REVIEW OF RESEARCH RELATED TO THE ENVIRONMENTAL IMPACT STATEMENT FOR THE YELLOWSTONE AND GRAND TETON NATIONAL PARKS AND THE JOHN D. ROCKEFELLER, JR. MEMORIAL PARKWAY

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Oliff, T.K., K. Legg, and B. Kaeding, editors. 1999. "Effects of winter recreation on wildlife of the Greater Yellowstone Area: a literature review and assessment." Report to the Greater Yellowstone Coordinating Committee. Yellowstone National Park.

Pages 16-17
Kurz, Greg L. 1998. "1997-1998 Hayden Valley Bison Monitoring Progress Report." Bison Management Office. Yellowstone National Park.

Executive Summary: Wildlife and Winter Recreation in Yellowstone National Park Studies

Unlike most of the reports reviewed in this document, the major report on wildlife issues does not represent a collection and analysis of data, but rather it is an extensive review of current literature (Oliff et al, 1999) on the effects of winter recreation on wildlife in the Greater Yellowstone Area. The Kurz report (1998) on bison in the Hayden Valley of Yellowstone, however, does follow the format of the other reports, that is, in the collection and presentation of data.

In general, both reports offer valuable insights into the impact of winter use on the wildlife of Yellowstone. In the development of park management policies, however, it would be helpful either to conduct or to examine further studies, with more data on specific management questions. For example, it would be useful to identify, over time, critical habitat for the various sensitive species. And given the fact that wildlife may be particularly sensitive to weather and climate conditions--which change over the course of time--, on-going monitoring would be extremely useful.

Oliff, T.K., K. Legg, and B. Kaeding, editors. 1999. "Effects of winter recreation on wildlife of the Greater Yellowstone Area: a literature review and assessment." Report to the Greater Yellowstone Coordinating Committee. Yellowstone National Park.

Introduction

The following is a summary and critique of the literature review on the effects of winter recreation on wildlife in the Greater Yellowstone Area (GYA). The literature review contains twenty reports; twelve of these are species specific, seven deal with specific issues such as the effects of two-stroke engines on aquatic resources, and one report focuses on effects on vegetation. For each of the species reviews, a summary is provided on the main points of the article, followed by a brief critique of the management recommendations the authors have suggested based on their review. Population trends, winter habitat, and specific documented or predicted effects of human disturbances for each species are listed in Table 1. The documented or predicted effects of the issue and habitat articles are summarized and critiqued under "General effects." It was not feasible to critique the primary literature cited in the reviews, as methods and results were generally not included.

Bighorn sheep

The decline of several bighorn sheep populations in the GYA is attributed to disease and human disturbances including habitat loss and winter recreation on winter ranges. Suitable wintering habitat is cited as the limiting habitat for bighorn, causing bighorn to use traditional wintering grounds each year. Human disturbance that excludes bighorns from these traditional habitats or causes increased energy expenditure during already energetically stressful winter months, may decrease survivability and productivity. Recreational activities such as ice climbing, snowmobiling, and skiing increase heart rates in bighorn sheep and displace them from foraging areas and escape routes. These effects are cited as the likely cause of decline in a Montana population affected by snowmobiling.

Because most bighorns winter at lower elevations, low-elevation activities such as hiking and ice climbing probably have a greater impact than high-elevation activities such as skiing, snowshoeing, and snowmobiling. The authors suggest that these activities be monitored to determine if bighorn sheep displacement is occurring. This guideline seems insufficient given the negative population trends of many GYA bighorn sheep herds and that displacement has already been documented in other populations. A more prudent strategy would be to carefully identify traditional wintering grounds and restrict activity within a defined buffer zone. Although herds wintering at higher elevations currently have infrequent contact with snowmobilers, skiers, and other recreationists, negative impacts on bighorn herds can be expected to increase as winter recreational activity increases in the GYA. Again, knowledge of traditional wintering grounds affords an opportunity to limit recreational use in these areas to minimize these negative impacts.

Bison

The effects of snowmobiling on bison are mixed. Bison use groomed snowmobile routes to travel among foraging areas, thereby decreasing energy expenditure of travel through snow; however, when bison encounter humans on the trail, they expend energy by fleeing from the disturbance. It is not clear how this affects net energy expenditure.

Flight distance from skiers is often greater than from snowmobilers. But it is not safe to assume that snowmobiles present less of disturbance than skiers. The authors did not account for the frequency of contact with skiers versus snowmobilers. Heavy snowmobile traffic may cause longer-term displacement from areas around trails, than less frequent contact with skiers. In addition, bison do not typically use ski trails for travel and therefore, are less likely to have contact with skiers than with snowmobilers. Finally, there are no studies that discuss the effects of snowmobile associated noise on bison.

There is not enough information to determine if there is a net directional effect of winter recreation activities on the Yellowstone bison population; however, it appears that frequent contacts with recreationists could result in enough energy expenditure and displacement from preferred foraging areas to limit bison populations, particularly during harsh winters. Like bighorn sheep, bison winter in fairly distinct areas, allowing for restrictions on some recreational activities in well-defined areas. Rerouting snowmobile and ski trails away from the three main bison winter range areas would minimize recreational disturbance to most of the Yellowstone herd.

Elk

Human disturbance of elk or elk habitat during winter months may be deleterious because individuals are generally winter-stressed and living in marginal conditions. Winter habitat is typically limited and comprises low quality forage, which is not easily accessible. This is compounded by the increased energy expenditure required by movement through snow. In addition, logging, roads, and recent development in the GYA have already excluded some elk herds from traditional, productive winter habitat. Winter energy requirements for bull elk are often exacerbated by injuries and poor physical condition resulting from the fall rut. Human recreational activities that increase energy expenditure by elk (i.e. by flight from disturbance) or further limit winter range to sub-optimal habitat are additive to existing conditions and could decrease survivability and productivity in affected herds.

Previous studies demonstrate that elk alter traditional travel routes in response to human disturbance such as development, hunting pressures, and roads. Contact with skiers or snowmobilers causes elk to flee, potentially depleting critical energy reserves. Recreational snowmobile activity was correlated with a decline in elk numbers in an Oregon population, and elk have been displaced from areas around heavily used, groomed snowmobile trails in Yellowstone National Park (YNP). There is some evidence that elk may become habituated to human activities if they are at predictable times and places. Thus, backcountry snowmobiling and cross-country skiing elicit a greater flight response than activities on established trails. However, habituation to winter recreationists may instead be a function of decreased ability to flee later in the winter season when energy reserves are low.

Compared to many species, the effects of winter recreation on elk are fairly well-documented. The authors present sufficient evidence that winter recreation activities have the potential to increase energy expenditure by elk and limit available winter habitat. But the connection between these effects and population trends of elk herds in the GYA is not well-established. Although winter recreation activities have increased in the GYA in recent years, there has not been a concomitant decrease in the elk population. To the contrary, an elk hunt was established to control population numbers on the National Elk Refuge in Jackson Hole after the increasing population threatened to affect forage and habitat quality on the refuge. In addition, all herds in the GYA are subject to regulated hunts while on some portion of their

range. Although the potential exists for winter recreation to decrease elk populations, it appears that current levels of recreation have not had that effect. The authors suggest management guidelines that will minimize development and human activities in low-snow, low-elevation areas favored by elk for winter range. To allow habituation of elk to human activity, the authors also suggest regulating recreational activities to occur in well-defined locations at regular times. Given the evidence presented above, these management guidelines seem appropriate assuming that elk herd numbers continue to remain stable.

Gray wolves

Most studies dealing with human disturbances on wolves document the effects of roads and trails. In general, wolves use roads or trails created by snowmobilers, skiers, and snowshoers to facilitate movement through snow when the trails or roads are not occupied by people. Conversely, wolves avoid roads, trails, and development where there is human activity. This effectively limits wolf movement across the landscape and may affect their ability to hunt. However, in YNP, wolves have been observed hunting on ungulate winter grounds near active snowmobile trails. Displacement from ungulate winter grounds may be especially harmful to wolves during the early spring denning period.

Protection of ungulate winter ranges, especially elk, will also serve to avoid disturbance of gray wolves. The management guidelines suggested by the author seem appropriate and include restricting human activity on ungulate winter grounds, as well as restricting snowmobile use and trail grooming after March 15 to avoid disturbance during the denning period.

Grizzly bears

There are three phases in the life history of the grizzly bear that overlap with winter recreation use: pre-denning, denning, and post-den emergence. During the fall pre-denning period, which is characterized by aggressive foraging to build up fat prior to winter, human recreational disturbance has the potential to displace bears from vital foraging grounds and increase the probability of bear/human conflicts. Likewise, bears may be negatively affected if disturbed during foraging for carrion or hunting on ungulate winter ranges during the spring post-denning period, particularly at higher elevation areas near geothermal features.

Although the effects of winter recreation on grizzly bears are not well-documented, other types of disturbances tend to have very little effect on denning bears. Thus, winter recreational activities probably have little effect on the Yellowstone grizzly population between mid-November to mid-February. However, concerns over human/grizzly conflicts during the pre- and post-denning periods are warranted, if not well-established. To limit displacement of grizzlies from foraging grounds and to avert bear/human conflicts, the authors suggest limiting human recreational activity (including snowmobiling, skiing, antler collecting, etc.) in grizzly foraging areas during these times. These temporal restrictions on winter recreational activities seem well-justified.

Lynx

Lynx naturally occur at very low densities; however, population declines have made the species extremely rare in the GYA. Because lynx are both rare and highly secretive, very little research has been conducted on the species. The authors are only able to speculate on the potential effects of winter recreation. Winter recreation activities such as snowmobiling provide additional roads and trails into lynx habitat, and have the potential to

increase legal and illegal take of lynx by hunters, as well as mortality by roadkill. Increasing winter recreation activities, including backcountry skiing, snowshoeing, and especially backcountry snowmobiling, may also decrease suitable lynx habitat and critical connectivity among habitat patches. Stresses associated with these activities should be considered in the context of existing impacts such as development, and cyclical crashes in the snowshoe hare population, which is the main prey base for lynx.

It is difficult to justify an aggressive management strategy for a population at the extreme edge of its distributional range, with virtually no information on what areas are being used by existing lynx. However, the "threatened" status of the species warrants a conservative management approach. Additionally, the large home-range size and need for highly connected and high quality boreal forest habitat, mean that management of the species must occur on a very large scale. The authors recommend restricting recreational access, particularly snowmobiling, in backcountry areas identified as prime lynx habitat (high elevation forests with large snowshoe hare populations). Although this restriction seems valid, further suggestions of limiting snowmobile use on groomed motorized routes are not well-supported given a lack of evidence that lynx exist in these areas or that the habitat would become suitable at lower levels of snowmobile use.

Mid-sized carnivores (wolverine, fisher, marten, lynx, bobcat, red fox, and weasel)

Each of these species have low population densities, avoid humans, require large home ranges, and are expected to be affected similarly by human recreational activities. However, like other predators, few ecological studies have been conducted on these species and the effects of winter recreation are generally not known. Previous studies document wolverine abandonment from natal dens following human activity, and other mid-sized carnivores probably respond similarly.

Although physiological stress from interactions with humans may occur, there is no evidence to support this. Most studies on the effects of stress on wildlife from human disturbance have focused on ungulates, and it does not seem tenable to extend inferences to these other mammals, which are a very different class of wildlife. The author suggests that compaction of snow on snowmobile and ski trails destroys habitat for subnivean (beneath the snow layer) rodents that are a food source for predators. But the author does not estimate habitat loss by trail compaction or potential rodent population decrease, and it is not clear that effects on predators would be significant. To protect mid-sized carnivores, the author suggests excluding human recreational activities from important carnivore winter habitat. Given the large home range requirements and intolerance of these species to human activity, limiting off-trail backcountry recreational activities seems prudent. However, the author does not distinguish between types and frequencies of human disturbance. It seems that high density ski or snowmobile traffic may effectively fragment habitat, especially during daylight hours, while less-frequent and dispersed backcountry skiing or snowshoeing would have less of an effect.

Moose

There are three primary ways that winter recreational use may affect moose in the GYA. First, developments or high levels of human activity on traditional winter grounds could result in a loss of foraging habitat. Second, moose may become energetically stressed if they are forced to flee from human disturbance. There is mixed evidence as to how readily

moose habituate to human disturbance. Moose may use areas of heavy human activity if there is suitable forage and the disturbance is predictable. But, the human-tolerant reputation of moose may actually be due to the fact that moose stand their ground in the face of a threat, as opposed to running. Moose may still experience physiological stress and energy expenditure, while appearing to be unaffected by human activity and other disturbances. Third, moose are extremely susceptible to vehicular collision during winter months and as recreational use continues, mortality by cars is expected to increase.

To minimize the impacts described above, the author recommends limiting development of roads or structures on traditional winter grounds and restricting snowmobiling and skiing to designated trails in these areas to facilitate habituation. Given that the Yellowstone moose population is stable or increasing, these guidelines seem adequate. However, the moose populations in areas of high human activity should be carefully monitored and further restrictions on winter recreation use near traditional foraging grounds should be considered if populations decline.

Mountain goats

There are no previous studies that document the effects of recreational activities on mountain goats. However, inferences can be drawn from studies on the effects of industrial activity near goat habitat. While mountain goats appear to be able to habituate to regular human presence if no loud or sudden noises occur, several population declines have been attributed to nearby mining or logging activities. Although the potential exists for recreational activities such as skiing and snowmobiling to negatively impact goat populations, these activities do not typically occur in the steep, rocky habitat preferred by goats. Two activities that potentially occur on goat habitat are heliskiing and ice climbing. Mountain goats may be better able to habituate to ice climbing on defined routes, but are not likely to habituate to the loud helicopter noises that accompany heliskiing.

Because there are no documented effects of winter recreational activities specifically, the authors do not offer management recommendations. But the very restricted habitat requirements of mountain goats requires that managers maintain the integrity of the habitat as winter recreational use increases in the GYA. Snowmobile noise has the potential to disturb mountain goats where steep cliffs are adjacent to deep snow suitable for snowmobiling.These areas should be identified and snowmobiling restricted there. The effects of ice climbing should also be examined more carefully with the potential for restrictions if climbing coincides with goat winter range. Finally, there is sufficient evidence that heliskiing should be restricted in areas of mountain goat winter range.

Subnivean fauna

Subnivean fauna include small mammals such as pocket gophers, mice, voles, and shrews, which are active during the winter under the snow. Impacts to subnivean fauna are important because these species form the prey base for a number of predators. Compaction of snow by skis or snowmobiles may increase mortality of subnivean mammals by changing the microclimate under the snow.

Although the authors effectively document the physical changes in the subnivean space as a result of compaction, there is no information available to link these changes to actual effects on rodents. Even if cross-country skiing and snowmobiles cause a complete loss of habitat under trails, there is no evidence that this could significantly reduce rodent numbers

affect predator populations. The authors do not provide an estimate of total current trail area or the percentage of rodent habitat this represents. Without further research, winter recreation effects on subnivean fauna are purely speculative.

Bald eagles

Bald eagles are subject to human disturbance from high levels of recreational activity around the rivers and lakes used by eagles for nesting and hunting. Although some eagle pairs seem to habituate to human activities, several studies document nest abandonment as a result of human disturbance between the times of nest-building and egg hatch. Winter recreational activities in upland areas may displace eagles and prevent foraging for carrion and hunting for game birds, rabbits, and other high-quality food items during the food-stressed winter months. Disturbance by people on foot is more likely to cause nest abandonment or displacement from foraging habitat than predictable vehicular traffic.

Although there are no studies that deal specifically with the effects of winter recreation on bald eagles, the author presents valid evidence that similar human disturbances negatively affect bald eagle productivity. Some bald eagle pairs are able to nest successfully in areas of high disturbance; however, this behavior is highly variable among pairs, and habituation should not be expected. As a result of an aggressive recovery effort, management goals and guidelines for bald eagles are well-established (Bald Eagle Management Plan for the Greater Yellowstone Ecosystem) and should continue to form the basis of bald eagle management. The plan contains very specific guidelines that establish buffer zones around bald eagle home range, primary use, and nesting areas and restrict human activities to moderate, minimal, or no disturbance respectively in each of these areas. The author does not categorize skiing, snowshoeing, or snowmobiling by severity of disturbance, but it seems that high frequency of any of these activities would qualify as a large disturbance. For the guidelines to effectively buffer eagles from disturbance, nesting and foraging areas must be properly identified early in the winter season, requiring thorough surveys of known and suspected nest sites. In addition, locations of recreational use areas and trails would have to be flexible to maintain the integrity of buffer zones.

Trumpeter swans

The effects of winter recreation on trumpeter swans should be carefully assessed given the small size, low productivity, and declining trend of the GYA population. Anecdotal observations in Yellowstone and Idaho indicate the swans' reactions to winter recreationists range from swimming farther from shore to flying several miles away. No studies have examined the effects of snowmobile noise on trumpeter swans. Recovery of the GYA population has focused on habitat and stream flows, but human disturbance may exacerbate existing problems and further reduce productivity.

The author suggests that swans may be relatively tolerant of human disturbances because a Madison River population wintered near a busy snowmobile trail and because of increased tolerance of humans by swans during the winter months. It is incorrect to assume that use of a habitat necessarily implies the habitat is optimal. While it is possible that the human-impacted habitat was suitable, it is also possible that optimal habitat was not available or that the swans were using traditional wintering grounds that were later impacted by humans. Further, there is no indication that the mortality or productivity rates of that population were within normal ranges. Finally, increased tolerance of humans during winter

months may be a result of diminished energy reserves, rather than a true habituation to human activity.

The author suggests that snowmobile and ski trails be established away from open water. Open-water snowmobiling should also be prohibited in areas used by trumpeter swans. Given the precariousness of the GYA trumpeter swan population, there is sufficient evidence to support restriction of all human activities near sensitive wintering and nesting habitat.

General effects

Research conducted in Minnesota and Canada on the effects of snowmobiles on vegetation showed that compacted snow deep freezes, with subsequent death of soil bacteria. Snowmobiling also results in damage to shrubs, saplings, trees, and other vegetation, and contributes to erosion on steep slopes. However, these effects are more characteristic of dispersed backcountry use, while most snowmobiling in the GYA occurs on groomed, designated trails. Although snowmobiling may negatively affect individual organisms, there is no evidence of landscape level effects. Restrictions on snowmobile use in areas with unique or fragile vegetation are prudent and well-justified.

With increasing winter recreational use in the GYA, comes the potential for increasing development on both public and private lands, including new roads or expansion of existing roads, new structures, and other permanent alterations of wildlife habitat. The effects of development are well-documented for a number of wildlife species and include habitat loss and fragmentation, roadkill, increasing physiological stress, fire-suppression, and others. Development effects compound the energetic stresses most animals experience during the winter months.

Many of the literature reviews noted that human disturbance can cause increased energy expenditure by wildlife, and may lead to decreased survivability and productivity. Winter is already a stressful time for many species because of limited energy stores and decreased food availability. Winter recreation may decrease energy expenditure for animals that use snowmobile and ski trails to facilitate travel through snow, but may increase expenditure when animals run from human disturbance. Energy expenditure models indicate that repeated flights from human disturbance would pose an unacceptable energy depletion for large ungulates; however, many species do not initiate flight as readily if the stimulus is predictable, a process known as habituation. But habituation does not imply zero energy expenditure. Rather, many habituated animals continue to have elevated heart rates even though they do not flee as frequently. Energy expenditure associated with maintaining a chronically alert state may be offset if the food source is of especially high quality. In general, animals habituate much more readily to predictable human activities that do not involve humans on foot.

Two-stroke snowmobile engines can deposit a range of contaminants that pollute nearby water sources. Examples of research on the effects of outboard motors on aquatic resources indicate that nitrous oxides can contribute to eutrophication and persistent hydrocarbons can cause death of aquatic organisms. In addition to potentially increasing mortality in fish populations, contaminants in fish may also become available to fish-eating predators such as bald eagle, osprey, otter, pelican, and grizzly bear. Although no studies have been conducted to determine if these effects are occurring in the GYA, water bodies near groomed motorized roots and winter destination areas are most likely to be affected.

Snowmobiling over open, unfrozen water probably results in greater pollution of water bodies and should be completely restricted.

Heliskiing, in which helicopters transport skiers or snowboarders to remote mountain slopes, is not currently allowed in the GYA but is increasing in popularity elsewhere. The author cites several studies that document physiological stress in wildlife exposed to the loud noise and visual stimulus of helicopters. Of particular concern are mountain goats and bighorn sheep, which do not appear to habituate to the disturbance. Also potentially affected are eagles, elk, wolverines, and others. Although the author is justified in suggesting that heliskiing be restricted to a small area, it is unrealistic to suggest that areas without wildlife or suitable wildlife habitat can be accurately identified. While mountain goat and bighorn sheep may be conspicuous, less visible organisms such as nesting birds or wolverines will not likely be identified to avert heliskiing disturbance to these animals. Where heliskiing is allowed, wildlife disturbance seems probable.

When dogs are allowed off-leash, they can increase physiological stress, direct mortality, and disease transmission to many species of wildlife, especially deer. This is less of a problem in national parks, where pets are not allowed on trails. While there are many documented cases of dogs harming wildlife, the effects on populations are not known and are probably not severe.

Conclusions

The literature review on the effects of winter recreation on wildlife is reasonably thorough and summarizes the best available information. In many cases very little data were available on which to base management recommendations, but most authors appropriately extended inferences from the effects of human disturbance on similar species. Large mammals are better-represented than less economically or aesthetically appealing organisms, but some effort was made by including mid-sized carnivores, subnivean fauna, and vegetation in the review. Conspicuously absent, are literature reviews for resident birds not listed as threatened or endangered. Although information on winter recreation effects on other resident birds is probably very limited, there have been studies on the effects of roads, traffic, and other disturbances, which should have been incorporated into the review.

Notably, none of the authors suggested complete prohibition of snowmobiling in the national parks. But all of the authors presented realized or potential negative impacts of human recreational activities on wildlife and recommended spatial or temporal restrictions on snowmobiling, skiing, snowshoeing and other winter activities. The previous policy of encouraging dispersed human use over the landscape has unintended consequences for a broad range of wildlife. Although this policy dilutes human impacts over a broader area, it also exposes more of the landscape to these impacts. This is especially deleterious for species, including most predators, that require large tracts of undisturbed habitat. There is consensus among the literature reviews that activities such as snowmobiling should be restricted to defined trails during daylight hours. This would reduce the amount of area impacted by human activities and allow some animals to habituate to the predictable disturbance. It would also minimize vegetation destruction, erosion, and the total area of snow compaction, thereby preserving subnivean fauna.

Because concentrating human activities to well-defined areas would make these areas unavailable to many species, these sacrifice areas should be selected carefully. The list below

summarizes the habitat types that should be avoided by dispersed winter recreational activities and high-traffic snowmobile and ski trails:

- Traditional winter ranges of bighorn sheep and mountain goats including rocky cliffs, foraging grounds, migration routes, and escape routes to steep cliffs
- The three main bison wintering grounds and migration routes
- Low-elevation, low-snow, riparian and open habitats used or potentially used by elk and other ungulates during winter
- Important wolf habitat
- Whitebark pine forests used by grizzlies during spring and fall of years with large pine nut crops
- High elevation lynx habitat
- Predicted wolverine habitat with a five-mile buffer
- Bald eagle nesting and primary use areas
- Open water used by trumpeter swans

Some species, such as bighorn sheep, bison, and elk use traditional wintering grounds, which could be more easily avoided in the planning of recreational trails. Maintaining the integrity of ungulate winter grounds by limiting snowmobiling, skiing, snowshoeing, hiking, and antler collecting in those areas, would also benefit predators such as bald eagles, grizzlies, and wolves, that hunt or forage there. For species that do not exist as herds, specific locations would need to be determined each year. For instance, bald eagle nests and foraging grounds, water bodies used by trumpeter swans, and grizzly bear foraging areas should be identified annually. Restricting recreational activities near water bodies would minimize aquatic pollution, erosion, and impacts to bald eagles.

There was not consensus on how to manage cross-country skiing, snowshoeing, ice climbing, and other less frequent activities. Many animals studied appear to have a greater escape response to people on foot than to snowmobilers, warranting restrictions of these activities near very sensitive wildlife species (e.g. bald eagles) or at critical times in the life history of certain species (e.g. post-denning period of grizzly bears). But these activities occur in the backcountry at relatively low densities, and effects on many wildlife populations may be minimal. However, if the frequency of these activities increases, or there is evidence of significant effects on wildlife, activities should be restricted to defined areas and at predictable times of day.

Coexistence of winter recreational use and carefully protected wildlife habitat would require adequate resources and a flexible management strategy. Although the authors of the literature review did not recommend a no-access policy for winter recreationists, restrictions on activities near the critical areas listed above, would effectively eliminate large areas from recreational use. In addition, thorough and frequent surveys would be required to identify areas used by sensitive species each winter, prior to allowing use of recreational trails. Finally, many authors recommended a temporally variable management strategy that imposes restrictions on recreational activities based on current conditions such as winter severity and forage availability. In this way, more stringent restrictions may be imposed at times when wildlife populations are particularly energetically stressed.

Table 1. Summary of winter recreational effects on selected species of the Greater Yellowstone Area (GYA)

Species	**Population trends in GYA**	***Winter habitat***	**Documented and potential effects of winter recreation**
Bighorn sheep	Ten populations present in GYA. Limited to small areas of suitable habitat. Some populations declining due to habitat loss, disease, human activities, etc.	Most use lower elevation, low-snow habitat. Winter habitat more limiting than summer.	• Decreased survivability if human activities occur within 100 yards of escape terrain. • Increased stress, heart rate, energy expenditure due to contact with recreationists. • Declines in some populations attributed to snowmobiling or ice climbing. • Displacement from preferred foraging areas. • Habitat loss due to development on winter ranges/migration corridors. • Habituation to predictable human disturbance (no habituation if dogs present). • May congregate near humans to avoid predation.
Bison	Population relatively stable between 1967 and 1998. Some population reduction by managers in response to fear of disease transmission to livestock outside park boundaries.	Graze in meadows and thermally-influenced areas.	• Use packed and groomed snowmobile trails for travel. May decrease winter energy expenditure. • Displacement of bison within 63 yards of heavily used trails. • Increased energy expenditure caused by encounters with snowmobilers or skiers. Flee farther and more quickly following encounter with skier than snowmobiler. • Habituation can occur if gradually exposed to disturbance.
Elk	Most herds stable or increasing, a few decreasing. GYA elk herds subject to hunting in a portion of their range.	Migrate to traditional, lower-elevation, low-snow winter ranges, although habitat use is variable. Often use areas with mixture of shrubs and forest stands.	• Cross-country skiing activity did not alter the large-scale distribution of elk, but individuals avoided ski trails. • Increased recreational snowmobiling in Northeastern Oregon correlated with decrease in elk population. • Decreased flight from snowmobiles and skiers later in the season. Attributed to habituation or decreased energy reserves. • Flight distances slightly higher from skiers (53.5 m) than snowmobilers (33.8 m). Flight distances from skiers greater in backcountry than on established trails. • Repeated flights from human disturbance use energy reserves critical for winter survival. • Some Yellowstone populations used groomed snowmobile trails for travel when snow was deep off-trail. Travel by groomed trails and roads may increase mortality by vehicular collision. • Antler hunting occurs during late winter on elk winter range and may be a particularly stressful disturbance to winter-stressed elk. • Documented declines in use of habitat near roads (0.25 – 1.8 miles).
Gray wolves	Experimental/non-essential. Reintroduced population. As of 1999, 116 wolves in 7 packs in the GYA.	Not habitat specific but spend most of winter hunting on ungulate (especially elk) winter range.	• Canadian wolves used roads and snowmobile and ski trails for travel. Wolves in Voyagers NP avoided areas of snowmobile activity. Wolves in Kenai avoided year-round roads but used roads closed to public. In YNP, wolves used areas near snowmobile activity if near ungulate winter range. • Human developments impair wolf movements. • Potential for displacement of wolves during sensitive denning period.

Species	Population trends in GYA	*Winter habitat*	Documented and potential effects of winter recreation
Grizzly bear	Threatened. Historical declines attributed to habitat loss. Modest population increases in recent years.	Enter dens around Nov. 9 and leave dens between mid-February to mid-April. Average elevation of dens is 10,000 feet. Use ungulate winter ranges to feed on carrion in spring.	• Radiocollared denning bears had elevated heart rates when disturbed by noise from winter seismic surveys in Alaska. Authors concluded that degree of disturbance not great enough to affect survivability. • Grizzlies in the Northwest Territories denned successfully despite noise disturbance by mining. • Black bears abandoned sites in response to disturbance.
Lynx	Threatened. Present but uncommon in YNP.	Mature forests and a variety of early forest stages with high connectivity between adjacent habitat patches.	• 22% of re-introduced lynx in New York killed by automobiles, although no roadkills documented in the GYA. Lynx often hunt snowshoe hare along roadsides.
Wolver-ine, fisher, marten, bobcat, red fox, weasel	Wolverine: Rare in the GYA, species of special concern Fisher: Possible population in Wyoming portion of GYA, species of special concern Marten: Stable, indicator species Bobcat: Stable, furbearer Red fox: Stable, furbearer Weasel: Unprotected	Wolverine: low to mid-elevation coniferous zone and riparian areas. Fisher: Continuous forest canopies, low-snow. Marten: Variable, but generally old-growth forests. Bobcat, red fox, weasel: variety of habitats.	• Human disturbance may increase stress and mortality. Inferences made from studies on ungulates. • Human activities near wolverine dens around kit-rearing period can cause den abandonment. • Compaction of snow decreases small mammal (prey) populations under snowmobile, ski trails. • Human activity has little effect on fisher movement, but fishers more common where human densities are low.
Moose	Less common than other GYA ungulates, but populations stable or increasing .	Highly variable. Often use early seral stages, willow, riparian areas. Use traditional winter grounds.	• High level of habituation to human activity if it is predictable in time and place. Habituated moose show short flight distance and tolerance of humans at close distances, mining activity, vehicular traffic, machinery, etc. • Moose near human development may benefit from decreased predation by wolves and others. • Forage availability a better predictor of moose presence than human disturbance in western Wyoming. • Trucks and people on foot, skis, or snowshoes caused more disturbance of moose than snowmobiles. • Moose in Alberta did not use habitat around heavily used ski trails. • High mortality caused by collisions with trains and cars.

Species	**Population trends in GYA**	*Winter habitat*	**Documented and potential effects of winter recreation**
Mountain goats	Populations are hunted and are stable or increasing.	Use steep, rocky terrain and adjacent talus fields and meadows. Must have low snow accumulation.	• Populations declined when logging or mining occurred in or near goat habitat. Due to physiological stress, improved access to hunters, or displacement from habitat. • Habituation to humans on foot and to vehicular traffic if not harvested or harassed and disturbance is predictable. Loud noises continued to caused alarm responses in habituated goats. • Very few cases of aggressive goats attacking humans.
Small mammals (subnivean)	Stable, unknown.	Variable. Are active under the snow during winter.	• Increased carbon dioxide levels under packed snow may be toxic to mammals. • Packed snow may increase drowning of animals during spring runoff. • Snowmobile-packed snow has a decreased subnivean airspace, and less stable temperatures. • Skis compact snow more than snowmobiles.
Bald eagle	Threatened, population stable or increasing.	Near open water, such as unfrozen parts of lakes and rivers. Forage in upland areas for carrion, game birds, etc.	• Human disturbance during nest-building to incubation may cause nest abandonment. • Human activities during winter and spring can reduce feeding and displace eagles from foraging areas. • May habituate to regular traffic noise but may be more disturbed by snowmobiles because of the loud noise and exposed operator. Hikers very disruptive. • Human disturbances have greater impact when eagles forage on ground, as opposed to in water. • Some eagles may habituate to human disturbance. In some areas, eagle pairs initiated nest building during peak snowmobile activity.
Trumpeter swans	Species of special concern, small and declining population in the GYA, very low productivity.	Ponds, marshes, lakes, and occasionally portions of slow-moving rivers	• Tolerance for humans varies by season and area. May habituate to predictable human disturbance, but this may lead to greater predation and roadkill. • Swans on Yellowstone River reacted to winter recreationists by swimming further from shore. Swans in Idaho reacted to skiers and snowmobilers by flying, often several miles away.

Kurz, Greg L. 1998. "1997-1998 Hayden Valley Bison Monitoring Progress Report." Bison Management Office, Yellowstone National Park.

Summary

During the winter of 1996-1997, 1,084 bison were slaughtered as they left Yellowstone National Park because of rancher fears that bison may transmit brucellosis to cattle. Members of the Fund for Animals voiced concerns that a network of snowmobile trails facilitated movement of bison onto private lands where their protection could not be guaranteed. In response to ensuing litigation, the Park Service initiated a study to monitor bison use of groomed roads during winter.

During the 1997-1998 winter, researchers used four monitoring methods to determine whether bison were traveling on roads in the Hayden and Pelican Valley areas of Yellowstone. First, in the "ground monitoring" method, two people traveled on snowmobiles while counting bison on or near roads during morning and evening hours when bison are most active. Second, cameras placed at four photo point locations took pictures at two-hour intervals to document wildlife and human traffic on and off the road. Third, four aerial surveys were conducted over the study area to determine bison herd sizes and use of roads. Finally, road groomers were asked to fill out a data sheet during each grooming run to document bison observations on or near groomed roads.

In the ground monitoring portion of the study, only 2% of 1,112 bison sightings were of bison on groomed roads. The majority of the bison observed were engaged in feeding or resting; fewer than 5% of observed bison were traveling. Due to logistical problems with the cameras, data from the photo points were sporadic. Bison were photographed on the road during only one photo period (one week during late March), while 8 of the photo periods showed bison off of the road. Groups of bison were observed traveling on roads during two of the four aerial flights. Of the 123 grooming runs made, groomers observed bison on the road three times.

The author concluded that bison use of roads as travel corridors was not significant during the study year. But the study year coincided with El Nino and weather conditions were not severe. Without additional years of study, the 1997-1998 data can only serve as baseline for future efforts.

Critique

The strength of this study lies in the use of four independent survey methods. While ground surveys may cause bison to leave roads because of the sound of the snowmobiles or grooming machines used by surveyors, photo points and aerial surveys would not have a similar bias. The study methods will be further strengthened in future years by using cold-tolerant cameras and more dependable radiocollars for bison (many radiocollars failed and very little data was available). The four survey methods corroborate one another well, and indicate that bison did not significantly use roads during the study year.

Despite these results, there are several reasons to believe that bison may use roads for travel during other years. First, a 1981 study by Aune documented the frequent use of roads by bison in Yellowstone. Unfortunately, the author did not indicate what the weather conditions and snow levels were like during that winter. Second, almost half of the bison observed that were traveling, were "on or within 20 meters of the groomed road surface." Although statistics were not provided, this frequency of road use is probably greater than

expected by chance. Because over 95% of the observed bison were feeding or resting, the sample size of traveling bison was very small, and it is difficult to generalize about what trails bison use. Finally, two of the four aerial surveys documented relatively large bison groups traveling on roads.

All of the survey methods were conducted during daylight hours, when bison are more visible and typically more active. Bison are known to be occasionally active on moonlit nights (Knopf, 1997), and may travel along groomed roads at night, when human traffic is minimal. In future years, technicians should conduct occasional night surveys to rule out the possibility that bison preferentially use roads at night.

The author is correct in suggesting that the value of the data collected is in providing baseline information for future surveys. The mild, El Nino winter of 1997-1998 probably presented very different environmental conditions than the previous winter when bison migrated from the park in large numbers. During low snow years, bison may be less likely to travel large distances to lower elevation, low-snow areas in search of forage. If they do migrate during mild winters, off-trail travel through shallow snow would not result in the high energy expenditure associated with travel through deep snow. Thus, there would potentially be less incentive in low-snow years for bison to travel on roads where contact with humans is more likely, and energy expenditure is not significantly reduced. Although the survey methods employed in this study are excellent, implications for bison use of groomed roads cannot be drawn for other years without additional surveys in a range of winter conditions.

Literature cited

Knopf, A.A. 1997. National Audubon Society Field Guide to North American Mammals. Chanticleer Press, Inc, New York. 937pp.

SECTION B: AIR QUALITY AND SNOW CONDITIONS

Reports Reviewed:

Pages 21-22
Carroll, J.N. and J.J White. 1999. "Characterization of Snowmobile Particulate Emission" Final Letter Report. Southwest Research Institute. San Antonio, TX.

Pages 23-26
Kado, N.Y., P.A. Kuzmicky and R.A. Okamato. 1999. "Measurement of Toxic Air Pollutants Emitted from Snowmobiles at Yellowstone National Park" Draft Final Report. University of California. Davis, CA.

Pages 27-32
U.S. Department of the Interior and National Park Service, Air Resources Division. 2000. "Air Quality Concerns Related to Snowmobile Usage in National Parks." USDI and NPS. Denver, CO.

Pages 33-37
Morris, J.A., G.A. Bishop and D.H. Stedman. 1999. "Real-time Remote Sensing of Snowmobiles Emissions at Yellowstone National Park: An Oxygenated Fuel Study, 1999." Western Biomass Energy Program. Lincoln, NE.

Pages 38-41
Carroll, J.N and J.J White. 1998. "Emissions from Snowmobile Engines using Bio-Based Fuels and Lubricants." Southwest Research Institute. San Antonio, TX.

Pages 42-43
Alger, R., S. Gruenberg and G. Gwalteny. 2000. "Snowmobile Trail Bump Formation Analysis, Prediction, and Modeling." Draft Report for NPS-YNP May 2000. Michigan Technological University. Houghton, MI.

Pages 44-45
U.S. Department of the Interior U.S. Geological Survey. 1998. "Effects of Snowmobile Use on Snowpack Chemistry in Yellowstone National Park." Water Resources Investigations Report 99-4148 (18a).

Executive Summary: Air Quality Issues Pertaining to Yellowstone National Park Studies

The studies by Carroll and White (1999), White and Carroll (1998) and Morris et al (1999) together give good information on snowmobile engine emissions. It is clear that snowmobiles that use 2-stoke engines emit substantially higher hydrocarbon (HC) (approximately factor of 50) and particulate matter (PM) concentrations (approximately a factor of 100) than similar size 4-stoke engines. Emissions of carbon monoxide (CO) and oxides of nitrogen (NOx) are broadly similar.

Off-road vehicle emissions are at present unregulated, and as such, manufacturers of snowmobiles have no incentive to attempt to reduce emissions from snowmobile engines. Substantial pollution emission reductions would be achieved by adopting direct injection 2-stoke engines. Levels would be further reduced if 4-stroke engines were used. The adoption of catalytic converters would reduce pollutant emissions further still. However, at this time, emission standards are still in the development stage.

The studies by Morris et al. (1999) and Kado et al. (1999) provide some degree of assessment of the impact of snowmobile use on the air quality of YNP. While both studies suffer from methodological issues some broad conclusions can be drawn. Various measurements at the West Entrance site reveal that concentrations approaching National Ambient Air Quality Standards (NAAQS) and Occupational Health and Safety Administration Standards (OSHA) are being measured. While the studies do not directly assess these standards, other work by the Montana Department of Environmental Quality (MDEQ) that does claim to meet EPA protocols, has reported concentrations almost equal to the NAAQS. Therefore, it is clear that there is a genuine air quality problem. It is interesting to note that atmospheric deposition data by U.S. Geological Service (1999) indicates that water quality is probably not threatened at present.

The National Park Service (2000) report is an excellent summary paper of the YNP air quality issue with respect to snowmobile usage. It is evident that the problem can be seen as an ambient air quality issue with respect to NAAQS, a workplace exposure issue with respect to OSHA standards and a Clean Air Act issue with respect to the Class I status of Yellowstone National Park.

For the first two issues it is also clear that the entry point of West Entrance is the primary cause for concern. Pollution levels may be reduced by redesigning the entrance area at West Yellowstone. The kiosks could be separated in a manner to enhance dispersion.

Alternatively, pollution from snowmobiles entering the park should be reduced. This can either be achieved by reducing emissions from snowmobiles or reducing the number of snowmobiles. In the short term, the latter is the only viable solution. Emission control legislation, even if passed tomorrow, will take time to affect the overall fleet emission profile. Thus, in terms of the NAAQS and OSHA limitation of snowmobile use would be a viable solution if the relevant standards were exceeded.

The situation is less clear for meeting the requirements of the Clean Air Act. The Class I status of YNP means that the highest level of protection is required. If, for example, scenic vistas are being affected by snowmobile emissions then this would be a violation of the stated Clean Air Act goal of “the prevention of any future, and remedying of any existing, impairment in mandatory Class I Federal area which impairment results from manmade air pollution.”

The National Park Service (2000) states that management Policies are clear that in cases of doubt as to the impacts of existing or potential air pollution on park resources, the Park Service will err on the side of protecting air quality and related values for future generations.

In order to meet the requirements of Class I status it would again appear that one of two options could be justified, namely emission reduction or emission elimination. The latter option would be a ban on snowmobiles. This approach would be harder to justify given that automobiles and snow coaches would presumably still be allowed within National Parks. If emission level is the issue, maybe the use of 4-stroke snowmobiles needs to be considered. If a ban is put in place based purely on air pollutant emissions, then the question remains as to whether these types of snowmobiles would be allowed entry to YNP.

It is clear from the reports evaluated that more monitoring and modeling is required. This work should focus on whether ambient or workplace air quality standards are being exceeded and whether the Clean Air Act with respect to the Class I status of YNP is being violated.

An assessment of the validity of any decision is not possible since a final decision with respect to snowmobile use has not yet been made. Furthermore, it is inappropriate for a "second guess" since we do not at present have access to all the information used to make this decision.

Carroll, J.N. and J.J White. 1999. "Characterization of Snowmobile Particulate Emission" Final Letter Report. Southwest Research Institute. San Antonio, TX.

Summary

This study measured pollutant emissions from a Polaris snowmobile engine. This engine is considered by the authors to be representative of those used in Yellowstone National Park.

The emission rate pollutants, including hydrocarbons (HC), carbon monoxide (CO), oxides of nitrogen (NOx), and particulate matter (PM) were measured. Testing was undertaken in the laboratory. Emissions were measured using a 5-mode steady state snowmobile engine test cycle. The emission rates of HC, CO and PM were reported as high whereas those of NOx were reported as low. The categories of high and low are given by comparison to 4-stroke engines engines. Higher emission rates are expected from a 2-stroke engine. Particulate emissions are comparable to those of older pre-control diesel engines.

The authors compared PM emissions from operation with a conventional mineral lubricant to operation with a bio-synthetic lubricant. They report that gaseous emissions were very similar whereas PM emissions were approximately twice as high with the biosynthetic lubricant. Particulate matter was further characterized in terms of volatile organic fraction, particle size and biological activity.

Particulate matter emissions were expected to consist primarily of volatile organic matter mainly from unburned lubricant. The volatile organic fraction of total PM was reported as 73% for the conventional lubricant operation and 53% for the biosynthetic lubricant. The authors also calculated the contribution of unburned oil to the volatile organic fraction by crude “fingerprint analysis”. The contributions were 67% for the conventional lubricant and 50% for the biosynthetic lubricant. The analysis given by the authors confirms the importance of the lubricant to particulate emissions. This is expected given the mechanics of the engine. The average volatile organic fraction of PM can thus be calculated as approximately 60%. This value can be compared to a value of approximately 30% for the contribution of total volatile fraction to PM for modern on road diesel engines. The total volatile fraction would include moisture and sulfates as well as volatile organics.

Particle size analysis is important to determine the respirable particle fraction of PM emissions. Particles initially form as nanoparticles and then coagulate to become larger particles. This process is controlled by time and particle concentration. The data reported indicates emission of smaller particles at higher speeds and larger particles at lower speeds. The highest concentrations of particles were emitted during “medium” engine speed and load. The authors reported this effect as being due to higher scavenging losses and poorer combustion efficiency. This behavior is typical of part load two-stroke engine operation.

The size distribution of PM exhibited a wide variation, however the majority were in the range of 20 to 60 nm. The particle diameters were typically below 100 nm, which is the respirable range for humans. This range is similar to that of particle emissions from diesel engines.

Particulate bioassay determined mutagenic activity in terms of revertants per microgram of particulate matter. Bioassays are used to measure damage to genetic material. This damage is also termed as genotoxicity and is thought to be important with respect to developing cancer. The number of revertants indicates the level of genotoxicity. The author's report that the number of revertants per horsepower hour was approximately an order of

magnitude higher from snowmobiles compared to diesel engines studied elsewhere. The emissions from snowmobile engines were reported as being more similar to those from heavy-duty diesel engines.

The authors make two main conclusions from this study, namely (i) Particulate matter emissions are primarily volatile organics derived from the lubricant and (ii) Particle diameters were typically less than 100 nm, which is of respirable range.

Critique

The report provides valid information on exhaust emissions from a single Polaris snowmobile engine. Whether this is representative of the snowmobile fleet or even this model of engine is a valid question. The age of the engine was not noted nor whether it was “tuned” prior to testing or whether it was purchased or supplied by the manufacturer. Thus, it is questionable whether it is valid as a sample as at least three engines would be required to enable calculation of standard deviation. Similar arguments apply to the comparison of one of each of two different lubricant types.

Perhaps the most important statement is that regarding the levels of emissions. Emissions of hydrocarbons, carbon monoxide and particulate matter are high and those of oxides of nitrogen are high compared to 4-stroke engines.

It is important, however, to note that testing occurred at ambient temperatures far exceeding those experienced in the field. This would be expected to have a non-linear effect on emission characteristics of the measured pollutant emissions. The emission rates reported can therefore be considered as unrepresentative of normal operating conditions. This is analogous to making measurements outside the calibration range of an instrument.

The authors' two main conclusions presented in the paper are valid, not withstanding the criticism of sample size and testing protocol. Particulate matter emissions are primarily volatile organics derived from the lubricant. Particle diameters were typically less than 100 nm, which is of respirable range. The data produced gives good information for the assessment of snowmobile emission rates. It is however not suitable for definitive assessment of lubricant effects.

Kado, N.Y., P.A. Kuzmicky and R.A. Okamato. 1999. "Measurement of Toxic Air Pollutants Emitted from Snowmobiles at Yellowstone National Park" Draft Final Report. University of California. Davis, CA.

Summary

This study examined human and ecosystem exposure to particulate matter (PM) and toxic pollutant concentrations. The toxic pollutants measured were all hydrocarbons (HC). The study measured pollutant concentration at fixed sites and also performed personal exposure measurements. Sampling took place during the period February 13th to 22nd, 1999.

The fixed sites within Yellowstone National Park (YNP) were located at West Entrance, Madison Junction and Old Faithful. Sampling at West Entrance was at the entrance lanes to YNP. Sampling at Madison Junction was 10 feet North of the "warming hut". Sampling at Old Faithful was 30 to 40 feet upwind from the warming hut closest to the two car parks. Two sites in the town of West Yellowstone were also included in the study as background data.

The personal exposures were separated into a number of categories namely, West Entrance, Madison, Old Faithful, Patrol, Mechanics and Office.

Particulate matter measurements, of less than 2.5 micrometers ($PM_{2.5}$) and less than 10 micrometers (PM_{10}), were made at the fixed sites. Personal exposures measured less than 4 micrometers (PM_4).

Hydrocarbon monitoring was performed at both fixed sites with short (seconds) and longer (hours) time resolved sampling. The latter were personal exposure measurements of HC. Benzene, toluene, ethyl benzene, xylenes, trimethylbenzenes and formaldehyde measurements were performed. Formaldehyde measurements were only performed for personal exposures.

Bioassay analyses were also performed on PM obtained from a snowmobile engine dynamometer study conducted elsewhere. Particulate matter was found to be mutagenic, which in broad terms means that it is able to damage DNA material. Snowmobiles operating with mineral based lubricants were found to produce PM matter that is more mutagenic than similar emissions when using a biosynthetic lubricant. The authors inferred that polcyclic aromatic hydrocarbons were probably present on the PM. The authors report that the activity in terms of "mutagenic activity" from snowmobile emissions were similar to those from heavy-duty diesel engines that use pre-1993 No. 2 diesel fuel.

For the fixed site monitoring, the highest concentrations of PM and HC were reported at the West Yellowstone site. Reported levels of PM were approximately twice as high at this site compared to Madison Junction and Old Faithful. Measurements were performed for four hours during both morning and afternoon at the West Entrance during "Presidents' weekend" (February 13th and 14th). These are days associated with higher traffic flows than usual, with 802 and 739 snowmobiles counted. The lower PM concentration at Madison Junction and Old Faithful were reported to be due to "a more openness of the area near snowmobile emissions compared to the area at the West. Also snowmobilers appear to turn off their snowmobiles upon arrival at Madison and Old Faithful." The authors report that PM_{10} data measured at Old Faithful was higher than that at an EPA sanctioned site in the town of West Yellowstone. The authors believe that the observed pollutant concentrations were related to the movement of snowmobiles.

The authors also compared PM_{10} and $PM_{2.5}$ data from two sets of simultaneous measurements. The authors report that "There was no difference…. which indicates that PM_{10} was identical in particle size to $PM_{2.5}$.

For the personal exposure data for PM_4 concentrations were highest from one measurement on a mechanic. Other data generally showed the range of West Entrance > Mobile Patrol > Old Faithful/Madison > Office. A bimodal pattern of exposures was evident at the West Entrance with a group of five measurements at about 60 ug/m^3 and another group of five measurements at about 130 ug/m^3. The latter group was associated with working outside for a whole shift on the express lane.

Neither the averaging nor sampling times are reported for the personal exposure data. Shift measurements were reported which are assumed to match those used for the PM sampling. In terms of benzene concentrations, a similar pattern of exposure is evident as for the PM sampling. The range of West Entrance > Mobile Patrol > Old Faithful/Madison > Office was reported. For benzene, average concentrations of 212 ug/m^3 (6 samples) at the West Entrance compare to 25 ug/m^3 (2 samples) at the offices. It is interesting to note that a bimodal distribution was not present at the West Entrance as reported for PM. It is not clear whether the HC monitoring was carried out in the morning, afternoon or for the whole working shift. Measurement of aldehydes again showed similar trends as the PM data.

Hydrocarbon measurements from fixed sites with sampling times of seconds were also reported for the West Yellowstone Entrance site. Seven grab samples were reported for four hydrocarbon parameters, excluding Exit Lane at 4pm and West Office air measurements, the average benzene concentration was approximately 500 ug/m^3.

Critique

Did the authors follow EPA criteria for the location of the fixed sites in Yellowstone National Park? How would one define the measurement locations? If we desire an indication of the local pollution level, assessment and measurement are required away from the direct influence of emission sources. This is not the case for this study. The choice of sampling locations merits some concern. This study seems to aim to report the highest concentrations possible. This concern is based on the assertion that monitoring here should attempt to assess compliance with National Standards.

Frequent comparison is made to lower air pollutant concentrations reported for the same parameters in LA. It should be noted that while vehicles in LA have high levels of emission control, it is likely that if measurements were taken on the freeway next to an intersection with stationary traffic, the results would show much higher pollutant concentrations than the LA comparison data. For determination of the impact of control legislation in urban areas, background measurements are required as opposed to near source measurements. It appears as though the comparison data referred to is background urban air although no reference is given. Measurements at close proximity to the source are good for emission profiles but are not representative of the general pollution climate.

While concentrations are reported in vehicles operating in California were these vehicles running along a quick flowing interstate or stuck in a 2 hour long traffic jam?

It is totally inappropriate to compare four hour peak measurement of PM to National Standards that are based on 24 hour sampling, in particular when a distinct diurnal pattern of concentration is expected. The authors state "The a.m. concentrations exceed the 24 hr

Federal standard of 65 ug/m^3." While the authors add "The time-weighted average exposure for the entire work shift is at or near this standard."

By taking the reported data at face value, the following alternative interpretation can be used. The a.m. averages for the President weekend were 116 and 112 ug/m^3, which represents 80% of total PM for the two, four hour monitoring periods. Therefore, the average concentration for the daytime monitoring would be as follows from the four monitoring periods:

= ((116 + 112) + ((116 + 112) * 0.2) / 4
= (228 + (228 * 0.2)) / 4
= (228 + 45.6) / 4
= 273.6 / 4
= 68.4 ug/m^3

As an alternative to assuming the 80% statement to be true, the graphical data presentation given by the authors was enlarged and gave values of 116 and 34 for the 13th and 112 and 18 for the 14th. This leads to an average concentration for the daytime monitoring as follows from the four monitoring periods:

= (116 + 34 + 112 + 18) / 4
= 70 ug/m^3

The authors state that 90% of the snowmobiles enter the park during daytime monitoring. Other data by Alger et al. (2000) shows that all but approximately 10% will enter and that about 60% of snowmobiles will depart between 8:30 and 4:30 from the park. This means that as far as total vehicle count is concerned approximately 25% of vehicle passage will be missed. If we assume a direct relationship between snowmobile passage and PM concentration then we can calculate the following:

If 75% of the snowmobile movement produces a PM concentration of 70 ug/m^3 (using a higher estimate) over an eight hour time period, then:

25% of snowmobile passage over the remaining 16 hours will produce a PM concentration by the following calculation:

100% in 1 hour = (70*(100 / 75))*8 = 746.7
25% in 1 hour = 746.7* (25 / 100) = 186.7
25% in 16 hours = 186.7 / 16 = 11.7 ug/m^3

Thus for a 24 hr period which can estimate a PM concentration as follows:

24 hr PM concentration = (11.7 * (2/3)) + (70 * (1/3)) = 7.8 + 23.3
24 hr PM concentration = 31.1 ug/m^3

This estimate of 31.1 ug/m^3 assumes background contribution for the estimated period is the same as the measured period. This value is considerably less than the Federal Standard of 65 ug/m^3. This is significant since this is estimated from high traffic days. It is also a widely

different interpretation from the authors. Thus the interpretation of the authors is highly misleading. When comparing measured data to a National Standard, that states it level with respect to 24 hour time sampling, the comparison data MUST have the required time period. Please note that this calculation is for indicative purposes and should be treated with caution for the same reasons as those given directly above. There may be a massive night time source of PM emission affecting YNP. If we do not monitor then we will not know.

With respect to the PM_{10} monitoring the authors attempt to discount the EPA site due to local near source pollutant emissions. This rationale is hard to understand and can only be justified in terms of an attempt to get a background measurement. Then one needs to consider what an appropriate background measurement would be. Would it be when no snowmobiles operate? A good indication of background data would be achieved by reviewing NOx and CO data from a continuous monitoring site with knowledge of the levels of snowmobile use.

The authors state that there was no difference between simultaneous data collected for PM_{10} and $PM_{2.5}$. This is untrue since viewing of the authors' data for the second (p.m.) of two samples indicates approximately a 25% difference. While the concentration in this sample is low there is a difference. This point is again indicative of the incomplete analysis given in this report. An example of the poor quality of this report is the comparison between ONE Tedlar bag sample and ambient concentrations in California. This is ridiculous. A grab sample measurement, e.g. Tedlar bag, could be taken in any city at a set of traffic lights with static traffic and then compared to the results from a site measuring ambient urban air, and similar results would be achieved. Near source and ambient monitoring should only really be compared with respect to pollutant ratios to enable identification of, for example, emission sources.

The final section of this report is entitled "Recommendations for Future Research." In this section, the authors conclude their work. Exposures are noted as being high compared to levels measured inside vehicles traveling in LA. The authors state, “Approaches to dramatically decrease exposure to Park employees to toxic air pollutants should be investigated immediately.” The authors also believe that more monitoring is required and that annual as opposed to seasonal data is required.

Appropriate monitoring is required but not in a similar fashion to the piecemeal approach adopted in this study. Reference to National Standards is required using agreed upon monitoring protocols.

Future monitoring requires a more systematic approach than what was evident in this study. Such monitoring should include Wyoming DEQ, Montana DEQ, Idaho DEQ and the EPA. All emission sources affecting the area as well as background contributions should be assessed. This would enable the generation of an emission inventory. This could then be used for determining management scenarios. Such assessment would probably require year round monitoring and modeling.

U.S. Department of the Interior and National Park Service, Air Resources Division. 2000. "Air Quality Concerns Related to Snowmobile Usage in National Parks." USDI and NPS. Denver, CO.

Given the nature of the USDI/NPS report, for this review, the summary and critique are written together for each section of the report. The assessment here is focused upon solid statements that are important to the decision-making process as well as those which are open to debate.

Background

The National Park Service (NPS) is considering a petition to ban snowmobile use in national parks. The authors state, with respect to the report, that "It is necessarily limited by the scope, methods and content of the studies cited."

Snowmobile Emissions

It is noted that snowmobiles use two-stoke engines that are known to emit substantially more pollutants than other types of engines. With two-stroke engines, up to one third of the fuel passes through the engine unburned. Lubricant is mixed with the fuel and becomes part of the exhaust. The combustion process itself also results in relatively high levels of emissions. As with any combustion engine, a number of different pollutants are emitted including carbon monoxide (CO), carbon dioxide (CO_2), oxides of nitrogen (NOx), sulfur dioxide (SO_2) and hydrocarbons (HC). The latter class may contain toxic components such as benzene.

Emission factors for transport sources of these pollutants can be expected to vary depending on a number of factors; whether one is considering automobiles, heavy duty diesel trucks, snowmobiles or airplanes. These factors include sample size and distribution of tested vehicles, analysis methods of the researcher, types of engines used, age of engines, fuels used and testing protocol. However, if using a broad base of information from a variety of sources it is possible to determine approximate factors for different categories. These categories can be compared sensibly as long as the limitations of such analysis are also considered.

Table 1 gives an excellent summary of various snowmobile emission factors. When compared to automobiles a snowmobile with a two-stroke engine operating for four hours can emit between 10 and 70 times as much CO and between 45 and 250 times as much HC as an automobile driven 100 miles.

In this section the authors discuss the study by Bishop et al. (1999). It is interesting to note that the authors state "the results showed that a reduction of CO of 7% (+/-4%) could be achieved in Yellowstone National Park (YNP) using oxygenated fuels." This is misleading since the vehicles with the oxygenated fuel were already operating and account for approximately 75% of snowmobiles entering the Park; i.e., those from the West Entrance. The reduction refers to those vehicles when re-fueling in the Park and those entering from other entrances. The stated value itself can be disputed (see summary of Bishop et al., 1999). The authors also state, "However, oxygenated fuels did not appear to reduce HC emissions." It is interesting to compare the phrasing of the latter two quotations. Hydrocarbon emissions were actually higher from the ethanol fueled vehicles. The latter sentence should be reversed and written as follows:

"Oxygenated fuels were found however, to emit greater quantities of HC and given emission mechanisms, probably air toxics as well."

The authors use the term “showed that” for the positive and “did not appear to” for the negative statement with respect to the bias toward oxygenated fuels.

Snowmobile emissions within YNP will depend upon a number of factors including number of vehicles entering, the number of hours operated, the engines and fuels used, engine speed, elevation, ambient temperature and how well engines are tuned. Again in this section the authors state, “…and oxygenated fuels can reduce the levels of certain pollutants.” No mention is made that the studies that this assertion is based upon found that other pollutant emissions were increased.

Yellowstone National Park: An Air Pollution Emissions Case Study

At YNP, the snowmobile season lasts from mid December to mid March. The authors provide an excellent assessment of the overall transport related emission of pollutants at YNP. This is achieved by calculating emissions from vehicle counts, emission factors and distance traveled.

Although the number of snowmobiles is determined on an annual basis, a factor of approximately 16 lower than automobiles entering YNP, annual emissions of CO and HC from snowmobiles can exceed those of all other transportation sources combined. The estimated contribution of snowmobiles to total emissions is reported to range from 35% to 68% for CO and from 68% to 90% for HC. Snowmobiles are also estimated to account for 2% of NO_x emissions and 39% of PM emissions.

Table 2 gives a good summary of different emission rates of CO and HC from mobile sources relevant to YNP. The authors also reported snowmobile emission rates from the work of White and Carroll (1998) for benzene of 1.26 g/hp-hr and 31.78 g/hp-hr for toluene. These values do not compare very well with data reported by Kado et al. (1999) given in the next section.

Air Quality and Personal Exposure Standards

Any appropriate and defensable stance on the impact of snowmobile emissions upon air quality must relate to air quality standards. The authors write an excellent summary of the applicable air quality standards.

National ambient air quality standards (NAAQS) have been established for CO, sulfur dioxide (SO_2), nitrogen dioxide (NO_2), ozone (O_3), lead (Pb) and particulate matter less than 10 microns in size (PM_{10}). These standards are designed to protect the general public from the harmful effects of air pollutants within an adequate margin of safety. These standards apply to areas to which the general public has access and do not apply to the workplace. Compliance is determined through the use of designated reference methods, established by the Environmental Protection Agency (EPA), at appropriate sampling locations representative of human exposure. It should be added that inappropriate sampling locations can lead to bogus non-compliance results. The authors note that non-compliance requires states to take appropriate measures to reduce air pollutant emissions sufficient to attain and maintain the NAAQS in question.

Workplace standards are set by the Occupational Safety and Health Administration (OSHA). Permissible exposure limits (PELs) have been established for a number of pollutants

including CO, benzene and toluene. These limits are based on average concentrations during an eight hour working shift that must not be exceeded during a 40-hour working week. Short-term exposure limits (STELs) exist for a number of pollutants including toluene. These limits are based on concentrations that are measured over a 15-minute sampling time, which must not be exceeded on any working day. The National Institute for Occupational Safety and Health (NIOSH) has published eight hour and 15 minute recommended exposure levels (REL's) that are not to be exceeded.

Tables 3 and 4 summarize the ambient and workplace standards of relevance. The authors note that some studies indicate that standards may have been exceeded at YNP, particularly on those days with peak snowmobile traffic. If this is the case, then regulatory or NPS management action will be required to mitigate or eliminate these impacts." Unfortunately, no reference is given for the first part of the quote. Also, the authors use the words, "may have been" when referring to exceedence of the standards. Standards are either exceeded or not. The word "may" should not be connected since compliance is based upon measurement data, which is performed according to set protocols. This does not make sense. The second part of the quotation, while no one can disagree, is based upon the phrase, "if this is the case." That is a question for which appropriate data seems to be lacking.

Potential Effects on Air Quality: Ambient and Personal Exposure Monitoring

The authors note that measurement of CO made during the winter of 1995 showed that CO levels could exceed NAAQS standards. However, the authors also state that grab samples were used for this. Time averaged measurements of at least one hour are required for assessment. In addition the data was collected at "an area immediately adjacent to the entrance station booths." Is this an area to which the public has access i.e. is this ambient or workplace air? This is a point of debate. While the public will pass through this area they will not remain for an hour. Furthermore, these measurements may have been taken prior to the establishment of an express lane in late 1995. The authors do not make this issue clear. Monitoring also indicated that CO levels decrease by a factor of ten within 25 meters. More recent monitoring by the State of Montana has recorded an eight hour concentration for CO of 8.9 ppm. This value is very close to the NAAQS standard. The authors note that this study used EPA approved protocols. Air dispersion modeling by the State of Montana indicates that the one hour CO standard could be exceeded. This is more representative of modeling, or potential values, and not monitoring, which would represent actual values.

The authors also cite the study by Snook and Davis (1997) that showed that moving measurements at distances of 25 to 100 feet from an operational snowmobile ranged from 0.5 to 23.1 ppm. This raises questions with respect to exposure to the general public using snowmobiles.

The authors report the PM data reported by Kado et al. (1999) and cite an average Presidents' weekend daytime concentration of 78 ug/m^3. It would be intriguing to find out how this value was calculated. (Please refer to the separate critique of Kado et al. (1999).) The stated value seems suspect.

With respect to the study by Kado et al. (1999) the authors state, "The study showed that the concentration of benzene for some employees could approach the RELs as established by NIOSH." The study supported the following hypothesis by stating, 'Park employees and the surrounding environment are exposed to high levels of many toxic pollutants as a result of snowmobile use within the Park…' Kado *et al*. 1999)." First the data is not cited. The REL for

benzene is 326 ug/m3. The highest of five measurements at the West Entrance was 303 ug/m3. The average at this site was 212 ug/m3. All other benzene measurements are below the average at West Yellowstone. But we should remember that these are supposed to be eight hour samples. The sampling time is not stated by Kado et al. (1999). What do the authors mean by "high?" The measured data is all below the NIOSH standard, assuming that data is collected according to appropriate protocols. The reference to a hypothesis would make one believe that a scientific test was being undertaken. For a hypothesis to be tested we need a probability level. This is absent. The statement is inconclusive because the term “high” has no level attached to it.

The following paragraph then continues, “These monitoring results indicate levels of individual pollutants, including carcinogens such as benzene that result from snowmobile exhaust, can be high enough to be a threat to human health.” This is a wild leap and is not supported by any data, in particular that of Kado et al. (1999). This paragraph continues with lead on sentences that eventually get to the statement, “It would seem that visitors would likewise want to minimize their exposure to what are likely unhealthy levels of air pollution”.

Potential Effects on Air Quality: Health Effects Associated With Vehicle Emissions

This section gives an excellent summary of the health impacts of selected pollutants.

Potential Effects on Air Quality: Welfare Effects Associated With Snowmobile Use

The authors also make the important point that under certain conditions, haze may develop along trails potentially impairing visibility and degrading scenic vistas. This is of prime importance given the Class I designation of YNP. The Clean air Act established as a national goal “the prevention of any future, and remedying of any existing, impairment in mandatory class I Federal area which impairment results from manmade air pollution.” Again, adequate assessment would be required to determine if “impairment” is occurring due to snowmobile emissions.

Status of Efforts to Reduce Snowmobile Emissions: Proposed Regulations

The EPA is at the early stage of the process leading to the development of emission standards for snowmobiles. However, the authors note that even if emission standards are adopted there will be a lag time associated with full implementation into the operating fleet of snowmobiles. Large reductions of emissions from snowmobiles are possible through simply using direct-injection 2-stroke or 4-stroke engines.

Status of Efforts to Reduce Snowmobile Emissions: Two-stroke Versus Four-stroke Engines

Direct injection two-stroke engines reduce emissions of HC by approximately 70% to 75% compared to conventional 2-stroke engines. This statement is derived from a personal communication. It should be noted that a published reference would be more appropriate for factual statements. The use of catalytic converters could further reduce pollutant emissions. While 4-stroke engines produce about the same level of CO emissions as 2-stroke engines HC emissions are reduced by approximately a factor of 40. However, NOx emissions are increased with 4-stroke engines.

Status of Efforts to Reduce Snowmobile Emissions: Oxygenated Fuels

The example of air quality improvement for CO in Missoula, Montana due to switching to oxygenated fuel is given. (Please refer to the separate critiques given for the authors White and Carroll.) Based on the work of the aforementioned authors, this report states that, "Tests…..indicate substantial reductions in emissions of total HC (16%), CO (9%) and PM (24%) over conventional gasoline." This statement is open to debate on a number of levels. First, on the original data analysis and second, that it is partially contradicted by the work of Morris et al. (1999). The authors state the calculated impacts of oxygenated fuels on CO emissions and note no apparent difference in the amount of HC emitted." The latter is quite simply not true if one looks at the data reported by Morris et al. (1999). The HC emission rates from ethanol fueled snowmobiles at the West Entrance was 312 gHC/kg of fuel. This value compares to values of 297 and 267 gHC/kg of fuel for the conventional gasoline fueled snowmobiles at the South and West exits. These represent higher HC emission levels with the oxygenated fuel of approximately 5% and 15%, respectively.

Management Considerations and Options: National Park Service Management Policies

It is noted that the National Park Service (NPS) policies seek to attain the best possible air quality in parks and that managers are required to assume an aggressive role in promoting and pursuing measures to safeguard air quality related values for the adverse impacts of air pollution. While air pollution sources must comply with all Federal, State and local regulations in National Parks, the authors add that, " National Park Service Management Policies are clear that in cases of doubt as to the impacts of existing or potential air pollution on park resources, the Park Service will err on the side of protecting air quality and related values for future generations."

Management Considerations and Options: Existing Air Quality

This section defines procedures associated with actions related to NAAQS non-attainment areas.

Management Considerations and Options: Clean Air Act Area Classifications

This section explains the Clean Air Act classifications of Class I and Class II areas and the protection that is required for these areas. This section also explains the Prevention of Significant Deterioration (PSD) program, which aims to protect areas with clean air such as YNP, that are designated as Class I areas. The authors state that Congress intended that Class I areas be afforded the greatest degree of air quality protection and specified that only very small amounts of air quality deterioration be permitted. Congress also established a national goal of remedying existing man-made visibility impairment and preventing future impairment in Class I areas. This seems to be the position adopted by the NPS .

Management Considerations and Options: Preventing Significant Air Quality Deterioration

The authors note that PSD permitting requirements of the Clean Air Act apply only to stationary sources. This issue is related to the modeled analysis of allowed increments, which are pollutant emissions that do not affect attainment of applicable standards. For example, it is possible that since the establishment of baseline conditions in YNP in 1979, snowmobile

along with other mobile emissions have increased to such a level as to consume increment for PM emissions.

Management Considerations and Options: Air Quality Levels and Employee and Visitor Health

The authors note that it is important to protect employee and visitor health with respect to pollutant emissions. The authors state that some of the quickest ways of reducing emissions in parks are to minimize the total number of snowmobiles entering parks or to regulate the number entering parks at any given time.

Management Considerations and Options: Management Options

The authors give a clear and sensible description of management issues related to the use of snowmobiles. The authors outline options, the most extreme of which is to ban the use of snowmobiles.

Morris, J.A., G.A. Bishop and D.H. Stedman. 1999. "Real-time Remote Sensing of Snowmobiles Emissions at Yellowstone National Park: An Oxygenated Fuel Study, 1999." Western Biomass Energy Program. Lincoln, NE.

Summary

The primary aim of this work was to identify the effect of oxygenated fuel on emissions from snowmobiles. The authors used remote sensing data to derive, through a series of calculations and corrections, emissions in terms of units of mass per unit of fuel. The authors paid particular attention to carbon monoxide (CO) and hydrocarbons (HC). The report also contains measurements of the hydrocarbon toluene.

Measurements were made with optical line path techniques. The study is split into three main sections namely, (i) ambient measurements at West Yellowstone, South Entrance and West Exit. (ii) fuel switching measurements from three different snowmobiles and (iii) direct comparison between emissions from two different snowmobiles of the same model using different fuels.

The authors state that the main objective was to determine the extent to which the ethanol blended oxygenated fuels lowered CO emissions. The authors note that the evidence for reduced CO and HC emissions from ethanol-blended fuel is from automobile engine data, which have different combustion processes than snowmobile engines. The 2-stroke engines employed in snowmobiles are expected to have certain emission characteristics. For example, as the ambient temperature decreases the emissions of CO should be reduced since there is relatively less oxygen in colder air.

Most measurements for part (i) of the study were taken at West Entrance, South Entrance and West Exit. The authors report mean emissions in percent CO as 6.0 (+/-0.1), 6.4 (+/-0.2) and 7.1 respectively, at these locations. The reported HC values were 2.5, 2.2 and 1.9 percent, respectively. The authors conclude that at the West Entrance where an ethanol blend was used in the snowmobiles there was a 7%+/-4% decrease, corrected for temperature, in CO emissions compared to the South Entrance where non-oxygenated fuels were used.

For HC the authors state that since HC emissions from snowmobiles are variable with many different parameters that could not be controlled, an ethanol effect could not be clearly identified and an ethanol penalty cannot be discounted. Measurement issues are noted in the critique. The authors point out a number of other factors that could account for the "analogous" HC data. The authors expect that the mechanics of snowmobile engines may be important, in that warmer engines tend to be associated with decreased HC emissions. The South Entrance snowmobile measurement site is 2.5 miles from the main starting point, which is the Flagg Ranch. The entry road has a speed limit of 45 miles per hour (mph). The West Yellowstone measurement site is only 0.5 miles from the town of West Yellowstone and has a speed limit of 20 mph. The authors note that higher HC emissions are associated with increased power demand and believe that this may account for the reported data differences along with measurement issues noted in the critique.

It is interesting to note that at West Yellowstone it is estimated that 60 to 80% of the snowmobile rental fleet were predicted to be fueled with oxygenated gasoline. At the South Entrance, a maximum of 5% of the snowmobile fleet was expected to be using oxygenated fuel. At the West Exit, the snowmobiles are expected to have a mix of ethanol and conventional gasoline, since that was the only fuel available inside YNP at the time of this report.

An ambient temperature effect for CO was also reported for this phase of the study. Lower emissions were calculated at lower temperatures. This was the case at both the West and South Entrances. The temperature effect was quantified as 8% +/-4% from 273 to 258 degrees Kelvin.

Further evidence for a temperature effect was derived from assessment of the comparison between afternoon measurement at the West Exit and undefined morning data. For CO, an increase of 18% was reported from the morning to the afternoon. For HC, the opposite effect was reported with a 20% decrease from the morning to the afternoon. The authors account for this change by a combination of different fuel usage, warmer operating temperatures and a warmer operating mode since ambient temperatures were the same.

The calculated emission rates for snowmobiles from this study were compared to those from laboratory testing. Given the wide methodological differences, the data are broadly comparable. This study reports values between 489 and 617 grams of CO per kilogram (gCO/kg) of fuel and 267 and 312 grams of HC per kilogram (gHC/kg) of fuel. These values compare to the laboratory values of between 665 and 872 gCO/kg of fuel and between 271 and 319 gHC/kg of fuel.

For part (ii) of this study three different snowmobiles were used. These were a 1999 Polaris, a 1996 Polaris and a 1984 Arctic Cat. Measurement of the emissions from each snowmobile was undertaken using an ethanol blended gasoline and a conventional gasoline. For consistency, the same drivers were used for testing each snowmobile. The emissions of CO were higher with the ethanol fuel for both the Polaris models. For the 1999 Polaris, a value of 6.9 % CO (+/-0.2) for the ethanol fuel compares to a value of 5.9 (+/-0.2) with the conventional gasoline. For this model, emissions of HC are higher with the ethanol blend compared to the conventional gasoline with percent HC values of 1.7(+/-0.1) and 1.3 (+/-0.1). For the 1996 Polaris, levels of both percent CO and percent HC are broadly similar with error bars overlapping for both parameters. For the 1984 Arctic Cat, percent CO is higher while percent HC is also higher for the conventional gasoline compared to the ethanol gasoline. The authors state that these results are not entirely surprising since the CO and HC distributions in the earlier figures show very large intrinsic variability.

For part (iii) of this study two 1999 Ski-Doo Rotax snowmobiles were compared, one using ethanol blended gasoline and the other using conventional gasoline. Higher CO emissions were reported for the engine using conventional gasoline compared to the other engine that used ethanol-blended fuel. The error bars overlapped for HC data indicating no significant difference.

Remote sensing measurements of the hydrocarbon toluene were also performed for the first time in this study. At the West Entrance, a mean concentration of 1976 part per million (ppm) was reported. The toluene concentrations were positively correlated with the percent HC measurements. This was explained by the assertion that the majority of emissions is from the loss of fuel rather than incomplete combustion.

The authors noted that the distribution of measurements from the snowmobiles was much less skewed than that from areas dominated by motor vehicles. The valid measurements of CO reported in Figure 1 for the snowmobiles ranged from 1% to 13%. The authors see the reported variation as indicative of the advantage of remote sensing measurements compared to laboratory testing which has a smaller sample size.

The authors conclude that in the first experiment for the comparison at the West and South Entrances there is an obvious difference between the emissions for percent CO; while

for percent HC it is concluded that snowmobiles emit approximately sixty times as much as automobiles.

Critique

The paper is written with a high level of jargon and a large amount of technical calculation data. Put simply the report is not well written and reads more like a rushed preliminary draft than a final report. How accurate is the data presented? While the authors present errors bars, which are useful, it is unclear whether all uncertainty has been considered.

Again, there is cause for concern with the use of optical line path remote sensing for air pollution evaluation. Some remote sensing equipment utilizing spectral information measures pollution while asserting to measure more specific commodities such as benzene and toluene. In a 1994 paper[1] regarding the wide differences in ambient data reported from conventional and remote sensing equipment for benzene and toluene, spectral techniques were shown to tend to suffer from a number of issues not least overlapping, i.e. interference or contamination, of compounds in the same spectral region. The authors here admit this with the following statement:

"One possible reason for the differences in the HC emissions is because ethyl alcohol (ethanol) absorbs light in the same wavelength region as propane therefore increasing the signal as compared to non-oxygenated fuels".

Put in layman terms the authors are saying that their methodology is not capable of measuring HC. Or in a nutshell our HC data is suspect and hard to quantify and that is why we are not producing calculated differences. For an air pollution measurement scientist, this type of data production and analysis is truly disheartening to read.

The authors report further methodological problems. Interference from snow spray was noted. The measurement sites needed to be within 50 meters of Stop signs at the West Entrance and South Entrance to reduce this effect. Snowmobiles were thus in acceleration mode. At the West Exit a similar situation was not available so measurement were made at higher speeds in cruise control with greater interference from snow spray.

The authors do not explain the exact impact of this interference. Are measurements not possible or is the quality reduced? The authors also make assertions that the measurements are in realistic operation, is acceleration from a stop sign realistic for running on the trails of Yellowstone National Park? The West Exit measurements are hard to compare as they are made at a location where the snowmobiles are in a different operation mode and it should be added would have much hotter engine temperatures. Furthermore the authors state that "valid measurements could only be collected for the slower moving snowmobiles (5-15 mph)". Thus the sample data may further skewed with respect to "realistic operation" or other measurement sites, for which vehicle speeds are not reported.

In a preliminary study by Bishop and Stedman 1998 (Appendix A) further measurement methodology problems are noted which are not stated in the final report. The same equipment was used for both studies. The authors state " The HC channel in the remote sensor can be positively interfered with by liquid water vapor (steam) and report this interference as HC emissions." Snowmobiles can be liquid cooled or air cooled. For liquid

[1] Field R.A., S. Neville, D. Vowles, M.E. Goldstone, J.N. Lester, and R. Perry. 1994. "Factors controlling the variation of benzene and toluene concentrations at two proximate central London sites." Fresnius Environmental Bulletin, 3, 667-672.

cooled snowmobiles steam emissions are often emitted, as reported by the authors, in large amounts. Furthermore the authors state " It is therefore possible that the higher HC emissions observed from the liquid cooled sledges could be the result of positive water inference during the measurement."

There is room for concern with the validity of the data for the aims of the study, as there is some question as to the level of confidence merited by the HC data.

Remote sensing is a useful tool if applied in an appropriate manner, i.e. tracking emission plumes and gaining an indication of relative pollution levels. Indeed for the former application it is unrivaled. However for accurately discerning pollution differences in the manner applied in this study is questionable.

Also cause for concern, the authors seem to be fitting the unstated hypothesis that oxygenated fuels reduce CO emissions from snowmobile engines. In the executive summary no mention is made of the data they measured which showed the reverse for newer snowmobiles. The report therefore is of questionable balance in its summation in the executive summary.

The authors state "The emissions from CO and HC from the West and South Entrances should reflect an ethanol effect if all other variables are the same, but that is not the case". The authors report that the temperatures were different. The temperature effect was quantified as a reduction of CO emissions of 8% +/-4% from 273K to 258K. Maybe warm winter days should be banned as opposed to conventional gasoline since the temperature effect is greater than that calculated for fuel switching to ethanol blended gasoline for CO emissions.

The authors do not calculate a percentage reduction or enhancement for HC emissions. This is probably due to the methodological problems noted above combined with that the authors do not have a hypothesis that can be matched to the data. Indeed the authors 'shoot themselves in the foot' since they produce the "warm snowmobile theory" which has as a major premise the difference between the measurement sites in terms of prior speed, duration of warm-up, inferred engine temperature. The authors state that the engines would be warmer at South Yellowstone and use this as explanation of relatively higher HC measurements compared to West Yellowstone. Why not use this difference to further 'interpret' the CO measurements. Previously the authors imply that the sites are similar and not the distance from Stop Sign as being of particular importance. The authors calculate an ambient temperature effect on engine operation for CO emissions. If engines are warmer at South Entrance this may warm intake air and thus may partially account for the higher emission of CO at this site. Since higher CO emissions are associated with higher temperatures.

Further evidence for a temperature effect was derived from assessment of the comparison between afternoon and morning data. The CO increase of 18% and the HC decrease of 20% were accounted for by a combination of different fuel usage, warmer operation temperatures and operating mode since ambient temperatures were the same. If this is a valid interpretation then the 7% (+/-4%) fuel reduction effect for CO emissions using ethanol-blended fuel is put into context.

With respect to the analysis and interpretation, ignoring measurement methodology issues a number of other observations can be made for the remainder of the report.

Part (ii) of the study is that which suffers from the least methodological problems since emissions from the same engines are directly evaluated with the two fuels of interest. They are occurring at the same location at about the same time with similar operation. This

cannot be the case for the ambient comparison in part (i) of this study. It is interesting to note that the data from this part of the study yield contradictory data to that reported for part (i) of the study, in particular for the 1999 Polaris model testing which has lower CO emissions from the conventional fuel and the 1984 Arctic Cat which has lower HC emissions from the oxygenated fuel. The authors account for this by stating "Method 2, individual snowmobile measurements, is probably not a suitable test for comparison to a fleet of snowmobiles, but is representative of the variability of individual measurements of an individual snowmobile". It may have been useful to analyze the data in terms of measurement pairs, i.e. related the emissions of CO and HC for each evaluated snowmobile in part (i) of this study. This raises another question the authors speak of valid measurements were these one per snowmobile? If not were the number of valid measurements per snowmobile consistent? If not the sample data would be skewed with respect to the representation of the fleet.

For part (iii) of the study it is important to realize that the two snowmobiles while being of the same model may have had different emission characteristics. Each of the engines tested should have used both fuels as per part (ii) of the study. It is not possible therefore to determine if the differences of emissions are due to the different fuel or the different snowmobile. This part of the study could be discounted. Furthermore different drivers were used for each snowmobile. It is interesting to that that the statements of "variability of individual measurements…" are not made here as they are by the authors for part (ii). As the authors state "an apparent ethanol effect is present for CO emissions". A cynical person may see this statement as being present as due to the data matching the main hypothesis of the study.

The authors make two main conclusions with respect to the issue of concern. First, emissions of CO from snowmobiles are reduced with ethanol-blended fuel compared to conventional gasoline. It could be argued that the authors have used the CO data in an appropriate fashion for the conclusion of an obvious ethanol-blended fuel effect. According to their own data error bars this difference could be as low as 3%. For the type of study with the intrinsic variability involved both controllable (measurement and analysis methodology) and uncontrollable (environmental) this is really a meaningless number.

Second that HC emissions from snowmobiles are about 60 times those from automobiles. This value is a reasonable estimation given the large amount of information on automobile emissions and the similarity of reported values in this study for other emission rates of HC from snowmobiles. Given the methodological issues noted the conclusion is valid given the large degree of difference. Even if the snowmobile data were 100% too high the difference would still be a factor of thirty higher for the snowmobile compared to automobile HC emission.

It is important to note that the calculated emission of CO and HC from this study are broadly comparable to that generated from the laboratory. Combined with the laboratory data this report does yield good information for the calculation of a broad emission factors for use in emission inventories. This would be for the category "Snowmobile". This would ignore the differences due to fuel, temperature, operating mode or where measured.

While this study has methodological problems emission inventories are designed to use all information to determine factors that are always open to revision and adjustment. This is traditionally of great importance to policy makers who need to understand air pollution problems with respect to measured representative ambient air concentrations and total emission inventories.

Carroll, J.N and J.J White. 1998. "Emissions from Snowmobile Engines using Bio-Based Fuels and Lubricants." Southwest Research Institute. San Antonio, TX.

Summary

This study measured pollutant emissions from Polaris and Arctic Cat snowmobile engines. The Polaris engine was representative of a fan-cooled engine whereas the Arctic Cat engine was representative of a liquid-cooled engine. These engines are considered by the authors to be representative of snowmobile engines used in Yellowstone National Park (YNP). During 1995 and 1996, these engines accounted for approximately 80% of the 1,400 snowmobile fleet of West Yellowstone, Montana. Engines were new and broken in according to manufacturer's instructions.

Testing was undertaken in the laboratory. Different dynamometers were used to regulate the two engines. The dynamometer used for the Polaris tests had less control of test variables than that used for the Arctic Cat tests. Emissions were measured using a five mode steady state snowmobile engine test cycle. The authors compared emissions from a matrix of different fuel and lubricant combinations. The fuels tested were a reference conventional gasoline, gasohol (90% gasoline mixed with 10% ethanol) and an aliphatic gasoline. The lubricants tested were a biosynthetic lubricant, a synthetic lubricant, a high polyisobutylene (PIB) lubricant and a conventional lubricant. A complete matrix of tests was not undertaken.

Eleven tests were undertaken with the Polaris engine. Of the 11 Polaris tests, four were tested with conventional gasoline, five with gasohol and two with the aliphatic fuel. Lubricant tests on the Polaris consisted of three tests with biosynthetic lubricant, one with the synthetic lubricant, one with the PIB lubricant and six with the conventional lubricant. The combination of conventional gasoline and conventional lubricant was tested three times. One of these tests used rich fuel conditions to evaluate the effect of engine set-up. The combination of gasohol and conventional lubricant was tested twice with normal operation. Three of these tests, including the gasohol and conventional lubricant combination, were run back to back with evaluation of only one of five modes of the test cycle used in other tests.

Three tests were undertaken with the Arctic Cat engine. The combination of conventional gasoline fuel and conventional lubricant was tested twice. For the third test gasohol was as the fuel with the conventional lubricant again used.

The emission rates of pollutants, including total hydrocarbons (THC), carbon monoxide (CO), sulfur dioxide (SO_2), oxides of nitrogen (NOx), particulate matter (PM), speciated hydrocarbons (SHC), speciated polycyclic aromatic hydrocarbons (PAH) and ammonia (NH_3) were measured. In general terms, the emission rates of THC, CO, PM, SHC and PAH were reported as high whereas those of NOx were reported as low. The categories of high and low are given by comparison to 4-stroke engines. Emission rate differences are expected from a two-stroke engine. Emissions of hazardous air pollutant (HPA) species were reported being in similar proportions to that of 4-stroke engines; however, the emission rate is higher for snowmobiles considering the size of engines compared.

Oxygenated fuels such as gasohol are associated with reduced emissions of CO. Since the introduction of oxygenated fuels, a reduction of approximately 24% was reported for ambient CO levels in Missoula, Montana. Gasohol was reported as producing the lowest emissions for the fan cooled engine when considering THC, CO and PM, with reductions of 16, 9 and 24% respectively, compared to conventional gasoline operation.

The liquid cooled engine emissions exhibited less than a 6% difference. Emissions using oxygenated fuel may be reduced by enleanment due to the extra oxygen in the fuel. Engine modification could produce similar effects.

The aliphatic gasoline produced the highest THC and 1,3-butadiene emissions and the lowest benzene and ozone formation potential of the tested fuels.

Gasohol was adopted as the preferred fuel for the Yellowstone area. The authors state that snowmobile operators reported excellent service with this fuel with no loss of performance and less engine maintenance. Furthermore, no fuel freeze-ups were reported.

Since lubricant is combusted with the fuel, the lubricant will contribute to engine emissions. An aerosol of unburned lubricant would be expected to be the main source of PM emissions. Lubricants would also contribute to exhaust emissions of volatile and particulate phase hydrocarbons. The PIB lubricant produced significantly lower emissions of PM than the other tested lubricants. Unfortunately, the PIB lubricant is not biodegradable. The biosynthetic lubricant was reported to produce approximately a 60 to 70% increase in emissions of PM compared to operation with the conventional lubricant. This was thought to be due to the composition of the biosynthetic lubricant that had enhanced “front end” volatility.

The importance of engine type and engine set-up were noted by the authors. The emissions of PM from the liquid-cooled engine were reported to be double those of the fan cooled engine. This was thought to be due to the higher spark plug seat temperatures and by inference cylinder temperatures of the fan cooled engine. The lubricant rate was also noted to be of importance to PM emissions. Appropriate engine tuning for operation in cold elevated conditions was also noted. The emissions of HC, CO and PM were all reported as significantly increased by richer operation from incorrect set-up. The differences between this test and the baseline level were greater than the difference between the baseline condition and the gasohol operation.

Critique

This report failed to use the scientific method in a useful manner and failed to present any meaningful results. The concluding sentence of the executive summary which states, “Results show that moderate reductions in emissions can be achieved in the near future through the use of gasohol and low PM lubricants," is lacking in meaning. In this sentence a definitive statement is made and is not backed up by meaningful analysis and appropriate data. This statement is further “validated” by anecdotal evidence. There doesn't seem to be any consideration of other variables, measurements, data or analysis to back up the authors' statement, “The visible haze associated with snowmobile operation was reportedly reduced compared to the previous winter." The authors seem to use such statements to justify adherence to their own “untested hypotheses” with respect to gasohol use. If gasohol is a better fuel with respect to pollutant reduction, in particular CO, appropriate evaluation is required.

The authors state, “A wide range of emission measurements were made to thoroughly characterize fuel and lubricant effects”. This seems to be an untrue statement. A complete test matrix was not undertaken. Furthermore, analysis of the data given in the appendices reveals information not highlighted by the authors. In the summary section of this report, it was noted that two sets of duplicate runs were undertaken, one set for each engine using conventional fuels and lubricants. Table 1 gives a percentage difference calculation between these runs. For

the Polaris engine this is calculated from “composite data” (modes 1 to 5) given in pages B1 and B5 for emissions in grams per horsepower-hour (g/hp-hr). For the Arctic Cat engine this is calculated from grams per hour data for mode 1 and brake horsepower (BHP) data given in pages B16 and B25 to yield data in g/hp-hr. The emission data for these duplicate tests were compared to yield percentage difference. This was calculated for THC, CO, NOx and PM as follows:

((Test 1 – Test 2) / 100) *100

Table 1 Percentage (%) difference between test 1 and test 2 for the conventional gasoline and conventional lubricant combination for evaluated snowmobile engines.

Parameter	Polaris	Arctic Cat
HC	+24	-10
CO	+12	+1
Nox	+9	-6
PM	+43	-19

Thus, when considering any of the reported results for the Polaris engine one should adopt limits of uncertainty, confidence limits or error bars based on the duplicate data. This would yield, from an average value, the following:

HC +\- 12%
CO +\- 6%
NOx +\- 5%
PM +\- 22%

Given that only two repeat measurements were performed these can be considered as lower limits. However, it is clear that if emission rates from other operation modes are within these ranges, a significant difference is not apparent. While the authors state on page 17, “Engine emissions were not as repeatable as we would have liked” a greater realization of the impact of this lack of repeatability is required. It is highly misleading not to use error analysis, especially when comparing emissions as differences may be due to “test noise." Similar arguments hold for the Arctic Cat data. Table 8 on page 19 reveals that THC and NOx data differences are within the error bars of the duplicate measurements. The executive summary does, however, state percentage differences for all four components given above. All of the differences given in the executive summary are below 10%. It is extremely dubious to state any difference exists. Similar arguments hold for the statements given in the executive summary for the Arctic Cat engine. While differences are greater so are the error bars. It is important to note that no duplicates are given for the gasohol operation. If this had similar “test variability” then the correct interpretation of the data would state that it would not be scientific to state that any difference existed. On page 12 the authors state, “The gasohol results indicate substantial emission benefits may be obtained using oxygenated fuel in snowmobiles." The analysis given above may place a question mark next to this statement. The authors explain the variability in terms of the test procedure with the difficulty of control. This is part of the experimental protocol and should be evaluated as such. The authors also state on page 19, with respect to the variability of the duplicate results, “This may be due to

the type of carburetion employed with these engines, which uses three different circuits to control fuel delivery." Again, this implicates part of the sample variability, which needs to be considered when drawing conclusions. This indicates that a larger sample size was required and that these engines are not “precision engineering."

When comparing the biosynthetic and conventional lubricant, the authors explain the lower emissions of THC and NOx as follows, “… it is unlikely that this was due to a lubricant change. HC and CO reductions were not observable in the gasoline-based comparison for these lubricants, and it is more likely that these emission differences reflect engine drift between tests." This is a case of forcing a one way hypothesis. If engine drift is the cause, a minimum level of error due to drift can be calculate for HC and CO emissions by evening the numbers and calculating the error percentage. Taking data from pages B16 and B25 and using the percentage difference calculation employed above, values of –9% and –3% are obtained for THC and CO, respectively.

While most of the actual measurement techniques are valid it should be noted that the authors believe that trap overloading occurred for measurement of higher molecular weight hydrocarbons and that the analysis was not appropriate. The identification and quantification of speciated C_1 TO C_{12} hydrocarbons and PAH could also be questioned; however, given the lack of analysis this is not of issue.

The analysis of speciated HC, PAH, SO_2 and NH_3 data is limited and firm conclusions cannot be derived from the data in terms of comparison. At best, the data would be useful for these parameters as indicators of expected overall emissions for the "snowmobile" category for emission inventories.

The authors state in the executive summary that results show that moderate reductions in emissions can be achieved in the near term through the use of gasohol and low PIB lubricants. The conclusion section adds that while these reductions are significant they are less than would be achieved with advanced engine technologies. This is of importance to the future.

The most valid aspects of this report are the realization of the importance of appropriate engine set-up for cold elevated conditions and the noting of the influence of engine cooling system to PM emissions.

The validity of comparative emissions is questionable for all fuel and lubricant combinations for THC, CO, NOx and PM with the exception of reduced PM emissions with the PIB lubricant.

It is important to note that testing occurred at ambient temperatures far exceeding those experienced in the field. This will be expected to have a non-linear effect on emission characteristics of the measured pollutant emissions. The emission rates reported can therefore be considered as unrepresentative of normal operating conditions. This is analogous to making measurements outside the calibration range of an instrument.

Alger, R., S. Gruenberg and G. Gwalteny. 2000. "Snowmobile Trail Bump Formation Analysis, Prediction, and Modeling." Draft Report for NPS-YNP May 2000. Michigan Technological University. Houghton, MI.

Summary

The primary aims of this work were to devise a methodology to accurately measure bump (mogul) formation, to understand the mechanism of bump formation, to produce a model to predict bump formation and to suggest possible strategies to alleviate the bump problem.

The authors noted that it is inevitable that bumps will form where there are snowmobiles traveling on trails. Approximately 1000 vehicles enter Yellowstone National Park (YNP) each day at the West Entrance. Many of these vehicles travel to Old Faithful. This trail rapidly "bumps up" within an hour of the start of the peak flow out to this location in the morning. Indeed the vehicle flow patterns at this site are analogous to those of city traffic flows with morning and late afternoon peaks. During the 7 a.m. to 11 a.m. morning peak hours at West Yellowstone, over 90% of vehicles travel on the outward lane. The evening peak is less distinct and occurs between 1 and 6pm. The authors noted the importance of the traffic flow profiles during the day for snowmobile movement along the trails.

Bump and vehicle flow measurements were made at a variety of locations under different weather conditions. These measurements are used for the model generation. Corners, hills and intersections were noted as locations where bumps are more likely to form. However vehicle flows were viewed as a more important factor.

The authors note that the situation is complicated by the fact that two different main categories of vehicles travel on the trails, namely snowmobiles and snow coaches. These categories will have inherent differences between and within them. There are many different models of snowmobiles and three main types of snow coaches. The types of vehicles are important, as a first step to understanding bump formation is to determine how snow moves on the surface as a vehicle moves forward. The authors report that the two main categories deteriorate the trail differently. While snowmobile trafficked areas are associated with bumps those of snow coaches appear different. The authors report that while the snow was loosened and the trail rutted it was much smoother with respect to bumps. The ruts ran parallel with the trail. The trail characteristics noted may, however, be controlled to some extent by low vehicle flow volume, which is apparent for snow coaches.

The authors measured the effect of vehicle movement by placing a line of ash on the trail. The movement of this ash was observed. This movement was thought to be representative of snow movement. Measurements were made at the top of bumps and at the bottom of troughs. On the bumps the majority of ash was moved forward in the direction of travel. In the troughs, while movement of ash was predominately forward, reverse movement was also observed.

The authors attempted to gain an understanding of the importance of other variables, in particular weather related issues, with respect to bump formation. Variables including snow and air temperature, wind, free water content, precipitation amount, precipitation type, snow wetness, snow strength, amount of new snow and solar radiation were considered.

The authors aimed to determine how fast bumps formed and how many vehicles traveling on a trail caused this formation of bumps. The authors report that the bumps formed

rapidly under all weather conditions tested. The trail was found to become rough after only "a limited number of passages". This problem was accelerated by warm weather.

The study noted the importance of snowmobile suspension to the formation bumps and ease of traveling over them.

Furthermore, the authors noted that grooming is of prime importance to the trail smoothness. An important finding was that bumps formed in the same locations over the testing period despite daily grooming. It can therefore be inferred that current grooming practices are not working effectively and improved methods are probably the key to alleviating the problem of bump formation. The authors state, "This justifies the thought that current grooming practice does not cut deep enough to eliminate the signature of old bumps".

Critique

The authors have developed a "state of the art" technique to measure bump formation. This enables the generation of a vast amount of data. Furthermore the techniques enabled more realistic assessment than previously possible. The report is preliminary and much of this data is still under analysis, in particular with respect to the model formation of bump development. The authors are considering variables including weather factors, traffic volume and behavior, vehicle types and grooming procedures. These are the key factors.

Despite the preliminary nature of the report and the lack of quantified analysis many important issues are addressed in the preliminary report. Bumps will form with the high traffic flows at YNP. Procedures are not yet in place to control this problem whether related to usage patterns or grooming activities.

There are no fundamental flaws that can be identified from the analysis and interpretation of the preliminary report.

U.S. Department of the Interior U.S. Geological Survey. 1998. "Effects of Snowmobile Use on Snowpack Chemistry in Yellowstone National Park." Water Resources Investigations Report 99-4148 (18a).

Summary

The authors focus their attention on the potential influence of emissions from snowmobiles entering sensitive watersheds and animal habitats.

The current study is performed in addition to the monitoring of atmospheric deposition for between 50 and 60 sites in the Rocky Mountain Region performed by the United States Geological Survey and United States Forest Service. Some of these sites are located in Yellowstone National Park (YNP). This data indicated a positive correlation between snowmobile use and the concentrations of ammonium and sulfate. This study aimed to provide more data for YNP.

Measurements of ammonium, sulfate, nitrate, benzene, toluene, xylenes and a number of other major inorganic ions, including calcium, magnesium, sodium and chloride were performed for the collected samples. Sampling was undertaken during March 1998.

In this study, snowpack samples were collected from a range of locations that reflected different amounts of snowmobile use. In addition sample pairs were taken with one site located directly at the snow packed roadway and the other located at an off-road site between 50m and 100m away from the first site. This was undertaken to determine the dispersion of pollutants from the on road sites.

The authors note that in areas with the greatest snowmobile use, elevated levels of by-products of gasoline combustion such as ammonium and benzene have been detected in snowpack samples. The authors report that there was a positive correlation between snowmobile use and the level of most of the parameters measured. The weak correlation of ammonium and sulfate concentrations ($r^2 = 0.12$) in the Rocky Mountain region increases ($r^2 = 0.56$) when areas of high snowmobile use are compared.

In areas of high snowmobile use, most of the major inorganic ion analyses showed higher concentrations, particularly ammonium and sulfate. The highest concentrations were reported at the West Entrance and Old Faithful sites. Similar distributions were apparent for the measured hydrocarbons. At the West Yellowstone site, the authors note slower speeds and a considerable amount of acceleration and deceleration for the large number of snowmobiles present at this site. Lower traffic volumes move much more smoothly and faster at the South and East Entrance sites.

Nitrate concentrations were reported to be minimally affected by snowmobiles and probably reflect regional deposition climate.

For the paired sampling the authors report that concentrations of the measured parameters decreased rapidly with distance from the roadway. This indicates that watershed-scale effects from winter traffic are unlikely. The range of in-road measurements for ammonium and sulfate were approximately 3 to 4 times higher than those reported for off-road (less than 50m away). A similar but more pronounced effect was apparent for the measurement of hydrocarbons. For benzene, in-road measurements of between 37 ng/L and 1820 ng/L compared to values of less than 10 ng/L for the off-road samples. High blank values of approximately 1500 ng/L were reported on two occasions for toluene.

Preliminary sampling of snowmelt runoff was undertaken. This sampling aimed to assess the impact of pollutants contained within the snowpack on local surface water quality. For the measured hydrocarbons, the authors believe that these species readily mix with the atmosphere once in solution and tend to volatilize into the gaseous phase as they enter the atmosphere. Indeed, the deposition of hydrocarbons is reported elsewhere to be a process that can be viewed as an intermediate step with re-volatilization resulting in further transport.

The authors report that contamination from snowmobiles for the inorganic parameters is restricted to at least within 50m of highway corridors. The authors note that the hydrocarbon concentrations are low in the snowmelt at Yellowstone compared to a variety of locations in the United States. Drinking water standards far exceed the levels reported for snowmelts in Yellowstone.

The authors make three main conclusions. First, that enhanced levels of ammonium, sulfate, benzene, toluene and xylenes were evident at sites with high levels of snowmobile traffic. Second, that excluding the West Entrance and Old Faithful sites snowmobile use is not thought to be substantially affecting atmospheric deposition of the measured parameters. Third, that snowmelt runoff appears to be at levels that do not threaten human or ecosystem health. However, the authors do note the possibility of localized episodic acidification at areas with high levels of snowmobile traffic.

Critique

The authors have produced a well written report, which tackles the issue of atmospheric deposition of emissions from snowmobiles. The authors draw on a wide background data base which gives extra credence to the analysis of the new data from Yellowstone National Park.

While toluene data should be discounted due to the potential influence of contamination in the measurement methodology, the rest of the data was collected and analyzed in an appropriate manner.

There are no fundamental flaws that can be identified from the analysis and interpretation of the report. The main conclusions given by the authors are supported by the reported data. Enhanced levels of ammonium, sulfate, benzene, toluene and xylenes were evident at sites with high levels of snowmobile traffic. Excluding the West Entrance and Old Faithful sites, snowmobile use is not thought to be substantially affecting atmospheric deposition of the measured parameters. Snowmelt runoff appears to be at levels that do not threaten human or ecosystem health.

SECTION C: SOCIO-ECONOMICS

Reports Reviewed:

Socio-Demographic Use Pattern Analysis

Page 48

Freimund, Wayne A. 1996. "Examining Indicators of Quality Winter Use in Yellowstone National Park." University of Montana, Missoula, MT.

Pages 49-55

Borrie, William T., Wayne A. Freimund, Mae A. Davenport, Robert E. Manning, William A. Valliere, and Ben Wang. 1999. "Winter Visit and Visitor Characteristics of Yellowstone National Park: Final Report 1999." University of Montana, Missoula, MT.

Borrie, William T., Wayne Freimund, Robert Manning, and Ben Wang. "Social Conditions for Winter Use in Yellowstone National Park: Final Report on Phase Two Contract #CA 1268-0-0623." University of Montana, Missoula, MT.

Pages 56-59

Littlejohn, Margaret. 1996. "Grand Teton National Park Visitor Study." Visitor Services Project Report 74. Cooperative Park Studies Unit. University of Idaho. Moscow, ID.

Littlejohn, Margaret. 1996. "Yellowstone National Park Visitor Study." Visitor Services Project Report 75. Cooperative Park Studies Unit. University of Idaho. Moscow, ID.

Pages 60-62

Davenport, Mae A. 1999. "Yellowstone National Park Winter Visitor Stories: An Exploration of The Nature of Recreation Experiences and Visitor Perceptions of Management Culture." Master's Thesis. University of Montana, Missoula, MT.

Economic Data Analysis

Pages 63-82

Duffield, John W. and Christopher J. Neher. 2000. "Final Report: Winter 1998-99 Visitor Survey Yellowstone N.P., Grand Teton N.P., and the Greater Yellowstone Area." Bioeconomics, Inc., Missoula, MT.

Duffield, John W., David Patterson, and Christopher J. Neher. 1999. "Final Report: Yellowstone National Park Visitor Survey Summer 1999." Bioeconomics, Inc., Missoula, MT.

Duffield, John W., David Patterson, and Christopher J. Neher. 2000. "Final Report: National Telephone Survey of Attitudes Toward Management of Yellowstone National Park." Bioeconomics, Inc., Missoula, MT.

Executive Summary: Socio-Economic Studies Pertaining to Yellowstone National Park

The studies reviewed here fall into two broad categories: socio-demographic use pattern analysis and economic data analysis. Several sets of related reports are reviewed together. In these instances each set of reports was conducted by the same researcher or team of researchers, and most were sub-sections of larger research projects. This is the case with the reports by Duffield et al, Borrie et al, and Littlejohn. In each instance, these reports have been assigned a number for the section and are referred to in the review by that number (e.g., "Report 1," "Report 2," and so on); major findings of the reports follow the combined reviews in the form of addenda. The Davenport thesis (1999) is, to some extent, in a category by itself, since its purpose is to gain qualitative data on why people use the national parks in question.

In general, it is the estimation of the reviewers here that the reports are methodologically sound. Specific problems with methodologies are addressed in the summaries and/or the critiques of each report. Since it is not the purpose of the reports reviewed here to arrive at conclusions per se, but rather to analyze and present the data collected in the respective investigations, critique is largely centered on validity of data based on the means of attaining those quantitative results (i.e., methodology).

The reports provide useful and relevant baseline data for those concerned with the management of the national parks of the Greater Yellowstone Area. They also provide some indication of what socio-economic aspects of park use might be appropriate themes for more specific and in-depth study in the future, particularly for the development of management options.

Freimund, Wayne A. 1996. "Examining Indicators of Quality Winter Use in Yellowstone National Park." University of Montana. Missoula, MT.

Summary

The National Park Service was required to initiate a Visitor Use Management (VUM) Plan when visitation exceeded a threshold determined in the 1990 Winter Use Plan and Environmental Assessment. In response to this mandate the authors of this report were invited to evaluate visitor conditions in the YNP to help develop policies and procedures for the VUM. The methodology consisted of evaluating previous studies, a "windshield survey" related to congestion, informal interviews, and personal observations.

The authors conclude that apparent use levels are high enough to have negative effects on the park's users. In particular, snow quality and sound conflicts are the primary problem. YNP needs to assess the degree to which snowmobilers would be able to make changes that would increase the ability of other users to have a positive non-motorized experience. The authors recommend that studies be done to define what kinds of standards would be acceptable to users to assist in providing a broad range of experiences for visitors to YNP.

Major Findings

- Researchers encountered over 450 snowmobiles during a 30-minute period in the 15-mile stretch between Madison and the West Entrance.
- Congestion problems were apparent.
- Speeding problems were not documented, though suspected.
- Researchers witnessed several wildlife harassment events (not elaborated or defined).
- Skiers appear to dislike snowmobiles' noise, pollution, and encroachment.
- Behavior problems with snowmobilers were documented.
- Encounters with snowmobiles detract from other visitors' experience.

Critique

While the study revealed some interesting ideas, it was not an empirical piece. Conclusions drawn were based mostly upon personal observation and thus susceptible to the authors' biases. The observational nature of the study indicates a need for further research. Claims about congestion detracting from snowmobiler's experiences were not validated and, based upon other studies[2], may be questionable. The windshield survey that measured the number of snowmobilers passing during the 30-minute survey period does not qualify assertions concerning other times of day. Clearly, there may be a problem with visitor experience conflicts, but the extent of the problem needs more systematic analysis. For example, statements by the authors that snowmobiler/skier conflicts range from health to behavior of snowmobilers exclude a possible simpler reason: Skiers often do not like snowmobiles. Ultimately, however, the authors do point to the need for more in-depth studies, especially to develop criteria that can be used to manage the two groups with minimal conflicts.

[2] Borrie, William T., Wayne A. Freimund, Mae A. Davenport, Robert E. Manning, William A. Valliere, and Ben Wang. 1999. "Winter Visit and Visitor Characteristics of Yellowstone National Park: Final Report." University of Montana, Missoula, MT.

<u>Report 1</u>: Borrie, William T., Wayne A. Freimund, Mae A. Davenport, Robert E. Manning, William A. Valliere, and Ben Wang. 1999. "Winter Visit and Visitor Characteristics of Yellowstone National Park: Final Report 1999." University of Montana, Missoula, MT.

<u>Report 2</u>: Borrie, William T., Wayne Freimund, Robert Manning, and Ben Wang. "Social Conditions for Winter Use in Yellowstone National Park: Final Report on Phase Two Contract #CA 1268-0-0623." University of Montana, Missoula, MT.

Report 1 is part of a larger body of research, a project titled, "The Yellowstone National Park Winter Use Project." The project consists of three parts: Phase I, initiated in the 1996-1997 winter season, which was a preliminary assessment of indicator importance and data collection for travel pattern modeling; Phase II, consisting of research conducted in the winter season 1997-1998, which is reviewed here under the rubric of Report 2; and, Phase III, consisting of data collected during the 1998-1999 which was under analysis at the time the report for Phase II was published.

Report 2 (Phase II of the research) provides a detailed investigation of winter visitors to Yellowstone and modeling of their travel patterns. Overall, the strength of the report is in the demographic information collected and in information collected on how respondents access and travel within the park. The travel pattern model, when considered alone and not in combination with data from motivational clusters, also provides good information about winter visitors and their activities in the park

Summary of Reports 1 and 2

The goal of this research project was to gain information about Yellowstone National Park (YNP) winter visitors' experience, values, motivations, and management action support, as snowmobile use, including air pollution, is impacting the public's use and enjoyment of Yellowstone. The data indicate how park users feel about noise, crowding, and the aesthetic impacts associated with high levels of snowmobile use, and they measure public opinion about potential management changes to control pollution.

Four questions are addressed which are the primary focus and organization of the study:

- Who are the visitors to YNP and why did they visit?
- What are the characteristics of the winter visit and how do visitors travel within the park?
- What are the visitor evaluations of current social conditions?
- Are potential management actions consistent with desired expectations?

Data were gathered for the study in three ways: through a mail-back questionnaire, an on-site survey, and via hourly traffic counts. The mail-back questionnaire was distributed to 1505 winter visitors. Visitors were selected from 1818 contacted proportionately across the four entrance stations on thirteen random days during January, February and March of 1998. This resulted in a 71% response rate of 1064 questionnaires. The on-site survey was conducted at two sites in the park. It was administered to 208 visitors on nine random days within the same time period used for contacting visitors for the mail-back survey. On-site hourly traffic counts were collected at two interior sites of the Park on groomed roadways and at the four entrances.

In order to gauge the specific reasons why visitors came to Yellowstone, respondents were asked to rate what motivated them to come to the park and how satisfying the experience was with respect to that motivational factor. Respondents rated each motivational item on a one to five scale and indicated their satisfaction with the item, also with a one to five rating. Examples of items include: enjoy natural scenery, have fun, snowmobile or ski in wild/natural setting, learn more about nature, see Old Faithful, and help reduce tension.

There were over forty motive items included in the survey. In an effort to pare them down and elicit any patterns, they were analyzed to reveal whether a simpler underlying structure could represent motives. The authors used cluster analysis to group variables. Details of the procedure were not included, but typically one first clusters variables to create a new variable, and then clusters respondents to group respondents. It must be assumed that the authors did something similar.

The results of the paring down are six "factor summaries" representing visitors' motivations: self-help and reflection; learning about nature; solitude, peace and quiet; thrills and spills; skills and fitness; and family and friends. Details of who fit into which group (based on recreation preferences and demographics), which entrance each group used, and the numbers of each group who snowmobiled are provided in the report. The link between motivation and satisfaction is addressed as well.

The second part of the paper involved computer simulation modeling of travel patterns at Yellowstone National Park. Methods used for gathering inputs, model construction, outputs and validity testing of the model are described in good detail. Indicator variables targeted in the model are vehicles-per-viewscape (VPV), encounters, and counts. VPV is measured in minutes per hour, but it is not clearly indicated what is being measured. Encounters are not explicitly defined but seem to be simply when one visitor or party meets another. Counts indicate the number of vehicles that pass an average spot in the specified zone.

Indicators were calculated for three total daily use levels, 1200, 1600 and 3200. Units are not indicated. Average conditions were calculated for three different zones: the whole road system, the West Entrance to Old Faithful and Hayden Valley Road. Results were then divided into three time periods, 8am to 11am, 11am to 2pm, and 2pm to 5pm.

Model validation was accomplished by checking model outputs against empirical data. Comparisons are presented graphically for "exits by entrance", "east entrance exits", "entrance exits" and "Mammoth Exits". The paper reports Chi-square tests that showed, "encouraging results for comparisons of exit frequencies through the day at South and East Entrances and also for comparisons of vehicle frequencies at a point south of Madison Junction." The tests provided no evidence that the model output was significantly different from field count data, though the authors state that the validation tests had mixed results. However, tests for comparisons of exit frequencies through time at mammoth and West Entrances and for comparisons of distribution of exits across the exits gave results suggesting the model may be "significantly different from field counts." The conclusion reached in the report is that the statistical tests provide "some confidence that the model output is a good general estimation of actual snow vehicle use."

The paper also presented research on respondent attitudes to encounters with other users (encounter norms). Respondents were asked to measure conditions of 0 to 50 snowmobiles per hour as unacceptable to acceptable on a -4 to + 4 scale. Encounter norms data were also analyzed in terms of acceptability vs. number of encounters expected and in terms of acceptability by motivational cluster. Encounters norms were further analyzed in chart form

by looking at meeting and overtaking encounters by motivational cluster; and meeting and overtaking encounters by expectation. These results were presented in a tabular format.

Encounter acceptability was also considered in terms of viewscape. Responses were based on four scenarios linked to computer-manipulated photographs, which graphically demonstrated use for each scenario. Respondents were asked which scenario represented the highest level of winter snowmobile use the NPS should allow with the option that none of the scenarios represented that condition. Results are presented as acceptability vs. scenario, acceptability vs. scenario by cluster, acceptability vs. scenario by expectation and as the number and percentage of respondents who said that scenario represents the highest use the NPS should allow.

Respondents were asked what they would do if the route to Hayden Valley were closed to snow vehicles, in order to gauge visitors' responses to potential management actions. They were also asked what were the most rewarding places and highlights of respondents. Lastly, respondents were asked to express their support for different potential management initiatives on a scale of one to five. Responses to all initiatives and just those initiatives meant to protect the bison herd are presented in separate tables. Differences in responses were looked at in terms of motivation clusters and by entrance used. Management initiatives for protection of the bison herd in terms of motivation clusters were also looked at.

Reports 1 and 2 Conclusions

Conclusions presented in the paper, as put forth in the executive summary, addressed the four questions posited by the report. The question, "Who are the winter visitors to YNP?" was answered with demographic information specifying averages and ranges of the data collected. According to the report, this demographic information compares closely with previous studies of winter visitors to Yellowstone.

Next in the executive summary is the answer to the question, "How do winter visitors access and travel within the park?" In terms of entrance stations, 60% of visitors come through West Yellowstone; 19% come through the south entrance; 16% through the north entrance and a mere 5% enter through the eastern portal. In a very telling statistic, the authors put forth that 70% of winter visitors use a snowmobile in the park. Six percent use a car, 7% use a snowcoach and 3% ski. The remaining 14% engage in some combination of those activities. Also cited are numbers indicating the percentage of snowmobilers who rented snowmobiles near each entrance station; where people stayed; how long people stayed; and if they recreated in areas other than Yellowstone National Park during their trip and how long.

The report states that the park is generally regarded as a place for scenic beauty, as a wildlife sanctuary and as a place for protection of fish and wildlife. And the report states that although "there is not a 'general' audience to Yellowstone survey respondents indicated personal benefit and reflection, learning about nature, solitude and peace quiet, thrills, skill and fitness building, and time to spend with family and friends as draws to the park." Based on these categories, Borrie et al combine visitors into the four clusters (personal growth, nature study, quiet activity, or "no highly defined outcome" or "accidental" tourists). They state that demographic variables are similar for the four clusters. The survey did pick up differences in cluster membership when viewed across entrances and activities. The "quiet activity" group represented over 50% of the visitors using the north entrance (skiers dominate this group). And, importantly, irrespective of motivation, the survey indicated most respondents were satisfied with their visit.

The question on visitor travel patterns and perceived social conditions was based on travel pattern modeling. The data from this study validated a winter use travel pattern model of Yellowstone developed in 1998. The summary states visitors perceive current traffic conditions to be acceptable and would not become unacceptable until use levels tripled. How expectations and clusters influence respondents' perceptions of encounters with other visitors are other topics discussed. Visitors expecting more encounters were more tolerant of those encounters; those who were expecting a more solitary experience were less tolerant of encounter. As could be expected, encounter tolerance varied by motivation group. The quiet group was least tolerant of encounters and the accidental group was most tolerant of encountering other visitors. This portion of the summary ends with a brief discussion of the results of questions pertaining to the potential closure of Hayden Valley.

Regarding what type of management winter visitors would support, most visitors support requiring strict but reasonable emission and noise standards on snowmobiles. Visitors also support management actions that are "relatively unobtrusive." Examples include providing more information on appropriate and expected behavior, snow conditions, points of interest and of things to do outside the park. Respondents also support more aggressive enforcement of speeding and safety violations, "they are generally willing to see sanctions placed on violators of the park rules and values." Also addressed are respondents preferences on increasing/decreasing facilities in the park, increasing trail grooming, closing roads, requiring visitors to watch a 30 minute video that would improve conditions for bison, wait (up to an hour) to travel, travel at particular times of day or during the week, travel in a shortened season, obtain a permit, and limit group sizes.

Critique of Reports 1 and 2

Strengths of the study include the statistics on demographics, winter access and travel within and around the park. The statistics are based on solid research, are well presented, and can serve as the basis for further research, policy, or decision making.

The paper falters in its attempts to classify why respondents visit Yellowstone. The transition between six factor summaries of motive scores (page 29) and the four motivational clusters, although explained statistically, is poorly explained qualitatively. It would have been more informative to have respondents indicate a primary reason, if any, for which they had made their trip to Yellowstone. Furthermore, if the "snowmobile or ski in wild/natural setting" were broken into two choices (snowmobile or ski) a better idea of what percentage of visitors came to Yellowstone for what type of recreation could be gauged. The reason for making this distinction is not to test whether snowmobilers are the dominant user--that is already well known--it is to evaluate potential selection bias in choosing the sample.

The report also suffers from the mundane but important problem of not defining terms and units. In the data presentation section of the report, vehicles-per-viewscape (VPV) is not defined. There are no units to correspond with the total daily use levels of 1200, 1600, 3200. Are these the number of snowmobiles, visitors, or groups? Nor are encounters explicitly defined.

This lack of definitions is the primary drawback to the travel pattern modeling section of the report. If one can decipher the terms and discount analysis done with motivational clusters there is some valuable information that can be gleaned from the modeling efforts.

The authors state that this effort is a pilot project and the results should be taken with caution due to the small number of respondents. The modeling framework is interesting, but it

is unclear how the model really helps a manager with decision-making; moreover, validation is not well reported. For the most part responses to questions related to congestion issues were not conclusive. This could be partly due to the way questions were asked, for example:

"The percentage of time you experienced noise from vehicles not in your group":

Very unimportant to very important

Given this question format, it is difficult to assess whether individuals were responding to a hypothetical question or the conditions they were experiencing at the moment. Also the scale does not distinguish between "important" in a positive way or "important" in a negative way. It is hard to know what policy recommendations should come from the responses.

Some of the conclusions are not well substantiated. With respect to questions about user encounters and pollution, the overwhelming majority picked neither important nor unimportant, and a small number picked the extremes.

Overall, the report offers good demographic information and information pertaining to respondents' visits to both Yellowstone National Park and the surrounding area. Moving to a policy arena, however, the report does not offer much insight directly related to snowmobiling.

ADDENDUM: MAJOR FINDINGS OF REPORTS 1 AND 2 (Borrie et al, "Winter Visit," 2000; and Borrie et al, "Social Conditions," 2000)

The major findings of the demographic and user preference analysis portion provide a profile of snowmobilers that is very similar to other studies. The following points were taken from the demographic and visitor preference analysis:

- 63% of respondents were male
- Average age was 45 with a unimodal distribution
- 51% had some college or were college graduates
- 59% lived in a small city
- 70% lived in a community with a population of 5,000 or more.
- The average income level fell between $60,000 to $79,999 with a second bimodal node between $100,000 and $200,000
- 83% were family group visits
- 60% entered through the West entrance
- Over 71% of respondents were snowmobilers
- Over 70% rented snowmobiles at the North, West, South entrance
- 84% stayed in the vicinity of YNP
- 41% of respondents who recreated outside of YNP did so for more than two days

Other Findings

- The cluster analysis came up with groups remarkably close to the groupings done by another study on snowmobiles for all Wyoming residents[3] that used a similar methodology. There were some minor differences, but other categories were very similar. Cluster analysis started with six factor groupings:
    - Factor 1 Self –help and personal reflection
    - Factor 2 Learning and nature
    - Factor 3 Solitude, Peace, and Quiet
    - Factor 4 Thrills and Spills
    - Factor 5 Skills and Fitness

[3] See May, Juleit A, David T. Taylor, Christopher Bastian, and Glen D. Whipple. "Economic Benefits of Snowmobiling to Wyoming Residents". A report submitted to the Wyoming Department of Commerce, Division of State Parks and Historic Sites. 1997.

- Factor 6 Family and Friends

From this group of general motives the following clusters or motives were developed:

- Personal Growth motives – primarily self-help and reflection motives
- Nature Study
- Quiet Activity – tranquility, get away fro the crowds, etc.
- Accidentals (miscellaneous grouping – no social psychological motives dominated the group)

- Respondents rated "Meeting Encounters" as less problematic than "Overtake Encounters" – people passing them going the same direction.
- Quiet and skill and fitness seekers were less tolerant of higher levels of encounters than other visitors, while the "accidental group" was more tolerant.
- Importance of the percentage of time in sight of other vehicles: 32% unimportant, 40% important, 29% neither
- Importance of the sound of other vehicles: 35% unimportant, 29% important, 36% neither
- Most respondents did not want YNP to change policies.
- Winter visitors are supportive of management plans that would facilitate or improve the experiences they are currently afforded.
- Strong disapproval to plowing of the road to Old Faithful

Report 1: Littlejohn, Margaret. 1996. "Grand Teton National Park Visitor Study." Visitor Services Project Report 74. Cooperative Park Studies Unit. University of Idaho.

Report 2: Littlejohn, Margaret. 1996. "Yellowstone National Park Visitor Study." Visitor Services Project Report 75. Cooperative Park Studies Unit. University of Idaho.

Summary of Reports 1 and 2

Reports 1 and 2, produced by the National Park Service Cooperative Park Studies Unit at the University of Idaho, are surveys of winter visitors to Grand Teton National Park (GTNP) and Yellowstone National Park (YNP), respectively. Both were conducted in February of 1995. The surveys gathered data on visitors' trips, demographics, information and services used, preferences on park qualities and activities, expenditures, and planning for the park's future.

Both reports begin with a summary of results, providing statistics on the number of respondents, where they entered, and group size, origin, and characteristics. Both are divided into four main sections: methods, visitor results, menu for analysis (designed to assist managers in requesting additional analysis), and a copy of the questionnaire. Report 2 divides survey responses into four categories based on activities (cross-country skiing, snowcoach use, driving for pleasure, and snowmobiling). Curiously, this division of responses by activity is not touched upon in the body of the report. Nevertheless, good information is provided on group size, expenditures, and preferences for limiting winter visitation by activity group.

The respective methods sections provide details of questionnaire design and administration, including where sampling took place, when sampling took place, format details, and procedures that were followed during the administration of the survey. A general overview of data analysis is also provided. Limitations of the surveys are discussed, including the following issues:

- It is not possible to know whether visitor responses reflect actual behavior. This disadvantage applies to all such studies and is reduced by having visitors fill out the questionnaire soon after they visit the park.
- The data reflect visitor use patterns of visitors to the selected sites during the study period of February 11-20, 1995. The results do not necessarily apply to visitors during other times of the year.
- Caution should be exercised when interpreting data with a sample size of less than 30, as the results may be unreliable .

With a good attention to detail, two special conditions are mentioned. First, weather conditions in GTNP and YNP at the time the survey was administered are documented. Secondly, it is noted that visitors who entered via Moran and visited both parks are included in each report.

The final presentation in Report 1 shows categories mentioned in visitor comments. Comments were made on how the park could be improved as well as what visitors liked or did not like about their visit. The most frequent comments were that people enjoyed their visit, they intend to return, and the park is beautiful. There were numerous responses that touched on more specific items, but more often than not they were only indicated by a handful of people.

In Report 2, the results section shows visitor contact information (numbers of visitors contacted, the percent accepting questions, response rate) and travel characteristics (group types, with guide or not, number of winter visits to Grand Teton and Yellowstone, proportion of visitors originating from different states and countries, length of stay, activities, recreation outside the parks, national park information sources, sites visited, and educational and information services used.)

Critique

Overall, the reports present a great deal of valuable information in a clear and organized manner. Managers or other interested parties may find the report summaries somewhat too focused. They may be advised to look closely at the reports to find information pertinent to their particular interest instead of relying on the summary. Lastly, the "menu for further analysis" in both reports is helpful; it is designed to allow managers and others to request additional data analysis. That could be an extremely useful part of making these and similar reports pertinent to the specific management or individual needs.

ADDENDUM: MAJOR FINDINGS OF VISITOR STUDIES REPORTS 1 AND 2

Major Findings of GTNP Study (Littlejohn, 1996)

User Characteristics/Park Attributes

- 472 persons answered the survey, an 81% response rate.
- Group size averaged about four persons (mostly family/friends).
- Only 15% of respondents were on a guided tour.
- Over half of respondents were repeat visitors.
- Half stayed at least one night.
- Visitor activity categories and respective respondent percentages: view scenery (84%), wildlife viewing (76%), photography (56%), snowmobiling (41%).
- Similar findings with YNP as to source of park information.
- "Important" visitor service categories and respective respondent percentages: restrooms (64%), Visitor Center(54%), information/direction signs (47%), groomed snowmobile routes (38%), ungroomed ski trails (36%).
- "Extremely important" park qualities: scenery, wildlife, clean air, quiet and solitude all exceeded 61%.

Expenditures

- Over 67% spent more than $200 in and outside of parks.
- More expenditures were made outside both parks than inside.

Visitor Use Limits in Winter

- Sixty-three percent responded "no" to limiting winter visitor numbers.
- Options to limit winter use and respective respondent percentages: 58% via reservation system, 40 % daily use limits

Major Findings of YNP Study (Littlejohn, 1996)

Park Attributes

- Visitor services (e.g. restrooms, ranger stations, law enforcement patrol, etc.) were similarly evaluated for use, importance and quality. The most popularly used services were the restrooms and groomed snowmobile routes. Scoring high in terms of quality and importance were ranger stations, overnight lodging, visitor centers and warming huts. The lowest overall scores went to food service. In all cases the majority of respondents indicated each service to be "extremely important."
- Park qualities (scenery, clean air, thermal features etc.) were evaluated for importance. Again, the majority of respondents indicated each park quality to be "extremely important." Park activities (skiing, snowmobiling etc.), and educational opportunities were generally evaluated, but no data is provided for specific activities or opportunities.
- The survey gathered information on visitor preferences in terms of what they liked the most and least. Results show the number of times various categories were indicated in

visitor responses. Results for "likes" also showed a "general impressions" category where the vast majority of respondents indicated that they like wildlife and scenery/beauty.

Visitor Use Limits in Winter

- Opinions were gathered about winter visitor use limits in Yellowstone. Sixty-two percent of visitors favored having no limits on winter use, while 38% favored limits. Of those who favored limitations, 71% preferred a reservation system, 44% favored a "first come first served" system, while 34% suggest other means of limiting visitor use.
- The final section of the survey gathered information on how respondents might like Yellowstone to plan for the future. The specific question was, "If you were planning for the future of Grand Teton and/or Yellowstone National Park, what would you propose?" As with likes and dislikes results show the number of times various categories were indicated in visitor responses. By far the greatest policy change indicated by visitors would be to limit snowmobile use/numbers.

Davenport, Mae A. 1999. "Yellowstone National Park Winter Visitor Stories: An Exploration of The Nature of Recreation Experiences and Visitor Perceptions of Management Culture." Master's Thesis. University of Montana, Missoula, MT.

Summary

This master's thesis by Mae Davenport, is a significant compliment to the body of recreation research conducted in Yellowstone National Park (YNP) and the Greater Yellowstone Area (GYA). Rather than attempting to quantify experiences and preferences, the author takes a qualitative approach and gathers visitor stories. She analyzes the stories and presents them in such a way as to overview thoroughly the diversity of opinions on the controversial and non-controversial aspects of recreation at YNP.

Davenport puts forth and discussed three ideas as the basis for the need for a qualitative study on recreation in Yellowstone: (1) the dual mandate requiring the National Park Service (NPS) to provide for the enjoyment of the people while protecting the resource; (2) the range and complexities of the Yellowstone National Park experience; and (3) the ambiguity and limitations of earlier quantitative research on the Yellowstone experience.

It is important to note that nature of the study is to represent the range of experiences and points of view regarding winter recreation in Yellowstone National Park. The study does not intend to represent all visitors to Yellowstone, but rather, to represent a range of experiences and perceptions visitors have in the winter setting. As such, and it is clearly stated in the report, results are not statically generalizable to other populations. If cited in future research or used in developing policy, this study cannot be used to put forth an artificial plurality of any point of view, but can and should be used to elucidate the sentiment behind the different points of view.

Based on these arguments, as well as some guiding questions and a thorough literature review, Davenport puts forth both goals and objectives for her work:

> The insights that research like the 1998 Winter Use Study gives management are integral, because they tell management who YNP's winter visitors are (demographic information), what they are seeking in the Park, and how visitors might respond to various management actions. Yet what eludes researchers and managers still is an understanding of *why*: understanding why people chose YNP over other winter recreation sites, understanding why winter visitors find wildlife and natural scenery so important to the YNP experience, understanding why visitors prefer different types of winter experiences, and understanding why YNP visitors are or are not supportive of certain management actions. The goal of this study is to explore visitor stories and to understand these whys…

The objectives Davenport puts forth are nonstandard, but firmly support her goals:

> How do we answer "why"? Because recreation experiences are subjective, dynamic and complex, a more holistic and intensive approach is needed. The qualitative research approach adopted here addresses these issues in four ways: perspective, context, range, depth.

The author takes the time to elaborate on this four-faceted approach. Perspective refers to the examination of issues from the visitor perspective with the resulting benefit of bringing the

researcher closer to the visitor experience. Context means that interviews are conducted during the recreational experience. Interviews were conducted on-site at different stages of the recreational experience. The more conventional alternative is to hand out a survey, which is filled out at some later time, thus losing immediate impressions of the experience. By range, the author simply wants to ensure that a range of experiences is represented in the study. And finally, depth is the true strength of Davenport's methodology. It logically results from the qualitative approach, where participants are not merely checking boxes or listing events of an experience. The approach Davenport uses is meant to encourage storytelling and to evoke rich details.

She documents a sound rationale for her approach, methods, and analysis. As a portion of her literature review she provides validation of her method of studying experience through stories. She argues:

> Wiggins (1975) sees strength in studying experiences through narratives, because stories express the interdependence of the objective and subjective world. He believes that "stories present us with gifts," in which we find "symbol, metaphor, image in incarnated speech and action" (p. 18-19). Thus, because these are our aims in studying the YNP winter experience, a narrative or storytelling approach is called for.

In support of her methodology, Davenport provides background on the interviewer's role in her study and theme development, which helps her guide conversations. She also documents her general interview procedure and sampling frame.

She breaks the data analysis of her study into three stages: data organization, interpretation, and theory building. She details and provides support for how her interviews were transcribed, coded, and categorized, and how themes were developed from underlying patterns in the data.

The two sections on results and conclusions are, perhaps, some of the most insightful writing on recreation in the Yellowstone area available. In the results chapter, with the limitations of the data (specifically, that data are not representative of all winter visitors to Yellowstone), she accomplishes her goal of presenting a wide range of ideas about a wide variety of topics relevant to recreation in the area. She offers visitor stories and her own commentary on the following topics:

- Yellowstone National Park's unique winter setting;
- the importance of wildlife in Yellowstone's winter setting, including wildlife abundance and diversity;
- the importance of scenery in Yellowstone's setting, including aesthetic beauty, geological features, and fire affected landscapes;
- the nature of the recreation experience in YNP's winter setting, including the snowmobiling, skiing, and snowcoach touring experiences in Yellowstone;
- perceptions of social conditions with three distinct themes: crowding and visitor use, motorized use, and road conditions;
- interviewee support for management action, including issues of what the park is for (people, animals, or both), environmental degradation (including those who perceive potential problems and those who do not), impacts on visitor experience, and trust in management.

Davenport thoroughly covers the range of ideas that surround recreation in Yellowstone, particularly snowmobiling, snowcoach touring, and cross-country skiing, including the perceived draws and drawbacks of each. She does not shy away from any potential controversies surrounding alternate forms of recreation or alternative management actions.

Report Conclusions

The final chapter of the thesis provides a discussion, which leads up to and provides a detailed explanation behind the report's conclusions. There are a total of four conclusions that are presented as the final word of this last chapter:

- In unique natural settings which offer a diversity of winter recreation opportunities, including snowmobiling, cross-country skiing, and snowcoach touring, the quality of visitor experiences is directly linked to issues of access, freedom, interaction with the environment, relaxation, and escape.
- In protected areas offering motorized and non-motorized winter recreation, visitor perceptions of social conditions are highly influenced by other visitors' behavior, emissions and noise from motorized use, and road conditions. The sheer number of visitors in the area may be less significant than these factors.
- When faced with potential management change, visitors contemplate the validity of this change in terms of four factors: (1) the worthiness of the cause or role of the protected area; (2) visitor awareness of a problem; (3) the potential impacts of the change on visitors' own experience; and (4) trust in management.
- Managers can gain public acceptance of management change by clearly defining their role and mission in managing in the protected area, demonstrating a need for change based on science, exploring the impacts of management change on the visitor experience, and clearly articulating to the public the objectives, impacts, and expected outcomes of management change.

Critique

Davenport's research is a significant compliment to other studies on winter recreation in the Yellowstone area and fills in many gaps left by those other studies. Her methodologies are sound and her qualitative approach provides answers where previous works left only questions. (For example, why respondents to other surveys state in general terms they support wildlife protections, yet fail to follow up on that sentiment with more specific questions on ways to protect wildlife.) This study provides a valuable resource and necessary compliment to other (particularly quantitative) research on winter recreation in the Yellowstone Area. As noted in the report itself and in this review, given the qualitative nature of the research, results should not be generalized as representative of other populations.

Report 1: Duffield, John W. and Christopher J. Neher. 2000. "Final Report: Winter 1998-99 Visitor Survey Yellowstone N.P., Grand Teton N.P., and the Greater Yellowstone Area." Bioeconomics, Inc., Missoula, MT.

Report 2: Duffield, John W., David Patterson, and Christopher J. Neher. 1999. "Final Report: Yellowstone National Park Visitor Survey Summer 1999." Bioeconomics, Inc., Missoula, MT.

Report 3: Duffield, John W., David Patterson, and Christopher J. Neher. 2000. "Final Report: National Telephone Survey of Attitudes Toward Management of Yellowstone National Park." Bioeconomics, Inc., Missoula, MT.

This review examines three related reports, all of which were surveys gathering the public's views on winter park management and wildlife management, including bison management, in Yellowstone National Park (YNP) and the surrounding area. The first two reports survey respective attitudes of winter and summer visitors to YNP; the third is a national telephone survey of attitudes toward management of the park. All three surveys ask general questions about respondents' demographic background and general wildlife values. The winter and summer surveys sought to quantify respondents' willingness to pay (WTP) for one of two potential bison management programs. The winter visitor survey expanded on this by surveying WTP for additional costs for snowmobile rentals, increased total trip costs, increased park entrance fees for road plowing, for an annual ski pass, as well as for bison management alternatives. All three surveys cover the same topics allowing results to be compared across the surveys.

These three documents are a gathering and analysis of economic data. The authors do not draw conclusions, other than to present the findings of the surveys. This review of the reports, then, essentially examines and critiques the methodology used to conduct the surveys; critiques of specific aspects of the reports are included in the summaries; more general critiques follow each summary. Finally, the surveys' major findings are included at the end of the three summaries, in the form of an addendum.

Summary of Report 1: Winter Visitor Survey

The winter visitor survey was broken down into two primary sample groups, (1) visitors of national parks and (2) visitors of national forests and other areas. All results are presented for both groups except where noted. The survey was conducted during three four-day sampling periods from February 2, 1999 to March 2, 1999. National forest visitors were surveyed on these dates as well as during a fourth sampling period from March 11-14, 1999. Details of distribution methods and response rates are provided in the report.

Like the summer survey and national telephone survey, the winter survey had the goals of measuring the experiences, perceptions and attitudes of summertime visitors to Yellowstone National Park. Unlike the other two surveys, which divided respondents into three groups based on their residence, the winter survey, for the portion of the paper on trip expenditures, divided their samples into two subgroups: residents of Idaho, Montana and Wyoming; and nonresidents. This is somewhat confusing because some of the data were reported only for all respondents, some of the data were reported for residents of GYA and nonresidents of GYA, and some of the data were reported for residents of the 3-state area and nonresidents. This

makes comparison between questions difficult, in that significant parts of Wyoming, Montana and Idaho are not in the GYA.

Much like the summer survey, the winter survey was broken into four sections. The first section focused on the characteristics of respondents' trips including expenditures. The second and third sections asked for respondent views on winter management and wildlife management issues. The fourth section presented socioeconomic data on visitors.

The first section addressed respondents' trip characteristics. It presented information on the percent of respondents who visited various national park areas in the Yellowstone area, the main purpose of their trip, they type of group with which they traveled, the length of their trip and the number of people traveling together. Also presented were days of participation in various winter activities (such as cross-country skiing, snowmobiling, and snowboarding), percent of visitors participating in those activities, and the average number of hours of their participation. Activity participation was broken down into percent participating in each activity by each entrance, the average number of hours spent in a national park and the average number of hours spent in national forests and other areas.

Economic data were presented on percentage of visitors through each entrance station, number of overnight stays in each community by entrance station, and expenses incurred on the trip. Expense data were presented in four tables so as to distinguish between resident and nonresident as well as park and forest samples. The tables break down expenses by the geographic area where expenses were incurred. They present information on expenses for the entire trip, for the Greater Yellowstone Area and for the group of states, Montana, Idaho and Wyoming.

The second section of the report asked respondents' opinions on winter use and management within the Greater Yellowstone Area. Responses are presented based on anticipated and estimated changes. Responses to questions of anticipated changes are given in percentage of types of visitors (same types as used in trip expense analysis) who would alter their travel patterns to specific options based on changes in management. Estimated changes in visitation associated with changes in winter management show absolute number of responses and calculated percent changes. Responses, for both anticipated and estimated changes, are presented for the following scenarios:

- If the road from West Yellowstone to Madison to Old Faithful was plowed and open for car/bus travel only (snowmobile trailer parking & rental available in Old Faithful).
- If YNP and Grand Teton National Park (GTNP) were open only to snow coach, skiing and snowshoeing, but not snowmobiles.
- If the roads from Mammoth and West Yellowstone to Madison, and Madison to Old Faithful were closed to all vehicular travel from Nov. 1 to April 30, and other roads groomed for snowmobiles.
- If the road between Colter Bay and YNP's south entrance in GTNP was not plowed, and instead a groomed trail was opened for snowmobiles and snowcoaches.

The last winter management question regarded winter access to Old Faithful. The four sample categories responded to questions on their preference to maintain the existing policy of grooming roads for snowmobiles with various permutations of vehicle and ski access.

Section three of the report gathered respondents' views on park wildlife. They were first asked what wildlife species they saw on their trip, whether the possibility of seeing bison or wolves affected their decision to visit the GYA, and about their knowledge of current policy for management of bison infected with brucellosis. These questions were followed with an

inquiry of visitors' opinions regarding different statements on wildlife and bison management. Responses could range from strongly agree to strongly disagree with an option for "do not know". Overall results are presented as well as results are for the four sample categories.

These wildlife management questions were divided by the surveyors into general and specific policy questions. As in the summer and national telephone surveys, there was one wildlife management question that is was vaguely worded, "It is appropriate to kill bison at park boundaries as necessary to protect domestic livestock?" The question uses the very specific term "kill" in relation to the very vague term "necessary" without providing any specific information. It could be argued that of all the specific policy questions, the results for this question are open to interpretation due to word choice and the structure of the question. A survey, or section of a survey, specific to this issue with more concise questioning and word choice should be conducted.

Visitors' reactions to statements were followed with various Bison management questions. In the first two questions respondents were given a statement and asked to indicate a preferred policy choice. For example, respondents were told, "Grooming the roads into YNP from West Yellowstone and Mammoth Hot Springs for oversnow vehicles provides an easier winter route out of the park for bison." They were then asked to decide among four road closure policy options.

The survey, while still looking at bison management, began to look at willingness to pay (WTP) for different winter activities and management alternatives. WTP in this format is a widely recognized and legitimate means of estimating demand for recreation or policy. Results are presented in tabular format. First, visitors responded if they rented a snowmobile. They were then asked specific WTP questions: if they would be willing to pay more for cleaner and quieter snowmobiles, if they would still visit Yellowstone National Park if total costs increased, if they would pay entrance fees for plowing the road for car and bus travel, if they would be willing to donate to a trust fund to purchase bison habitat (next year scenario), and if they would be willing to donate to a trust fund to purchase bison habitat (10 years scenario). Skiers were asked if they would pay more for an annual pass to support trail grooming in the park. Responses to the WTP questions were broken down into park and forest samples and logistic regressions were used to calculate estimated willingness to pay and standard error.

The last section of the survey was designed to collect demographic data. Data were gathered on number and percentage of visitors to national parks and national forests by state, number of visitors to YNP by country (just the park sample); and other demographic data including gender, ethnicity, race, education level, and income.

Report 1 Conclusions

General conclusions were presented in the executive summary and generally follow the format of the four sections of the report. In addressing characteristics of respondents' trips and their expenditures it was determined that nonresidents spent considerably more than regional residents on their trip:

> On average, nonresidents in the park sample spent $1,129 for the entire trip whereas resident park visitors spent an average of $273 for their trip to the GYA. Expenditures by National forest visitors were similar to those of park visitors with nonresidents spending $1,203 and residents spending an average of $323 per trip.

The second section dealt with respondents' views on winter management issues. Respondents were asked how their plans to visit YNP would change under four winter management scenarios:

- If the road to Old Faithful were plowed, 29.5% of the park sample and 24.2% of the forest sample said they would visit less frequently. Nine percent of park respondents and 6.8% of forest respondents said they would visit more frequently.
- If YNP was open only to snow coach, skiing and snowshoeing, but not snowmobiles, 42.2% of the park sample and 41.4% of the forest sample said they would visit less frequently. A smaller share said they would visit more frequently--14.6% of park respondents and 13.8% of forest respondents.
- If the west-side roads between Old Faithful, West Yellowstone, and Mammoth were closed from November 1 through April 30, for the park sample, 32% of respondents said they would visit less. This percentage was 26.8% for the forest sample. A total of 5.1% of the park respondents and 10.9% of national forest respondents said they would visit more under this scenario.
- The final management option asked about the effect of not plowing the road between Colter Bay and Yellowstone's South Entrance. Overall 10.6% of the park sample and 9.4% of the forest sample said they would visit less under this scenario, and 6.5% of park visitors and 10.3% of forest visitors said they would visit more.

Respondents were presented with a set of policy statements and asked to indicate their level of agreement or disagreement. The questions were divided into general and specific policy questions. Respondents showed overall concern for wildlife in the general questions but mixed results in the specific policy questions. This is to be expected. General policy issues tend to be ambiguous and thus garner little opposition. Specific policy issues, by definition, are not ambiguous. They are more likely to reflect actual points of view and thus show the mixed results stemming from a variety of opinions.

There were also several questions about winter road closure. A plurality of both resident and nonresident park visitors favored the existing policy of grooming roads for snowmobile use. The next most favored policy for both resident and nonresident respondents was allowing only snowcoach, ski and snowshoe travel. In the context of bison management, a question addresses the possibility that if roads throughout the park were not groomed, more bison might remain in the park. Still, a majority of park visitors favored the current access policy (52.1%). The remaining respondents were closely divided between closing motorized access and not being sure which policy to prefer. The final question in this section again brought up the possibility of plowing the road from West Yellowstone to Old Faithful, but in the context of bison management. Again, a majority of both the park sample and forest sample favored the existing policy over the alternatives.

The willingness to pay (WTP) questions yielded the following results:

- For a cleaner, quieter snowmobile, renters in the park sample were willing to pay an extra $46.09 per day.
- Respondents in the forest sample were willing to pay an extra $35.89.
- For an increase in overall trip costs the estimated median WTP for residents, $30.33, is much lower than for nonresidents, $144.66.
- For an increase in entrance fees for road plowing to allow car and bus travel respondents were estimated to have a median WTP to plow the road from West Yellowstone to Old Faithful of $6.14.

- Cross-country skiers indicated an estimated median WTP for the annual ski pass of $46.31 ($45.09 for park visitors) if the funds would support trail grooming in the park.

The final WTP question attempted to gauge support for a program that would increase winter range for bison migrating out of Yellowstone National Park. WTP was measured in terms of a voluntary contribution to a trust fund for two scenarios, increased range in one year and increased range in ten years. Unfortunately, overall valuation estimates could not be derived because the estimated one-year and ten-year WTP estimates were not significantly different.

Critique of Report 1

Like the other two reports, the winter visitor survey is well written. There are, however, two related drawbacks to the presentation of the study. The first is the sheer volume of information and alternatives presented. It is challenging to really understand respondents' opinions on all the options presented. The second drawback is the lack of any maps. Many of the survey questions have a spatial component. For example, "Table D-4 Estimated changes in trips under alternative management options using median values: If the road between Colter Bay and YNP's south entrance in Grand Teton NP was not plowed, and instead open a groomed trail for snowmobiles and snowcoaches." It is difficult to grasp the question or compare this management alternative to others without clearly understanding the spatial aspect of the question. A small selection of maps would have helped explain a number of questions in and conclusions of the survey.

While the sample size seems adequate, there are several concerns with the sampling procedures for this study. First, the national forest sample was a convenience sample rather than a probability sample, which limits its reliability as an indicator of forest visitor population characteristics and perceptions. Secondly, while the winter season in the GYA runs from December through March, the sampling was primarily done in February. As such, the report states that one should use caution in extrapolating the results to the entire winter population. As noted by Norma Nickerson of the University of Montana in her review of the summer visitor study, “Our studies of nonresident visitors to Montana show substantial differences in June visitors compared to August visitors.” This comment probably also holds for winter visitors. For example, there are likely to be substantial differences between nonresident winter visitors during the Christmas season and winter visitors over Washington’s Birthday weekend. Finally, the report notes that the possibility exists that more frequent visitors to the park and forest were over-sampled in the study. Due to this "avidity bias," the individual level responses may not be representative of the winter visitor population. While the report recognizes all these problems, no attempt was made to account for them in the analysis.

Several more specific problems also arise with regard to particular portions of the report:

- In order to estimate the economic impact of changes in winter use management an estimate of expenditures by WY, MT, and ID residents who do not reside in the GYA would be needed. However, apparently only expenditures for all WY, MT, and ID residents are reported.
- The discussion of the number of times that GYA residents plan to visit the GYA between December 1998 and March 1999 is confusing. GYA residents presumably live in the GYA, so how can they visit? This comment also applies to the change in the number of trips if snowmobiles were not allowed.

- The fact that in some cases the amount spent in the three-state area is less than the amount spent in the GYA suggests that the respondents may not have totally understood the question.
- The fact that 13.4% of the respondents surveyed in the national forest sample indicated that they had not visited national forest lands during the trip suggests that respondents may not have totally understood the question.

These are concerns but do not necessarily invalidate the results or usefulness of the analysis. The work should be considered as a useful intermediate step in developing policy but not directly dictating policy. An exception to this would be the results from the national forest land sample. Given the potential "selection bias" associated with a convenience sample these results are of limited usefulness.

Summary of Report 2: Summer Visitor Survey

This report documents perceptions of summer visitors to Yellowstone National Park. The survey was conducted in May and June of 1999. It was distributed at five entrances to Yellowstone National Park proportionally to visitation expected at each entrance station. Visitors were surveyed during four different periods and also sent follow-up postcards and survey mailings. Distribution details, as well as postcard and second survey mailing dates are provided in the report.

The survey was broken into four sections. The first section pertained to information on the respondent's trip. The second section gathered information on alternative winter management policies. The third section collected information on wildlife seen and opinions on wildlife management. The fourth section gathered socioeconomic data on the respondents.

The first section offers a breakdown of respondents having their first trip to Yellowstone, main reasons for visiting Yellowstone, type of group the respondent is traveling with, length of trip, activities the respondent engaged in, communities in the Greater Yellowstone Area (GYA) visited during the trip, average number of overnight stays in the GYA, and expenditures.

Questions on winter use management are covered in the second section of the survey. Addressed were a breakdown of previous and hypothetical winter visits to Yellowstone, possible changes in travel patterns, given changes in winter access in the park, and preferences on access to Old Faithful.

The third section offers data on wildlife seen, preferences on wildlife viewing, visitors' perceptions of their knowledge of current bison management policies in regard to brucellosis, and general and specific opinions on wildlife management. In asking questions on opinions of alternate wildlife management practices, the survey designers divided their questions into two categories, general and specific policy issues. These questions were nearly identical to those in the national telephone survey. Results were presented as an aggregate and broken down into the geographic area of the respondents' residence (residents vs. non-residents). Specific policy issue questions regarded:

- mechanized access to Yellowstone National Park
- livestock grazing on national forest lands
- killing bison at park boundaries
- allowing bison to range onto public lands outside the park
- rounding up bison to test for brucellosis and either slaughter or vaccinate.

As in the case of the winter visitor survey, respondents showed overall concern for wildlife in the general questions but mixed results in the specific policy questions. This reflects the typical tendency of respondents to show little opposition to general policy issues, which tend to be ambiguous, and at the same time to express a variety of actual points of view with regard to specific policy issues, which by definition are not ambiguous. As in the telephone survey, the one exception to the lack of ambiguity in specific policy issues brought up in this survey was the question pertaining to killing bison at the park boundary, "It is appropriate to kill bison at park boundaries as necessary to protect domestic livestock?"

Section three of the summer report did expand on the national telephone survey. It addressed visitors' preferences for bison management policies that could result in changes in access for motorized winter recreators relative to policies that might promote bison to stay in the park and policies that may facilitate bison leaving the park. Specifically indicated are visitors' preferences for bison management policies that could curtail motorized winter access into Yellowstone. Results are broken down by residents/nonresidents and self-descriptions of being more or less knowledgeable on the issues.

The fourth section of the survey asked about willingness to pay (WTP) additional travel expenses in order to make a trip to Yellowstone and WTP to protect bison. For travel cost increases, "Bid" amounts, or options for WTP were $25, $50, $100, $200, $500 and $1,000. Responses were broken down by resident/nonresident status. It was noted the resident sample consists of only 160 responses and these are distributed across six bid levels. The implication is the resident sample size may be too small. There was no statistical analysis provided to reinforce or refute the implication. Additionally, the wording of the WTP questions made it unclear if the hypothetical increase in travel costs was to be incurred per individual or for the entire traveling party. Due to this possible confusion a remedy was used. Bid amounts were divided by the number of people in the visitors party in order to get an individual, even if conservative, welfare measure.

Results were reported as percent and number of respondents who indicated each overall bid level, broken down into resident and nonresident categories. Regression models are similarly broken down resulting in a significantly higher willingness to pay by non-residents than by residents. Aggregate results for willingness to pay are not reported.

In one of the most interesting aspects of the data analysis of the survey a multivariate WTP model was created. This model can lend insights into which trip and visitor characteristics influence WTP for the trip. Results showed a higher WTP for a longer trip, if a greater number of elk are seen, and for both older and higher income individuals. The number of bison seen and numbers of wolves seen were of no effect and statistically insignificant, respectively. Possible influences on these results are also discussed.

Questions on WTP models to protect bison were led off with a question inquiring if respondents were familiar with natural resource trust funds. WTP was assessed by using bid pairs, a pair being dollar amounts the visitor was willing to pay for land acquisition or vaccination with a 1 year or 10 year response. All results were sorted by resident/nonresident visitor status. A summary of results was presented which showed parity among residents and nonresidents by program. Both were willing to pay about $25 per year for land acquisition and $12 per year for vaccination. It is pointed out that in all cases standard errors are large, thus these estimates may not be very precise.

Also addressed in this section are visitors' preferences for bison management policies that could curtail motorized winter access in Yellowstone. Overall results are presented, as well

as results sorted by respondents' self-proclaimed knowledge of the issues. Respondents who do not feel informed were mostly likely to indicate they were "not sure" which policy to support. They also support maintaining the status quo, assumed to be the current policy. The write-up reports and the numbers show that "both informed residents and nonresidents support closing access by a considerable margin compared to the existing policy, and the only group that overall supports the existing policy are those residents who classify themselves as uninformed."

Report 2 Conclusions

Beyond this policy preference analysis, the authors put forth numerous conclusions to the report:

- Nonresident visitors spent more than regional residents on trips to the Yellowstone area, $736 vs. $ 174 respectively.
- A greater percentage of regional residents than nonresidents report having visited the park in the winter; 46.5% vs. 6.8%.
- If the road to Old Faithful were plowed in the winter there would be a possible decrease in winter visitation for both regional residents (residents of Idaho, Montana or Wyoming) and visitors from outside the region. Residents reported a larger decrease in visitation, from 35.6% to 23.0% of respondents. The decrease is significant at the 95% confidence level.
- If the park were only open to snowcoach travel, skiers and snowshoes, there would be a possible decline in regional resident visitation, but also a potential increase in winter visitation by non-residents.
- There is a general attitude of concern for the well being of wildlife: concern with wildlife habitat (96.9% agree), protection of rare plants (89.9% agree), concern for disturbance of Yellowstone wildlife in winter (61.3% agree), a willingness to donate to help animals (59.9% agree) and a view that wildlife species should be protected, regardless of benefits to humans; 72.3% disagree with the opposite view.

Much of the survey seeks to document fundamental economic data. Coupled with data on preferences, this provides a substantial base for an analysis of the economic impact of alternative management scenarios outlined in the survey. Number of nights spent in what town, how many dollars spent etc., could be looked at in terms of increased and decreased visitation levels for each suggested policy alternative. These projections were not attempted in this report.

Critique of Report 2

Critique of specific aspects of the report is provided in the text of the summary as well as in the "Major Findings" section which follows. Generally, as noted in the report, because the survey was not conducted during all of July or any of August, it may not be representative of all summer visitors to YNP. Norma Nickerson's comment that “studies of nonresident visitors to Montana show substantial differences in June visitors compared to August visitors” applies directly to this report. As a result the report may not be a reliable indicator of the overall views of summer visitors to YNP.

In general, the report provides useful intermediate data; as in the case of the winter visitor survey, the results of this survey would be helpful in the development of policy, though they do not necessarily indicate directly any distinct policy option.

Summary of Report 3: National Telephone Survey

This study was the national segment of three related surveys for gathering the public's views on winter park management and wildlife management, specifically bison management, in Yellowstone National Park (YNP). The national telephone survey began with a preliminary survey conducted in April of 1999. The objective of this preliminary survey was to verify the effectiveness of survey questions. As needed, questions were rewritten for the final survey in order to improve clarity and overall understanding of the question.

The actual survey was conducted in May and June of 1999. It had the specific goal of measuring the experiences, perceptions, and attitudes of summertime visitors to Yellowstone National Park. The survey sampled three geographic areas: (1) local: residents of the Greater Yellowstone Area, defined as a 17 county area; (2) regional: residents of Idaho, Montana and Wyoming; and (3) national: residents of the other 47 United States.

The survey was initiated with "prior contact letters" sent to all potential respondents. These letters were followed up with the actual survey telephone call. In the event contact was not made via telephone the first try, attempts to make contact were repeated up to six times.

One thing the national survey addressed, which was not addressed in the summer visitor survey, was the demographic nature of responses. In general, the survey showed an under-representation of nonwhites and females in the local and regional samples and an under-representation of nonwhites in some regions of the national sample. Results were modified to corresponded to census weights in order to closely align with racial, gender, and geographic distribution of respondents with U.S. census data. All results reported are for census-weighted samples. In keeping with its pattern of excellent documentation, the survey report provided a reference as a basis for this data alteration, included a discussion in the main body of the work and an appendix on modification specifically to contingent valuation method.

In order to access not just attitudes toward management and willingness to pay, but also to quantitatively analyze where those attitudes may be coming from, the survey was broken into four sections. The first section looked at respondents' participation in outdoor and wildlife related activities including visits to national parks. Sections two and three asked for respondents' views on management issues and policies of YNP, including willingness to pay (WTP) to support additional bison management options. The fourth and final section asked respondents demographic questions.

The first section provides a general breakdown of respondents' participation in outdoor winter activities (bird watching, wildlife viewing, snowmobiling, cross-country skiing, non-participation in these activities) and a breakdown of frequency of participation (frequently, occasionally, rarely, never) for each activity. It also documents which respondents have visited national parks in the last two years, if respondents had ever been to Yellowstone National Park, why (if appropriate) they had never been there, year of most recent visit and percent of respondents who visited in the winter season.

One minor point of potential confusion is the question of visitation to a national park in the past two years. It was not made clear in the question if the survey was inquiring about just national parks (essentially a political designation) or all national park areas (e.g. national battlefield, national seashore, national monument, etc.). Addressing the existence of other

national park sites in the question would have lead to more specific results. In the results report there was a category for "do not know."

Section two of the survey gauged respondents' familiarity with and opinions on winter use and bison issues in Yellowstone. It asked respondents to report their knowledge about winter use management, indicate preferences for different management options for winter access to Old Faithful, report on knowledge of bison management policy, and gathered opinions on wildlife and bison management.

As in the summer survey in asking questions on alternate wildlife management practices, the survey designers divided their questions into two categories, general and specific policy issues. Specific policy issue questions regarded:

- mechanized access to Yellowstone National Park
- livestock grazing on national forest lands
- killing bison at park boundaries
- allowing bison to range onto public lands outside the park
- rounding up bison to test for brucellosis and either slaughter or vaccinate.

Respondents showed overall concern for wildlife in the general questions but mixed results in the specific policy questions. This is to be expected. General policy issues tend to be ambiguous and thus garner little opposition. Specific policy issues, by definition, are not ambiguous. They are more likely to reflect actual points of view and thus show the mixed results stemming from a variety of opinions. As in the related reports, there is one exception to this in the specific policy issues brought up in this survey, the question pertaining to killing bison at the park boundary, "It is appropriate to kill bison at park boundaries as necessary to protect domestic livestock?"

The telephone survey had problems with another question on wildlife management as a result of a wording change after the preliminary survey. The question read, "All bison should be rounded up and tested for disease rather than either slaughtered or vaccinated" The intended wording, used in the winter and summer surveys was "All bison should be rounded up and tested for disease than either slaughtered or vaccinated" The results clearly state the revised wording in the telephone survey makes the responses less useful for policy purposes.

The last portion of section two presents information on respondents' preferences for road closure preferences related to bison management as discussed earlier in this review.

Section three of the survey addressed respondents' WTP for one of two different programs designed to protect bison and related questions. Both programs required a theoretical donation to a trust fund. The first addressed WTP for increased bison winter range outside of Yellowstone National Park. The second addressed WTP for a vaccination program designed to eliminate brucellosis in the park. Questions related to WTP for bison management covered winter travel preferences under different management policies and knowledge of trust funds to conserve natural resources.

Data was analyzed using a multinomial logistic regression to ultimately come up with WTP figures for all categories of visitors (local, regional and national) regarding both questions. Also addressed were protest responses to the CVM question and a possible caution on interpretation of CVM results for the national sample because the response rate was less than fifty percent.

The last section of the survey was designed to collect demographic data. Questions were asked on respondents' gender, ethnicity, race, educational level, and household income. Also included in this section was a compilation of surveyor assessments of respondents'

attentiveness during the interview process and if the respondent had difficulty understanding the trust fund question.

Report 3 Conclusions

The survey concluded, like its counterparts, with agreement on general issues but division on specific policy issues faced in the Yellowstone area. Regarding possible road closures, the local population was twice as likely to favor the existing policy of grooming roads for snowmobile use as the national population. Among the local population, there were an equivalent number of people who favored skiing, snowshoeing, and grooming for snowcoaches. About 10% of locals, 14% of regional residents, and 25% of national residents favored only allowing skiing or snowshoe access. In the regional and national samples, the majority of respondents favored the set of alternatives that did not include snowmobile access.

Critique of Report 3

Of the three reports, the national telephone survey is probably the best, given the sampling technique, which avoids over-sampling of certain groups and uses census figures to ensure a group of respondents reflective of the general population. As in the case of the visitor surveys, methodologies of the telephone survey are very sound, with only a few specific problems, which have been addressed in the summary.

General Critique of Duffield Reports 1, 2, and 3

Overall, the reports provide quality baseline data, relevant to park management and policy. In few instances, however, does the data indicate overwhelming public support for a particular management practice or policy. With respect to such issues as snowmobile admittance, trail grooming, and bison management, for example, conflicting responses indicate a certain degree of public disagreement with regard to specific potential management and policy alternatives. One issue where public agreement does seem to exist, nonetheless, is with respect to respondents' willingness to pay more for cleaner, quieter snowmobiles--a finding which is in line with the findings of these and other reports that suggest elements such as peace and solitude as important to an individual's choice to visit the park. In a general sense, it is also clear from the data that the public values the resources present in the Greater Yellowstone Area, and they value access to these resources. It is not clear from the data, however, how people would respond to changes in management of and policy affecting the parks.

ADDENDUM: MAJOR FINDINGS RELATED TO WINTER USE FROM REPORTS 1, 2, AND 3

Major Findings of Winter Survey (Duffield and Neher, 2000)

(Note: Because the national forest sample was only a convenience sample only the park sample is discussed here.)

Survey Trip Characteristics (Winter Park Visitors):

- 83.8% of visitors visited YNP, 30.9% visited GTNP, and 35.7% visited adjacent National Forest land.

- Visiting YNP was the main purpose of the trip for 74.1% of visitors sampled. Visiting GTNP was the main purpose for 23.1% of visitors sampled. Visiting National Forests was the main purpose for 28.9% of the visitors sampled. Visiting other areas of WY, MT, or ID for recreation was the main purpose for 24.2% of the visitors sampled.

- The average number of people traveling together was 6.1 people, average total nights away from home was 4.8 nights, average nights spent in GYA was 3.6 nights.

- 66.8% of visitors snowmobiled while visiting the GYA, 30.0% cross country skied, 6.7% snowshoed, and 0.8% went on snow coach tours. At the East Entrance, 93.3% of visitors snowmobiled, 13.3% cross-country skied, 6.7% snowshoed, and 0.0% rode snow coach tours.

- For visitors who were residents of WY, MT, and ID, the average expenditure for the entire trip was $272.62 per person per trip. Of this total $210.14 was spent just in the GYA. For nonresident visitors, the average expenditure for the entire trip was $1,128.87 per person per trip. Of this total $679.68 was spent in the three-state area, and $607.95 was spent just in the GYA.

- 44.6% of non-GYA resident visitors were visiting the area for the first time, the average number of expected visits to the GYA between December 1998 and March 1999 was 2.1 times, the average number of times that YNP was the primary destination was 1.05 times, and the average number of times that GTNP was the primary destination was 0.3 times.

- Only 7.0% of GYA resident visitors were visiting the area for the first time, the average number of expected visits to the GYA between December 1998 and March 1998 was 12.6 times, the average number of times that YNP was the primary destination was 3.5 times, and the average number of times that GTNP was the primary destination was 5.9 times.

Winter Use and Management within the GYA (Winter Park Visitors)

- If YNP and GTNP were open only to snow coach, skiing and snowshoeing, but not snowmobiles, 45.8% of non-GYA residents would visit less frequently and 11.2% would

visit more frequently. 31.2% of GYA residents would visit less frequently and 26.7% would visit more frequently.

- If YNP and GTNP were open only to snow coach, skiing and snowshoeing, but not snowmobiles, the net number of trips to the GYA by non-GYA residents would decrease by 31.6% and the net number of trips to YNP would decrease by 20.5%. The net number of trips to the GYA by GYA residents would decrease by 12.7% and the net number of trips to YNP by GYA residents would decrease by 0.04%.

- 45.3% of residents of MT, ID, and WY preferred the existing policy of grooming roads for snowmobile use in order to allow winter access to Old Faithful. 12.8% preferred to plow the road and groom a parallel route for snowmobile use. 25.3% preferred to allow snow coach, ski, and snowshoe travel only, not snowmobiles. A total of 58.1% preferred some form of snowmobile access, either the existing policy or grooming a parallel route.

- 63.4% of nonresidents preferred the existing policy of grooming roads for snowmobile use in order to allow winter access to Old Faithful. 13.0% preferred to plow the road and groom a parallel rout for snowmobile use. 16.8% preferred to allow snow coach, ski, and snowshoe travel only, not snowmobiles. A total of 76.4% preferred some form of snowmobile access, either the existing policy or grooming a parallel route.

Wildlife Management (Winter Park Visitors)

- 90.4% of visitors saw bison; the average number seen was 120 head.

- 53.9% of visitors indicated that seeing bison was one of the reasons for visiting GYA on this trip. 46.1% indicated that it was not one of the reasons.

- 67.2% of visitors would still have chosen to take this trip even if bison were not present. 12.2% would not have chosen to take the trip and 20.6% were unsure.

- 90.2% of residents of MT, ID, and WY indicated that they knew a fair to great deal about the current bison management policy. 45.2% of nonresidents indicated that they knew a fair to great deal about the current bison management policy.

- 97.2% of visitors expressed a moderate to strong concern for protecting wildlife habitat. 67.1% of visitors expressed moderate to strong support for mechanized winter access into YNP. 61.2% of visitors expressed moderate to strong concern about the possible disturbance of Yellowstone wildlife in winter.

- 52.1% of visitors supported keeping the current policy of grooming roads despite the possibility that more bison might remain in the park if they were not groomed. 23.4% supported closing motorized winter access and 24.6% were not sure.

Nonmarket Valuation Question Analysis (Winter Park Visitors)

- 42.0% of visitors rented snowmobiles during their trip to GYA.

- The median willingness to pay to rent a cleaner and quieter snowmobile was $46.09. This amount would be in addition to the existing rental rate.

- The median willingness to pay to visit the GYA in winter for residents of MT, ID, and WY was $30.33. The median willingness to pay to visit the GYA in winter for nonresidents was $144.66.

- The median willingness to pay for an annual ski pass to support cross-country trails grooming in the park was $46.31.

- The median willingness to pay for purchasing bison winter range outside of YNP was $47.06 for land purchased next year and $52.16 for land purchased in 10 years.

Visitor Characteristics (Winter Park Visitors)

- 66.5% of respondents were male.

- Average age of respondent was 45.3 years.

- 99.1% of respondents were white.

- 88.7% of respondents had at least some college education.

- 77.9% of respondents reported annual household income of $40,000 or more.

Major Findings of Report 2, Summer Survey Related to Winter Use (Duffield et al, 2000)

Data Collection:

Mail-back survey administered at each park entrance according historic visitation levels. The survey was conducted in four, seven-day sampling periods from May 24, 1999 to July 11, 1999. A total of 1,902 survey packets were distributed at park entrances. Of these, 1,302 useable surveys were returned and entered into the database. The overall response rate was 68.4%.

Survey Trip Characteristics:

- The report found that the average total trip expenditure per visitor for nonresidents was $736.19. This would represent about $60.84 per day. Average trip expenditure per visitor for nonresidents in the GYA was $225.59 or about $43.38 per day.

- The report found that the average total trip expenditure per visitor for residents of MT, ID, and WY was $173.86. This would represent about $41.39 per day. Average trip expenditure per visitor for residents in the GYA was $95.20 or about $31.73 per day.

- The report found that 46.5% of resident summer visitors had visited YNP in the winter. 6.8% of nonresident summer visitors had visited YNP in the winter. Overall, 13.5% of all summer visitors had visited YNP. (Note: Regardless of expressed intentions in later questions only 13.5% of summer visitor had visited YNP in the winter. This does not indicate a great deal of actual crossover between seasons by visitor.)

- The report found that 72.0% of resident summer visitors who had not previously visited YNP in the winter were considering a future winter visit. 33.9% of nonresident summer visitors who had not previously visited YNP in the winter were considering a future winter visit. Overall, 38.0% of all summer visitors who had not previously visited YNP in the winter were considering a future winter visit.

- The report found that 35.6% of resident summer visitors who had not previously visited YNP in the winter were planning to visit in the next winter season. 2.9% of nonresident summer visitors who had not previously visited YNP in the winter were planning to visit in the next winter season. Overall, 6.2% of all summer visitors who had not previously visited YNP in the winter were planning to visit next winter season.

Winter Use and Management within GYA

- The report found that if YNP was only open to snow coach, skiing, and snowshoeing, but not snowmobiles, the percent of resident summer visitors that would consider a future winter visit to YNP decreases from 72.0% to 22.4%. The percent of nonresident summer visitors that would consider a future winter visit to YNP decreases from 33.9% to 20.1%.

The percent of all summer visitors that would consider a future winter visit to YNP decreases from 38.0% to 20.4%.

- The report found that if YNP was only open to snow coach, skiing, and snowshoeing, but not snowmobiles, the percent of resident summer visitors that plan to visit YNP next winter decreases from 35.6% to 16.4%. The percent of nonresident summer visitors that plan to visit YNP next winter increases from 2.9% to 4.7%. The percent of all summer visitors that plan to visit YNP next winter decreases from 6.2% to 5.9%. Based on this information the report concludes that, "If the park was open only to snowcoach, skiers, and snowshoeing, there is a possible decline in regional resident visitation, but also a potential increase in winter visitation by nonresidents." (Note: The report does not mention that total visitation next winter season would probably decline [6.2% to 5.9%]. The report also does not mention that future visitation [beyond next winter season] could decline for both residents and nonresidents. Overall the decrease is from 38.0% with snowmobiles to 20.4% without snowmobiles.)

- The report found that the largest percentage of residents and nonresidents prefer the policy of plowing the road and grooming a parallel route for snowmobile use (31.0% for residents and 36.8% for nonresidents). There was also a relatively high preference by residence for allowing snow coach, ski, and snowshoe travel only, but not snowmobiles (28.6%). For nonresidents, the second highest response was for maintaining the existing policy of grooming the roads for snowmobile use (23.3%). Combining the "motorized access" alternatives show that a majority of both residents and nonresidents respondents to this question favor some sort of individualized mechanized access to Old Faithful. (Note: The report does not mention that the majority of both resident summer visitors (56.6%) and nonresident summer visitors (60.1%) favor some form of snowmobile access either through the existing policy or by grooming a parallel route beside the plowed road.)

Wildlife Management

- The report found that the three types of animals that were seen by the greatest number of visitors were bison (96.6%), elk (89.0%), and deer (65.0%). The average number of bison seen was 97. For bison, about one half of the residents and nonresidents said that seeing bison was one of the reasons for visiting the GYA. The majority said they would still visit the GYA even if bison were not present (70.1% resident, 78.3% nonresident).

- The report found that the majority of residents indicated that they knew a fair amount (45.0%) or a great deal (36.7%) about the current bison management policy. The majority of nonresidents indicated that they had never heard of the situation (45.4%) or had heard about it but didn't know much about it (27.3%). (Note: At least from the perspective of the general public, bison management seems to be primarily a regional rather than a national issue.)

- The report found that looking at summer visitors' attitudes as a whole, there is a general pattern of concern for the well-being of wildlife. However, on the specific policy issues at hand, the public is generally quite divided in its opinions regarding mechanized winter

access to Yellowstone, livestock grazing on National Forest lands, killing bison at park boundaries, allowing bison to range onto public lands outside the park, and rounding up bison to test and slaughter or vaccinate. It appears that these are divisive issues on which there is little consensus. (Note: Overall more summer visitors were supportive of mechanized winter access than were against mechanized winter access (39.8% vs. 27.2%).)

- Given the possibility that if roads were not groomed, more bison would remain in the park, the report found that residents were evenly divided between the current winter policy allowing motorized winter access (37.4%) and a policy closing motorized winter access (37.4%). The most frequent response by nonresidents was that they were not sure which policy they preferred (40.3%).

- The report found that the respondents' knowledge regarding the bison issue influenced their policy choice. Respondents that did not feel themselves to be well informed were more likely to respond "not sure". Also respondents who did not feel themselves to be well informed were more likely to support the status-quo – in this case the existing winter policy. Finally the report indicates that both informed residents and nonresidents support closing access by a considerable margin compared to the existing policy, and the only group that overall supports the existing policy are those residents who classify themselves as uninformed. (Note: The implication is clear that with education on policies, people's opinions may well change. There is some ambiguity in regard to respondents who consider themselves uninformed, i.e., how does he or she now what the status quo is? No attempt was made in the survey to determine whether the respondent was actually more or less knowledgeable, but rather it relies on self-estimation of knowledge. It is also important to note that respondent preferences are based on tastes and preferences subject to income and wealth constraints.)

- In terms of plowing the road from West Yellowstone to Old Faithful, the report indicates little support from either residents (11.8%) or nonresidents (7.7%). The report concludes that the responses to this question indicate that, "…a plurality of residents prefer access over closure and a plurality of nonresidents prefer closure over motorized access." (Note: This last conclusion is not supported by the data. According to Table 4.20, 52.0% of residents prefer motorized access with 34.6% opposed and 38.0% of nonresidents prefer motorized access with 35.1% opposed.

Major Findings of Report 3, National Telephone Survey (Duffield et al, 2000)

Participation in Recreation Activities

- Respondents participating in snowmobiling: Local = 26.7%, Region = 16.9%, and National = 7.7%.

- Respondents participating in cross-country skiing: Local = 29.5%, Region = 17.1%, and National = 9.3%.

(Note: Participation rates for both snowmobiling and cross-country skiing are significant for all regions, especially local and regional. The comparison with bird watching and wildlife viewing may not be appropriate since the latter are much more passive recreation activities. Along with downhill skiing, snowmobiling and cross-country skiing are probably the three most popular winter recreation activities in the 3-state region.)

- The report indicates that, "A minority of respondents answered that they frequently or occasionally have participated in this activity (snowmobiling)." (Note: If non-participants are excluded 66.3% of local, 71.1% of regional, and 63.7% of national populations that snowmobile do so frequently or occasionally. This suggests that snowmobiling is important to participants in this activity.)

Visitation to YNP

- Respondents reporting having visited YNP at any time in the past: Local = 98.3%, Regional = 88.5%, National = 33.7%. (Note: The finding that about one-third of the nations population has visited YNP seems high. Based on the information in the report this estimate implies about 6 million visitors per year to YNP between 1996 and 1999. However, NPS statistics suggest at most only about 3 million visitors per year during this time period.)

- Main reason why respondents have never visited YNP is because of it would cost too much: Local = 0.0%, Regional = 9.5%, National = 7.9%. (Note: Cost does not seem to be a major reason for not visiting YNP. This may be a policy relevant result for management and use strategies)

- Respondents who reported visiting YNP during the winter season: Local = 48.5%, Regional = 32.0%, and National = 4.8%.

Familiarity With and Opinions on Winter Use and Bison Issues

- Respondents reporting that they know a great deal or know a fair amount about winter use management in YNP: Local = 51.1%, Regional = 37.2%, and National = 13.6%. Respondents reporting that they know little or nothing about winter use management in YNP: Local = 48.2%, Regional = 61.4%, and National = 84.5%. (Note: Even at the local level winter use management in YNP does not seem to be burning issue with much of the

population. The issue becomes even less important to the general public at the regional and national level. This is also a function of the publicity related to winter use in YNP).

- The report indicates that 40.4% of local respondents prefer to keep the existing policy of grooming the road for snowmobile and snowcoach use, while 39.7% prefer to allow ski or snowshoe access, but also groom for snowcoaches. For regional residents, 37.3% prefer to allow ski or snowshoe access, but also groom for snowcoaches, while 32.8% prefer the existing policy of grooming the road for snowmobile and snowcoach use. For national residents, 35.1% prefer to allow ski or snowshoe access, but also groom for snowcoaches, while 20.0% prefer to keep the existing policy of grooming the road for snowmobile and snowcoach use. (Note: This question must be considered carefully. The question only asks about winter management options for Old Faithful, not the entire park. Also none of the alternatives presented to respondents specifically mentions eliminating winter access for snowmobiles. One alternative reads "Allow ski/snowshoe and groom for snowcoaches", but doesn't specifically state "not snowmobiles". This is an important omission, particularly at the national level, since 84.5% of the national respondents indicate that they know little or nothing about winter use management in YNP. It is also important at the local and regional level since 48.2% of local residents and 61.4% of regional residents also indicated that they know little or nothing about winter use management in YNP. The wording of this alternative in the telephone survey is also not consistent with the winter and summer visitor surveys. In the winter visitor survey the wording of the alternative is, "allow snow coach, ski, and snowshoe travel **only**." In the summer visitor survey the wording of the alternative is "allow snow coach, ski, and snowshoe travel only, **not snowmobiles**. As a result respondents may not have realized that they supporting the elimination of snowmobiles when they selected the alternative in the telephone survey. Also the winter and summer visitor surveys provided an alternative of "plow the road and groom a parallel route for snowmobile use." In fact the largest proportion of both residence and nonresidents preferred this alternative in the summer visitor survey. However, this alternative was not included in the telephone survey.)

- Respondents reporting that they know a great deal or know a fair amount about bison management in the GYA: Local = 69.2%, Regional = 53.2%, and National = 18.8%. Respondents reporting that they know little or nothing about bison management in the GYA: Local = 30.3%, Regional = 45.0%, National = 80.5%. (Note: Bison management in YNP does not seem to be an important issue to most people at the national level. It also doesn't seem to be an important issue to a significant portion of the regional and local population.)

- The report indicates that there was a pattern of general support across all three populations for the well-being of wildlife. However, on the specific policy issues being faced today in the Yellowstone area, the public – again across all three populations – is generally quite divided in its opinions concerning: mechanized winter access to Yellowstone, livestock grazing on National Forest lands, killing bison at park boundaries, and allowing bison to range onto public land outside the park. These are divisive issues on which there is little consensus.

- The report indicates that 50.0% of the local respondents prefer the existing policy of grooming for over-snow vehicles, while 38.2% prefer closing motorized winter access to allow for bison control. Among regional residents, 48.2% prefer closing motorized winter access to allow bison control, while 41.3% prefer the existing policy of grooming for over-snow vehicles. Among national residents, 58.8% prefer closing motorized winter access to allow bison control, while 29.6% prefer the existing policy of grooming for over-snow vehicles.