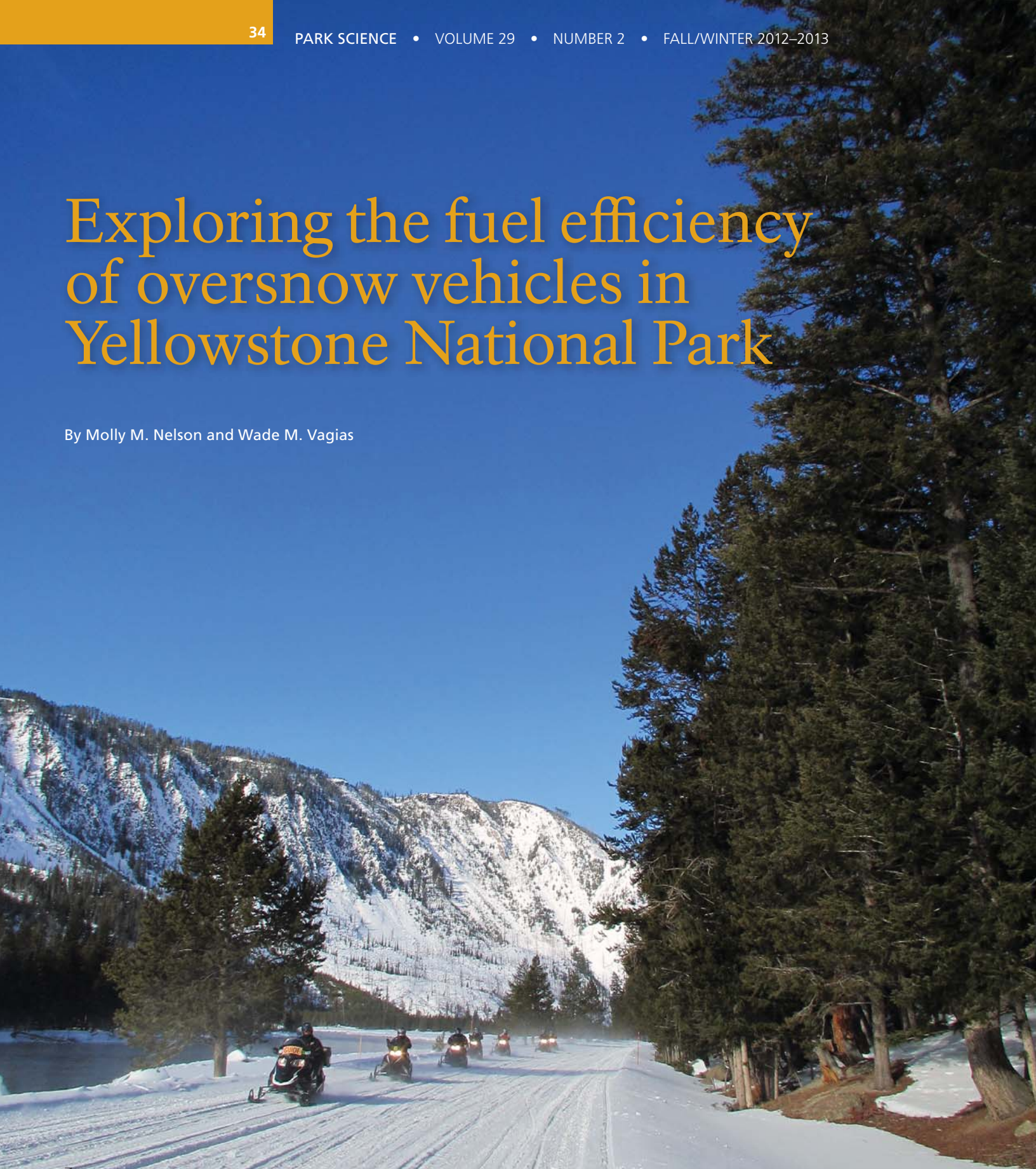
Exploring the fuel efficiency of oversnow vehicles in Yellowstone National Park

By Molly M. Nelson and Wade M. Vagias



NPS PHOTO/MOLLY NELSON

Snowmobilers set out to enjoy Yellowstone in winter. The preferred alternative for Yellowstone winter use calls for guided trips comprising groups averaging seven snowmobiles or a single snowcoach per "transportation event" and limiting the number of these events. The new management approach aims to increase the proportion of time natural soundscapes predominate and reduce disturbances to wildlife while maximizing the number of people who can enjoy the park.

Abstract

Winter use planning for Yellowstone National Park is one of the most contentious issues in the National Park Service, with the debate primarily centered upon the impact of oversnow vehicles (OSVs, or snowmobiles and snowcoaches) on park resources, including wildlife, air quality, and natural soundscapes as well as the visitor experience. Recently, several conservation advocacy groups have suggested that snowcoaches are more fuel efficient at the per-person level than snowmobiles. The purpose of this research was to assess fuel efficiency for a representative cross section of oversnow vehicles from Yellowstone's commercial tour operators' fleet regarding two primary metrics: miles per gallon (MPG) and person-miles per gallon (PMPG). Our analysis shows snowcoaches to have fuel efficiency averages ranging from 1.7 to 5.3 MPG (0.72 to 2.3 kilometers per liter) and 15 to 45 PMPG (6.4 to 19 passenger-kilometers per liter) and snowmobiles to have averages of 14 to 25 MPG (6.0 to 11 kilometers per liter) and 16 to 30 PMPG (6.8 to 13 person-kilometers per liter). Average fuel efficiency rates vary considerably among different models of snowcoaches and snowmobiles, but for the most popular models of OSVs in use in the park, neither category is decidedly more fuel efficient than the other at the PMPG level.

Key words

fuel efficiency, oversnow vehicles, snowcoaches, snowmobiles, winter use, Yellowstone National Park

WINTER USE IN YELLOWSTONE NA- tional Park (Wyoming, Montana, and Idaho) has been the subject of ongoing public debate for more than 75 years. Since the 1930s the National Park Service (NPS) and interested stakeholders have debated if and how the park should be accessed in winter. The sidebar below explains the laws that necessitate special winter planning. The past decade of winter use planning and associated rulemaking efforts has been particularly contentious, with debate primarily centered upon the impact of oversnow vehicles (snowmobiles and snowcoaches, collectively OSVs) on wildlife, air quality, and natural soundscapes. To help address these questions, since 1997 Yellowstone has completed four environmental impact statements (EISes)—a fifth is currently in development—and two environmental assessments (EAs) and promulgated three long-term rules, only to have those regulations overturned by federal courts. The 2001 rule to phase out snowmobiles from Yellowstone, signed off on the last day of the Clinton administration in January 2001, was delayed by the incoming Bush administration and eventually vacated by the U.S. District Court of Wyoming. Subsequent EISes were completed in 2003 and 2007, both of which were vacated by the U.S. District Court for the District of Columbia (see Yochim 2009 for a discussion of winter planning use in Yellowstone).

Not surprisingly, given the role of Yellowstone National Park in the conservation movement and the American psyche, the ongoing debate about what is best for Yellowstone in winter has polarized stakeholders and elevated the issue to the national spotlight. Organizations, including the Greater Yellowstone Coalition (GYC), National Parks Conservation Association (NPCA), Sierra Club, and Coalition of National Park Service Retirees (CNPSR), have, for more than a decade, advocated for the abolition of snowmobiles in favor of a snowcoach-only transportation paradigm. The GYC describes its goal as "to phase out snowmobiles in Yellowstone in favor of cleaner, quieter, more efficient snowcoaches" (Greater Yellowstone Coalition 2012). Access-oriented organizations and stakeholders, including the Blue Ribbon Coalition, International Snowmobile Manufacturers Association, and various state-level snowmobile clubs, have advocated for continued access by snowmobiles, but have not advocated for the elimination of snowcoaches.

Stakeholders' substantive observations and comments have elevated the level of discourse throughout the numerous winter use planning processes that have transpired over the past 15 years. This continual external examination of data and analyses has worked effectively alongside the park's own, raising important questions and helping ensure fidelity to the law, use of the best available science, and management decisions that are in the long-term interest of the park and the American people. All the while, new management strategies and OSV technologies introduced in the past decade have served to significantly improve resource conditions.

For instance, requiring best available technology (BAT) snowmobiles eliminated the "blue haze" that was common in the park in the 1990s and capped the maximum noise output of a snowmobile (currently the loudest commercial OSVs in the park are snowcoaches). The requirement that all trips be led by guides greatly reduced instances of wildlife harassment.

As resource conditions have improved, some stakeholder groups have sought new reasons to support their respective positions. A concern recently brought to the attention of winter use planning staff is the relative fuel efficiency of OSVs in use in the park. In comments received during the scoping process for the 2012 Winter Use Plan/Supplemental Environmental Impact Statement, the CNPSR, GYC, Natural Resources Defense Council, Sierra Club, and Winter Wildlands Alliance expressed interest in comparing the two different forms of winter transportation modes (snowmobiles and snowcoaches) using "per-visitor" impacts, contending that such analysis "might be most revealing in the context of *fuel efficiency* and emissions" (emphasis added) (Coalition of National Park Service Retirees et al. 2012). The working assumption is that because snowcoaches hold more people, they are more fuel efficient at the per-person level than snowmobiles.

Previous OSV fuel use studies

Our review of the literature and the administrative record found few instances of data or analyses to support the contention that snowcoaches are more efficient at the per-person level than snowmobiles, and the data that were present were not convincing. Those few analyses evaluated fuel efficiency peripherally, usually as a minor subset of tailpipe emission studies (see Bishop et al. 2006 and 2007, and Ray et al. 2012). Furthermore, those studies have been limited by small sample sizes, varying fuel efficiency estimation methods, or used fuel efficiency estimations provided by manufacturers. These limitations reinforced the need for more thorough analysis of the fuel efficiency of OSVs in use in winter in Yellowstone National Park.

The 2012 Yellowstone Final Winter Use Plan/ Supplemental EIS

The preferred alternative in the 2013 Final Winter Use Plan/Supplemental Environmental Impact Statement (SEIS) is to manage OSV access by "transportation events," defined as one snowcoach or a group of seven snowmobiles (averaged seasonally and with a daily maximum of 10 snowmobiles per event) traveling together within the park (Yellowstone Final Winter Use Plan/SEIS 2013). This approach differs from previous management alternatives that were based on managing by absolute numbers of OSVs rather than managing by groups (or transportation events). The rationale for the shift is based on the empirical evidence that impacts on soundscape and wildlife resources stem from transportation events rather than absolute numbers of vehicles. By packaging traffic into transportation events and limiting the total number of transportation events allowed access into the park each day, the park is able to lessen disturbances to wildlife and improve natural soundscape conditions, in addition to allowing more visitors to see the park in winter. Data collected and analyzed during the 2012 SEIS process indicate that snowmobile and snowcoach transportation events have comparable adverse impacts on Yellowstone's resources and values. However, greater insight into the fuel efficiency of OSVs could shed additional light on the comparability of the two types of transportation events. We also note that fuel efficiency is distinct from tailpipe emissions and air quality as an impact topic, and is therefore not directly under evaluation in the SEIS. Nevertheless, this issue has been raised by stakeholders commenting on the current planning process, could influence the vehicles that commercial tour operators and the park choose to use, and provides insight into the amount of fossil fuels required to power OSVs in Yellowstone.

Study purpose

We sought to advance understanding of the relative fuel efficiency of a representative cross section of OSVs used in Yellowstone in winter for two primary metrics:

- Miles per Gallon (MPG): The number of mile(s) a vehicle travels using one gallon of fuel; calculated as miles traveled divided by gallons of fuel expended on a trip. Miles per gallon is commonly used to describe the fuel efficiency of a vehicle but does not provide insight into fuel efficiency on a per-person basis. It is also expressed in kilometers per liter (KPL).

- Person-Miles per Gallon (PMPG): Fuel efficiency on a per-person basis; calculated as miles traveled times the number of persons on board divided by fuel expended. The person-miles per gallon metric is often used to compare fuel efficiency of various mass transit systems and allows for a more appropriate comparison of relative rates of fuel consumption. It is also expressed in person-kilometers per liter (PKPL).

Methods

Data collection

Five commercial OSV tour operators based in West Yellowstone, Montana, and one commercial OSV tour operator based in Jackson, Wyoming, were asked to record fuel consumption during the 2011–

2012 winter season for a variety of OSVs from their respective fleets. The goal was to generate a fuel consumption data set for a representative cross section of OSVs currently in use in the park. We provided each operator with a standardized data input form that requested information related to the date of each trip, the type of OSV (including associated engine and ski/track configuration), a description of the trip (origin, destination, and number of miles traveled), the number of persons per vehicle for the trip, and the total amount of fuel consumed.

Our *unit of analysis* was a single OSV; we used this term to denote either a specific snowcoach in the commercial fleet or all snowmobiles of a certain make, model, and year. For example, the "2011 Ford" is a single snowcoach owned by a single operator in West Yellowstone. A "2012 Ski-Doo GT1200" represents data from many individual snowmobiles of this particular make, model, and year that were reported separately but averaged together. Our *level of analysis* (a "data point") was a single OSV making a single round-trip from a known point of origin to a known destination and back. We analyzed trips to the most popular destinations in Yellowstone: between West Yellowstone and Canyon Village, between West Yellowstone and Old Faithful, and from the South Entrance to Old Faithful and back. Filters were applied to ensure that all data used in the fuel efficiency calculations were as reliable and representative as possible and not unduly influenced by outlying cases. We retained for analysis only OSVs with six or more reported trips. We included trips with passenger loads falling within two standard deviations of the arithmetic mean for each individual snowcoach and did not use trips with outlier-load characteristics like those in which an OSV towed a luggage trailer. We did not take out any snowmobile trips based on outlier ridership, as ridership for a snowmobile is always between 1 and 2, and both values are common. We retained 1,249 snowmobile and 137 snowcoach data points (individual round-trips by a single vehicle) after data filtering and processing.

The person-miles per gallon metric is often used to compare fuel efficiency of various mass transit systems and allows for a more appropriate comparison of relative rates of fuel consumption.

NPS PHOTOS (3)

Figure 1. Four of the snowcoaches represented in the data set, clockwise from top left: 1956 Bombardier, 2011 Chevrolet, 2011 Turtle Top, and 2001 Chevrolet.

Distance and passenger estimates

When available, exact round-trip distances for snowmobile trips were used; these ranged from 63 to 71 miles (101–114 km) for West Yellowstone to Old Faithful and 106 to 115 miles (171–185 km) from West Yellowstone to Canyon Village. When exact mileage data were not provided, the arithmetic mean for known trip mileage events (equal to that used for snowcoaches) or the operator-estimated mileage (in the case of South Entrance trips) was used. We did not use snowcoach odometer readings because the circumference differences between track systems and standard tires rendered the values invalid, and we were not in a position to fit OSVs with GPS tracking devices to record total mileage. Round-trip distances for all snowcoach trips were estimated at 65 miles (105 km) for West Yellowstone to Old Faithful and 111 (179 km) miles for West Yellowstone to Canyon Village. Round-trip distances from the South Entrance to Old Faithful were estimated at 94 miles (151 km) during December and 100 miles (161 km) in January through March, the difference owing to additional site visits in the Old Faithful area later in the season when road conditions improved. These estimates were based on conversations with operators and

Table 1. Attributes of analyzed oversnow vehicles

	Study Name	Data Points	Vehicle Year, Make, Model	Engine Size (cylinders/liters displacement)	Fuel	Track Type	Max. Capacity	Gate of Origin
Snowcoaches	1956 Bombardier	14	1956 Bombardier B-12	8 cylinders, 5.3 L	Gas	Bombardier Skis/Tracks	11	West
	2001 Chevrolet	9	2001 Chevrolet Express Van Terra	8 cylinders, 8.1 L	Gas	Mattracks 150, YS3-175*	15	West
	2011 Chevrolet	28	2011 Chevrolet Passenger Van	8 cylinders, 6.0 L	Gas	Mattracks 150	15	South
	2006 Ford	6	2006 Ford E-350 Passenger Van	8 cylinders, 5.4 L	Gas	Mattracks 150	15	West
	2010 Ford	7	2010 Ford E-350 Passenger Van	8 cylinders, 5.4 L	Gas	Mattracks 150	15	West
	2011 Ford	24	2011 Ford E-350 Van Terra	10 cylinders, 6.7 L	Gas	Mattracks 150, YS3-175*	15	West
	2011 Turtle Top	49	2011 Ford F-550 Turtle Top	8 cylinders, 6.7 L	Diesel	GripTrac	31	West
Snowmobiles	2012 Arctic Cat TZ1	58	2012 Arctic Cat TZ1	2 cylinders, 1,056 cm^3	Gas	N/A	2	West
	2011 Arctic Cat TZ1	89	2011 Arctic Cat TZ1	2 cylinders, 1,056 cm^3	Gas	N/A	2	West
	2012 Ski-Doo GT1200	24	2012 Ski-Doo GT1200	3 cylinders, 1,170.7 cm^3	Gas	N/A	3**	West
	2012 Ski-Doo GT600 ACE	130	2012 Ski-Doo	2 cylinders, 600 cm^3	Gas	N/A	2	West
	2011 Ski-Doo GT600 ACE	948	2011 Ski-Doo	2 cylinders, 600 cm^3	Gas	N/A	2	South

*YS3-175 tracks are experimental tracks used by one operator out of West Yellowstone; they are intended to improve vehicle operation in several ways, so trips using these tracks are specifically noted in the data.

**According to the manufacturer, this vehicle can hold three people. Operators usually only fill it to this capacity if the group consists of one adult and two small children.

reported snowmobile mileage (snowmobile odometers are correctly calibrated).

Exact passenger numbers were provided for all snowcoach trips so no passenger number estimations were necessary. Exact passenger numbers were provided for many of the snowmobile trips and when known were used to inform calculations. When exact passenger numbers were unavailable (as with some of the data points starting at West Yellowstone), estimations were based on the average snowmobile ridership, 1.4 persons per snowmobile, from the 2009–2010 through 2011–2012 seasons' visitation data from the West Entrance (Yellowstone Draft Winter Use Plan/Supplemental Environmental Impact Statement 2012).

Results

Our data set contained data on 10 individual snowcoaches and three different makes/models of snowmobiles. We attempted to get a representative cross section of the park's OSV fleet, and the majority of the vehicles in our data set are very popular models. Table 1 describes characteristics of each OSV retained for analysis, and figure 1 (previous page) contains photos of 4 of the 10 snowcoaches we analyzed. Snowcoaches ranged from a repowered 1956 Bombardier B-12 to a 15-passenger Ford, and Chevrolet vans up to a large 30+ passenger bus. During the winter of 2011–2012, approximately 27% (N = 21) of the snowcoaches used in the park were Bombardiers (primarily model B-12), while 47% (N = 37) were standard vans and SUVs (Ford E-350 15-passenger vans, Chevrolet Express), and 26% (N = 20) were small and mid-sized buses (Van Terra, Odyssey, Krystal). The three snowmobile models retained for analysis (Arctic Cat TZ1, Ski-Doo GT600, and Ski-Doo GT1200) are among the most popular

makes and models in use in the park and all meet Yellowstone's best available technology (BAT) requirement.

Figure 2 presents the range of fuel consumption in miles per gallon for snowmobiles and snowcoaches. Overall, snowmobile fuel efficiency ranges from 14 to 25 MPG (6.0 to 11 KPL). Snowmobiles with smaller engines, such as the Ski-Doo GT600 ACE, which has a 600 cc engine, obtain nearly twice the MPG of those with larger engines, such as the Arctic Cat TZ1 and Ski-Doo GT1200. Ski-Doo GT 600 ACE snowmobiles based at the South Entrance, and traveling on the steep grade of the south entrance road, averaged 23 MPG (9.8 KPL), slightly less than the 25 MPG (11 KPL) the same snowmobiles originating at West Yellowstone averaged. In terms of fuel consumed per mile, the most efficient snowcoach was the 1956 Bombardier, which attained 5.3 MPG (2.3 KPL) on average, and the least efficient was the Ford F-550 Turtle Top, which attained 1.7 MPG (0.72 KPL) on average. The Bombardier is nearly twice as fuel efficient in terms of MPG as the next most efficient snowcoach, the 2010 Ford, which averaged 2.7 MPG (1.1 KPL).

Figure 3 shows person-miles per gallon for all vehicles tested, segmented into vehicles operating out of West Yellowstone and the South Entrance and ordered from most to least efficient. Table 2 (next page) gives additional statistics of person-mile per gallon calculations for each vehicle. Fuel efficiency at the PMPG level is not consistently different between snowmobiles and snowcoaches; however, it does vary considerably among different models of snowcoaches and snowmobiles. The top three vehicles out of the West Entrance in terms of PMPG efficiency are the 1956 Bombardier with a fuel-injected V-8 motor, which averages 45 PMPG (19 PKPL); the 2011 Ford F-550 Turtle Top snowcoach, which averages 38 PMPG (16 PKPL); and the Ski-Doo ACE 600 snowmobile,

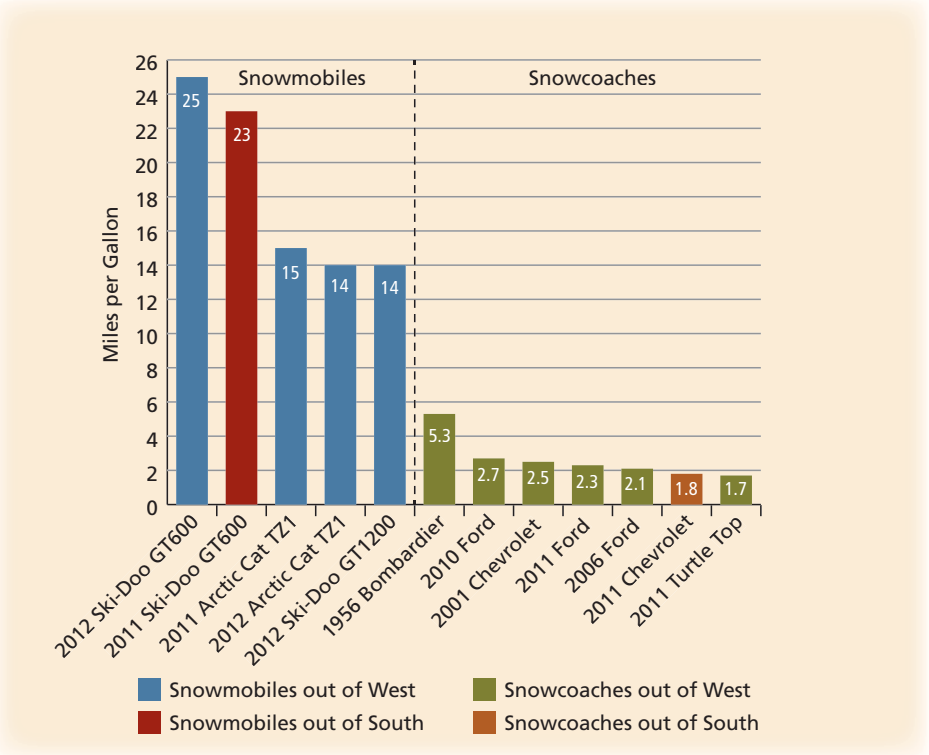


Figure 2. Miles per gallon for snowmobiles and snowcoaches, listed from most to least efficient and segmented by vehicle type.

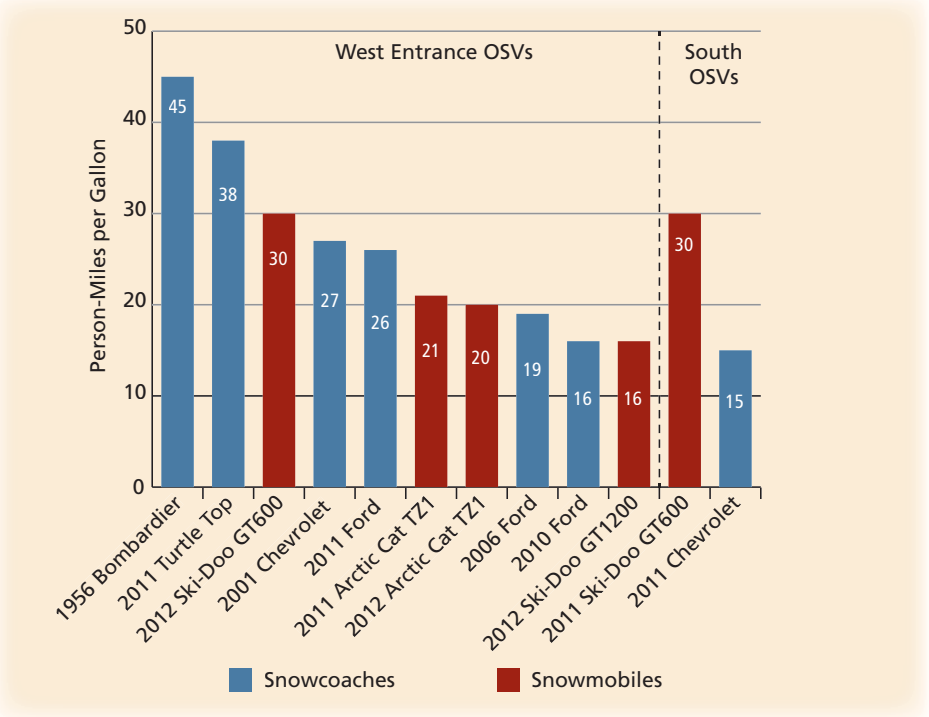


Figure 3. Person-miles per gallon for snowmobiles and snowcoaches, listed from most to least efficient and segmented by park entrance gate.

Table 2. Final MPG and PMPG values

Vehicle	Miles/ Gallon (avg.)	Persons/ Vehicle (avg.)	Person-Miles/ Gallon (avg.)	Min. PMPG	Median PMPG	Max. PMPG	SD PMPG
1956 Bombardier	5.3	8	45	26	42	82	14
2011 Turtle Top	1.7	22	38	14	40	60	12
2012 Ski-Doo GT600	25	1.2	30	19	29	49	6.8
2001 Chevrolet	2.5	11	27	17	26	38	6.9
2011 Ford	2.3	11	26	15	26	37	6.9
2011 Arctic Cat TZ1	15	1.4	21	15	20	38	4.3
2012 Arctic Cat TZ1	14	1.4	20	16	20	26	2.2
2006 Ford	2.1	9	19	11	20	26	5.8
2010 Ford	2.7	6	16	9.0	15	25	6.0
2012 Ski-Doo GT1200	14	1.2	16	10	13	48	7.9
2011 Ski-Doo GT600	23	1.3	30	13	28	74	10
2011 Chevrolet	1.8	8	15	7.9	15	26	3.9

which averages 30 PMPG (13 PKPL). For the South Entrance, the 2011 Ski-Doo Ace 600 is two times as fuel efficient at 30 PMPG (13 PKPL) as the 2011 Chevrolet snowcoach, which averages 15 PMPG (6.4 PKPL). There appears to be no relationship between the model year of an OSV and its fuel efficiency.

Discussion and implication

Overall snowcoach fuel efficiency ranged widely, a fact likely attributed to varying track types, power-to-weight ratios, snow conditions, road grades, engine sizes, and differential gearing, among other variables. Without question, the most fuel-efficient OSV in our analysis at the PMPG is the repowered Bombardier snowcoach, which averages 45 PMPG (19 KPKL). This vehicle is purpose-built for oversnow travel and has a relatively long track design allowing it to stay at the top of the snow-road surface, a lightweight frame and body, and ample power from its V-8, fuel-injected motor. These attributes combine to afford it the ability to operate in higher gears while under power and cruising in the park. The second most efficient snowcoach at the PMPG level is the Ford F-550 Turtle Top at 38 PMPG (16 PKPL). Unlike the Bombardier, which has a relatively high power-to-weight ratio but only carries up to 11 people, the Ford is efficient at the PMPG level because it has a very large diesel motor and carries up to 31 people. Snowmobile fuel efficiency also varies widely. The Ski-Doo GT ACE with the 600 cc engine is nearly twice as fuel efficient at approximately 30 PMPG (13 PKPL) as snowmobiles with larger engines, such as the Ski-Doo GT1200 and Arctic Cat TZ1, which averaged approximately 16 and 21 PMPG (6.8 and 8.9 PKPL), respectively.

Though limited, this study is informative. By analyzing OSVs in the current Yellowstone commercial operator fleet under a wide range of operating conditions and with various passenger loads, we have been able to ascertain fuel efficiency rates for a representative cross section of these vehicles. The repowered Bombardier and large Ford bus are considerably more fuel efficient at the per-person level than even the most efficient snowmobile we analyzed; however, both of these vehicles have significant limitations. Bombardiers have been out of production for decades, and acquiring replacement parts can be very difficult. Traveling in a "Bomb" (as they are affectionately called) is a unique experience and is one that does not appeal to all winter visitors to Yellowstone. The Ford F-550 Turtle Top also has significant limitations. Given its size and weight, this coach is only capable of making trips between West Yellowstone and Old Faithful and is unable to travel to the Canyon Village area or to the South, North, or East Entrance. There is also concern that snowcoaches of this size and weight may cause rutting of snow roads, affecting all winter vehicular travel, and pose safety risks to visitors in smaller snowcoaches and on snowmobiles.

The third most fuel-efficient OSV on a per-person level is the Ski-Doo ACE 600, which was more efficient than five of the seven snowcoaches we measured. Interestingly, compared with the two other snowmobile models measured (the Arctic Cat TZ1 and the Ski-Doo GT-1200), the Ski-Doo Ace was approximately 65% more efficient in terms of miles per gallon. This is an important finding for commercial tour operators and for the park's administrative snowmobile fleet. In terms of fuel efficiency across the various OSVs in use in Yellowstone and given the known limitations of the various OSVs, we conclude there is insufficient evidence to support a compelling advantage for one type of OSV transportation mode over another.

Study limitations

This analysis has several limitations that could be addressed in subsequent evaluations. Data were self-reported by operators. Variables such as road and weather conditions may influence fuel efficiency for a given vehicle, and the ability to assess these potential effects could be insightful. Estimation of distance traveled would be more accurate if OSVs were fitted with GPS units.

The shift [in management tactics] is based on the empirical evidence that impacts on soundscape and wildlife, stem from resources/transportation events rather than absolute numbers of vehicles.

Acknowledgments

We thank David Knaus of Scenic Safaris, Randy Roberson of Buffalo Bus, Scott Carsley of Alpen Guides, Jerry Johnson of Backcountry Adventures, and Ken Takata of Yellowstone Adventures for providing passenger and fuel use data.

Literature cited

Bishop, G. A., R. Stadtmuller, and D. H. Stedman. 2007. Portable emission measurements of snowcoaches and snowmobiles in Yellowstone National Park. University of Denver Department of Chemistry and Biochemistry, Denver, Colorado, USA.

Bishop, G. A., D. A. Burgard, T. R. Dalton, and D. H. Stedman. 2006. In use emission measurements of snowmobiles and snowcoaches in Yellowstone National Park. University of Denver Department of Chemistry and Biochemistry, Denver, Colorado, USA.

Coalition of National Park Service Retirees, Greater Yellowstone Coalition, et al. 2012. Technical comments and recommendations on the 2012 draft supplemental environmental impact statement. On file with the Office of the Management Assistant, Yellowstone National Park, Wyoming, USA.

Executive Order 11644. 1972. Use of off-road vehicles on public lands. Federal Register 37(February 8, 1972):2877. Available at http://www.archives.gov/federal-register/codification/executive-order/11644.htm and also on page 666 of 3 CFR (Code of Federal Regulations) 1971–1975.

Executive Order 11989. 1977. Supplement and amendment to Executive Order 11644. Federal Register 42(May 24, 1977):26959.

Greater Yellowstone Coalition. 2012. Yellowstone winter use: Park taking another look at plan. Accessed 30 October 2012 from http://greateryellowstone.org/issues/lands/Feature.php?id=40.

Ray, J. D., G. Bishop, B. Schuchmann, C. Frey, G. Sandu, and B. Graver. 2012. Yellowstone over-snow vehicle emission tests—2012: Preliminary report. Version 4.1. National Park Service Air Resources Division, Denver, Colorado, USA.

Yellowstone Final Winter Use Plan/Supplemental Environmental Impact Statement (Winter 2013). Yellowstone National Park, Wyoming, USA. Available at http://parkplanning.nps.gov/document.cfm?parkID=111&projectID=40806&documentID=48306.

Yochim, M. J. 2009. Yellowstone and the snowmobile: Locking horns over national park use. University Press of Kansas, Lawrence, Kansas, USA.

About the authors

Molly M. Nelson *is a research engineer with the Georgia Tech Research Institute and a partner with Yellowstone National Park. She can be reached by phone at (307) 344-2311 and e-mail at molly_nelson@partner.nps.gov.* ***Wade M. Vagias*** *is the management assistant, Yellowstone National Park.*