52.8, and 60.6 cannot, and mile 37.6 is very unlikely to, meet the 5-year standard. Over the next two years mile 21.6, 52.8, and 60.6 must maintain 10-minute gaps in traffic for over 100% of sampled hours and 37.6 must maintain 10-minute gaps for an average of 98% of sampled hours to meet standard. To date, none of these sites have not exceeded a sheep gap maintenance rate of 93.3%. One sheep gap site (mile 68.5) will likely meet the 5-year standard.

However, sheep gap results have been reported conservatively because they are only measured during the busiest times of day although the VMP defines them by a 24-hour standard. Data collected at one sheep gap site using a near-continuous dataset from a traffic counter (Grassy Pass) provides evidence that 10-minute nighttime gaps are common. Modifying the method of sheep gap monitoring to capture 24 hours of data will improve the accuracy of future reports and could improve results. We recommend the use of automated, remote traffic counters at each sheep gap site to meet these goals. 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.

The VMP indicators do not require, and current protocols do not call for, collecting continuous counts of vehicles at rest stops or viewscapes. However, adding continuous counts of vehicles at these sites to the protocol would improve the interpretability of temporal statistics, trends, and patterns and will improve the accessibility of the findings within annual reports.

We successfully increased the field-based data collection effort by an average of 84% in 2015. The amplified field-based sampling and the staffing model developed to support such an effort should be continued moving forward.

Eighty-six percent (38 of 44 metrics) of all VMP standards were met in 2015 up from 2014 (70%) but down from 2013 (89%). Nonetheless, a sustained effort to increase and maintain compliance through continued education outreach to road users, the integration of VMP-related Terms and Conditions into contracts and operating plans, along with road use permits and careful traffic scheduling, particularly nighttime projects, are imperative for continued progress toward meeting 100% of the VMP standards.

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Introduction

For nearly 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 narrow ribbon of road winds 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 to 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 as far as the Savage River Bridge (~ mile 15) and it is only widened to the Teklanika River (~ mile 31). Westbound visitors cross the Teklanika River Bridge and enter the rustic character of road that has persisted since 1937.

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 them accessible for people to enjoy. The challenge is particularly great in Denali, where park managers must balance the growing demand for visitor opportunities to tour the park road with the need to ensure that park resources are protected and visitors continue to have a safe, high-quality experience. 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 substantial increase in motor vehicle access to the park resulting from the opening of the George Parks Highway. 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 increased steadily. In 2006, park managers were faced with increasing visitation and pressure to maintain or increase the annual vehicle limit and initiated a road capacity study to comprehensively evaluate the strategy 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 are 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 et al. 2001, Jaeger 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 movements 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 viewscales, 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 viewscales. 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 can be 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 by holding and releasing seats or adding bus routes depending on demand. 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 developed to improve management of vehicle traffic during the regulatory period for the next 15 to 20 years and was approved in September of 2012 (NPS 2012). Approval of the VMP commits the park to amend a rule regarding the regulatory *season* vehicle limit (10,512) with a *daily* limit of 160 vehicles and applies only to the controlled section of Denali Park Road (west of the Savage River bridge at mile 14.9); this rule change has yet to take effect and requires replacing language in the U.S. Code of Federal Regulations.

The goals of the VMP are to ensure that visitors have a high-quality experience, wildlife and other park resources are protected, and the unique 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 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, (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-yr standard is less strict than the 5-yr standard to allow for an aberrant year of increased activity without necessarily causing the 5-yr standard to be exceeded. The results from the comprehensive monitoring program and the BACCA study will enable park managers to make empirically-based, informed decisions regarding changes to 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 viewscapes) 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. Managers and visitors alike expect Subzone 1 to have the greatest volume of traffic and consequently, the most 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 vehicle traffic of certain user groups, 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 viewscapes, (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. Therefore, this report does not include these data. 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 1). Four indicators have 1- and 5-yr 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-yr standards only (see Appendix A for a table of the tier-1 indicators and 1-yr and 5-yr standards).

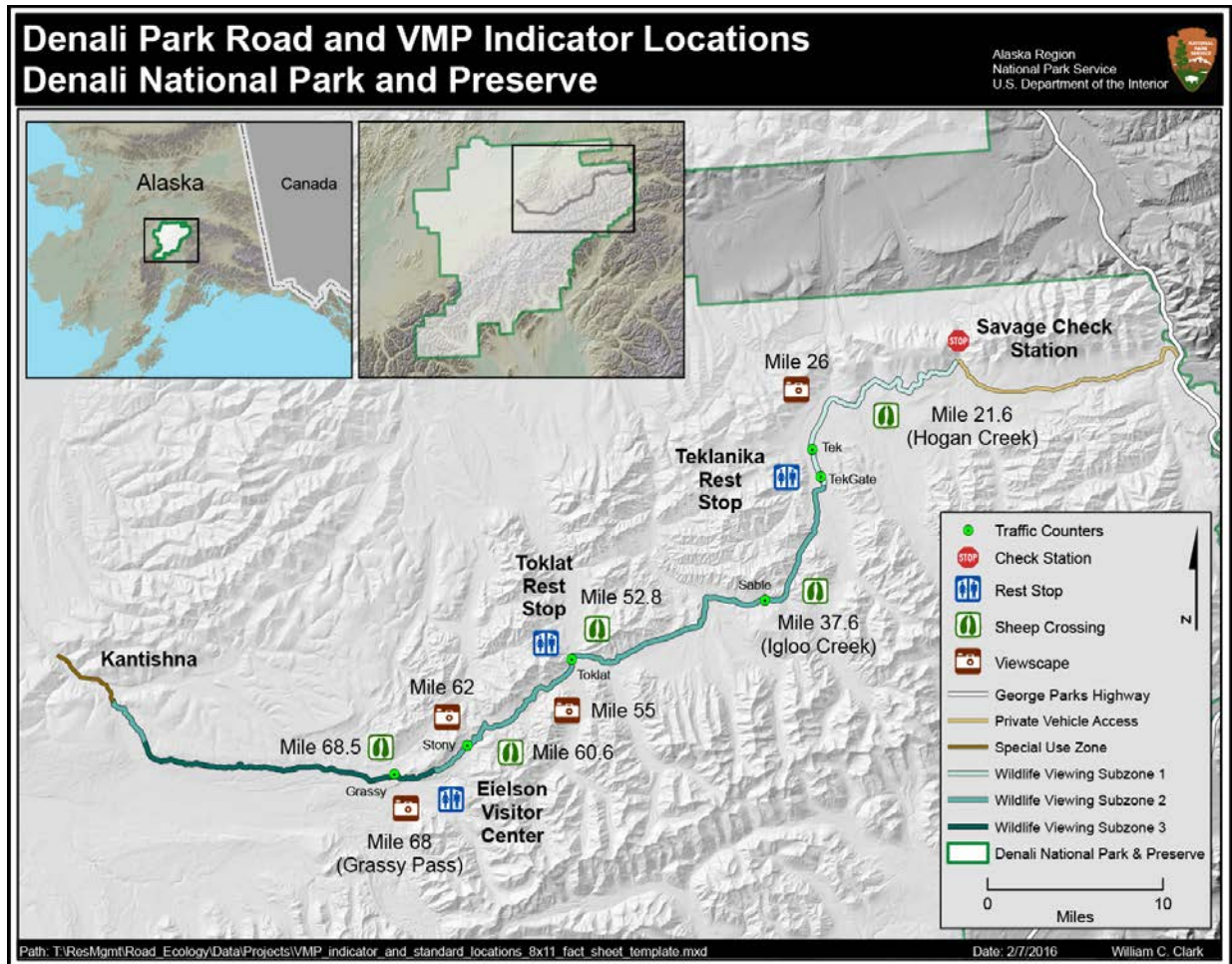


Figure 1. The Denali Park Road corridor traverses the northeast portion of Denali National Park and Preserve, Alaska, USA. There are 12 VMP indicator sites visited by field staff: five sheep gaps, four viewscapes, and three rest stops. VMP standards for wildlife stops and viewscapes vary by Subzone. Six remote, automated traffic counters are also distributed along the road and provide continuous data on traffic volume.

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 2). 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.



Figure 2. 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.

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. 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.

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 3). The design standards and capacity for each facility's parking lot were used to inform the VMP standard.



Figure 3. The number 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 4). 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-yr 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-yr) 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 more road sinuosity the landscape will obstruct visibility and fewer vehicles are visible.



Figure 4. 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. Red arrows indicate the end points of the viewscope. The standard varies by Subzone and is described by a minimum percentage of time that fewer than x 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 (near Hogan Creek), mile 37.6 (near Igloo Creek), mile 52.8, mile 60.6, and mile 68.5 (near Grassy Pass, Figure 5). 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-yr standards. The 1-yr standard requires at least one 10-minute gap in traffic per hour in 22 of 24 hours (90%); the 5-yr 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 viewscales, 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 5. The spacing of traffic at five sheep crossing locations (i.e. sheep gaps) is an indicator to measure desired resource protection efforts along the Denali Park Road (Denali National Park and Preserve, Alaska, USA). Red 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 with no more than six vehicles in any one hour. This indicator is measured using automated traffic counters installed at six locations (Figure 1). Both standards are to be met at least 95% of the time.

Hiker Wait Time

The amount of time hikers wait to be picked up by a bus is an indicator of how well the transit service is meeting demand. Hikers are defined as passengers that disembark a transit bus that later attempt to re-embark a bus to continue traveling or return to the park entrance area. The VMP established 1- and 5-yr 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. Meeting the demand for transit services takes priority over concessionaire tour and charter services according to the VMP.

Large Vehicle Traffic

Work by park scientists show that there is typically a positive, direct relationship between GVWR and noise. Noise, or non-natural sound, is an energy wave caused by vibrations that is well documented to cause negative effects on the health of animals and animal populations (Barber et al. 2010). The number of large vehicles (> 80,000 GVWR) travelling the park road is a VMP indicator to mitigate negative impacts on wildlife. The standard is defined as an hourly rate of ≤ 4 vehicles per hour. Because this indicator is defined by weight rather than dimension, the park requires a weighing system to evaluate this standard. This methodology has not been fully implemented. Recommendations for monitoring this indicator are included at the end of this report.

Methods

Study Area

Denali is located in interior Alaska between Anchorage and Fairbanks (Figure 1). Most Denali visitors access the park's 2.4 million hectares via the 92-mile road that connects George Parks Highway to the former mining community of Kantishna. The Denali 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*) and 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: Summers are short and cool with average minimum and maximum temperatures of 0° and 24°C, respectively (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.

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 operate 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 carry a purpose-specific permit in their personally owned vehicle (POV). POV permits are displayed on the windshield near the driver and are often difficult for observers to record. 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

Field data were collected either by: (1) a protocol conducted by NPS staff from a government vehicle (NPSO) or (2) a protocol conducted by NPS staff and volunteers from a VTS bus, a program called Ride, Observe, and Record (ROAR). Autonomous, battery-operated traffic counters collected additional data on traffic levels. The regulatory year is divided into three monitoring subseasons: Early, Peak, and Late to ensure adequate temporal sampling. For 2015 the subseasons were: Early season: May 23-June 17, Peak season: June 18-August 5, and Late season: August 6-September 15. Subseasons are defined by changes in the VTS bus schedule; peak season coincides with the highest level of park visitation and park road transit. There are 12 sampling sites visited between the two protocols: five sheep gaps, four viewscapes, and three rest stops.

For 2013 and 2014 we reported the results of on-board Global Position System (GPS) on concessioner buses, NPS vehicles, and Lodge buses (2014 only). This method collected nearly one million data points annually requiring careful quality control. Random and systematic errors made quality control long and intensive. For 2015, no on-board GPS data collection were collected because park management concluded that the technology as it exists was inefficient. Instead, resources were redirected toward increasing field-based data collection by NPSO and ROAR. Although the use of on-board GPS data was suspended, the quality controlled data collected from 2013 and 2014 were invaluable to the development of a behavior-based traffic model on which the parameterization was based.

NPS Observations (NPSO)

NPS staff collected data on viewscape and rest stop traffic volumes and sheep gap spacing at sites along the controlled portion of the park road. At least one NPSO protocol observation was planned for each week of the 2015 regulatory year with the start date of the observation determined by modified random sampling scheme. A Julian Day calendar and a random number generator (RNG; www.random.org) were used to determine the initiation dates of 1- or 2-night observation periods. The RNG was constrained to appropriate values for the regulatory year (i.e. between 143 and 257). RNG results marked the start of an observation period (e.g. a result of 202 created a July 21-22 observation period). Location of the overnight stay can affect the strategy of the second day of sampling. The RNG was also used to determine in which field station (given vacancy) observers spent the night.

Results of the RNG were modified to ensure observations during Memorial Day weekend (May 23-25), Independence Day (July 3-5), the Kantishna Music Festival (August 15-16), and Labor Day weekend (September 5-7) and if a particular day of week (e.g. Tuesday) went without sample the schedule was adjusted. The goal of the program is to be able to answer questions about both fine- (day of week) and coarse-scale (month of season) temporal trends and patterns. Results of all temporal analyses are included in Appendix B of the report.

During each subseason, NPS staff collected data during five hour blocks of the day that cover the concessionaire bus operating hours of 0600-2200. The five sampling hour blocks are: 0600-0900, 0900-1200, 1200-1500, 1500-1800, and 1800-2200. Although physical and scheduling logistics (e.g. transit between sampling locations and considerations for efficiency) prevent truly randomized sampling within the daily sampling blocks, monitoring staff were required to monitor each indicator within each time block at least twice (Early season) and three times (Peak and Late season). This ensured all indicators were sampled to capture patterns in daily variations of traffic.

Ride, Observe, and Record (ROAR)

ROAR observers recorded data at wildlife stops, rest stops, and hiker pickups during trips along the park road. ROAR trips were scheduled to proportionally reflect the current VTS schedule. Observations were scheduled to cover daily variation: early- (before 0930), mid- (0930-1230), and late-day (after 1230). As suggested by the 2014 report, overnight ROAR trips were scheduled in 2015 to collect data from the eastbound camper bus that departs early mornings from Wonder Lake. ROAR trip destinations were Toklat, the EVC, Wonder Lake, and Kantishna.

NPS staff, while primarily collecting data using the NPSO protocol, took additional observations at rest and wildlife stops using the ROAR protocol to increase sample size. Simultaneous observations from a ROAR and NPSO observer were discounted from analysis.

ROAR observations were recorded as features in a data dictionary on Trimble JUNO™ Series Handheld GPS Devices (Trimble, Sunnyvale, CA); all features include geographic coordinates (WGS84), date, and time (UTC -0900). Additionally, wildlife stop features included species, number of individuals, sex and age (when possible), and distance from the road. Distance was determined using calibrated range finders (Nikon Aculon 6x20, Bushnell Elite 1500, and Legend 1200). Rest stop features include rest stop name and the maximum number of vehicles parked at one time by vehicle type upon arrival and departure. Hiker wait time features include, if the bus had available seats to pick up hikers, the number of hikers picked up, and their wait time. Data are quality controlled and processed using the Pathfinder Office platform (Trimble, Sunnyvale, CA). Data were run through a custom Python script to linearly reference the dataset to the Denali Park Road so that mile information can be appended to the attribute table.

Traffic Counters

Six traffic counters collect continuous data every day of the regulatory year. Five counters parsed data into 10-minute bins, the sixth counter, Grassy Pass, was programmed to parse data into 1-minute bins (finer resolution) as a means to additionally monitor the nearby sheep gap (mile 68.5).

Supplemental Data

The concessionaire provided VTS bus driver-collected and EVC dispatch data for monitoring hiker wait time. 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, invaluable for ROAR 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 present vehicles except their own. Since the government vehicle driven by the NPS staff member was present to count vehicles, it was not included in analysis – every observation it recorded would be inflated otherwise.

ROAR data were collected beginning at each trip's initiation point (either the Wilderness Access Center or park headquarters). Data collected outside of the controlled portion of the road and data that were missing location information (unknown stop location) were discounted from analysis. Often, two ROAR observers would be in the field on the same day and time. To reduce pseudo-replication, observations of the same species, on the same day, within a three minute window, and less than ½ mile apart but made by different observers were considered duplicate observations. One of the duplicates 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) by site. 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 calculation to normalize the number of wildlife stops that occurred in each Subzone was calculated as:

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

The 5-yr VMP standards were calculated using weighted averages to avoid sample size bias:

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

Where: x is the current year.

This year, in the equation above, $i = x - 3$ because there were only three years of data to consider.

Number of Vehicles at Rest Stops

We used NPSO and ROAR data to assess crowding conditions (maximum buses and maximum vehicles) at three rest stops (Figure 3.). 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 (ten observations). This was 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. Within the same 2-minute interval, if the maximum number of vehicles was reached more than once (as vehicles arrive and depart), the composition of the vehicles was not edited; 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 since in the vehicle count. NPSO protocols exclude the vehicle in which staff travels because the vehicle is present only for monitoring. Thus, zero values are possible using the NPSO protocol. However, they are not considered in analysis because the standard is based on social normative values making monitoring without visitors present inappropriate.

Rest stop data were summarized in Excel by site and vehicle category and maximums 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 provided a relative sense of traffic pattern. Results of rest stop temporal analyses are included in Appendix B of the report.

Number of Vehicles in Viewscapes

We assessed the viewscape standard using the NPSO protocol at four sites (Figure 4). Observers recorded the composition and maximum number of vehicles travelling within the borders of the viewscape at the same time during 2-minute intervals for a period of 20 minutes (ten observations). This was 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. Within the same 2-minute interval, if the maximum number of vehicles was reached more than once (as vehicles arrive and depart), the composition of the vehicles was not edited; the composition of the maximum reflects that of the first instance of the maximum for that interval. The composition of the maximums was recorded in the same seven categories as rest stops.

Viewscape data were summarized in Excel by site. Tour, VTS, and Lodge bus categories were summed to derive total bus count. Zero values are included in this analysis since visitors may see zero vehicles in the landscape ahead of them and thus this is a reflection of the visitor experience. Calculations for the proportion of observed time when traffic volumes met the viewscape standards within a Subzone defined in the VMP 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 as in rest stop analyses. Viewscape data are not continuous counts but maximums within 2-minute bins. Thus, temporal analyses only provided a relative sense of traffic pattern. Results of viewscape temporal analyses are included in Appendix B of the report.

Sheep Gap Spacing

We assessed the standard for the sheep gap indicator using the NPSO protocol at five sites and the Grassy Pass traffic counter at one site (Figure 5). Using the NPSO protocol, sheep gaps were monitored for between ten and 60 minutes. The length of observation depended on traffic conditions. Once a 10-minute period passes with no vehicles, the observer recorded that a successful gap occurred. Some attempt was made to continue observing a site after a successful 10-minute gap to assess the true length of the gap. Achieving the minimum length, 10-minute gap, compared to achieving longer gaps is valuable information.

The time vehicles crossed a reference point were recorded to the second. Precision was achieved by maintaining a constant reference point and leveraging Excel's ability to record time when a cell is populated. 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 the sheep gap standards defined in the VMP was calculated as:

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

The Grassy Pass traffic counter was programed to collect data in 1-minute bins, similar to 2014. 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 (above).

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 on a per-observation basis using contingency tables because the data are binomial. Contingency tables answer the question: Given the total number of observations and given the number of failures of a 10-minute gap, is the proportion of failures higher than expected from random? We compared chi-squared (χ^2) results to a chi-squared table to determine if the null hypothesis (H_0) was accepted or rejected. Here, we tested a H_0 of if maintenance of 10-minute gaps was independent of day-of-week or week-of-year.

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 1). TRS traffic counters were seasonally stationed in protective cabinets and connected to dual inductive loops. Inductive loops were buried 6-10 inches beneath the gravel road surface which detected the signal of magnetic interference from passing vehicles and was interpreted and recorded by the counter assigning headway (direction of travel). West 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; to coincide with a later opening date, the collection period 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 standard 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 trends and patterns. As written in the VMP this indicator is not considered spatially. Rather, it is considered on a road-wide pass/fail basis. However, we assert that failures of this indicator at one location do not convict other locations to failure if the offending traffic volume does not propagate to that other location; the spatial context of nighttime traffic is important. Therefore, nighttime traffic standards are interpreted spatially by traffic counter location.

Hiker Wait Time

We used data from the EVC dispatch records, VTS driver manifests, and ROAR observations to evaluate the hiker wait time standards. The concessioner maintains a dispatch operation at the EVC to manage passenger requests during operating hours. Visitors who alter the standard out-and-back schedule by staying at the EVC longer or hikers using that EVC as a transit hub are coordinated by the EVC dispatcher who tracks their wait time.

VTS bus drivers pick up hikers at designated stops (e.g., Wonder Lake Campground) and any point along the road beyond mile 17. Drivers maintain a manifest and record how many passengers get on and off the bus, how long hikers waited for a bus to pick them up (< 30 min, < 60 min, < 90 min, or ≥ 90 min), and where pick-ups and drop-offs occur along the road. Pick-ups and drop-offs are recorded in 12 road segments (e.g. Teklanika rest stop to Tattler Creek) and two nodes (Toklat and EVC) each with separate west and eastbound records. These data were collected for all scheduled and unscheduled stops.

ROAR observers recorded hiker wait time while traveling the park road on VTS buses. The observer recorded the number of hikers, whether the bus driver asked them how long they had been waiting for a bus, and how long they had been waiting. If the driver did not ask the hiker the ROAR observer attempted to ask the hikers. ROAR observers recorded wait times as 0–29, 30–59, 60–89, and greater than 90 minutes. Calculations for the proportion of observed instances when hiker wait times met the standards defined in the VMP were calculated as:

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

For 2015, ROAR observers recorded a new metric related to hiker wait time, the instances when a bus being too full to pick up waiting hikers. We plotted 2013-2015 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.

Results

Data Collection Effort

Data were collected on 263 trips using the ROAR protocol and 60 trips using the NPSO protocol, a collection effort increase of 75% and 94%, respectively, compared to 2014. Consequently, sample size of staff-collected indicators increased 27% (hiker wait time) and up to 53% (viewscales). The average increase in sample size for indicators was 38%.

Of the 263 ROAR observations, 228 were conducted from a VTS bus and 35 from a GOV vehicle. Observations closely matched the schedule for the early and peak subseasons, observations drifted further from target values in the late subseason (Table 1). Data from 13 ROAR overnight trips are included.

Table 1. The distribution of ROAR observations compared to the 2015 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
		ROAR observations (actual)	VTS schedule (target)	
Early 2015 (May 23-June 17) (26 days)	Toklat	33.3	34.5	12
	EVC	44.4	43.6	16
	Wonder Lake	11.1	12.7	4
	Kantishna	11.1	9.1	4
Peak 2015 (June 18-August 6) (49 days)	Toklat	14.6	16.7	15
	EVC	38.8	33.3	40
	Wonder Lake	32.0	30.0	33
	Kantishna	14.6	20.0	15
Late 2015 (August 7-September 15) (41 days)	Toklat	13.5	11.0	12
	EVC	53.9	43.8	48
	Wonder Lake	21.3	38.4	19
	Kantishna	11.2	6.8	10

Each indicator site was sampled at least once during the early subseason ($n = 120$ in 26 days), three times during peak season ($n = 257$ in 49 days), and twice during late season ($n = 187$ in 41 days) using the NPSO protocol.

Number of Vehicles at Wildlife Stops

ROAR observers recorded 2,542 wildlife stops in 2015, 2,507 of which have GPS data. The majority of sightings, 83%, occurred in Subzone 2, 13% occurred in Subzone 1, and 4% occurred in Subzone 3. We normalized for the data by Subzone length to report wildlife stops per mile; Subzone 2 is clearly the most animal-dense road segment (Table 2).

Table 2. The number of ROAR observations recorded in each of the three Subzones during the 2015 regulatory year on the Denali Park Road (Denali National Park and Preserve, Alaska, USA). The number of stops was normalized to respective Subzone lengths (miles) to report stops per mile. Subzone 2 is the most animal-dense Subzone in the park.

Stop Type	Subzone 1	Subzone 2	Subzone 3
number of wildlife stops	326	2,071	110
stops per mile	15.5	54.3	5.9

All wildlife stop measures were within VMP standards in 2015 (Table 3). On average, 2015 data vary less than one percent from 2014 data. The large majority of wildlife stops had either one (57.4%) or two (26.7%) vehicles present. A maximum of nine vehicles was observed on one occasion for sheep at Polychrome. At that stop, four tour buses, three VTS buses, and two government vehicles were observed.

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 2015.

Method	Wildlife Subzone 1			Wildlife Subzone 2			Wildlife Subzone 3		
	% ≤ 3 vehicles	% ≤ 4 vehicles	% ≤ 5 vehicles	% ≤ 2 vehicles	% ≤ 3 vehicles	% ≤ 4 vehicles	% ≤ 1 vehicles	% ≤ 2 vehicles	% ≤ 3 vehicles
Standard	70	85	90	70	85	90	70	85	90
ROAR	92.0	96.9	99.4	83.9	94.6	97.5	73.6	94.5	100

Number of Vehicles at Rest Stops

Conditions of traffic volume at Teklanika, Toklat, and the EVC rest stops were observed on 1,964 occasions using the ROAR protocol. An additional 1,450 observations were recorded using the NPSO protocol. By every measure, the rest stops were within standard during the 2015 regulatory season (Figure 6, Figure 7, Figure 8). Eielson reached the maximum allowable number of parked buses (September 1st) and total parked vehicles (August 18th) each once. Toklat reached the maximum allowable parked buses once, September 8th (Table 4). Though it is a small sample size, all of these maximums occurred on Tuesdays (at 13:12, 10:30, and 11:06 respectively). The EVC had the highest average number of buses observed and the highest maximum and average number of all vehicles combined (Table 5, Table 6). There is a systematic decrease in the maximum number of vehicles observed (buses and total) and the average number of vehicles observed at each rest stop site depending upon the protocol used, NPSO or ROAR.

During a 4.5-hour road closure caused by snow, 16 buses were observed parked at Toklat because they could not proceed. We did not consider this datum within the dataset.

Table 4. 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 summer 2015 regulatory year on the Denali Park Road (Denali National Park and Preserve, Alaska, USA). All rest stop standards were met in 2015. Maximum standard values were met at both the EVC (total vehicle and total vehicle maximum) and Toklat (total bus maximum).

Method	Teklanika			Toklat			EVC		
	bus max	vehicle max	n	bus max	vehicle max	n	bus max	vehicle max	n
Standard	12	16	--	11	16		10	19	--
NPSO	7	8	490	7	9	480	10	18	480
ROAR	11	11	791	11	11	710	9	19	463

Table 5. Mean (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) 2015 regulatory year. ROAR data were consistently greater than NPSO data; the most buses were observed at the EVC.

Method	Teklanika		Toklat		EVC	
	mean (σ)	n	mean (σ)	n	mean (σ)	n
NPSO	2.0 (± 1.5)	490	2.2 (± 1.7)	480	2.2 (± 2.1)	480
ROAR	2.7 (± 1.6)	791	3.5 (± 1.9)	710	3.7 (± 1.7)	463

Table 6. Mean (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 2015 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 2015.

Method	Teklanika		Toklat		EVC	
	mean (σ)	n	mean (σ)	n	mean (σ)	n
NPSO	2.2 (± 1.7)	490	2.9 (± 1.9)	480	5.1 (± 3.4)	480
ROAR	2.9 (± 1.7)	791	4.1 (± 2.1)	710	7.1 (± 2.6)	463

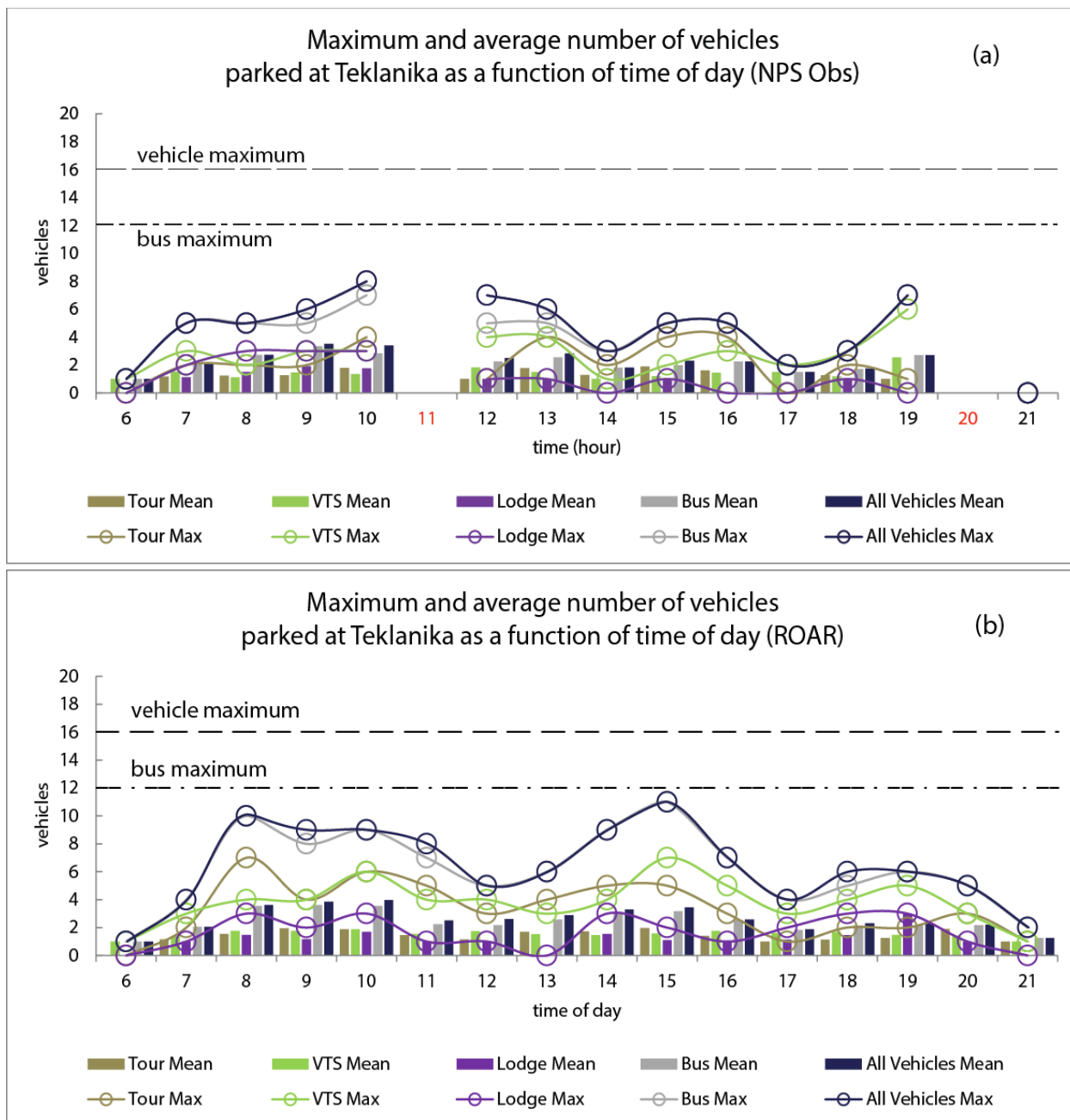


Figure 6. Maximum and average numbers of vehicles parked at the Teklanika rest stop based on the NPSO (a) and ROAR (b) protocols used at Denali National Park and Preserve, Alaska, USA. Red times of day indicate the time was not observed (no data available). Both protocols report that total vehicle and bus maximums did not exceed VMP standards for 2015.

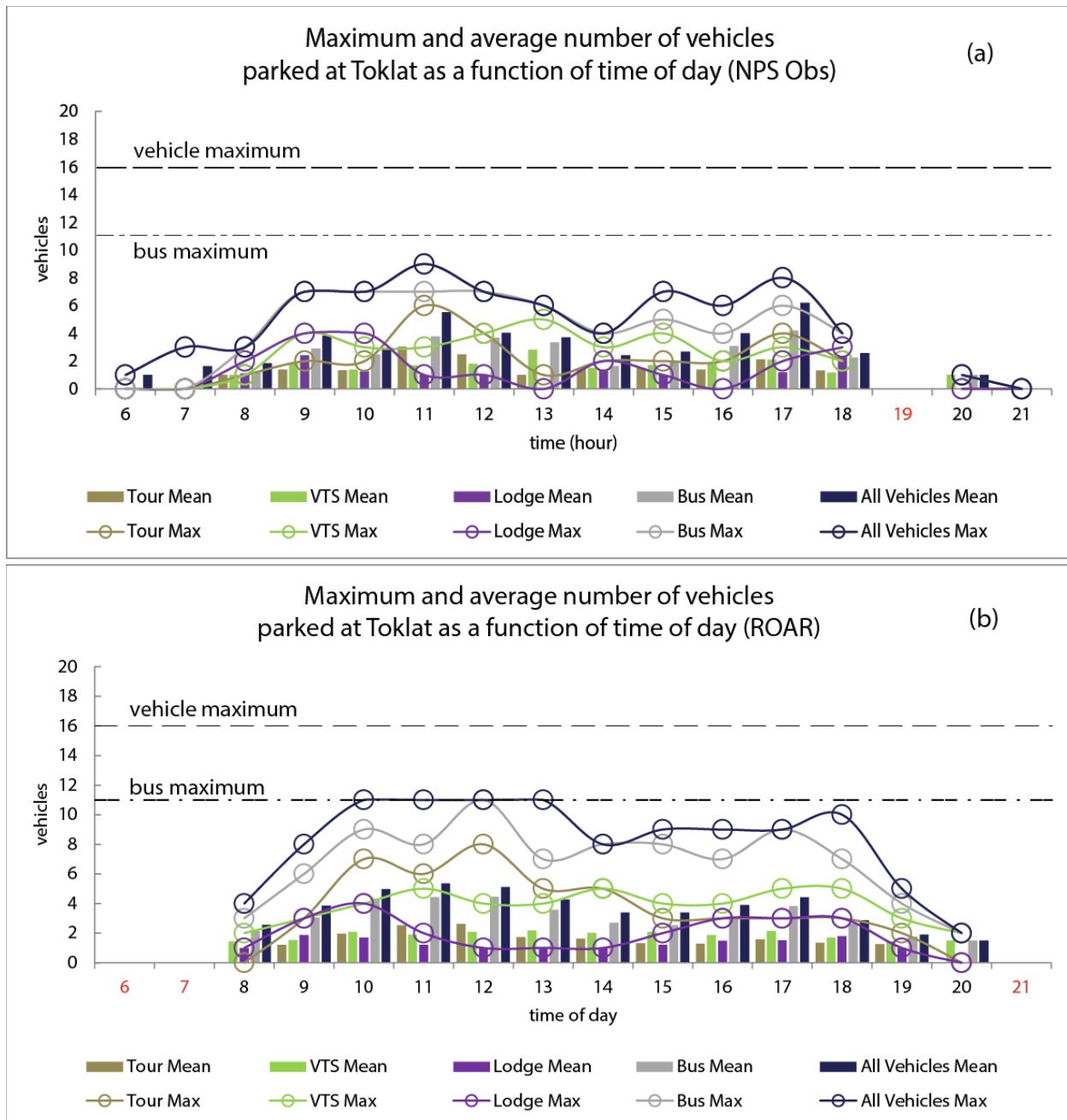


Figure 7. Maximum and average numbers of vehicles parked at the Toklat rest stop based on the NPSO (a) and ROAR (b) protocols used at Denali National Park and Preserve, Alaska, USA. Red times of day indicate the time was not observed (no data available). Both protocols report that total vehicle and bus maximums did not exceed VMP standards for 2015. However, the VMP standard bus maximum (11) at Toklat was equaled on September 8th during the 12-hour block.

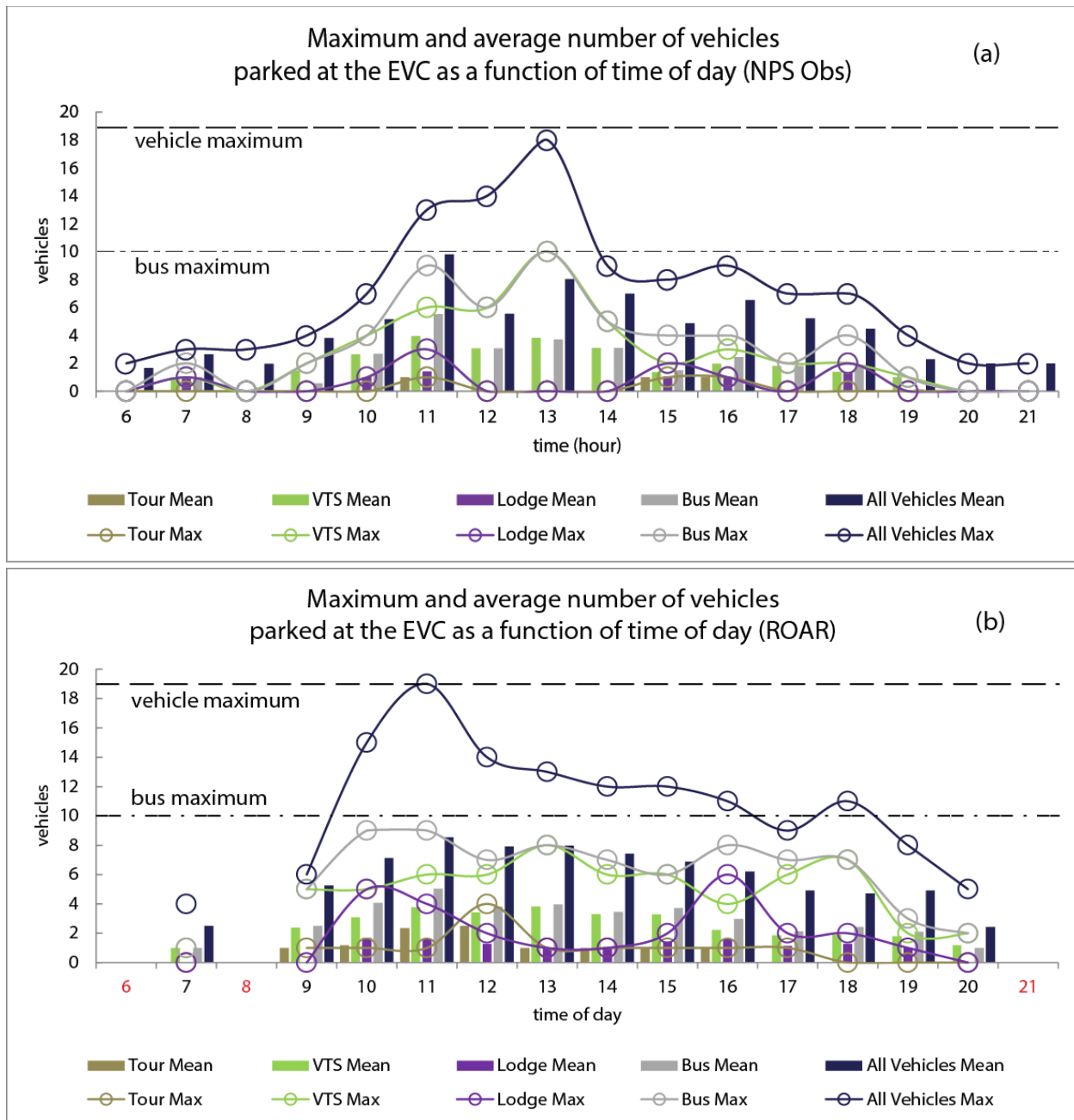


Figure 8. Maximum and average numbers of vehicles parked at the Eielson Visitor Center (rest stop) based on the NPSO (a) and ROAR (b) protocols used at Denali National Park and Preserve, Alaska, USA. Red times of day indicate the time was not observed (no data available). Both protocols report that total vehicle and bus maximums did not exceed VMP standards for 2015. However, the VMP standard total bus maximum (10) at the EVC was equaled on September 1st during the 13-hour block according to the NPSO protocol and the VMP standard for total vehicles (19) was equaled on August 18th during the 11-hour block according to the ROAR protocol.

Number of Vehicles in Viewscapes

We collected 1,870 viewscape observations in 2015 at mile 26 ($n = 480$), mile 55 ($n = 470$), mile 62 ($n = 460$), and mile 68 ($n = 460$). The VMP standards for the percentage of time specific numbers of vehicles are visible in each of the four viewscapes were met at all sites (Table 7). The highest average maximum number of vehicles visible at one time (2.9) was observed at mile 26 (Figure 9). The second highest average maximum number of vehicles (2.5) was observed at mile 55; mile 68 observations showed the lowest average maximum number of vehicles (1.5) and least variability ($\sigma = 0.5$). Peaks in volume occurred at eastern sites during morning hours and western sites during afternoon hours (Figure 9).

Table 7. 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 2015.

Method	Mile 26		Mile 55		Mile 62		Mile 68	
	% ≤ 3 vehicles	% ≤ 4 vehicles	% ≤ 2 vehicles	% ≤ 3 vehicles	% ≤ 2 vehicles	% ≤ 3 vehicles	% ≤ 1 vehicles	% ≤ 2 vehicles
Standard	80	90	80	90	80	90	80	90
NPSO	98.8	99.6	94.0	98.1	96.3	99.1	95.2	99.8

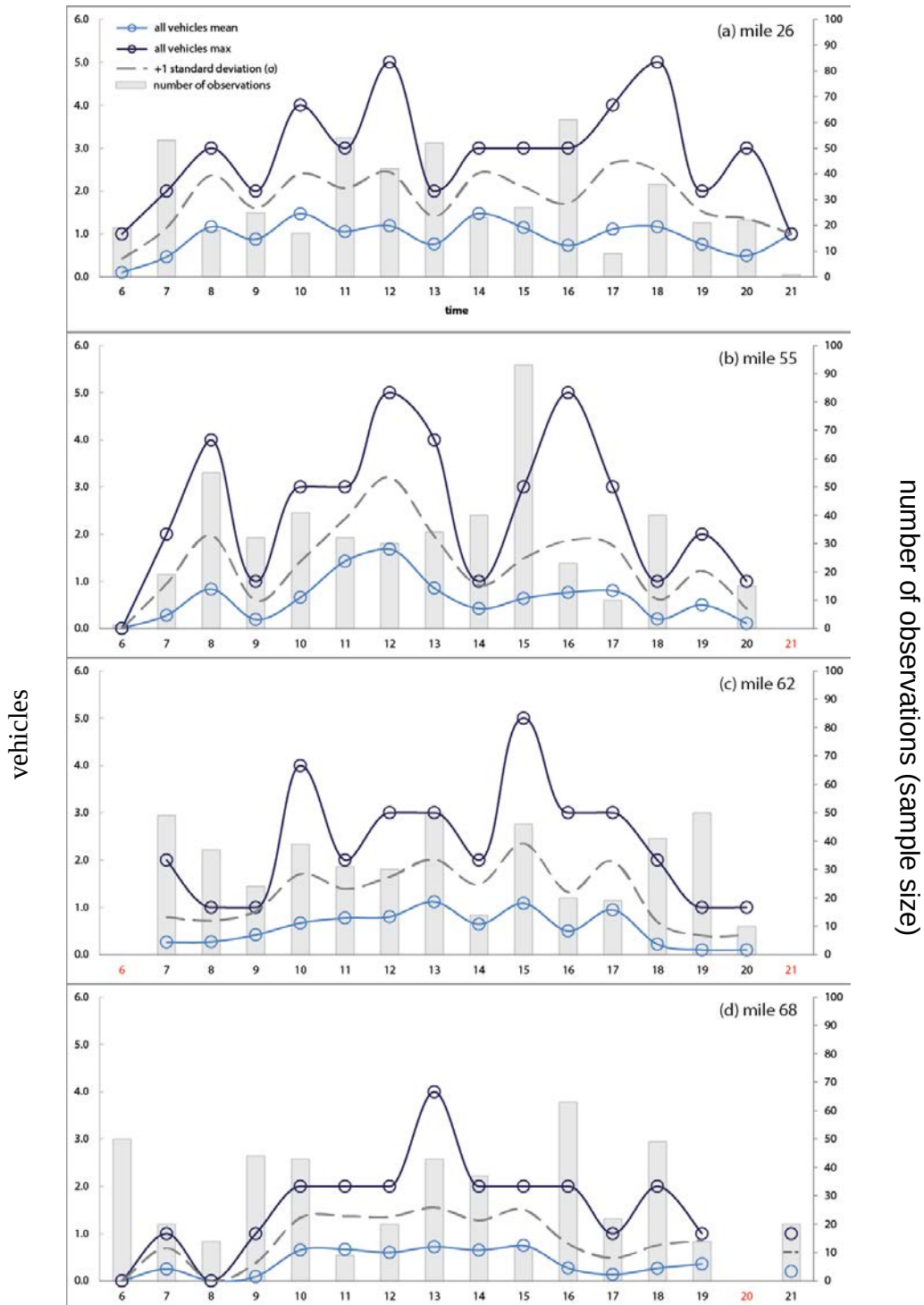


Figure 9. The maximum and mean (+1 σ) number of vehicles visible at one time at the mile 26 (a), 55 (b), 62 (c), and 68 (d) viewsapes on the Denali Park Road (Denali National Park and Preserve, Alaska, USA). Bars show the number of observations for that site and time. Red times of day indicate that the time was not observed at that site (no data available). The maximum number of vehicles seen at one time was five, which occurred during two-hour blocks at mile 26, two-hour blocks at mile 55, and one-hour block at mile 62. All VMP viewscape standards were met.

Sheep Gap Spacing

Staff recorded 232 sheep gap observations in 2015, representing a 52% increase in collection effort over 2014. Additionally, the Grassy Pass traffic counter recorded 2,616 hours of sheep gap observations at mile 68.5. VMP standards for the percentage of hours with at least one 10-minute gap in traffic was met at mile 21.6, mile 37.6, mile 52.8, and mile 68.5 (as measured by both NPSO and traffic counter). The VMP standard was not met at mile 60.6 (Table 8). At the sites that failed in 2014, the success rate increased in 2015 by 7.2%, 5.8%, and 4.7% at miles 21.6, 52.8, and 60.6, respectively.

Table 8. 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. Four of the five sheep gaps met the standard during the 2015 regulatory season; mile 60.6 did not meet the VMP standard (bolded text and starred). 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.

Method	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	91.8 (<i>n</i> = 49)	93.3 (<i>n</i> = 45)	91.1 (<i>n</i> = 45)	87.2* (<i>n</i> = 47)	100 (<i>n</i> = 46)
Traffic Counter	--	--	--	--	99.4 (<i>n</i> = 2616)

We examined the distribution of the maximum hourly traffic gap times from the near-continuous Grassy Pass sheep gap dataset (Figure 10). During bus operating hours (0600-2200), 16% of hours had no traffic; the gap was >59 minutes. Most instances of no traffic occur in the 0600 and 2100 hour blocks (Figure 11). Average sheep gap length during bus operating hours was 33.8 minutes. During non-operating hours (2200-0600), 78% of hours had no traffic and average sheep gap length was 54.7 minutes. All nighttime hours recorded achieved at least one 10-minute gap in traffic.

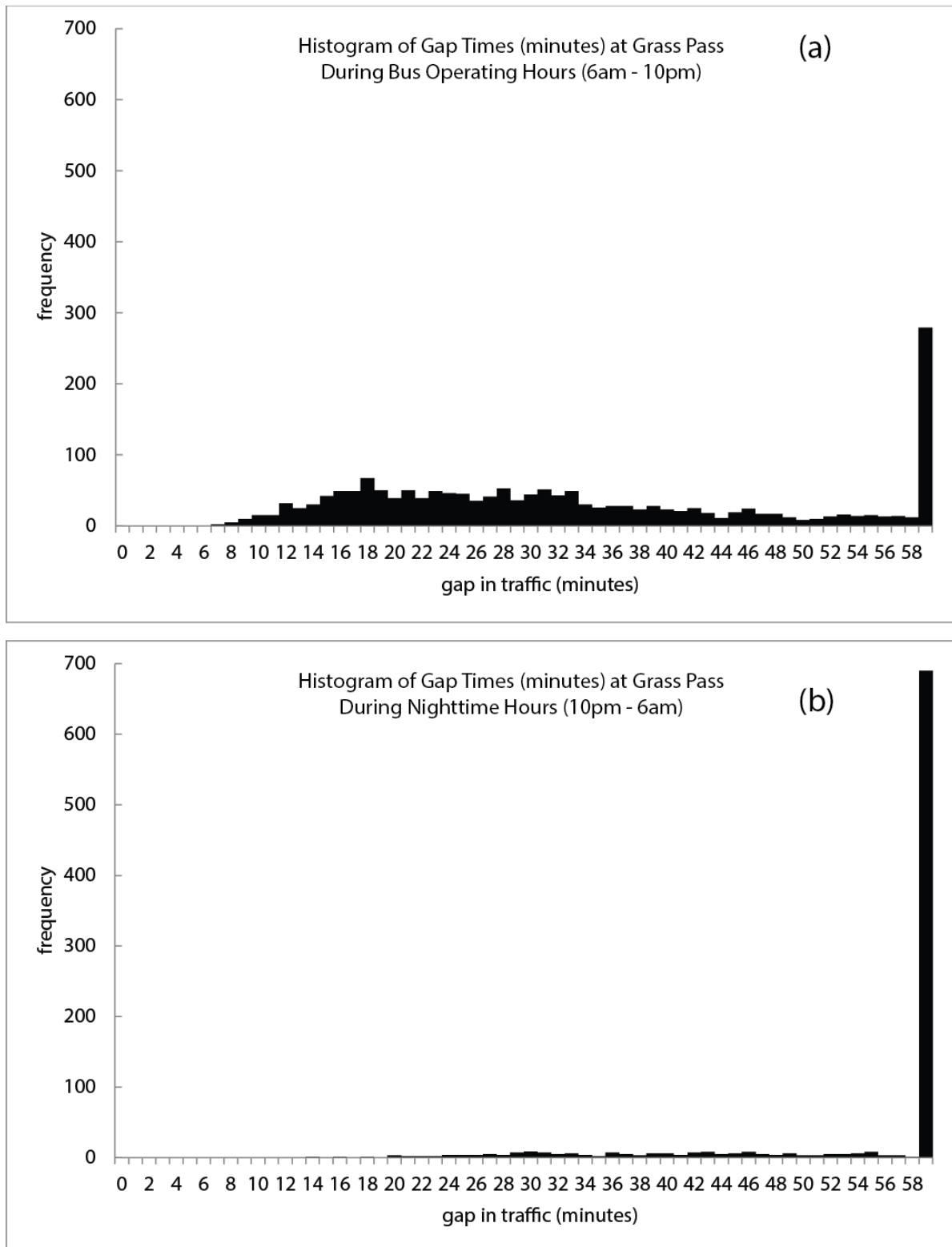


Figure 10. Histogram of hourly maximum gaps in traffic (minutes) at Grassy Pass (mile 68.5), Denali National Park and Preserve, Alaska, USA. Gaps in traffic decrease in length during bus operating hours (a) compared to non-operating hours (b). Traffic counters installed at each sheep gap site would inform management of detailed traffic patterns and the system's resilience, e.g. average sheep gap length.

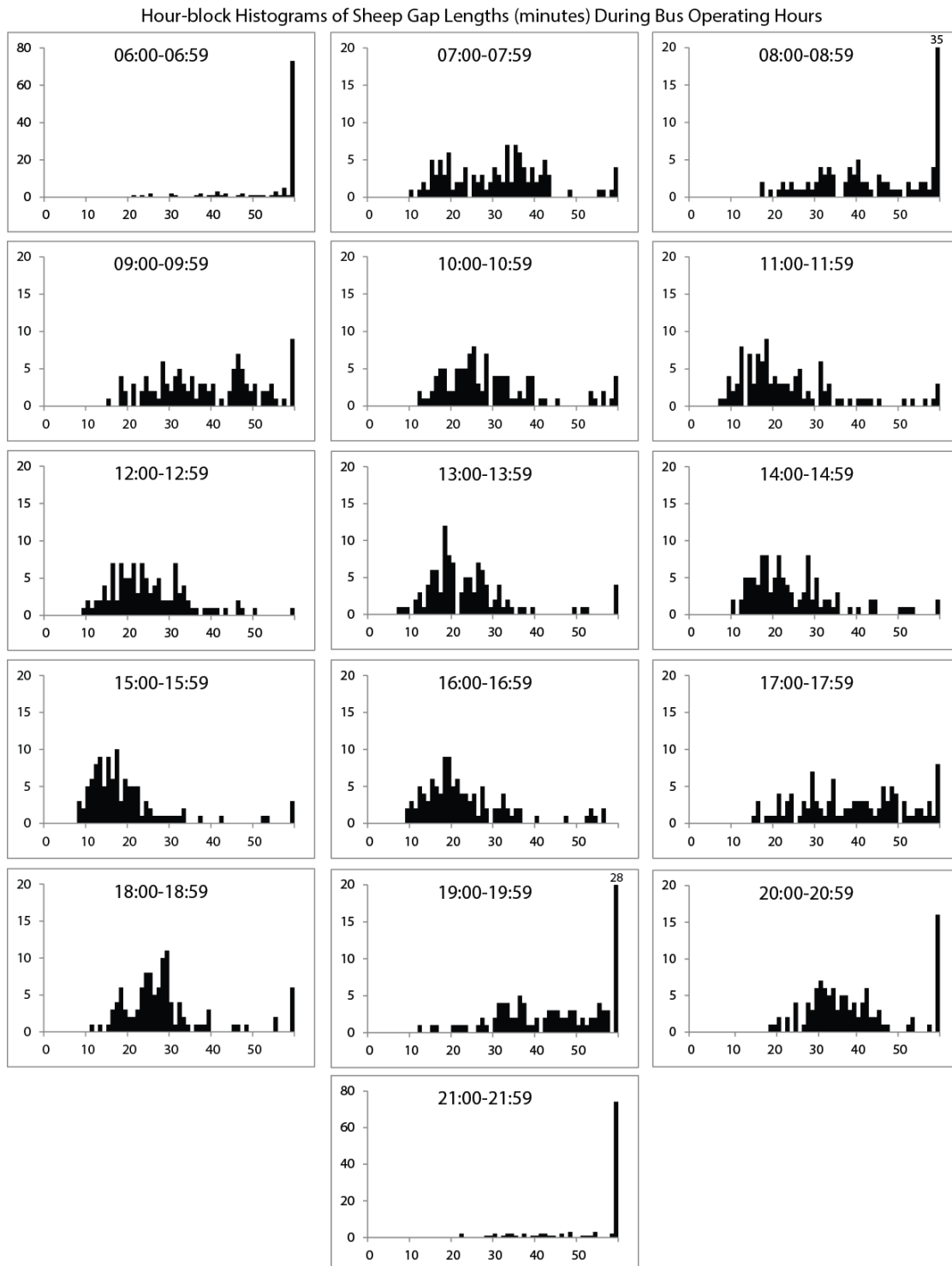


Figure 11. Histograms of bus operating hours and their maximum gap in traffic (minutes) at Grassy Pass (mile 68.5), Denali National Park and Preserve, Alaska, USA. As the shape of the histogram moves left, the average sheep gap length decreases. The 0600 and 2100 hour blocks have very little traffic. Traffic peaks at the 11 and 13-16 hour blocks. Note the y-axis range change for 0600 and 2100.

Nighttime Traffic

The road was open for 117 nights from the beginning of the controlled section to the Toklat rest stop and 108 nights to Kantishna. Most counters experienced interruptions in data collection due to battery failure, heavy rain, or other unknown causes (Figure 12). The Stony counter operated without failure during nighttime hours; the Toklat counter lost 18 nights of data (Table 9).

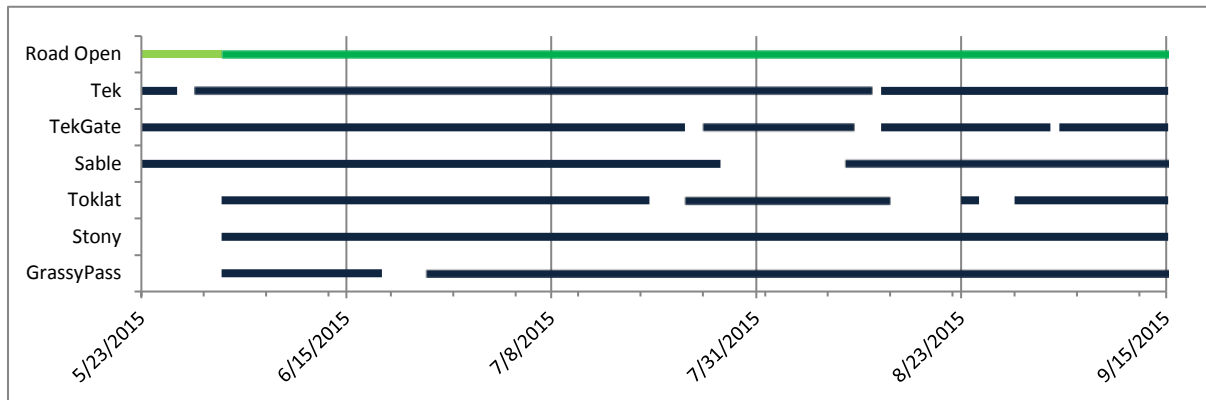


Figure 12. Gantt chart showing traffic counters operation periods compared to the Denali Park Road (Alaska, USA) regulatory year for 2015. The Stony counter functioned through all nighttime hours; the TekGate counter malfunctioned the most frequently but the Toklat counter failed to record the most number of nighttime hours.

Five of six traffic counter locations averaged three or fewer vehicles per hour on at least 95% of nights; TekGate (94.5%) did not (Table 9). Three traffic counter locations recorded several nights of > 6 vehicles in any hour and did not meet the 95% standard (Tek, TekGate, and Sable), while the other three counters recorded no nighttime hours of greater than six vehicles: Toklat, Stony, and Grassy. TekGate had the highest maximum nightly average rate of traffic.

Table 9. Summary of nighttime traffic (2200-0600) rates (vehicles/hour) and means on the Denali Park Road (Alaska, USA). The TekGate counter failed the ≤ 3 vehicles/hour and ≤ 6 vehicles in any one nighttime hour standard, while Tek and Sable also failed the ≤ 6 vehicles in any one nighttime hour standard (italics and starred).

Location	% nights ≤ 3 vehicle per hour	Number of nights sampled	Number of nights with >3 vehicles per hour	% nights ≤ 6 vehicles per any nighttime hour	Number of nights with >6 vehicles in any hour	Maximum nightly rate
Standard	95%	--	--	95%	--	--
Tek	97.3%	112	3	88.4%*	13	3.75
TekGate	94.5%*	109	6	89.9%*	11	5.83
Sable	100.0%	102	0	93.1%*	7	3.00
Toklat	100.0%	90	0	100%	0	1.88
Stony	100.0%	108	0	100%	0	1.50
Grassy	100.0%	102	0	100%	0	1.33

We looked at combinations of three variables of nighttime traffic to determine trends and patterns: time, location, and travel direction (headway). There is a spike in traffic on the east end of the road (Tek28, TekGate, Sable, July 14-23) but none to the west (Toklat, Stony, Grassy; Figure 13). This spike coincides with a scheduled nighttime material haul using heavy equipment to the Toklat road camp and accounts for nine, nine, and six nighttime failures at Tek, TekGate, and Stony respectively. The majority of nighttime traffic occurs on the edges of the nighttime time frame (0500, 2200, and 2300) and account for 63.7% (1,812 of 2,845 vehicles) of total traffic volume (Table 10).

Table 10. Summary of nighttime traffic hours (2200-0600) by hour block on the Denali Park Road (Alaska, USA). The majority of nighttime traffic occurs during the 22-, 23-, and 05-hour blocks.

Hour Block	All counters locations combined		
	% of eastbound traffic	% of westbound traffic	overall % of nighttime traffic
2200	33.7	26.3	29.3
2300	13.9	24.8	18.8
0000	10.5	9.6	10.2
0100	8.6	6.5	7.6
0200	7.1	5.1	6.2
0300	5.0	3.5	4.4
0400	7.0	3.7	5.7
0500	14.3	20.5	17.8

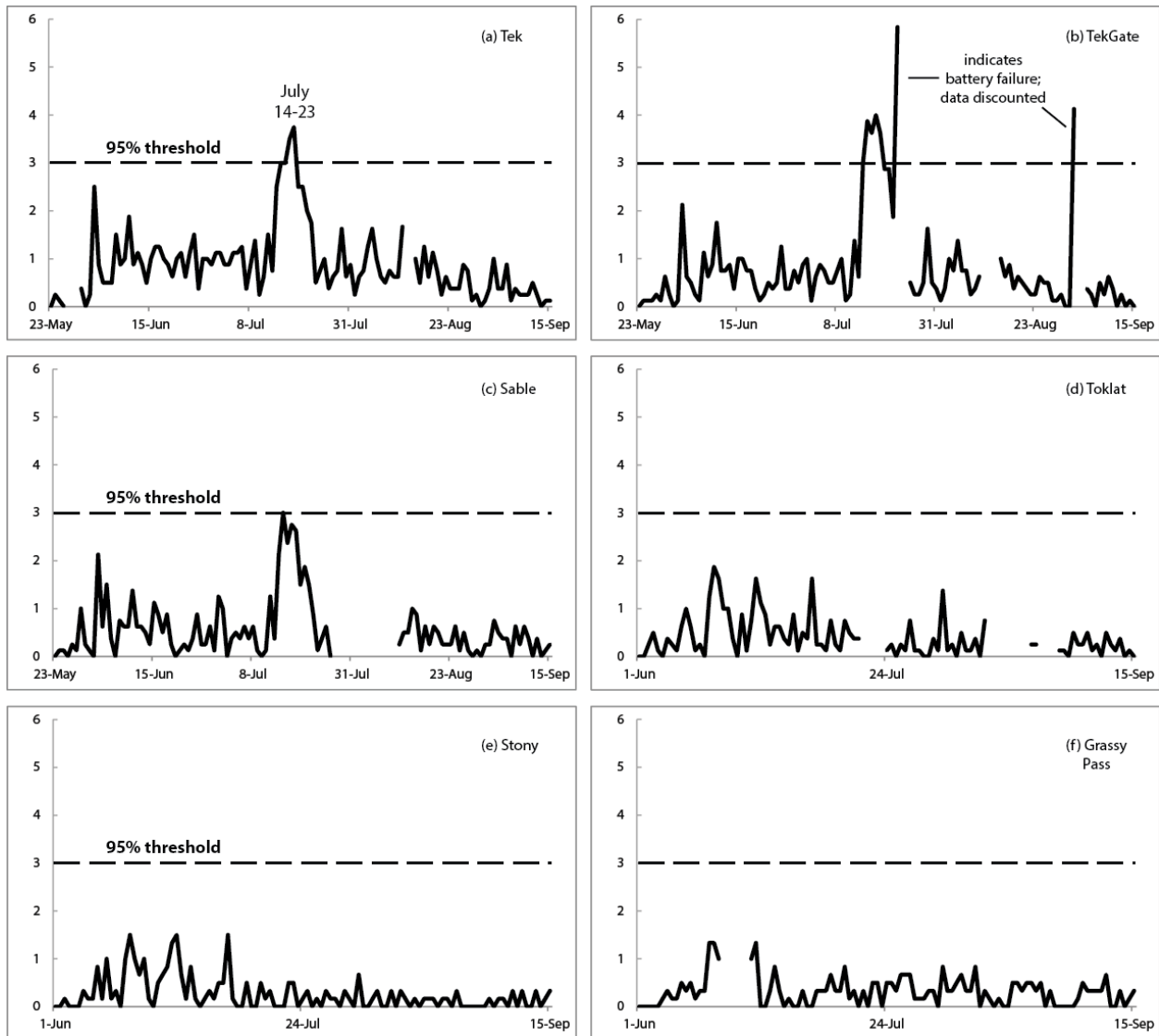


Figure 13. Average hourly (nighttime hours, 2200-0600) traffic rates (west- and eastbound combined) for all traffic counter sites (a) Tek, (b) TekGate, (c) Sable, (d) Toklat, (e) Stony, and (f) Grassy Pass at Denali National Park and Preserve, Alaska, USA. Increases in traffic just before no data was collected at TekGate indicate low battery. Those data were discounted from analysis. A spike in traffic from July 14-23 that propagates through Sable and coincides with a nighttime material haul to Toklat. The Toklat counter data gap disallows us to infer the volume of traffic that may have proceeded beyond the Toklat road camp. Breaks in the dataset indicate nighttime hours when the counter was not operating and data were not collected.

Hiker Wait Time

We collected data on 544 hiker pickups using the ROAR protocol. However, we collected wait time data on only 256 pickups. The standard for hiker wait time was met during the 2015 regulatory season (Table 11). Data from the EVC dispatch had the lowest percentage of hikers waiting less than 30 minutes for a bus. Additionally, we recorded 38 (7%) instances when the bus was too full to transport waiting hikers.

Table 11. 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 2015.

Method	% Time <30 min	<i>n</i>	% Time <60 min	<i>n</i>	% Time <90 min	<i>n</i>
Standard	70%	--	93%	--	98%	--
EVC Dispatch	87.1	12,454	98.9	14,140	99.9	14,276
VTS Driver	94.2	25,091	97.8	26,024	98.4	26,197
ROAR	89.1	228	95.7	245	98.8	253

The results of 2013-2015 hiker wait times were analyzed based on collection method (Figure 14). VTS drivers collect the largest dataset because they have the most opportunity; the fewest observations were collected using the ROAR protocol. Percentage of time meeting the standard is not affected by sample size.

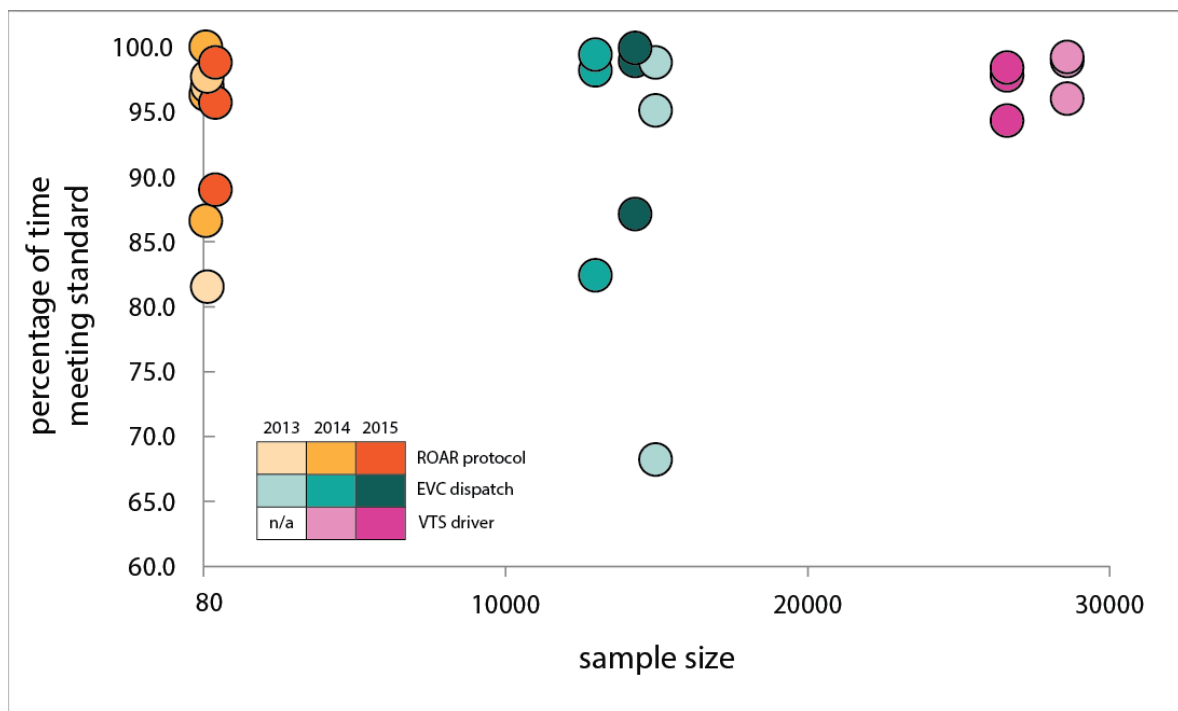


Figure 14. Percentage of time that hiker wait time standards were met as a function of sample size for the three methods used to collect hiker wait time data, 2013-2015, in Denali National Park and Preserve, Alaska, USA. Sample size does not affect the percentage of time that hiker wait time standards are met.

Discussion

The decision to forgo the use of the on-board GPS for monitoring VMP standards significantly decreased the sample size of most indicators. Comparison of 2013 and 2014 field-based and on-board GPS data makes clear that field-based data can appropriately monitor the behavior of Denali Park Road traffic. To improve our field-based monitoring efforts using ROAR and NPSO protocols, we increased collection effort to improve the statistical rigor of the sample set. We increased staffing to increase collection effort. As a result, the field-based effort increased by an average of 38% over all the indicators. We measured 43 of the 44 individual metrics related to the VMP. Of those, 38 met standard compared to 31 and 39 in 2014 and 2013, respectively.

For 2015, the REP consisted of seven staff member (including interns): five full-time seasonal staff, one part-time seasonal staff, and one full-time, year-round staff member. Five staff members were dedicated to data collection efforts, one of whom split duties between data management and data collection, and one oversaw the operations of the program. This new organizational structure created an efficient and productive monitoring effort and should be used as the model moving forward.

Number of Vehicles at Wildlife Stops

Of the six VMP indicators we monitored, only one directly measures on behalf of both the park's animal resources and the quality of visitor experience at the same time: the number of vehicles at a wildlife stop. It is important that this indicator meet standards because of its two-fold impact on park dynamics.

In 2015, the transportation system met this important standard while serving approximately 10,072 vehicle entrances. In fact, a single bus was stopped at a majority of wildlife stops (57%). Another 27% of total wildlife stops were shared between two buses. Only 16% of wildlife stops had greater than two buses stopped at one time.

Some caution is warranted in interpreting these results. Officially, this report accounts the conditions based on the 1-yr standards. However, we find it necessary to begin looking toward the 5-yr standards, which will be officially reported first in 2017. Five-yr standards are stricter than 1-yr standards to allow for an aberrant year without exceeding standards. With three years of data collected, Subzone 3 is on pace to fail the 5-yr standard for the percent time that one or fewer vehicles are present at wildlife stops by a very slim margin. The weighted average of 2013-2015 for the percentage of time that one or fewer vehicles are present at wildlife stops in Subzone 3 is 74.80%; the standard is 75%. In 2015, Subzone 3 met standard only 73.6% of the time. Thus, assuming similar sample size, this standard must average 75.2% or greater during the next two years to meet the 5-yr standard. All other wildlife stop standards have > 3 percentage-point margins to meet the 5-yr standard.

We do note that though the collection effort increased 75%, wildlife stops only increased 33%. At the same time, there is evidence that the probability of seeing wildlife increased slightly compared to 2014. It is possible then, that while the likelihood of seeing an animal has increased, the average number of animals seen per bus trip has decreased.

Number of Vehicles at Rest Stops

The standard for total buses and total vehicles parked at rest stops was met at all three sites in 2015. The data show room for cautioned growth because the standard for bus maximums were reached twice, once at the EVC and once at Toklat, and total vehicle maximum was reached once at the EVC. Unsurprisingly, the EVC continues to have the highest average number of parked vehicles. This is due, in part, to private vehicles of live-in maintenance staff and the daily GOV commuter vehicle for interpretation staff.

In five of the six maximums we report the ROAR protocol maximum is greater than the NPSO maximum (Table 4). This trend was also observed in 2013 and 2014. Since 2013, ROAR maximums have been greater than NPSO 14 times, less than NPSO three times, and equal once (McKenny et al. 2015, McKenny et al. 2014a). This may be caused by a difference in sampling behavior between the two protocols. The ROAR protocol is inherently tied to the bus network because the observer is travelling the road on a VTS bus. The ROAR observer is confined to the traffic network and its behavior is imposed on the sampling schedule. The NPSO observer travels both west and eastbound sampling sites in a nonlinear fashion and imposes *their* behavior on the sampling schedule. Therefore, we believe the ROAR protocol better captures visitor experience at rest stops than NPSO. This is supported by the fact that annual ROAR maximums are greater than those of NPSO.

Temporal patterns in relative rest stop traffic sightings are subtle. Decreases in rest stop traffic on Mondays and Wednesdays appear to be driven by fewer buses observed at Teklanika and the EVC and fewer non-buses recorded at the EVC. This pattern is not reflected in counts of vehicles travelling the road; Monday had the highest traffic counter counts and Wednesday had the second fewest (Appendix B Figure 1). It is possible that on Mondays and Wednesdays there is more through-traffic that does not stop at rest stops – possibly in-holder or employee permit holders who are instructed to avoid using rest stops.

Number of Vehicles within Viewscapes

The viewscope standard was met at all four sites. The viewscope at mile 55 had the most observed traffic in 2015. The consistency of this indicator stands out: Over the last three years, the maximum standard deviation for percent time meeting standard is 2.3% (McKenny et al. 2015, McKenny et al. 2014a). Each viewscope has a minimum 8.8 percentage point margin to meet the VMP 5-yr standard.

Though viewscope standards were met by wide margins, they are still a particularly vulnerable indicator. Because some viewscapes are located in landscapes with iconic mountain views, there could be a temptation to park in them to provide high quality recreational opportunities. Regular parking within a viewscope for extended periods would negatively affect this standard because it increases the proportion of time with one additional vehicle. Otherwise, viewscope standards are met because (1) stopped and parked traffic is infrequent, (2) the viewscope boundaries are short (1-2 miles), which makes travel-through times less than three minutes, and (3) traffic headed in the same direction do not often catch one another meaning they do not cluster.

Bus traffic dominates viewscope traffic volumes with some exceptions (Appendix B Figure 5a). The disparity between bus and non-bus sightings increases Friday-Sunday at mile 26 because many non-

bus sightings are of government and construction vehicles that were typically off duty Friday-Sunday (Appendix B Figure 6). Short spikes in non-bus sightings increased when road maintenance vehicles were observed because they travel slowly and remain within the viewscape boundaries for several minutes more than other traffic. Greater numbers of non-bus compared to bus traffic at the mile 26 viewscape is likely related to road construction projects near mile 21.6 and POV access to Teklanika Campground. Traffic behavior at mile 68 is expected because Lodge bus activity increases on Mondays and Fridays for guest and supply pick-ups at the train depot. Overall traffic rates do not increase on weekends (Appendix B Figure 11), although weekend traffic observed within the mile 68 viewscape markedly increased. Although traffic rates at mile 68 are the lowest and not cause for concern, this could be further investigated.

There are few trends in traffic pattern at viewscales on an hourly-basis. However the peak in hourly vehicle maximums that begins at mile 68 during the 13-hr block appears to propagate eastward through each viewscape. This could be a pulse of traffic returning to park headquarters near the end of the day.

Sheep Gap Spacing

The 1-yr sheep gap standard was met at four of the five sheep gap sites in 2015, which is a two-and-a-half-fold improvement compared to 2014. The site at mile 60.6 was below the 90% standard (87.2%). Though the sheep gap at mile 60.6 failed to meet the 90% standard, it was close. Given the sample size ($n = 47$), if two more successful observations were made at mile 60.6, the site would have met standard. This sheep gap site has never achieved 10-minute gaps in 90% of observed hours in the three years since monitoring began; every other site has met standard at least twice. It is hypothesized that the site's proximity to a popular overlook makes it difficult to meet standard.

The mile 60.6 sheep gap site is located at the base of a hill where the road climbs to the Stony overlook, an iconic vantage point of Denali (cover photo) 1.4 miles west. The Stony overlook is also the turn-around point for 80% of the popular Tundra Wilderness Tour (TWT). TWT buses stop at the Stony overlook for approximately 10-15 minutes. The proximity of this turn-around to the mile 60.6 sheep gap increases traffic return rates. With no other traffic it is possible to achieve a 10-minute gap between incoming and outgoing TWT trips. However, on busy days there can be 40-50 TWT trips, along with the VTS, GOV and POV traffic, leaving fewer opportunities to observe a 10-minute gap than other sheep gap sites.

The 5-yr standard for the sheep gap indicator presents a clear challenge to VMP compliance. The current 5-yr weighted average for percentage of hours with a 10-minute gap at each site is: 90.2 (mile 21.6), 93.0 (mile 376.), 89.6 (mile 52.8), 86.3 (mile 60.6), and 98.3% (mile 68.5). Under the current sampling scheme, sheep gaps sites at mile 21.6, 52.8, and 60.6 cannot meet the 5-yr standard because they must maintain 10-minutes gaps in traffic at averages over 100% of total sampled hours (102, 103, and 108%, respectively). Additionally, the sheep gap at mile 37.6 is unlikely to meet the 5-yr standard because it must maintain 10-minute gaps in traffic at an average of 98% of sampled hours for 2016-2017. The sheep gap at mile 68.5 will likely meet the 5-yr standard because it only has to average 90%. A larger sample size of positive results will help increase overall averages. However,

this year provided a larger sample size of positive results (relative to 2014) and sheep gap standards are still in danger of not meeting the 5-yr standard.

There is room for optimism. The VMP defines the sheep gap indicator as a 24-hour standard. Currently, it is only sampled during bus operating hours. The exception is mile 68.5 where a traffic counter is co-located and, directly related, has the highest sheep gap maintenance rate. All nighttime hours at this site achieved a 10-minute gap in traffic. In fact, most (78%) nighttime hours had no traffic (Figure 10). Other existing traffic counters are too far away from sheep gap sites to make more than weak inferences of traffic patterns though it is likely our methods under report sheep gap success rates at locations without co-located traffic counters.

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 make planning field operations difficult. With increased predictability, many hours of field time could be freed to collect data at other indicator sites (e.g. viewscales).
- 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 one sheep gap co-located with the Grassy Pass traffic counter.

Sheep gap sites would still require dedicated time to ground-truth and validate results. Additionally, as we have seen in the last several years, 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.

Nighttime Traffic

Nighttime traffic rates decreased in 2015 compared to 2014. Though about nine weather-related road closures (rain-induced washouts, snow, and ice) and one significant motor vehicle accident caused road closures during the 2015 regulatory season, their scale and scope of the damage was minor compared to the flooding events of 2014. Fewer maintenance vehicles and personnel were required for emergency repair work in 2015 compared to 2014.

Two nighttime spikes in traffic stand out, neither of which propagated beyond the Sable Pass site (mile 39.6): June 2 and July 13-19. The July 13-19 spike was part of nighttime operations associated with a Federal Highways project to attain materials (riprap) and coordinated between road maintenance staff and the REP. When all traffic hours are considered, these nighttime spikes smooth out and go unnoticed, which highlights their minor volume relative to the 24-hr volume. However, this spike did cause the nighttime traffic indicator to fail at three sites: Tek, TekGate, and Sable. If

we discount the data from this time period, each site achieves the 95% standard, Tek at 95.5%, TekGate at 97.2%, and Sable at 98%. The June 2 spike is yet unexplained.

When considering all hours of data, the most trafficked period is clearly June 17-24. We have no data to suggest why this is the most trafficked period.

The effect of nighttime traffic on the following day's wildlife sightings is still unclear. The park plans to continue working with researchers to elucidate possible deleterious effects of nighttime traffic on wildlife, wildlife sightings, and therefore, visitor experience. This standard will continue to be refined as more data is collected and analyzed during the first few years the VMP is fully implemented.

Hiker Wait Time

The hiker wait time indicator is the most direct measure of how well the transportation system is functioning for its primary purpose as a transit service. For the 2015 regulatory season, all measures of hiker wait time were within standard. Data from the EVC dispatch had the lowest percentage of hikers waiting less than 30 minutes for a bus, suggesting the EVC is relatively crowded for passengers seeking transit eastward. This pattern was also seen in 2014. It is possible, and the data suggest, there is a shorter wait for hikers to be picked up from a road segment rather than a transportation hub (i.e. EVC or Toklat).

If ROAR observers continue collecting hiker wait time data it needs greater emphasis during ROAR observer training. There is evidence from 2013-2015 hiker wait time data that the range of sample sizes from the three collection methods does not affect the detectability of if hiker wait time standards are being met (Figure 14). If collecting hiker wait time continues to be in the VTS driver job description, hiker wait times collected by the ROAR observers may be unnecessary.

Large Vehicle Traffic

Large vehicles are defined by the VMP as > 80,000 pounds GVWR. To assess weight, 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 on the park road. 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. The process is analysis-heavy and more subjective than WIM technology since weight will not be directly measured but rather estimated from a set of heuristics and institutional knowledge. Thus, this standard will continue to be refined during the first years of implementation of the VMP.

Research suggests that large vehicles have a greater impact on wildlife sightings (NPS 2012). Since park policy allows large vehicles to travel the road during nighttime hours only except during construction projects and emergencies, the effect of large vehicle traffic and the effect of traffic during nighttime hours are confounded. Additional experimentation with the volume, behavior, and spacing of large-vehicles would be valuable for refining the large-vehicle and nighttime traffic

standards. Monitoring should be conducted during these experiments to ensure contractors are abiding by conditions set forth in their contract (e.g., vehicle speed, use of air brakes, vehicle spacing).

Recommendations for Management

The following management recommendations are based on the goals and objectives of the VMP and the results presented in this report:

1. Program sampling scheme and structure:

- Continue the amplified effort focused on collecting field-based data using ROAR and NPSO protocols. This model was successful in its first year of use and we recommend it moving forward into the new concessionaire contract.
- Re-assess on-board (fleet-based) GPS technology periodically noting changes in longevity, reliability, and interchangeability that may improve the system's flexibility with shifting demands on various vehicle fleets on the Denali Park Road.
- Continue the organizational structure assumed in 2015: Program Manager, crew leader, and five seasonal, field staff. The REP would benefit from continuity as it is a 15-20-yr program (ending 2031-2036) including establishing a permanent position within its structure.
- Continue engaging youth interns, including SCA and YCC members.
- Continue scheduling overnight ROAR observations to collect westbound afternoon data and early morning eastbound data the following day. Ensure that Mondays and Fridays are included in the sampling to capture weekend conditions.
- Continue to ensure NPSO and ROAR monitoring strategies that emphasize distributing observations that cover all bus-operating hours. Continue scheduling early (e.g. 0500) and late (e.g. 1100) shifts because it distributes samples evenly around the 1200-1500 hour block: The busiest times of day receive the greatest data collection effort.

2. Indicators:

- Rest stops: Consider collecting continuous count data at rest stops to improve interpretability of temporal analyses.
- Rest stops: If priorities dictate monitoring efforts focus on certain indicators more than others, monitor rest stop less frequently using the NPSO protocol but maintain or increase their sampling frequency using the ROAR protocol.
- Viewscapes: Consider collecting continuous count data at viewscapes to improve interpretability of temporal analyses.
- Viewscapes: Improve the timing and increase the number of NPS observations conducted at viewscapes.
- Sheep gaps: Install TRS-style traffic counters at Hogan Creek (mile 21.6), Tattler Creek (mile 37.8), east of the Toklat bridge (mile 53.6), and east of Stony Dome (mile 60.6) to enable 24-hr sheep gap monitoring, increase analysis possibilities of the dataset, improve field sampling logistics, and free up observer time for viewscapes.

- Sheep gaps: Consider staying at sheep gap sites after achieving 10-minutes gaps to provide data about true gap length. This will help inform how much room may be in the system for growth. If TRS-style traffic counters are installed at sheep gaps this becomes unnecessary.
 - Nighttime traffic: The data from July 13-19 suggest there is room to improve the scheduling of special nighttime project work because we failed to meet nighttime standards at 50% of our monitoring sites. We suggest developing thorough operating plans for scheduled and proposed nighttime projects that require vehicle use of the park road. Negotiating operating plans provides a venue to manage by science and achieve buy-in from project leaders on the importance of maintain quiet nights.
 - Nighttime traffic: Develop a sampling scheme to disentangle the effects of nighttime traffic from nighttime large vehicle traffic on next day wildlife sightings.
 - Hiker wait time: Continue using ROAR observers to document occasions when VTS buses pass waiting hikers because they are full.
 - Hiker wait time: Consider only collecting VTS driver and EVC dispatch data for hiker wait times. ROAR-collected hiker wait times appear to be unnecessary.
 - Large vehicle traffic: Install TRS-style traffic counters co-located with remotely triggered camera technology to classify large vehicles at Savage (mile 14.9). Explore if similar technology should be utilized at two other sites to assess along the road length (e.g. east of Toklat, mile 53.6, and west of east of Stony Dome, mile 60.6).
3. Outreach messages:
- Continue to educate road users about the goals and objects of the VMP and how they can modify their behavior to assist the park in meeting standards.
 - Continue to include Terms and Conditions in road access permits to manage for VMP goals and objectives and to stay within or improve compliance with standards.
4. Further study:
- Determine the cause of weekend (Friday through Monday) traffic increases at mile 68 viewscape compared to no marked increase in traffic counter volumes on weekends.

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

Wildlife Stops:	Number of vehicles stopped at the same location to view wildlife at one time
<i>Wildlife Viewing Subzone 1</i>	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
<i>Wildlife Viewing Subzone 2</i>	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
<i>Wildlife Viewing Subzone 3</i>	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

Rest Stops:

Number of vehicles parked at one time at the Teklanika and Toklat and Eielson rest stops	
<i>Teklanika</i>	No more than 12 buses at one time with a total of no more than 16 vehicles
<i>Toklat</i>	No more than 11 buses at one time with a total of no more than 16 vehicles
<i>Eielson Visitor Center</i>	No more than 10 buses at one time with a total of no more than 19 vehicles

Viewscapes:

Number of vehicles visible at one time in four scenic viewscapes during bus operating hours	
<i>Mile 26 Wildlife Viewing Subzone 1</i>	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
<i>Miles 55 and 62 Wildlife Viewing Subzone 2</i>	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
<i>Mile 68 Wildlife Viewing Subzone 3</i>	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

Sheep Gaps:

Maintenance of at least one 10-minute gap in traffic per hour at designated sheep crossing locations	
<i>Mile 21.6, 37.6, 52.8, 60.6, and 68.5</i>	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)

Nighttime Traffic:

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)	
--	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.

Hiker Wait Time:

The amount of time a hiker spends waiting to be picked up by a bus	
<i>Less than 30 minutes</i>	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.
<i>Less than 60 minutes</i>	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.
<i>Less than 90 minutes</i>	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.

Large Vehicle Traffic:

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	
--	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 of Denali Park Road Indicators

Rest Stop Temporal Analysis

Temporal analyses of rest stop data (ROAR and NPSO combined) show consistent traffic volume through the monitoring period with a small decrease in traffic from June 15-21 (Appendix B Figure 1a). Teklanika is very strongly controlled by bus traffic behavior (Appendix B Figure 1b). Toklat is also controlled by bus traffic behavior but to a lesser degree (Appendix B Figure 2a). A gradual increase in non-bus rates at Toklat after July 13-19 accounts for increased total traffic variability. Buses spike in early season (likely due to a reduced schedule beyond Toklat) and late season (road closures further west).

Parking patterns at the EVC rest stop are equally tied to bus and non-bus use patterns. Non-bus patterns are caused by frequent GOV (interpretive staff duty location) and POV (live-in maintenance worker) vehicles (Appendix B Figure 2b). The week of Labor Day has the greatest amount of traffic (Appendix B Figure 3a). However, the busiest weekends were in June (Appendix B Figure 3b). The weekend before Labor Day was busier than Labor Day weekend. Traffic levels are consistent through the week with slight decreases on Mondays and Wednesdays apparently driven by fewer buses observed at Teklanika and fewer non-buses at the EVC (Appendix B Figure 4).

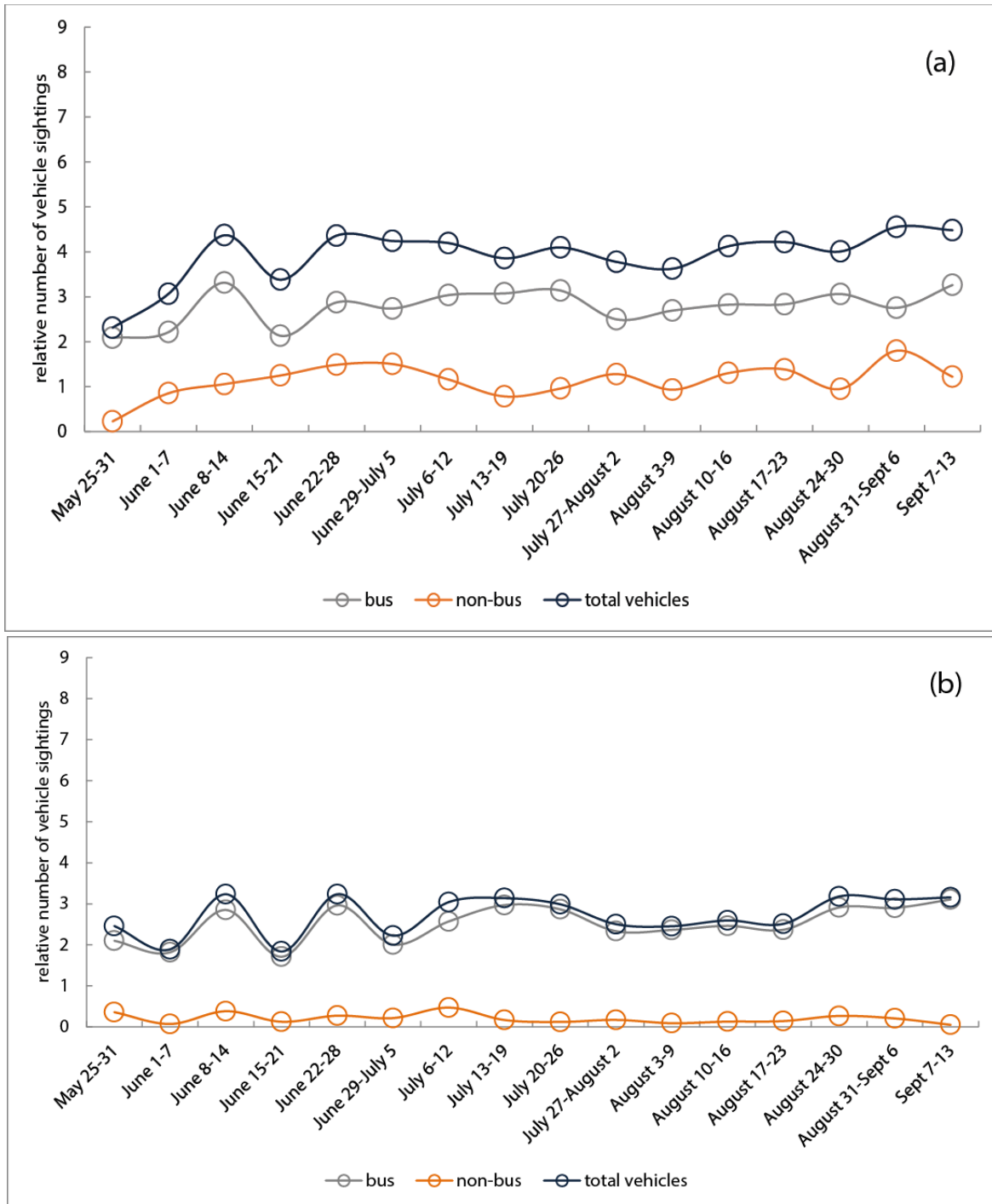
Viewscope Temporal Analysis

Temporal trends in viewscope observations are localized to the site scale and do not persist to all viewscales (Appendix B Figure 5). Temporal patterns include: (1) weekday non-bus activity was consistently greater than bus activity only at mile 26 (Appendix B Figure 6), (2) bus activity at mile 62 tended to increase as the season progressed but nearly on an every-other-week periodicity (Appendix B Figure 7), and (3) mile 68 traffic tended to be low Tuesday through Thursday and increase Friday through Monday (Appendix B Figure 8).

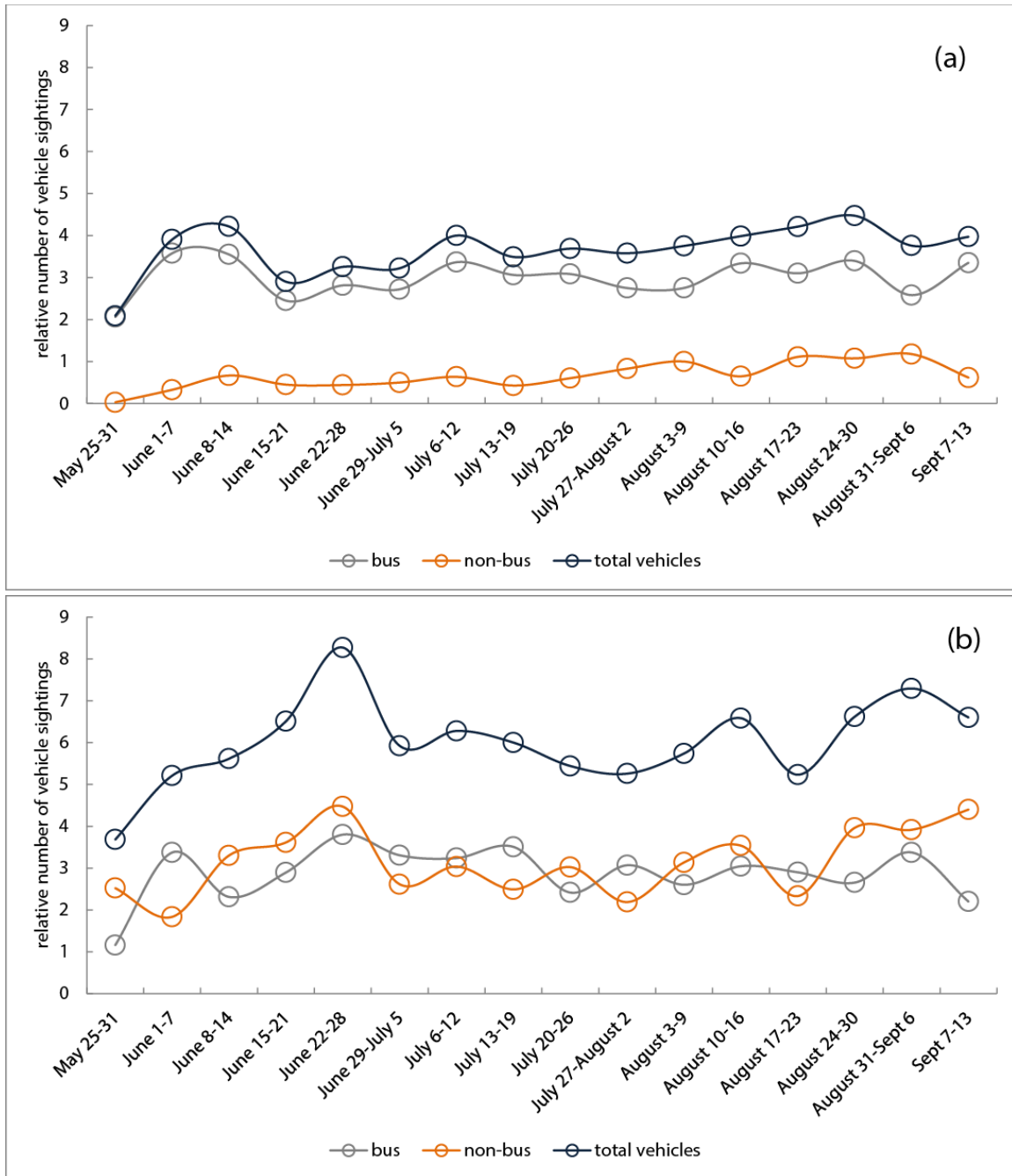
Mile 26 and 55 show similar increases in traffic to one another during the 8-, 10-, and 12-hr blocks (Figure 9). All viewscope sites appear to have one prominent peak: mile 68 during the 13-hr block, mile 62 (15-hr), mile 55 (16-hr), and finally mile 26 (17-, 18-hr). The most vehicles seen in a viewscope at one time was five: mile 26, 12- and 18-hr blocks; mile 55, 12- and 16-hr blocks, and mile 62, 13-hr block. There appears to be a peak in hourly vehicle maximums in viewscales that begins at mile 68 during the 13-hr block and propagates eastward: at mile 62 during the 15-hr, at mile 55 during the 16-hr, and at mile 26 during the 17- and 18-hr blocks.

Sheep Gap Temporal Analysis

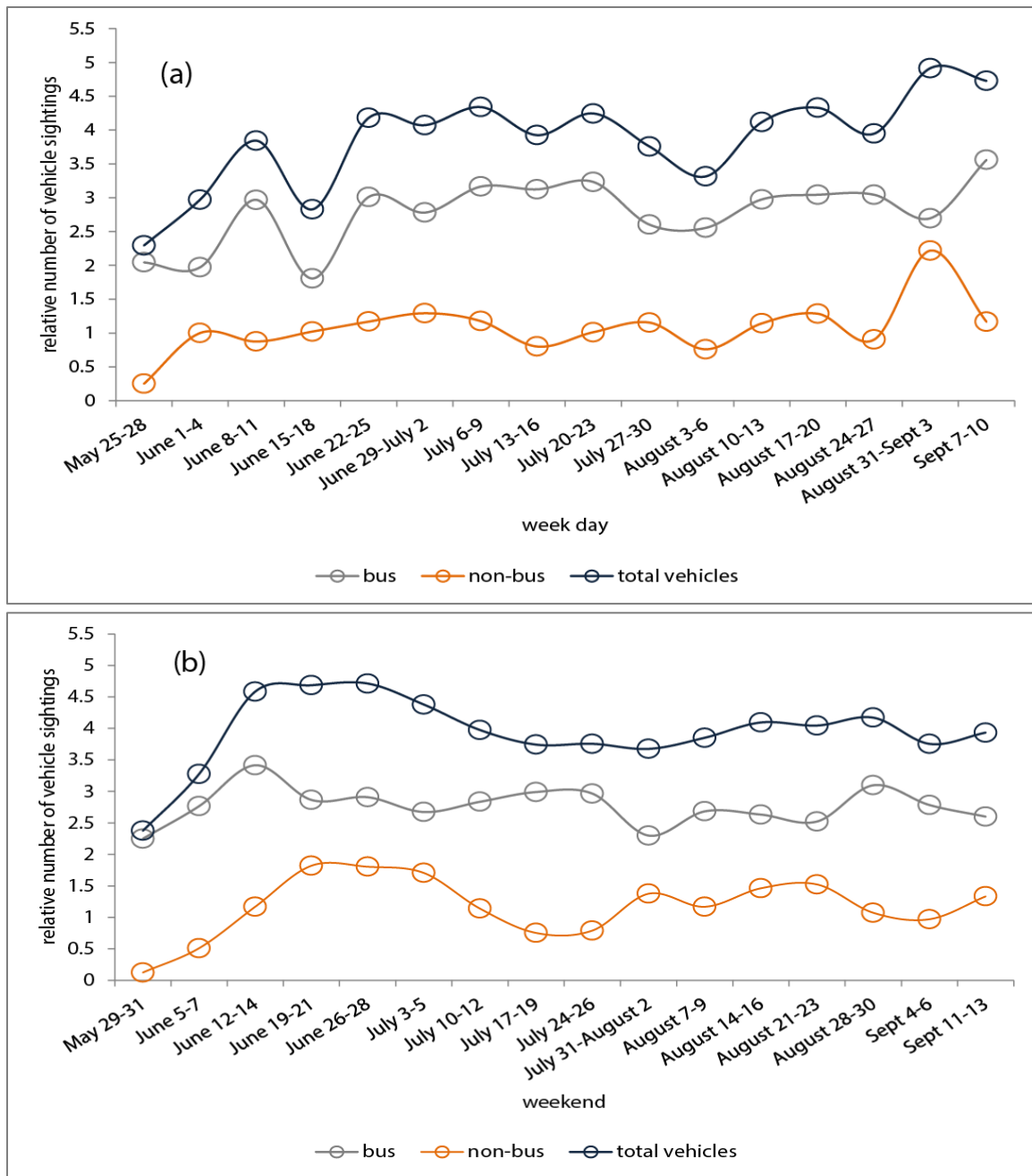
Temporal analysis of sheep gap observations show that the relative failure rate is highest on Wednesdays but not significantly (Appendix B Figure 9, Appendix B Table 1). Variability in failure rate cannot be attributed to day-of-week. Wednesday has the fewest sheep gap observations but no relationship between sample size and failure rate is apparent (Appendix B Figure 10).



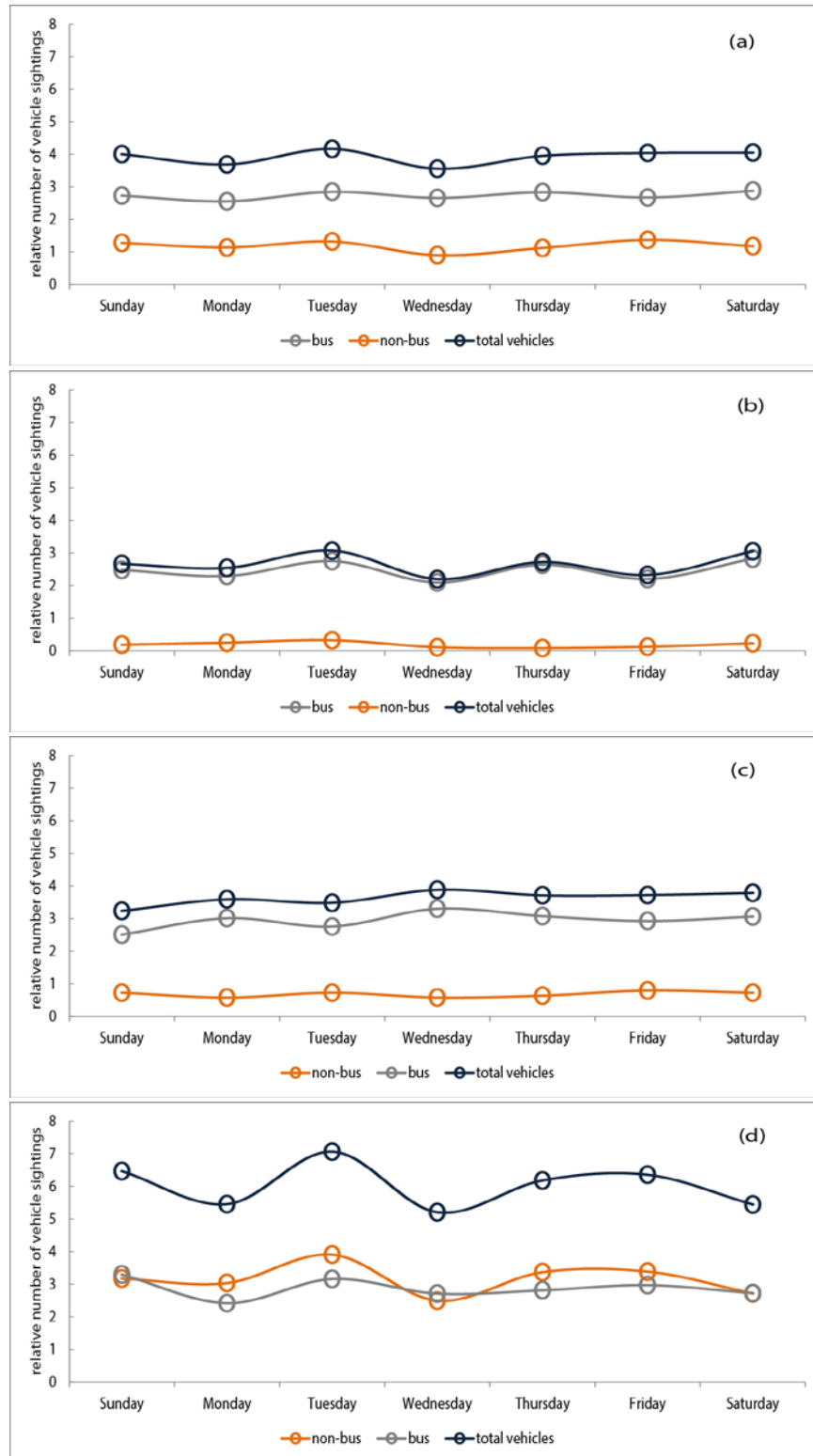
Appendix B Figure 1. Traffic volumes at rest stops (a) in Denali National Park and Preserve (Alaska, USA) show little variability throughout the summer season. There is a dip in bus traffic during June 15-21 that causes a dip in over volumes. Teklanika (b) experiences some periodicity in the early season. Traffic conditions at Teklanika are very strongly tied to bus traffic behavior.



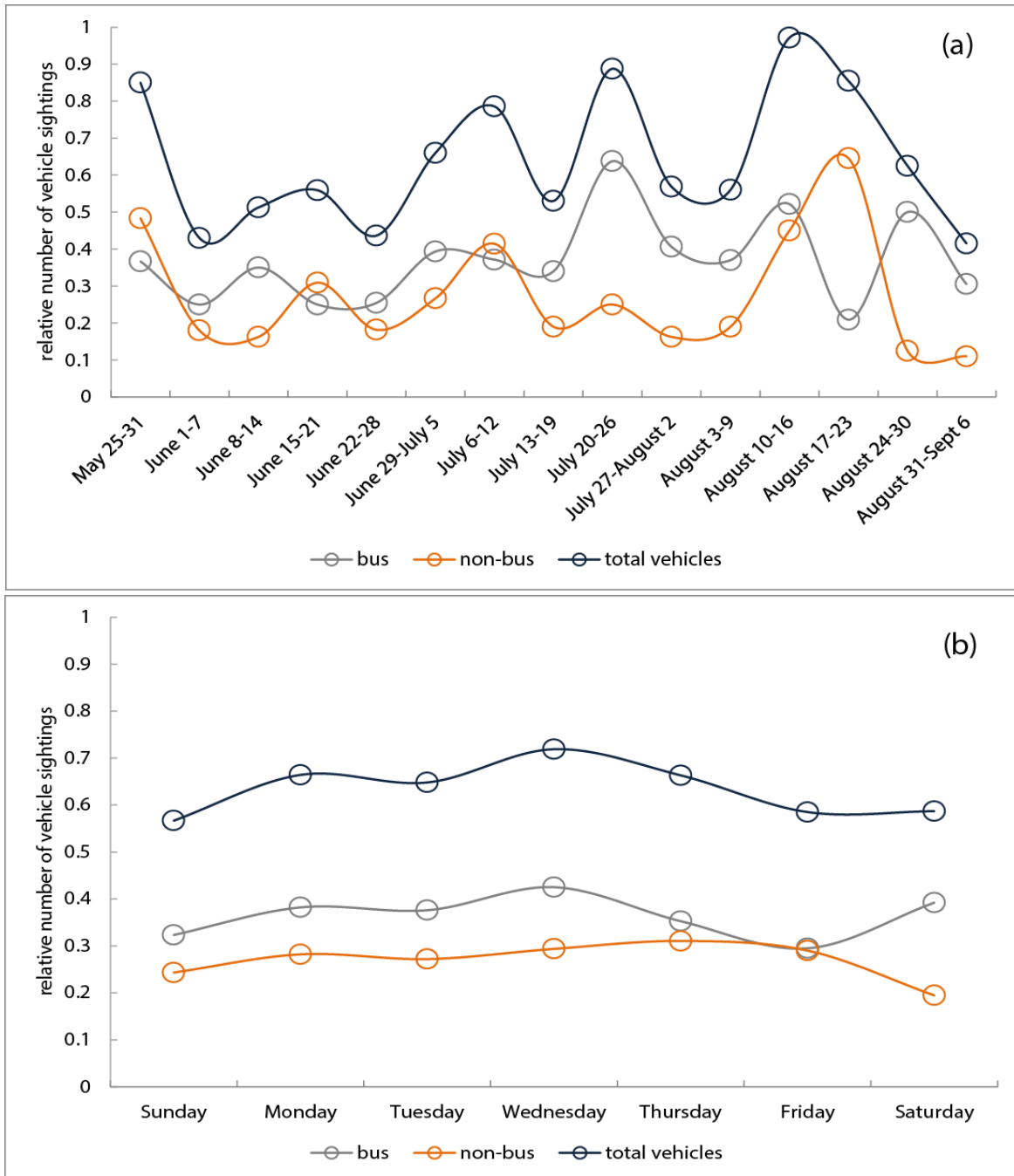
Appendix B Figure 2. Relative vehicle sightings at Toklat (a) and the EVC (b) rest stops in Denali National Park and Preserve, Alaska, USA. The Toklat rest stop has higher volumes of buses before the schedule is fully opened to the EVC and a small late season spike due to road closures further west. Conditions at the EVC are equally dependent on bus and non-bus traffic behavior.



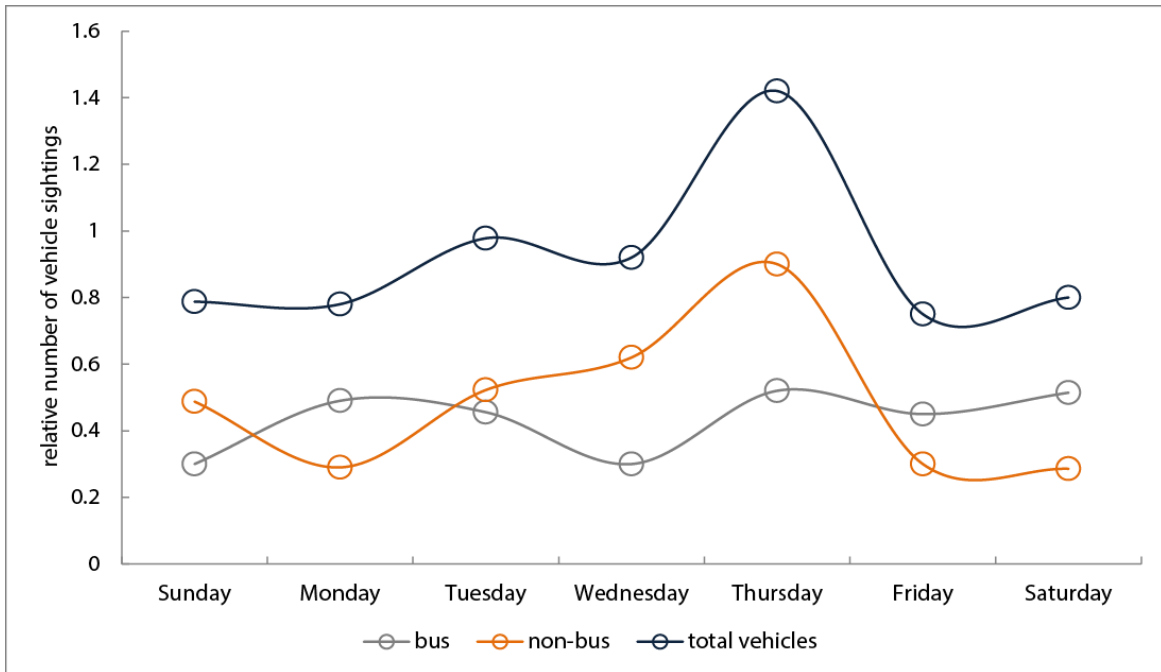
Appendix B Figure 3. Analysis of weekday (Monday-Thursday) (a) and weekend (Friday-Sunday) (b) relative rest stop vehicle sightings at Denali National Park and Preserve, Alaska, USA. Though the week leading into and out of Labor Day was the busiest, Labor Day weekend itself was not the cause - a lot of non-bus activity contributed to the spike. The busiest weekends occurred in June.



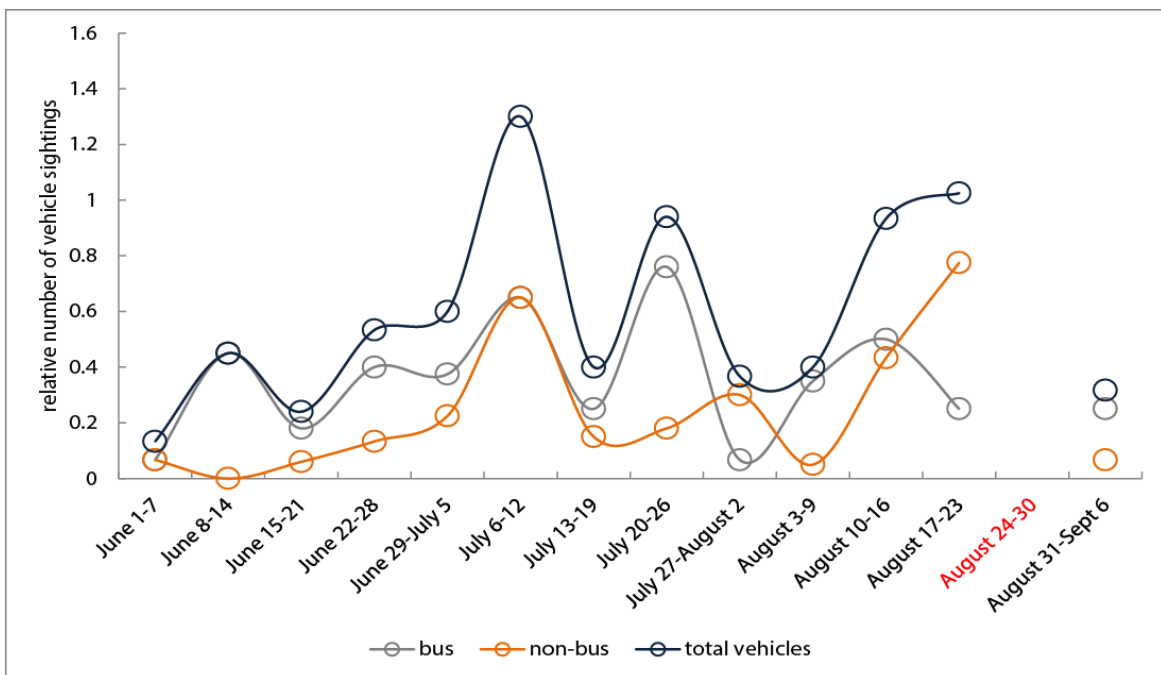
Appendix B Figure 4. Day-of-week analysis for all rest stop sites (a) at Denali National Park and Preserve, Alaska, USA. Decreases in vehicle sightings are observed on Mondays and Wednesdays and appear to be controlled by Teklanika (b) buses and EVC non-buses (d). Traffic conditions observed at Toklat (c) showed little day-of-week variability through the 2015 regulatory year.



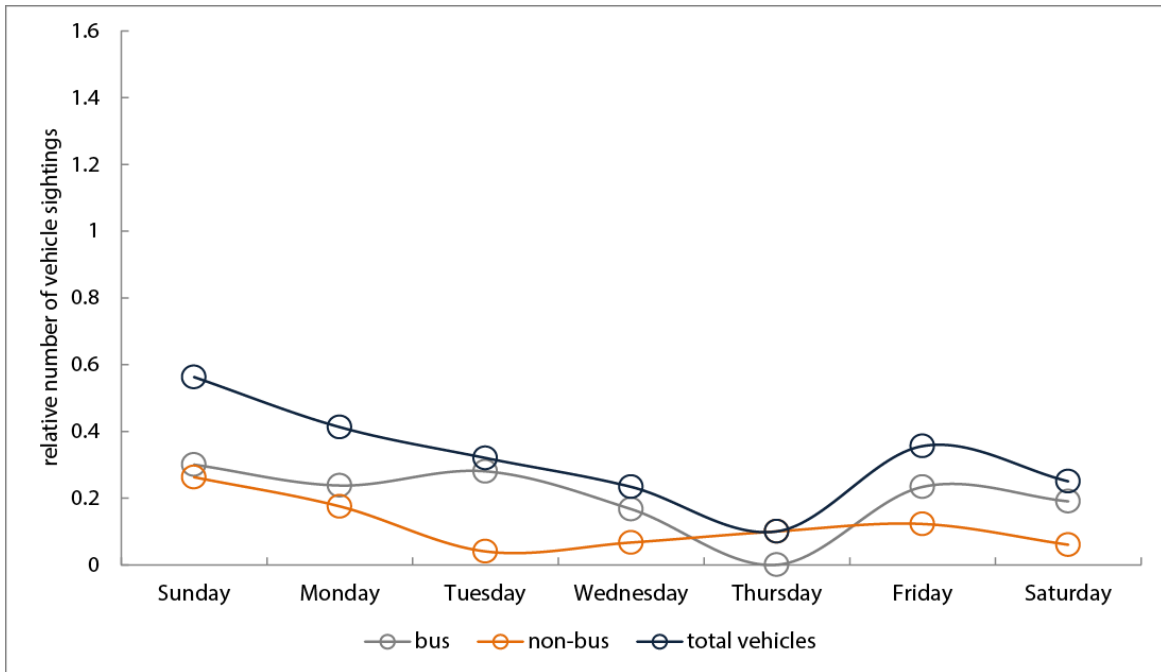
Appendix B Figure 5. Temporal analysis of all viewscape observations by week of year (a) and day of week (b) at Denali National Park and Preserve, Alaska, USA. Viewscapes conditions appear to be largely controlled by bus activity except for a large relative increase in non-buses observed August 10-23 (a). Viewscapes conditions appear to be independent of day-of-week (b).



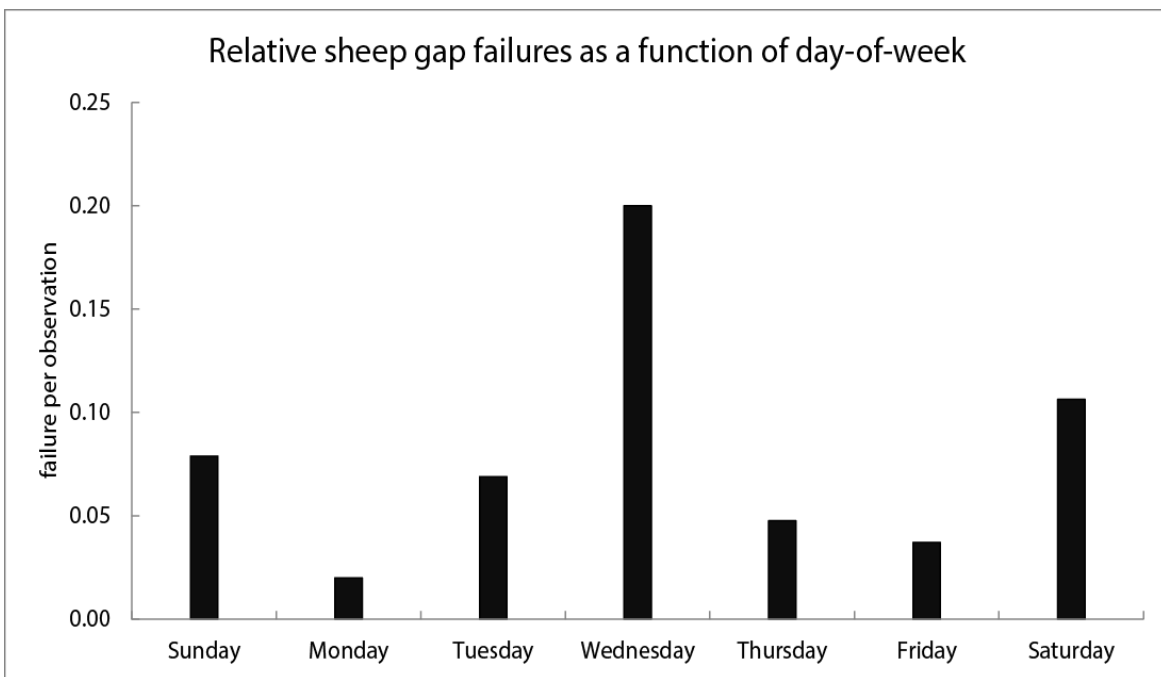
Appendix B Figure 6. Temporal analysis of the viewscape at mile 26 by day-of-week on the Denali Park Road (Alaska, USA). This is the only viewscape where the number of non-bus traffic was often greater than bus traffic.



Appendix B Figure 7. Temporal analysis of the viewscape at mile 62 on the Denali Park Road (Alaska, USA). Note the positive trend in number of bus sightings and the every-other-week cycle starting on the week beginning June 8 and continuing to June 22, July 6, and July 20. Red weeks indicate times when data are not available.



Appendix B Figure 8. Temporal analysis of the viewscape at mile 68 on the Denali Park Road (Alaska, USA). Mid-week vehicle activity (Tuesday-Thursday) is extremely low, whereas weekend (Friday-Monday) activity increases relatively significantly.



Appendix B Figure 9. Failure to maintain a 10-minute sheep gap rate as a function of day-of-week on the Denali Park Road (Alaska, USA). Wednesday has the highest failure rate. However, further statistical analysis shows that day-of-week is independent of failure rate.

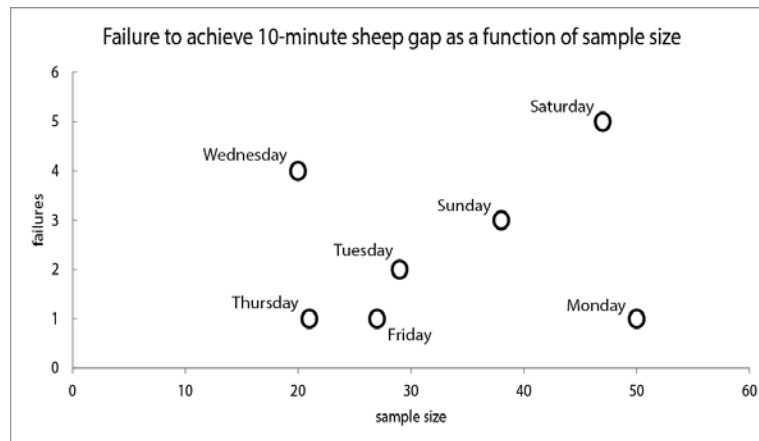
Appendix B Table 1. Contingency table assessing the effect of day-of-week on successful maintenance of 10-minute sheep gaps along the Denali Park Road (Alaska, USA). When graphing results, Wednesday had the largest effect on successfully maintaining a 10-minute gap; however, it is not significant.

sheep gap maintenance	Sheep gap maintenance by day-of-week														
	Day-of-week														
	Sun		Mon		Tue		Wed		Thr		Fri		Sat		Σ
	o	e	o	e	o	e	o	e	o	e	o	e	o	e	
yes	35	35	49	46	27	27	16	19	20	19	26	25	42	44	215
no	3	3	1	4	2	2	4	1	1	2	1	2	5	3	17
Σ	38		50		29		20		21		27		47		232

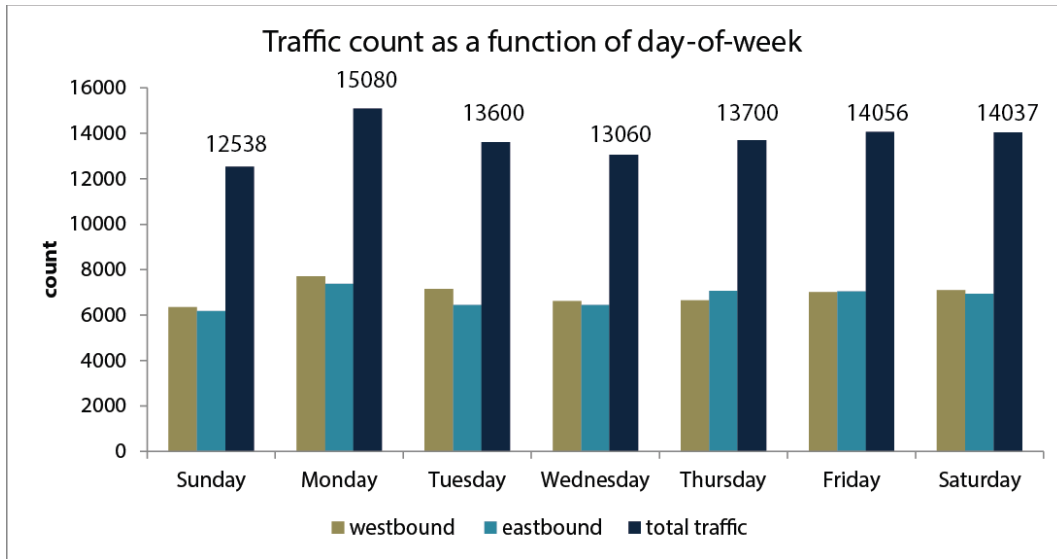
Table position	$(o_b - e_b)^2 / e_b$
n_{11}	0.0
n_{21}	0.0
n_{12}	0.2
n_{22}	1.9
n_{13}	0.0
n_{23}	0.0
n_{14}	0.3
n_{24}	4.4
n_{15}	0.0
n_{25}	0.2
n_{16}	0.0
n_{26}	0.5
n_{17}	0.1
n_{27}	0.7
Σ chi-squared	8.3

o = observed

e = expected



Appendix B Figure 10. Failure to maintain a 10-minute sheep gap as a function of sample size for the Denali Park Road (Alaska, USA). The high failure rate of sheep gap maintenance on Wednesday could be due to sample size.



Appendix B Figure 11. Overall traffic flow as counted by the six traffic counter locations on the Denali Park Road (Alaska, USA). Traffic volumes were greatest on Mondays and Tuesdays. Sunday recorded the lowest traffic volumes through the 2015 regulatory year.

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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