6 Off-Road and All-Terrain Vehicles, Including Snowmobiling

Chapter Summary
This chapter first defines off-road and all-terrain vehicles, including snowmobile, and gives illustrated examples of a range of such vehicles. It then briefly discusses the history and diversity of use of such vehicles before presenting recent data on user numbers. The final part of the chapter focuses on specific environmental impacts associated with off-road, ATV, and snowmobiles which include damage to soil and vegetation, water/air pollution and noise, and disturbance to wildlife. The final section considers the management of these activities and gives some examples of education initiatives that have been used in management attempts.

6.1 Definitions

6.1.1 Off-Road Vehicles (ORVs)

An ORV is considered to be any type of vehicle that is capable of driving on and off paved or gravel roads. These vehicles generally have large tyres with deep, open treads and flexible suspension (Fig. 6.1) or sometimes caterpillar tracks. Other vehicles that do not travel on public highways are generally termed off-highway vehicles and may include tractors, forklifts, cranes, bulldozers, and golf carts.

Due to their many uses and versatility, ORVs are popular, and several types of motorsports involve racing ORVs. The three largest "four-wheel vehicle" off-road types of competitions are rally, desert racing, and rock crawling.

Rallying is a form of motorsport that takes place on public or private roads (sometimes in forests) with modified production or specially built road-legal cars. It is characterised by driving in a point-to-point format (rather than on a circuit) in which participants and their co-drivers drive between set control points (special stages), departing at regular intervals from one or more start points. Rallies may be won by pure speed within the stages or alternatively by driving to a predetermined ideal journey time within the stages.

Desert racing, in its most organised form, began in Southern California in the 1920s. Desert racing takes place, as the name would suggest, in desert in two- or four-wheeled ORVs. Races usually consist of two or more laps around a course covering up to 40 miles. Races can take the form of hare and hound or hare scramble-style event and are often laid out over a long and difficult track through relatively barren terrain. Point-to-point races such as the famous Baja 1000 attract nationally ranked and celebrity drivers. The endurance and capabilities of driver and machine are tested. Sometimes organised clubs or teams may field multiple sponsored riders for particular events, but usually desert racing in its purest form is largely an individual endeavour. Winning

D. Huddart, T. Stott, *Outdoor Recreation*, https://doi.org/10.1007/978-3-319-97758-4_6

Fig. 6.1 A Ford Bronco dune bashing. Photo by Mtxchevy

drivers accrue points to improve their rank and placement in future competitions. Desert racing vehicles can include rugged enduro-style motorcycles, four-wheeled all-terrain vehicles (ATVs), pickup trucks, and dune buggies, all of which have specialised suspension with increased wheel travel.

Rock crawling is an extreme form of off-road driving using vehicles ranging from stock to highly modified types designed to overcome obstacles. In rock crawling, drivers drive highly modified four-wheel-drive (4WD) vehicles such as trucks, jeeps, and "buggies" over very harsh terrain. Driving locations include boulders, mountain foothills, rock piles, and even mountain trails. Rock crawling is about slow-speed, careful and precise driving and high torque generated through large gear reductions in the vehicles' drivetrain. Rock crawlers often drive up, down, and across obstacles that would appear impassable. The vehicles used to rock climb are primarily 4x4s. Rock crawling competitions range from local events to national series. A rock crawling competition consists of obstacle courses that are 100–200 m long with each obstacle set up with gates, similar to a ski or canoe slalom course.

Dune bashing (Fig. 6.1) is a form of off-roading on sand dunes where a large sport utility vehicle such as the Toyota Land Cruiser is used (however, lightweight vehicles often fare better in the extremely soft sand found on sand dunes). Vehicles driven on dunes may be equipped with a roll cage in case of an overturn. Experience and skill are required to manoeuver the car and prevent accidents. Before entering the dune system, tyre pressure is reduced to gain more traction by increasing the footprint of the tyre and, therefore, reducing the ground pressure of the vehicle on the sand as there is a greater surface area (much like a person wearing snowshoes can walk on a soft surface without sinking, but a person without them cannot). For example, tyres with a recommended pressure of 35 psi would be reduced to approximately 12–14 psi.

6.1.2 All-Terrain Vehicles (ATVs)

An ATV, also known as a quad, quad bike, three-wheeler, four-wheeler, or quadricycle as defined by the American National Standards Institute (ANSI), is a vehicle that travels on low-pressure tyres, with a seat that is straddled by the operator and handlebars for steering control. As the name implies, ATVs are designed to handle a wider variety of terrain than most other vehicles. Although street-legal in some countries, ATVs are not street-legal within most states and provinces of Australia, the USA, or Canada. By the current ANSI definition, ATVs are intended for use by a single operator, although some companies have developed ATVs intended for use by the operator and one passenger (referred to as tandem ATVs).

ATV riders sit on and operate these vehicles like a motorcycle, but the extra wheels give more stability at slower speeds. Although equipped with three or four wheels, six-wheel models exist for specialised applications. Engine sizes of ATVs generally range from 49 to 1000 cc. The three largest types of ATV/motorcycle competitions are motocross, enduro, and also desert racing (see above). The most common use of ATVs is for sightseeing in areas distant from roads. The use of higher-clearance and higher-traction vehicles enables access on trails and forest roads that have rough and low-traction surfaces. Other uses include border patrol, construction, emergency medical services, land management, law enforcement, military, mineral and oil exploration, pipeline transport, search and rescue, small-scale forestry, surveying, and wild land fire control.

6.1.3 Off-Road Motorcycles: Motocross and Enduro Motorcycling

Motocross is a form of off-road motorcycle racing held on enclosed off-road circuits. The sport evolved from motorcycle trial competitions held in the UK (Fig. 6.2). Motocross first evolved in the UK from motorcycle trial competitions, such as the Auto-Cycle Club's first quarterly trial in 1909 and the Scottish Six Days Trial that began in 1912. When later it became a race to become the fastest rider to the finish, the activity became known as "scrambling." The sport grew in popularity, and the competitions became known internationally as "motocross racing," by combining the French word for motorcycle, *motocyclette*, or moto for short, into a portmanteau with "cross-country." The sport has since evolved with sub-disciplines such as stadium events known as supercross and arenacross held in indoor arenas. Classes were also formed for ATVs. Freestyle motocross (FMX) events where riders are judged on their jumping and aerial acrobatic skills have gained popularity, as well as supermoto, where motocross machines race both on tarmac and off-road. Vintage motocross (VMX) events take place usually for motorcycles predating 1975.

Fig. 6.2 A motocross rider coming off a jump. Photo by Adriskala

An enduro motorcycle is an off-road racing motorcycle used in enduros, which are long-distance cross-country time-trial competitions.

Enduro motorcycles closely resemble motocross or "MX" bikes (upon which they are often based). They sometimes have special features such as oversized gas tanks, engines tuned for reliability and longevity, sump protectors, and more durable (and heavier) components. Enduro bikes combine the long-travel suspension of an off-road motocross bike with engines that are reliable and durable over long distances. Some enduro bikes have street-legal features such as headlights and quiet mufflers to enable them to be used in public roadways. The engine of an enduro bike is usually a single-cylinder two-stroke between 125 cc and 360 cc or four-stroke between 195 and 650 cc.

6.1.4 Snowmobiles

The challenges of cross-country transportation in winter led to the invention of the snowmobile, sometimes called ski-doo or snow scooter, an ATV specifically designed for travel across deep snow where other vehicles floundered. Snowmobiles, also known as snow machines, are vehicles designed for travel and recreation on snow. As they can be operated on snow and ice, they do not require a road or trail and so can be driven over frozen lakes or tundra. Snowmobiling is a sport that many people have taken on as a serious hobby. Older snowmobiles could accommodate two people, but most modern ones are for a single rider. Snowmobiles which can carry two riders are referred to as "two-up" snowmobiles or "touring" models and account for a very small share of the market. Snowmobile engines drive a continuous track at the rear and skis at the front provide directional control. Drivers are not enclosed, and there is normally just a windshield for protection (Fig. 6.3A). While early snowmobiles used rubber tracks, modern tracks are typically made of a Kevlar composite. Originally powered by two-stroke gasoline internal combustion engines, snowmobiles powered by four-stroke engines have more recently entered the market.

Recreational snowmobiling has become popular since the second half of the twentieth century. Riders are called snowmobilers or sledders, and recreational riding can take various forms such as snowcross/racing, trail riding, freestyle, mountain climbing, boondocking, carving, ditchbanging, and grass drags. In the summertime snowmobilers can drag race on grass, asphalt strips, or even across water. Snowmobiles are sometimes modified to compete in long-distance off-road races such as Trevor Erickson's #901 entry in the 2014 Vegas to Reno race.

6.2 History, Diversity, and Participation Numbers

6.2.1 ORVs

One of the first modified ORVs developed in Russia between 1906 and 1916 used an unusual caterpillar track which had a flexible belt instead

Fig. 6.3 (A) A snowmobile. Photo by Greg Gjerdingen. (B) Snowmobile being used by reindeer herders. Photo courtesy of altapulken.no

of interlocking metal segments. It could be fitted to a conventional car or truck to turn it into a half-track suitable for use over rough or soft ground. The system was later used in France on Citroën cars between 1921 and 1937 for off-road and military vehicles. There was a surplus of light ORVs like the Jeep and heavier lorries after Second World War. The Jeeps were popular as utility vehicles and "off-roading" as a hobby was born. When the wartime Jeeps wore out, the Jeep Company began to produce vehicles for the civilian market, when British Land Rover and Japanese Toyota, Datsun/Nissan, Suzuki, and Mitsubishi joined in the manufacture of these ORVs. Popular models included the US Jeep Wagoneer and the Ford Bronco, the British Range Rover, the station wagon-bodied Japanese Toyota Land Cruiser, the Nissan Patrol, and Suzuki Lj's series. Later, during the 1990s, manufacturers started to add more luxuries to bring these ORVs on par with regular cars, and what is now known as the SUV (Sports Utility Vehicle) evolved.

In order to be able to successfully drive off paved surfaces, ORVs need several characteristics: (1) a low ground pressure, so as not to sink into soft ground, (2) ground clearance so that they don't get hung up on obstacles, and (3) to keep their wheels or tracks on the ground so they don't lose traction. In wheeled vehicles this is accomplished by having a suitable balance of large or additional tyres combined with tall and flexible suspension. Tracked vehicles achieve this by having wide tracks and a flexible suspension on the road wheels. Most ORVs have special low gearing which allows the operator to utilise the engine's available power while moving slowly through challenging terrain. Power must be provided to all wheels in order to keep traction on slippery surfaces, so for a typical four-wheel vehicle, this is known as four-wheel drive. Vehicles designed for use both on- and off-road may be designed to be switched between two-wheel drive and four-wheel drive so that the vehicle uses fewer driven wheels when driven on the road.

Table 6.1 shows that the number of people (aged 16 and over) participating in off-highway driving in the USA rose by 16.9 million between 1982 and 2001, while snowmobiling rose by 6.1 million in the same period.

This rising trend in off-highway vehicle driving continued into this century (Table 6.2), with 20.6 million participants between 2005 and 2009, a percentage change of 34.5% (1999–2009).

Table 6.3, however, indicates that in the USA, snowmobiling participation in the 2005–2009 period was 5.5% lower than in the 1999–2001 period (a drop of 0.6 million).

Off-highway driving also made it into Cordell's (2012) list of activities which added more than 100 million participation days between 1999–2001 and 2005–2009 (Table 6.4).

6.2.2 ATVs

The first powered quadricycle was built and sold by Royal Enfield 1893 and resembled a modern ATV-style quad bike. The term "ATV" was originally coined to refer to non-straddle ridden six-wheeled amphibious ATVs used in military contexts. The first three-wheeled ATV was designed in 1967, and larger motorcycle companies like Honda entered the market in 1969. Suspension and lower-profile tyres were introduced in the early 1980s, and in1982 Honda produced a model which featured both suspension and racks, making it the first utility three-wheeled ATV. The ability to go anywhere on terrain that most other vehicles could not cross soon made them popular with US and Canadian hunters and those just looking for a good trail ride. Soon other manufacturers introduced their own models. Sales of utility machines skyrocketed as high-performance three-wheeler sport models were developed featuring full suspension, 248 cc air-cooled two-stroke engines, five-speed transmission with manual clutch, and a front disc brake.

Due to safety concerns of three-wheelers ceased, there was a ten-year voluntary cease of production between 1987 and 1997: three-wheelers were seen as being more unstable than four-wheelers (although accidents were equally severe in both classes). This led to widespread thought that the three-wheel machines were unregistrable, uninsurable, dangerous, and even illegal, but this was false. A Consumer Product Safety Commission (CPSC) study actually found that three-wheelers were no more dangerous than other

Table 6.1 Trends in number of people ages 16 and older participating in recreation activities by historic period in the USA, 1982–2001 (Source: Cordell 2012, p. 33)

	Total participants			Change
Activity	1982–1983	1994–1995	1999–2001	1982–1983 to 1999–2001
Walk for pleasure	91.9	138.5	175.6	83.7
View/photograph birds	20.8	54.3	68.5	47.7
Day hiking	24.3	53.6	69.1	44.8
Picnicking	83.3	112.2	118.3	35.0
Visit outdoor nature centre/zoo	86.7	110.9	121.0	34.3
Swimming in lakes/streams etc.	55.5	87.4	85.5	30.0
Sightseeing	79.8	117.5	109.0	29.2
Boating	48.6	76.2	75.0	26.4
Bicycling	55.5	77.8	81.9	26.4
Developed camping	29.5	46.5	55.3	25.8
Driving for pleasure	83.3	–	107.9	24.6
Motorboating	33.0	59.5	50.7	17.7
Off-highway vehicle driving	**19.1**	**35.9**	**36.0**	**16.9**
Primitive camping	17.3	31.4	33.1	15.8
Sledding	17.3	27.7	30.8	13.5
Backpacking	8.7	17.0	21.5	12.8
Fishing	59.0	70.4	71.6	12.6
Swimming in outdoor pool	74.6	99.1	85.0	10.4
Canoeing or kayaking	13.9	19.2	23.0	9.1
Downhill skiing	10.4	22.8	17.4	7.0
Snowmobiling	5.2	9.6	11.3	6.1
Horseback riding	15.6	20.7	19.8	4.2
Ice skating outdoors	10.4	14.2	13.6	3.2
Hunting	20.8	25.3	23.6	2.8
Cross-country skiing	5.2	8.8	7.8	2.6
Waterskiing	15.6	22.7	16.0	0.4
Sailing	10.4	12.1	10.4	0.0

Missing data are denoted with "–" and indicate that participation data for that activity were not collected during that time period
Source: NRS 1982–1983 (*n* = 5757), USDA Forest Service (1995) (*n* = 17,217), and USDA Forest Service (2001) (*n* = 52,607)
Note: The numbers in this table are *annual* participant estimates on data collected during the three time periods
1982–1983 participants based on 173.5 million people ages 16+ (U.S. Department of the Interior 1986)
1994–1995 participants based on 201.3 million people ages 16+ (Woods & Poole Economics, Inc. 2007)
1999–2001 participants based on 214.0 million people ages 16+ (U.S. Department of Commerce 2000)

Table 6.2 Trends in number of people ages 16 and older participating in recreation activities in the USA, 1999–2001 and 2005–2009 for activities with between 25 and 49 million participants from 2005 through 2009 (Source: Cordell 2012, p. 37)

	Total participants (*millions*)			Percent participating	Percent change
	1994–1995	1999–2001	2005–2009	2005–2009	1999–2001 to 2005–2009
Visit archaeological sites	36.1	44.0	48.8	20.8	11.1
Off-highway vehicle driving	**35.9**	**36.0**	**48.4**	**20.6**	**34.5**
Boat tours or excursions	–	40.8	46.1	19.6	13.1
Bicycling on mountain/hybrid bike	–	44.0	42.7	18.1	−3.0
Primitive camping	31.4	33.1	34.2	14.5	3.2
Sledding	27.7	30.8	32.0	13.6	3.9
Coldwater fishing	25.1	28.4	30.9	13.1	8.7
Saltwater fishing	22.9	21.4	25.1	10.7	17.2

Missing data are denoted with "–" and indicate that participation data for that activity were not collected during that time period. Percent change was calculated before rounding
Source: USDA Forest Service (1995) (*n* = 17,217), USDA Forest Service (2001) (*n* = 52,607), and USDA Forest Service (2009) (*n* = 30,398)
Note: The numbers in this table are *annual* participant estimates on data collected during the three time periods
1994–1995 participants based on 201.3 million people ages 16+ (Woods & Poole Economics, Inc. 2007)
1999–2001 participants based on 214.0 million people ages 16+ (U.S. Department of Commerce 2000)
2005–2009 participants based on 235.3 million people ages 16+ (U.S. Department of Commerce 2008)

ATVs. Nevertheless, from the mid-1980s, Suzuki took the lead in the development of four-wheeled ATVs, with models from Honda and Yamaha following. Suzuki manufactured a 500 cc liquid-cooled two-stroke engine model which reached a top speed of over 79 mph (127 km/h) in the late 1980s. At the same time, development of utility ATVs was rapidly escalating with 4x4 models being the most popular type with hunters, farmers, ranchers, and workers at construction sites.

Models today are divided between the sport and utility markets. Sport models are generally small, light, two-wheel drive vehicles that accelerate quickly, have a manual transmission, and run at speeds up to approximately 80 mph (130 km/h). Utility models are generally bigger 4WD vehicles with a maximum speed of up to approximately 70 mph (110 km/h). Utility models can haul small loads on attached racks or trailers.

6.2.3 Snowmobiles

The first motor sleigh or "traineau automobile" was developed in the USA in 1915, a snow vehicle using the traditional format of rear track(s) and front skis. Later Ford Model Ts were modified to have their undercarriage replaced by tracks and skis and were called Snowflyers. Snowmobiles are today widely used for travel in arctic regions though the small Arctic population means a correspondingly small market. Most snowmobiles are sold for recreational use in places where snow cover is stable during winter. The number of snowmobiles in Europe and other parts of the world is small but growing. Today there are four large North American snowmobile manufacturers: Bombardier Recreational Products (BRP), Arctic Cat, Yamaha, and Polaris. Modern higher-powered snowmobiles, with engine sizes up to

Table 6.3 Trends in number of people ages 16 and older participating in recreation activities in the USA, 1999–2001 and 2005–2009 for activities with fewer than 15 million participants from 2005 through 2009 (Source: Cordell 2012, p. 40)

	Total participants (*millions*)			Percent participating	Percent change
	1994–1995	1999–2001	2005–2009	2005–2009	1999–2001 to 2005–2009
Kayaking	3.4	7.0	14.2	6.0	103.8
Mountain climbing	9.0	13.2	12.4	5.3	–5.9
Snowboarding	6.1	9.1	12.2	5.2	33.7
Ice skating outdoors	14.2	13.6	12.0	5.1	–11.5
Snowmobiling	**9.6**	**11.3**	**10.7**	**4.5**	**–5.5**
Anadromous fishing	11.0	8.6	10.7	4.5	24.1
Sailing	12.1	10.4	10.4	4.4	–0.4
Caving	9.5	8.8	10.4	4.4	18.4
Rock climbing	7.5	9.0	9.8	4.2	9.5
Rowing	10.7	8.6	9.4	4.0	8.9
Orienteering	4.8	3.7	6.2	2.6	–21.7
Cross-country skiing	8.8	7.8	6.1	2.6	–21.7
Migratory bird hunting	5.7	4.9	4.9	2.1	–1.1
Ice fishing	4.8	5.7	4.8	2.1	–15.5
Surfing	2.9	3.2	4.7	2.0	46.3
Snowshoeing	–	4.5	4.1	1.7	–9.4
Scuba diving	–	3.8	3.6	1.5	–5.6
Windsurfing	2.8	1.5	1.4	0.6	–10.1

Missing data are denoted with "–" and indicate that participation data for that activity were not collected during that time period. Percent change was calculated before rounding.

Source: USDA Forest Service (1995) (n = 17,217), USDA Forest Service (2001) (n = 52,607), and USDA Forest Service (2009) (n = 30,398)

Note: The numbers in this table are *annual* participant estimates on data collected during the three time periods

1994–1995 participants based on 201.3 million people ages 16+ (Woods & Poole Economics, Inc. 2007)

1999–2001 participants based on 214.0 million people ages 16+ (U.S. Department of Commerce 2000)

2005–2009 participants based on 235.3 million people ages 16+ (U.S. Department of Commerce 2008)

1200 cc, can reach speeds of 150 mph (240 km/h), while drag racing snowmobiles can reach speeds in excess of 200 mph (320 km/h).

Recreational snowmobilers look for jumps for aerial manoeuvers. Riders often search for non-tracked, virgin terrain and are known to “trail-blaze” or “boondock” deep into remote territory where there is absolutely no visible path to follow. This type of trailblazing is known to be dangerous as contact with buried rocks, logs, and frozen ground can cause extensive damage and injuries. Riders tend to look for large open fields of fresh snow where they can carve. Some riders use extensively modified snowmobiles, customised with aftermarket accessories like handlebar risers, handguards, custom/lightweight hoods, windshields and seats, running board supports, studs, and numerous other modifications that increase power and manoeuvrability.

6.3 Safety and Legal Regulation

6.3.1 ORVs

ORVs are built with higher-ground clearance to enable off-road use and thus have a higher centre of gravity which increases the risk of rollover. When an ORV turns, the vehicle’s mass resists the turn and carries the weight forward, thus allowing the traction from the tyres to create a lateral centripetal force as the vehicle continues through the turn. ORVs are more likely to be in rollover accidents than passenger cars. According to a study conducted in the USA, ORVs have twice the fatality rate of cars and have nearly triple the fatality rate in rollover accidents. Of vehicles in the USA, light trucks (including ORVs and SUVs) represent 36% of all registered vehicles. They are involved in about half of the fatal two-vehicle

Table 6.4 Mean and total annual days for activities adding more than 100 million participation days between 1999–2001 and 2005–2009 (Source: Cordell 2012, p. 42)

	1999–2001		2005–2009		Percent change in total days	Change in total days (*millions*)
	Mean annual days (*millions*)	Total annual days (*millions*)	Mean annual days (*millions*)	Total annual days (*millions*)	1999–2001 to 2005–2009	1999–2001 to 2005–2009
View wildflowers/trees	61.2	5739.9	86.8	10,532.2	83.5	4792.3
View natural scenery	56.2	7141.5	77.5	11,608.6	62.6	4467.1
Walk for pleasure	103.2	18,109.3	104.6	20,927.8	36.7	2205.7
View/photograph birds	87.8	6009.3	97.7	8215.0	36.7	2205.7
Visit farm/agricultural setting	29.9	1750.4	48.5	3655.3	108.8	1904.9
View wildlife besides birds/fish	38.5	3630.6	46.7	5509.5	51.8	1878.9
Swimming outdoor pool	23.2	1971.1	25.7	2621.1	33.0	650.0
Off-highway driving	**19.7**	**710.4**	**21.6**	**1048.2**	**47.6**	**337.8**
Visit a beach	10.9	924.0	11.6	1184.2	28.2	260.2
Sightseeing	14.8	1616.5	14.9	1842.5	14.0	226.0
Gathering of family/friends	6.2	970.4	6.8	1179.3	21.5	208.9
Gather mushrooms/berries	10.2	614.3	10.3	733.0	30.1	184.7
Visit a wilderness	8.3	558.7	9.3	783.4	28.1	172.0
Visit a waterside besides beach	11.5	611.4	13.9	783.4	28.1	172.0
Swimming in lakes, streams etc.	12.4	1062.4	12.6	1232.4	16.0	170.0
Visit outdoor nature centre/zoo	5.1	620.9	5.5	736.4	18.6	115.5

Source: USDA Forest (2001) (n = 52,607) and USDA Forest Service (2009) (n = 30,398). Change in total days may not exactly equal the difference between the two time periods due to rounding

Note: The numbers are annual activity days estimates based on data collected during the two time periods. Mean days are the average annual number of days in which participants engage in an activity. Total annual days (in millions) is the product of the estimated number of participants and the mean annual days crashes with passenger cars, and 80% of these fatalities are to occupants of the passenger cars.

6.3.2 ATVs

Safety has been a major issue with ATVs due to the high number of deaths and injuries associated with them and the negligible protection offered by the machine. The modern breed of ATVs was introduced in the early 1970s and was almost immediately followed by alarming injury rates for children and adolescents. Based on analysis of the National Trauma Data Bank, ATVs are more dangerous than dirt bikes, possibly due to crush injuries and failure to wear safety gear such as helmets. They are as dangerous as motorcycles, based on mortality and injury scores. More children and women are injured on ATVs, who also present a lower rate of helmet usage (US Consumer Product Safety Commission 2011). Jennissen et al. (2014) claimed that more youth are killed every year in the USA in ATV crashes than on bicycles, and since 2001, one-fifth of all ATV fatalities have involved victims aged 15 years or younger. They administered a cross-sectional survey to 4684 youths aged 11 to 16 years at 30 schools across Iowa from November 2010 to April 2013 (Table 6.5) and found that regardless of rurality, at least 75% of students reported having been on an ATV, with 38% of those riding daily or weekly. Among ATV riders, 57% had been in a crash. Most riders engaged in risky behaviours, including riding with passengers (92%), on public roads (81%), or without a helmet (64%). Almost 60% reported engaging in all three behaviours; only 2% engaged in none.

Fatal accidents typically occur when the ATV rolls over. The correct use of protective equipment can prevent many common injuries. ATV manufacturers recommend at least a suitable approved helmet, protective eyewear, gloves, and suitable riding boots for all riding conditions. Sport or aggressive riders, or riders on challenging terrain (such as those rock crawling or hill-climbing), may additionally opt for a motocross-style chest protector and knee/shin guards for further protection. Proper tyres (suited to a particular terrain) can also play a vital role in preventing injuries.

In the USA, statistics released by the CPSC showed that in 2005, there were an estimated 136,700 injuries associated with ATVs treated in US hospital emergency rooms. In 2004, the latest year for which estimates are available, 767 people died in ATV-associated incidents. According to statistics released by CPSC, the risk of injury in 2005 was 171.5 injuries per 10,000 four-wheel ATVs in use or 1.7%. The risk of death in 2004 was 1.1 deaths per 10,000 four-wheelers in use or 0.01%. ATVs must bear a label from the manufacturer stating that the use of machines greater than 90 cc by riders under the age of 12 is prohibited. However, this is a “manufacturer/CPSC recommendation” and not necessarily state law. The American Academy of Pediatrics and the CPSC recommended that no children under the age of 16 should ride ATVs. A Canadian study stated that “associated injury patterns, severity, and costs to the healthcare system” of paediatric injuries associated to ATVs resemble those caused by motor vehicles and that public policies should reflect this fact. The United States government maintains a website about the safety of ATVs (United States Consumer Product Safety Commission 2018) where safety tips are provided, such as not driving ATVs with a passenger (passengers make it difficult or impossible for the driver to shift their weight, as required to drive an ATV) or not driving ATVs on paved roads (ATVs usually have a solid rear axle with no differential).

In 1988, the ATV Safety Institute (ASI) was formed to provide training and education for ATV riders. The cost of attending the training is low and is free for purchasers of new machines that fall within the correct age and size guidelines. Successful completion of a safety training class is, in many states, a minimum requirement for minor-age children to be granted permission to ride on state land. Some states have had to implement their own safety training programmes, as the ASI programme cannot include those riders with ATVs outside of the age and size guidelines, which may still

Table 6.5 ATV exposure and riding behaviours of pupils in Iowa schools from 2010 to 2013 (*n* = 4320)

Exposure/behaviour	All, no. (%)	Male, no. (%)	Female, no. (%)	*P* value[a]	Isolated rural, no. (%)	Rural, no. (%)	Urban, no. (%)	*P* value[a]
Exposed to ATVs								
Yes	3344 (77)	1620 (79)	1626 (76)	0.095	1196 (82)	1267 (75)	881 (76)	<0.001
No	976 (23)	442 (21)	502 (24)		269 (18)	429 (25)	278 (24)	
How often do you drive/ride on an ATV?								
Almost daily	666 (20)	378 (23)	263 (16)	<0.001	274 (23)	221 (17)	171 (20)	0.005
About once a week	606 (18)	301 (19)	289 (18)		226 (19)	231 (18)	149 (18)	
About once a month	636 (19)	276 (17)	341 (21)		221 (18)	231 (18)	184 (22)	
Only a few times a year	1436 (43)	665 (41)	733 (45)		475 (40)	584 (46)	337 (40)	
Have you ever ridden or driven an ATV with more than one person?								
Yes	2948 (92)	1409 (90)	1455 (94)	<0.001	1086 (92)	1065 (91)	797 (93)	0.19
No	261 (8)	155 (10)	100 (6)		89 (8)	109 (9)	63 (7)	
Have you ever ridden or driven an ATV on a public road?								
Yes	2534 (81)	1237 (81)	1226 (80)	0.75	889 (82)	952 (79)	693 (81)	0.096
No	604 (19)	292 (19)	298 (20)		191 (18)	255 (21)	158 (19)	
How often do you wear a helmet when riding an ATV?								
Always, almost always	530 (17)	288 (19)	233 (15)	<0.001	185 (14)	163 (22)	182 (22)	<0.001
More than half the time	251 (8)	139 (9)	104 (7)		99 (6)	75 (9)	77 (9)	
Less than half the time	366 (12)	200 (13)	157 (10)		142 (10)	119 (13)	105 (13)	
Never, almost never	2032 (64)	921 (59)	1052 (68)		731 (70)	833 (56)	468 (56)	

Data are provided as no. (column percentages). Column totals may not equal overall population totals because of missing indeterminate responses
Source: Jennissen et al. (2014, p. 312)
ATV = All-terrain vehicle
[a]Chi-square analysis for comparison of proportions

fall within the states' laws. In industry, agriculture workers are disproportionately at risk for ATV accidents. Most fatalities occur in white men over the age of 55.

In the UK a "quad bike" is recognised by law as a vehicle with four wheels and a mass of less than 550 kg. To drive a quad bike legally on a public road, in the UK, requires a B1 licence as well as tax, insurance, and registration. After consultation with stakeholders including farmers and quad bike manufacturers, Australia's Heads of Workplace Safety Authorities (HWSA) in 2011 released a strategy intended to reduce the number of deaths and serious injuries associated with quad-bike use. The strategy encouraged standard safety measures such as helmet wearing, recommended the development of a national training curriculum and point-of-sale material for purchasers, and, controversially, recommended that owners consider fitting of an aftermarket anti-crush device which may offer added protection in the event of a rollover. However, the industry argued that such devices had not been properly tested and that past studies of tractor-style full-frame "cages" around the operator were not only ineffective but could add to the risk to injury or death.

6.3.3 Snowmobiles

Snowmobiles are highly manoeuvrable and can accelerate quickly and reach high speeds. Skill and physical strength are required to operate snowmobiles, and snowmobile injuries and fatalities are high in comparison to road motor vehicle traffic. Losing control of a snowmobile can easily cause extensive damage, injury, or death. One such cause of snowmobile accidents is loss of control from a loose grip. If the rider falls off, the loss of control can easily result in the snowmobile colliding with a nearby object, such as a rock, tree, or other vehicles. Most snowmobiles are fitted with a cord connected to a kill switch, which would stop the snowmobile if the rider falls off; however, not all riders use this device every time they operate a snowmobile. Swerving off of the trail may result in rolling the snowmobile or crashing into an obstacle. Riders unfamiliar with their route have been known to crash into suspended barbed wire or fences (which may be concealed by fresh or blown snow) at high speeds. Each year a number of serious/fatal accidents have been caused by these factors.

Deaths of snowmobile riders occur every year from them colliding with other snowmobiles, automobiles, pedestrians, rocks, trees, or fences, or falling through thin ice. On average, ten people a year have died in such crashes in Minnesota alone, with alcohol a contributing factor in many cases. In Saskatchewan, 16 out of 21 deaths in snowmobile collisions between 1996 and 2000 were caused by the effects of alcohol. In the USA fatal collisions with trains have also occurred when snowmobile operators engage in the illegal practice of "rail riding," riding between railroad track rails over snow-covered sleepers. The inability to hear the sound of an oncoming train over the engine noise of a snowmobile makes this activity extremely dangerous. Collision with large animals such as moose and deer, which may venture onto a snowmobile trail, is another major cause of snowmobile accidents. Most often such encounters occur at night or in low-visibility conditions when the animal could not be seen in time to prevent a collision. A sudden manoeuver to miss hitting an animal crossing a trail can result in the operator losing control of the snowmobile. Many snowmobile deaths in Alaska are caused by drowning. Rivers and lakes are generally frozen over in winter. Riders who operate early or late in the season run the risk of falling through weak ice, and heavy winter clothing can make it extremely difficult to escape the frozen water. While a snowmobile is heavy, it also distributes its weight over a larger area than a standing person, so a driver who has stopped his vehicle out on the ice of a frozen lake can go through the ice just by stepping off the snowmobile. The next leading cause of injury and death in snowmobiling is avalanches, which can result from the practice of "highmarking," or driving a snowmobile as far up a hill as it can go. Risks from avalanches can be reduced through education, proper training, appropriate equipment (such as the wearing of avalanche airbags or transceivers as used by skiers and mountaineers), and attention to published avalanche warnings. It is recommended that snowmobile riders wear a helmet and a snowmobile suit.

6.4 Environmental Impact

In this section we see the environmental impacts of ORVs, ATVs, and motorcycles to be broadly similar, and so we discuss these in one section, whereas those of snowmobiles are in many ways different and, we feel, warrant a separate section.

6.4.1 ORVs, ATVs, and Motorcycles

6.4.1.1 Damage to Soil and Vegetation

In the USA the number of ORV users climbed sevenfold from 5 million in 1972 to 36 million in 2000. Government policies that protect wilderness but also allow recreational ORV use have caused debate across many countries. All trail and off-trail activities impact natural vegetation and wildlife, which can lead to erosion, introduce invasive species on tyres, and cause habitat loss and ultimately species loss decreasing an ecosystem's ability to maintain equilibrium. ORVs cause greater stress to the environment than foot traffic alone, and ORV operators who attempt to test their vehicles against natural obstacles can do significantly more damage than those who simply follow legal trails. Illegal use of ORVs has been identified as a serious land management problem ranked with dumping garbage and other forms of vandalism. Many user organisations, such as Tread Lightly! and the Sierra Club, publish and encourage appropriate trail ethics.

Since ORVs can cover large distances more rapidly than walkers or horse riders, their potential to cause substantial impact on the environment, even on one trip, is greater (Webb and Wilshire 1983; Parikesit et al. 1995). They have the potential to reach remote wilderness areas quickly. The forces created by spinning wheels in association with deep tread tyres can dislodge soil and vegetation rapidly (Cambi et al. 2015a, b). This damage is compounded by the desire of many ORV users to seek out steep, sometimes unstable slopes (Fig. 6.4A, B) where erosion is more easily started (Hammitt and Cole 1998), and once the stable vegetated surface is broken, an erosion cycle begins which can be one of the most significant impacts because of its irreversibility and its tendency to get progressively worse even without continued use. Motorised recreational vehicles can also cause damage to water quality (Marion et al. 2014) particularly where vehicles cross stream banks and enter watercourses (Fig. 6.4C). Damage to stream banks results in eroded soil being deposited in streams which increases sediment loads and turbidity. This extra sediment can clog up fish breeding grounds (e.g. trout and salmon) causing the eggs laid in gravels to be deprived of oxygen, resulting in reduced breeding success. ORVs driving along stream beds (Fig. 6.4C) can also dislodge fish eggs laid in gravels, again resulting in reduced breeding success.

In 2010 Roy Hattersley wrote in the *Guardian* newspaper on how Peak District parkland was under threat from the rise of the 4x4s, stating that off-road motoring was literally wearing parts of the Peak District away. The link to the article is here:

https://www.theguardian.com/uk/2010/mar/21/off-roading-national-park-countryside.

Weaver and Dale (1978) carried out an experimental study in Montana where they examined the effects of horses, hikers, and a lightweight, slowly driven motorcycle on trail erosion. Trails produced by 1000 horse passes were two to three times as wide and 1.5 to 7 times as deep as trails produced by 1000 hiker passes, whereas the effects of the motorcycle were in between these. Soil bulk density increased 1.5 to 2 times as rapidly on horse trails as on hiker trails. The motorcycle was, again, intermediate in severity. However, vegetation loss occurred much more rapidly on horse and motorcycle trails than on hiker trails. Motorcycle damage was greatest when going uphill (Fig. 6.4A), whereas horse and hiker damage was greatest when going downhill.

Anders and Leatherman (1987) examined the effects of ORVs on coastal foredunes at Fire Island, New York, USA. Using sequential quadrat surveys at adjacent control and impact sites over a two-year field study, they found significant loss of vegetation resulting from ORV impacts and concluded that this loss of vegetation resulted in an alteration of the natural foredune profile, which could increase dune erosion during storm wave attack.

Slaughter et al. (1990) reviewed the use of ORVs in permafrost-affected terrain of Alaska which had increased sharply. Until the early 1960s, most ORV use was by industry or government, which employed heavy vehicles such as industrial tractors and tracked carriers. Smaller,

Fig. 6.4 (A) Negative environmental effects caused by a motorcycle to a portion of the Los Padres National Forest, California. Photo by BeenAroundAWhile. (B) Land Rover Series III mud plugging. Photo by AndrewH. (C) A Jeep Grand Cherokee, in action, drives through a watercourse. Photo by DarkSaturos90

commercial ORVs became available in the 1960s, with the variety and number in use rapidly increasing. Wheeled and tracked ORVs, many used exclusively for recreation or subsistence harvesting by individuals, are now ubiquitous in Alaska. This increased use had led to concern over the cumulative effects of such vehicles on vegetation, soils, and environmental variables including offsite values. Factors affecting impact and subsequent restoration include specific environmental setting; vegetation; presence and ice content of permafrost; microtopography; vehicle design, weight, and ground pressure; traffic frequency; season of traffic; and individual operator practices. Approaches for mitigating adverse effects of ORVs include regulation and zoning, terrain analysis and sensitivity mapping, route selection, surface protection, and operator training.

During the 1960s and 1970s, concern about the long-term effect of off-road driving on tundra surfaces increased due to observed damage in northern Alaska and in the Canadian Northwest Territory (Råheim 1992). It was realised that the thermal instability associated with the removal of vegetation could lead to permanent surface modification. Commonly described effects were the deepening of the summer-thawed layer, the creation of permanent depressions due to differential thaw settlement, sediment instability and possible outwash, and scar development on slopes. Stott and Short (1996) studied erosion attributed to mining track in the Gipsdalen Valley in Svalbard (Fig. 6.5A, B). A mining exploration track was established by a Finnish company, which was prospecting for coal and oil in 1985. The track ran for some 18.5 km on the east side

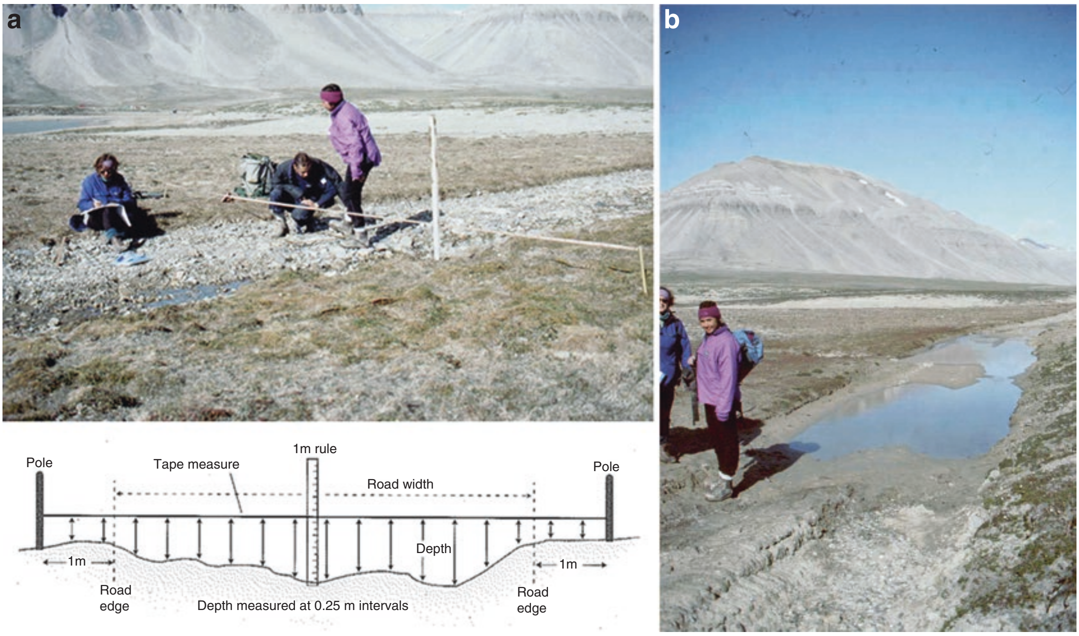

Fig. 6.5 (A) Surveying an eight-year-old vehicular track in Gipsdalen, Svalbard, to measure the eroded cross-section area (Stott and Short 1996). (B) An eight-year-old vehicular track in Gipsdalen, Svalbard, shows how erosion and compaction by ORVs in Arctic tundra can lead to deepening of the summer-thawed layer, the creation of permanent depressions due to differential thaw settlement, waterlogging, and removal of vegetation (Stott and Short 1996). Photos taken by Tim Stott

of Gipsdalen. An erosion survey of 10.25 km of this track was undertaken in summer 1993. It was estimated that approximately 6093 tonnes of soil had been removed due to the presence of this track. Assuming the track had been eroding for eight years, it had produced an average of 762 t $yr.^{-1}$. In order to compare this with the approximate drainage basin erosion rate estimated from fluvially transported sediments, this total was divided by the drainage basin area to give an erosion rate equivalent of 6 t km^{-2} $yr.^{-1}$. In other words, over eight years this track seems to have contributed more than half of the estimated natural background erosion in Gipsdalen. By 1987 the Norwegian government had banned use of the track by vehicles unless it was snow covered and frozen.

Kevan et al. (1995) reported that their examination of the effects of vehicle and pedestrian tracks of known age (13 or more years) and intensity of use (single to multiple passages) on high Arctic tundra vegetation, soil chemistry, soil arthropods, soil thaw characteristics, and small-scale hydrological changes showed clear and interrelated patterns. In general, all tracks, regardless of age, showed small increases in the depth of thaw beneath them (c. 2.8 cm). Tracks were generally depleted of carbon and, to a lesser but significant extent, of potassium and phosphorus. Slight increases in NO_3, NH_4, and calcium were noted. Magnesium and total nitrogen seemed unaffected. On all tracks which had suffered multiple passages, vegetation cover was significantly reduced. In a few sites where single passages were recorded, cover increased through proliferation of the sedge, *Kobresia myosuroides*. Abundance of soil arthropods was significantly reduced on tracks, but the diversity was not. In most sites, soil moisture and overground water flow did not seem affected. Only in sedge meadows where compression from a single passage resulted in channelling of water, and where multiple passages removed vegetation and initiated gulley erosion, were effects serious.

6.4.1.2 Pollution and Noise

ORVs, ATVs, and motorcycles have also been criticised for producing more pollution in areas that might normally have none. In addition to noise pollution that can cause hearing impairment and stress in wildlife, Brattstrom and Bondello (1983) reported on the effects of off-road vehicle noise on desert vertebrates. According to the US Forest Service, old-style two-stroke engines (no longer a component of new ORVs, although some are still in use) emit about 20–33% of the consumed fuel through the exhaust. In 2002, the United States Environmental Protection Agency adopted emissions standards for ATVs that "when fully implemented in 2012… were expected to prevent the release of more than two million tons of air pollution each year—the equivalent of removing the pollution from more than 32 million cars every year." Uberti et al. (2017) proposed the application of an integrated eco-innovation and technical contaminated approach for the design and development of a new concept of off-road motorcycle to meet the requirements of low environmental impact and light weight of the vehicle while maintaining the pleasure of riding in the nature.

The environmental impact of burning fossil fuels, in particular diesel, by ORVs in wilderness areas has led to investigation of alternative fuels such as biofuels. Popovicheva et al. (2015) evaluated the chemical composition of combustion aerosols emitted by off-road engines fuelled by diesel and biofuels. Particles produced by burning diesel, heated rapeseed oil (RO), RO with ethylhexylnitrate, and heated palm oil were sampled from exhausts of representative in-use diesel engines. Their findings provided functional markers of organic surface structure of off-road diesel emission, allowing for a better evaluation of relation between engine, fuel, operation condition, and particle composition, thus improving the quantification of environmental impacts of alternative energy source emissions.

6.4.1.3 Wildlife

The increasing popularity of recreational activities in the wild has led to concerns about their potential impacts on wildlife. ATVs often bring people into wildlife habitats, where they may disturb animal populations. There has been a plethora of studies on the impact of ORVs on wildlife, a few examples of which are summarised here.

ORV use is arguably one of the most environmentally damaging human activities undertaken on sandy beaches worldwide. Studies which focused on areas of high traffic volumes have demonstrated significantly lower abundance, diversity, and species richness of fauna in zones where traffic is concentrated. For example, in the 1970s Busack and Bury (1974) reported that the use of ORVs vehicles on the Mojave Desert eliminated vegetation and adversely affected lizard populations. Wolcott and Wolcott (1984) examined the potential and actual impacts of ORV use on beach macroinvertebrates on the Cape Lookout National Seashore (North Carolina). Mole crabs *Emerita talpoida* and coquinas *Donax variabilis* were not damaged. Ghost crabs *Ocypode quadrata* were completely protected by burrows as shallow as 5 cm and therefore were not subject to injury during the day, but they could be killed in large numbers by vehicles while feeding on the foreshore at night. Ghost crab populations on the seashore were large (10,000 km^{-1} of beach), and a small proportion of the population would be killed by a single vehicle pass. Nevertheless, predicted population mortalities calculated from observed kills of ghost crabs per vehicle-km ranged from 14% to 98% for 100 vehicle passes. Vehicle use on the beach was light, and essentially none occurred on the foreshore after dark. Little impact on beach macroinvertebrates would be expected from this usage pattern. Actual impact on ghost crab populations, assessed by burrow censuses, was negligible. No differences were detected between heavy-use and light-use sites in total population size, average crab size, or population change through the heaviest traffic season. However, increases in traffic to levels seen on other beaches, especially night driving, would probably have devastating effects on ghost crab populations. In heavily used areas, they suggested that banning of ORVs from the foreshore between dusk and dawn may be required to protect this species.

Davies et al. (2016) investigated the impacts of relatively low-level vehicle traffic on sandy beach fauna by sampling invertebrate communities at eight beaches located in south-western Australia. They found that even low-level vehicle traffic negatively impacts the physical beach environment and, consequently, the ability of many species to survive in this habitat in the face of this disturbance. Compaction, rutting, and displacement of the sand matrix were observed over a large area, resulting in significant decreases in species diversity and density and measurable shifts in community structure on beaches that experienced ORV traffic. Communities at impact sites did not display seasonal recovery as traffic was not significantly different between seasons. Given a choice between either reducing traffic volumes or excluding ORV traffic from beaches, their results suggested that the latter would be more appropriate when the retention of ecological integrity is the objective.

Borneman et al. (2016) investigated how ORVs affected nesting behaviour and reproductive success of American oystercatchers. Felton et al. (2017) designed a field experiment to study the responses of nesting American oystercatchers (*Haematopus palliatus*) to off-road passenger vehicles (ORVs) at Cape Hatteras and Cape Lookout National Seashores in North Carolina, USA. Using continuous video and heart rate recordings to assess changes in the behaviour and physiology of incubating oystercatchers, they conducted driving experiments affecting 7 nesting pairs in 2014 and 19 nesting pairs in 2015, between April and July of each year. They concluded that beach-nesting birds may benefit from reduced vehicle traffic at their nesting sites, allowing parents to spend more time attending the nest and less time on defensive behaviours.

In South Africa, ORVs are banned from most coastal areas, while some areas are designated for restricted ORV use, providing an opportunity to assess whether ORV traffic restrictions translate into biological returns. Working in Sodwana Bay, Lucrezi et al. (2014) investigated the impact of ORVs on ghost crab populations. During Easter 2012, ghost crab burrows were counted on beach sections opened and closed to traffic. Burrow density in the impact section was less than a third that of the reference section, and by the end of the study, burrow size in the impact section was half that of the reference section. ORV traffic caused a shift in burrow distribution to the lower beach. However, differences in burrow densities between sections were 14 times smaller than differences obtained at a time when ORV use in Sodwana Bay was not controlled. While confirming the well-established detrimental effects of ORV use on sandy beach ecosystems, these results demonstrated that traffic restrictions on beaches measurably minimise impacts to the fauna, thus translating into worthwhile biological returns.

St-Louis et al. (2013) assessed the influence of ATVs on the behaviour of mountain goats (*Oreamnos americanus*) in a long-term study population at Caw Ridge, Alberta, Canada. They used multinomial models containing environment-, disturbance-, and group-related factors, to evaluate the response of mountain goats to the approach of ATVs. Goats were moderately to strongly disturbed by ATVs 44% of the time, and disturbance levels were mainly influenced by the direction and speed of the approaching vehicles. Environment- or group-related factors (e.g. time of year, distance to escape terrain, group size or type) did not affect mountain goat responses to ATVs. Because goat reactions were influenced by disturbance-level factors, they proposed mitigating measures regarding the use of ATVs in the wild to minimise the disturbance to mountain goats and potentially other alpine ungulates.

6.4.2 Snowmobiles

6.4.2.1 Damage to Soil and Vegetation

Greller et al. (1974) described the effects of 1020 passages of snowmobiles, made over two winters, on three regularly winter snow-free alpine tundra plant communities. A cushion-plant community on a seven-degree slope showed a 31% reduction in total living plant coverage due to snowmobile impact. Destruction was greatest to soil lichens, rock lichens, and the cushion plants *Arenaria obtusiloba*, *Arenaria fendleri*, *Paronychia sessiliflora var. pulvinata*, *Silene acaulis*, *Eritrichium* *aretioides*, and *Phlox pulvinata*. Graminoids generally survived to increase in importance. On a flat site, a cushion-plant community with *Kobresia myosuroides* as its most important species showed the greatest loss of living plant coverage, namely 46%. This was due primarily to the destruction of *Kobresia*, although *Selaginella densa*, *Arenaria obtusiloba*, *Hymenoxys acaulis*, and *Eritrichium aretioides* also showed heavy losses. In a *Kobresia* turf community, destruction was decidedly less severe than in the cushion-plant communities, reduction in total living plant coverage being only 19%. Greller et al. suggested that the closed nature of the *Kobresia* turf, with its stiff tussocks, enabled it to absorb impact well. They recommended that snowmobile travel be confined to *Kobresia* or similar turfs, when such travel is necessary under snow-free conditions.

Keddy et al. (1979) carried out a study in Nova Scotia, Canada, to experimentally assess the effect of snowmobiles on old field and marsh vegetation. Snowmobile treatments ranging from a single pass to 25 passes (five passes on five separate days) were administered. The first pass by a snowmobile caused the greatest increase in snow compaction—roughly 75% of that observed after five sequential passes. Snowmobile treatment resulted in highly significant increases in snow retention in spring. Frequency was more important than intensity in this regard. Standing crop and species composition were measured the following summer. Standing crop in the field showed a significant reduction with increasing snowmobile use; frequency of treatment ($p < 0.01$) was more important than intensity ($p = 0.125$). *Stellaria graminea*, *Aster cordifolius*, *Ranunculus repens*, and *Equisetum arvense* all showed significant ($p < 0.05$) differences in percent cover resulting from the treatment. Marginally significant changes were observed in *Agrostis tenuis* and *Phleum pratense*. Marsh vegetation showed no significant effects of snowmobile treatment. This may have been because of solid ice cover during the winter. Overall it was concluded that snowmobile use could have a highly significant effect upon natural vegetation.

6.4.2.2 Pollution and Noise

There has been interest in snowmobile emissions for several decades. For example, Hare et al. (1974) described a research programme on exhaust emissions from snowmobile engines, including both emissions characterisation and estimation of national emissions impact. Tests were conducted on three popular two-stroke twins and on one rotary (Wankel) engine. Emissions that were measured included total hydrocarbons, (paraffinic) hydrocarbons by NDIR, CO, CO_2, NO (by two methods), NO_x, O_2, aldehydes, light hydrocarbons, particulate, and smoke. Emissions of SO_x were estimated on the basis of fuel consumed, and evaporative hydrocarbons were projected to be negligible for actual snowmobile operation. Based on test results and the best snowmobile population and usage data available, impact of snowmobile emissions on a national scale was computed to be minimal.

However, during a two-month monitoring campaign in 2007 in the Arctic town of Longyearbyen (Spitsbergen, Svalbard), Reimann et al. (2009) measured the aromatic hydrocarbons benzene, toluene, and C_2-benzenes (ethyl benzene and m-,p-,o-xylene) (BTEX). Reflecting the remoteness of the location, very low mixing ratios were observed during night and in windy conditions. In late spring (April–May), however, the high frequency of guided snowmobile tours resulted in "rush-hour" maximum values of more than 10 ppb of BTEX. These concentration levels are comparable to those in European towns and are caused predominately by the outdated two-stroke engines, which are still used by approximately 30% of the snowmobiles in Longyearbyen. During summer, peak events were about a factor of 100 lower compared to those during the snowmobile season. Emissions in summer were mainly caused by diesel-fuelled heavy-duty vehicles (HDVs), permanently used for coal transport from the adjacent coal mines. Reimann et al. concluded that these documented high BTEX mixing ratios from snowmobiles in the Arctic provide an obvious incentive to change the regulation practice to a cleaner engine technology.

Discharge of unburnt fuel from two-stroke snowmobile engines can lead to indirect pollutant deposition into the top layer of snow and subsequently into the associated surface and groundwater. As early as the 1970s, Adams (1975) reported that lead and hydrocarbons from snowmobile exhaust were found in the water at high levels during the week following ice-out in a Maine pond. Fingerling brook trout (*Salvelinus fontinalis*) held in fish cages in the pond showed lead and hydrocarbon uptake. These contaminants accumulated during the previous winter when snowmobile operation on the pond was equivalent to one snowmobile burning 250 litres of fuel per season on a 0.405 hectare pond with average depth of 1 m. Lead content of the water rose from 4.1 ppb before snowmobiling to 135 ppb at ice-out, with exposed trout contained 9 to 16 times more lead than controls. Hydrocarbon levels undetectable prior to snowmobiling reached 10 ppm in the water and 1 ppm in exposed fish. Trout held in aquaria for three weeks in melted snow containing three different concentrations of snowmobile exhaust also showed lead and hydrocarbon uptake. Their digestive tract tissue contained the most lead (2 ppm) and gills the least (0.2 ppm). Stamina, as measured by the ability to swim against a current, was significantly less in trout exposed to snowmobile exhaust than in control fish.

Maximum noise restrictions have been enacted by law for both production of snowmobiles and aftermarket components. For instance, in Quebec (Canada) noise levels must be 78 decibels or less at 20 m from a snowmobile path. As of 2009, snowmobiles produce 90% less noise than in the 1960s, but there are still numerous complaints. Efforts to reduce noise focus on suppressing mechanical noise of the suspension components and tracks. Arctic Cat in 2005 introduced “Silent Track technology” on some touring snowmobile models.

According to Mullet et al. (2017), snowmobiling in congressionally designated wilderness (CW) in Alaska is a contentious issue in the arena of appropriate use of public lands. The 1980 Alaska National Interests Lands Conservation Act permits snowmobiling in CW for traditional activities. Conversely, the 1964 Wilderness Act prohibits motor vehicles in CW to preserve its naturalness and opportunities for solitude. These conflicting mandates challenge the ability of managers to preserve CW character. The Kenai National Wildlife Refuge (KENWR) manages 534,300 ha of CW, where 253,200 ha are open to snowmobiling. Snowmobile noise degrades CW character, whereas natural quiet is indicative of naturalness and offers opportunities for solitude. In their study Mullet et al. (2017) determined the acoustic footprint of snowmobile noise and areas of natural quiet refugia in CW by recording the soundscape at 27 locations inside, and 37 locations outside, KENWR CW. They calculated soundscape power (normalised watts/kHz) from 59,598 sound recordings and generated spatial models of snowmobile noise and natural quiet using machine learning (TreeNet). They calculated the area of CW with the highest and lowest soundscape power for snowmobile noise and natural quiet, respectively. Snowmobile noise occurred during daylight hours, while natural quiet was predominant at night. Snowmobile noise was higher in February and March, while January was quieter. Snowmobile noise affected 39% of CW open to snowmobiling, while natural quiet made up 36%. Natural quiet occurred in 51% of all KENWR CW of which 39% was prohibited by management or inaccessible by snowmobiles. These models identified areas where conservation of winter soundscapes in CW should be focused (Fig. 6.6).

6.4.2.3 Wildlife

In an observational experiment, Fuglei et al. (2017) examined the impact of snowmobile traffic on the diurnal activity of Arctic fox in high Arctic Svalbard. They conducted the study in two areas in Svalbard, one control area with low snowmobile traffic and one experimental area with high snowmobile traffic. In each area ten camera traps, baited with reindeer carcasses, were positioned and programmed to take photographs every five minutes. The proportion of photographs with foxes was higher during the night than during the day, and the difference

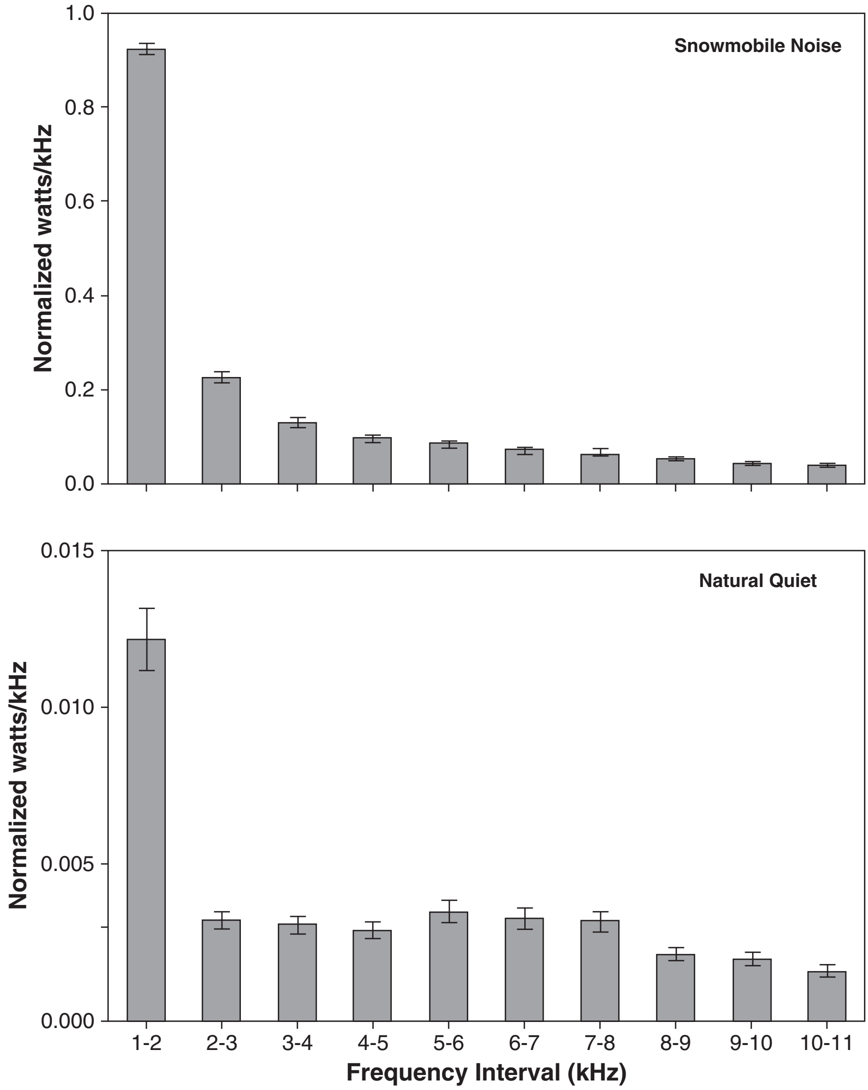

Fig. 6.6 Average soundscape power (normalised watts/kHz) and 95% confidence intervals within ten 1-kHz frequency intervals summarised for snowmobile noise and natural quiet identified from 59,598 sound recordings acquired over winter (December 2011–April 2012) in Kenai National Wildlife Refuge, Alaska. Source: Mullet et al. (2017)

between night and day was larger in the area with more snowmobile traffic. By using data obtained according to a similar study design in two Arctic Russian sites, Yamal and Nenetsky, with little human activity and low snowmobile traffic, they were able to compare Arctic fox activity patterns in Svalbard on a larger scale. Their results indicated that snowmobile traffic had an impact on the diurnal activity of the Arctic fox in Svalbard, while there were no obvious diurnal activity patterns among Russian foxes. Even the area with low snowmobile traffic in Svalbard showed increased use of the reindeer carcasses during the night compared to one of the Russian sites, where foxes used carcasses equally during day and night. Such knowledge is of importance in designing cautious management practices.

Andersen and Aars (2008) measured the distance at which polar bears detected and actively responded to approaching snowmobiles on Svalbard, an arctic island where human traffic had increased substantially in recent years. Fieldwork was conducted in April and/or May during the years 2003–2005. Polar bears were observed on ice with telescopes and binoculars. Undisturbed polar bears were observed continuously and their behaviours recorded, during the time when two snowmobiles moved towards the bear(s). Distances between the bear, the observer, and the approaching snowmobiles were measured using GPS positions taken on the track towards the bear. The responses of the polar bears to the snowmobiles were categorised according to intensity and persistence of reactions. Females with cubs and single medium-sized bears tended to show more intense responses than adult males and lone adult females. Wind direction affects sound and odour transmission, and although an effect on response distance was not found, the response intensity was affected by wind direction. They concluded that female polar bears with small cubs in particular may have a greater risk to being disturbed, since they reacted at greater distances with amplified reactions; thus, users of snowmobiles should take particular care in areas where females with cubs are present.

6.5 Management and Education

6.5.1 Introduction

In 1987 a report was published by the Royal Society for Nature Conservation in the UK entitled “Damage to Wildlife Sites by Off-Road Motor Vehicles” (RSNC 1987) which reported on a survey which had identified at least 130 sites of wildlife importance had been damaged by ORVs. Over half of the sites were Sites of Special Scientific Interest (SSSIs), and many had other conservation designations. The most affected habitats were grasslands and woodlands, followed by heathlands, saltmarsh, and moorland. It concluded that the following measures were needed to alleviate this damage to wildlife interests:

1. Education of the participants, so that they understood the damage that they could cause
2. Provision of alternative sites where ORV could be used without causing problems
3. A requirement for normal planning permission requirements to apply if a site was to be used for any off-road events
4. Stronger measures to prevent third-party damage to SSSIs

Measures to control ORVs used by conservation bodies included the erection of physical barriers like fences and gates the digging of ditches or erection of signs. However, it was recognised that physical barriers were not usually effective as determined riders could usually find their way onto a site. Many sites used a warden which was more effective as they were able to educate the riders rather than just imposing a prohibition without explanation. However, provision of wardens was seen to be expensive. Only in a minority of cases were conservation bodies able to reach agreements with a club or to suggest an alternative site. For some riders/drivers, the notion of using an alternative site can be a problem if the site is some distance away. The police had become involved at around half of the 130 damaged sites noted in the RSNC report, and the apprehension of just one or two persistent offenders by the police soon becomes news and can discourage others. However, police resources are stretched, and it is not always possible to access police support wherever and whenever it is needed. ORV damage is quite low on the list of police priorities.

6.5.2 Legal Controls

In the UK informal access to land by ORVs is controlled, in theory, by the Road Traffic Act 1972 (section 36) which specifies that it is a criminal offence to drive any motor vehicle off-road without the landowner’s permission (except within 15 m of the centre of a road for parking, for the saving of life, fire, or other emergencies). However, in practice the temporary use of land for organised scrambling or ORV events is permitted for short periods, with only activities lasting more than 14 days per year requiring planning permission. Problems can arise where there is informal use of a site by individuals without consent of the owner, who in some cases may turn a blind eye in the hope that the damage to the site will eventually lead to the removal of an SSSI designation.

In the USA the Bureau of Land Management (BLM) supervised several large ORV areas in California's Mojave Desert. In what has become known as the Mojave Desert controversy in 2009, US District Judge Susan Illston ruled against the BLM's proposed designation of additional off-road use on designated open routes on public land. According to the ruling, the BLM violated its own regulations when it designated approximately 5000 miles of ORV routes in 2006. According to Judge Illston, the BLM's designation was "flawed because it did not contain a reasonable range of alternatives" to limit damage to sensitive habitat, as required under the National Environmental Policy Act. Illston found that the bureau had inadequately analysed the route's impact on air quality, soils, plant communities, and sensitive species such as the endangered Mojave fringe-toed lizard, pointing out that the United States Congress has declared that the California desert and its resources are "extremely fragile, easily scarred, and slowly healed." The court also found that the BLM failed to follow route restrictions established in the agency's own conservation plan, resulting in the establishment of hundreds of illegal ORV routes during the previous three decades. The plan violated the BLM's own regulations, specifically the Federal Land Policy and Management Act of 1976 (FLPMA) and the National Environmental Policy Act of 1969 (NEPA). The ruling was considered a success for a coalition of conservation groups including the Friends of Juniper Flats, Community Off-Road Vehicle Watch, California Native Plant Society, the Centre for Biological Diversity, the Sierra Club, and The Wilderness Society who initiated the legal challenge in late 2006.

Many US national parks have discussed or enacted roadless rules and partial or total bans on ORVs. To accommodate enthusiasts, some parks like Big Cypress National Preserve in Florida were created specifically for ORVs and related purposes. However, such designations have not prevented damage or abuse of the policy. In 2004, several environmental organisations sent a letter to Dale Bosworth, Chief of the United States Forest Service, and described the extent of damage caused by ORV use, including health threats to other people. It was articulated that the proliferation of ORV and snowmobile use placed soil, vegetation, air and water quality, and wildlife at risk through pollution, erosion, sedimentation of streams, habitat fragmentation and disturbance, and other adverse impacts to resources. These impacts were causing severe and lasting damage to the natural environment on which human-powered and equestrian recreation depended and altered the remote and wild character of the backcountry. Motorised recreation sometimes monopolised forest areas by denying other users the quiet, pristine, backcountry experience they seek. It also presented safety and health threats to other recreationists. In 2004 the Supreme Court Justice Antonin Scalia listed several problems that result from ORV use in natural areas. From the Environment News Service article, Scalia noted that ORV use on federal land has "negative environmental consequences including soil disruption and compaction, harassment of animals, and annoyance of wilderness lovers."

A number of environmental organisations, including the Rangers for Responsible Recreation, continue to campaign to draw attention to a growing threat posed by ORV misuse and to assist land managers in addressing ORV use impacts. These campaigns in part have prompted congressional hearings, and key to the discussions was the "travel planning process," a complex analysis and decision-making procedure with the aim of designating appropriate roads and trails. Both the Forest Service and the BLM have identified unmanaged recreation—including ORV use—as one of the top four threats to the management and health of the National Forest System.

Adams and McCool (2009) outlined how the Forest Service and the BLM were revising their local travel management plans. These plans govern much of the allocation of recreation experience opportunities, including the balance between ORV and non-motorised opportunities. Their paper explored the historic management of ORVs by the Forest Service and the BLM, as well as laws and regulations governing ORV management, in order to (1) explain how Forest Service and BLM travel management works, (2) evaluate the ORV and non-motorised allocations for multiple-use lands, and (3) provide suggestions for improved agency management of ORVs. Ultimately, concerns regarding appropriate allocations, the escalating conflicts between recreationists, increasing demand for outdoor recreation, the rising stakes associated with allocation decisions, and the plainly political nature of allocation decisions all point to a better, long-term solution: a new statutory recreation policy for multiple-use lands.

6.5.3 Managing ORV Use and Experiences

While most research on ORV use has focused on its potential environmental impacts and conflicts with other types of recreation, Hallo et al. (2009) examined the ORV experience itself. The concept of indicators and standards of quality has emerged in the literature as a conceptual framework for understanding and managing outdoor recreation. Their study applied the concept of indicators of quality to ORV use at Cape Cod National Seashore (Cape Cod). Qualitative interviews were conducted during the 2004 use season with 61 ORV users at Cape Cod to gather information on indicators of quality for the ORV experience. A content analysis was performed on the transcripts, and results suggested that crowding, the portion of the ORV route open, ease of obtaining a permit, amount of litter, availability of support facilities, and the behaviour and actions of ORV users are potential indicators of quality. The portion of the ORV route open may be a less useful indicator because it is not easily adaptable due to current legislative and regulatory guidance for the management of threatened shorebirds. The other variables are better potential indicators because they may be more readily measured and managed.

New research methods such as the use of airborne remote sensing (e.g. Dewidar et al. 2016) and GIS (Geographical Information Systems) (e.g. Rybansky 2014; Westcott and Andrew 2015; Kobryn et al. 2017) offer managers concerned with ORV impacts new tools for gathering data and informing planning and decision-making.

The tremendous growth of recreational ATV use in Canada and the USA has led to rapidly increasing pressure on local authorities and provincial/state governments to either sanction increased access to ATVs or restrict their use on community trails and local roadways. Given this increased pressure, there is a growing need for a policy development tool to assist decision-makers in making prudent policy decisions that carefully balance special interest lobbying with the broader public interest, whether that be at the local or community level or in the broader context of provincial or state legislative policy. Bissix (2015) presented a decision support framework that guided policy decision-makers to consider a broad range of health and safety factors along with environmental, social, and economic considerations. He hoped that by using this multidimensional assessment framework in an open and transparent way, policy actors would be encouraged to rely on defensible scientific evidence and best practices rather than react to the vociferous advocacy of policy champions.

SAE International, the Society of Automotive Engineers, is a US-based, globally active professional association and standards developing organisation for engineering professionals in various industries. Each year it opens a competition called the SAE Clean Snowmobile Challenge. The University of Idaho's entry into the 2016 SAE Clean Snowmobile Challenge (Savage et al. 2016) was a 2013 Ski-Doo MXZ-TNT chassis with a reduced-speed 797 cc direct injected two-stroke engine, modified for flex fuel use on blended ethanol fuel. A battery-less direct injection system was used to improve fuel economy and decrease emissions while maintaining a high power-to-weight ratio. A new tuned exhaust was designed to accommodate the lowered operating speed of the engine while improving the peak power output from 65.6 kW (88 hp) to 77.6 kW (104 hp). Noise was reduced through the implementation of a mechanically active quarter-wave resonator, Helmholtz resonator, and strategically placed sound-absorbing/deadening materials and by operating the engine at a lower speed. A muffler was modified to incorporate a three-way catalyst, which reduces engine emissions while not significantly reducing power output or increasing sound output. Such developments are promising and show that the manufacturing industry is making efforts to minimise the environmental impacts of snowmobiles.

6.5.4 Education and ORV Users

Like naturalists, motor sports enthusiasts are legitimate users of the countryside, but they need to recognise that their activities can cause damage and conflicts with other interests. Such recognition can be brought about by education of the participants by interested parties. Once ORV users begin to realise the problems they can cause on inappropriate sites, they may be more willing to move to alternative areas. However, there may still need to be strong protective measures for the most important nature conservation sites.

It appears that many users of ORVs regard areas of wildlife habitat, even nature reserves, simply as areas of derelict land, and this ignorance in many cases is genuine. The majority of ORV users cannot be accused of mindless vandalism; they are often genuinely concerned about the problems they may have caused and may not be aware of the damage done until it is pointed out to them. The more responsible and organised motorsport participants will belong to an organisation or club. For example, in the UK, Offroad Motorsport UK is a professional organisation which understands the requirements for holding events whether they are motocross, trials, enduro, practice events, or other off-road activities and can offer their services and insurance at competitive costs. Their aim is to promote good family events, and to do this they issue their members with an exemption permit under the Motor Vehicle (off-road events) Regulations 1995. Most genuine off-road motorsports clubs in the UK are affiliated to Offroad Motorsport UK. Organisations like this ensure that their affiliated clubs and their members are well aware of the damage that can be done to wildlife by their activities and, where possible, encourage members to enter organised events where measures are taken to control their impact and operate legally.

It is more difficult, however, to get the nature conservation message across to the large body of off-road motor sport participants who do not belong to recognised clubs or organisations. Articles in motorsport magazines can reach some as can websites and social media or even reports published by pressure groups (see, e.g., Fig. 6.7). Another widely effective measure is for manufacturers or retailers of machines intended to be used off-road to provide point-of-sale information about specific rights and responsibilities of those riding or driving off-road in the countryside (including nature conservation information). This, of course, does not necessarily reach people buying ORVs in the second-hand market, however.

In response to issues and challenges facing the operators of nature-based tours, Lyngnes and Prebensen (2014) examined snowmobile tours in Svalbard, Norway. They explored the awareness of the tour guides of the fragile nature of the environment in which they were operating and how this awareness was implemented in their offerings. The results showed that the guides were aware of the fragile nature and did strive to promote sustainable behaviour during tours. In particular, they focused on informing and teaching the tourists about environmental aspects of the tour through storytelling and staging during the tour. By empowering the tourists through education and involvement, they aimed to make the tourists change their focus from riding the snowmobile to learning about the fragility of the nature and wildlife. Further, the guides stated that the tourists may even become spokespersons for sustainable tourism due to the tour which they had experienced.

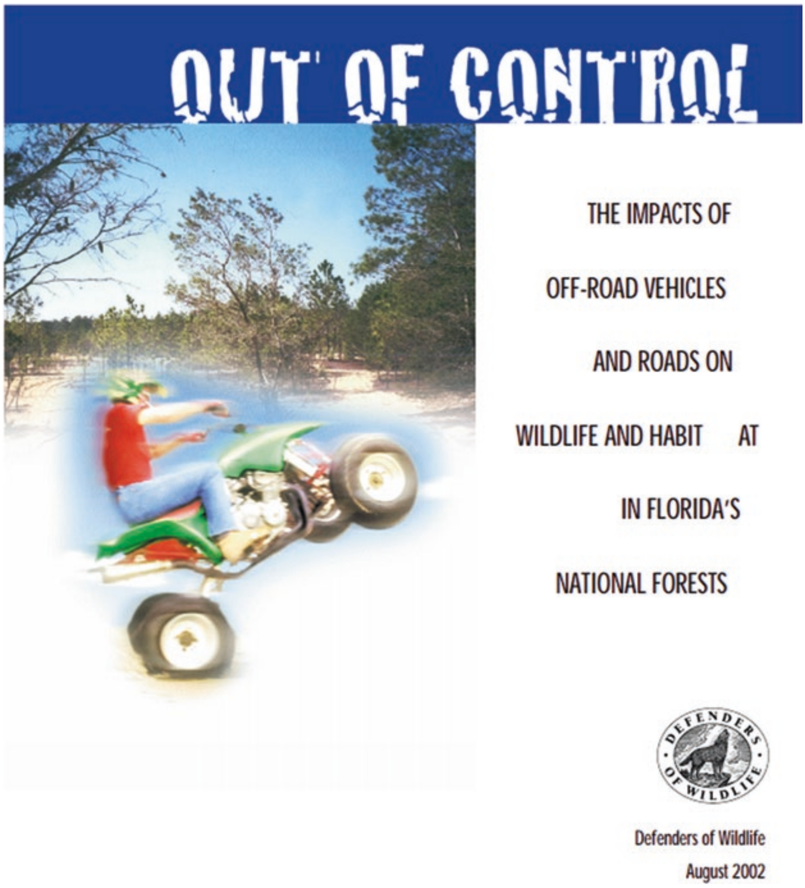

Fig. 6.7 Out of control: the impact of ORVs and roads on wildlife and habitat in Florida's national forests: an educational publication by Defenders of Wildlife. Source: https://defenders.org/sites/default/files/publications/out_of_control_orvs_and_floridas_forests.pdf

6.6 Future Trends

Table 6.6 shows the 2008 number of participants, participation rate, days, and days per participant for motorised activities (motorised off-road use and motorised snow use) as compared with other outdoor recreation activities in the USA.

Bowker et al. (2012) used sophisticated modelling procedures to projected motorised off-road participation and use (off-road driving) by adult US residents, 2008–2060 (Table 6.7).

According to Bowker et al. (2012) participation in off-road driving averaged about 20% of the adult US population, or about 48 million adults annually between 2005 and 2009 (Table 6.7). Based on the projections made by Bowker et al. (2012), future participation rates in off-road driving are expected to decline under two of three Resources Planning Act (RPA) scenarios, RPA A2 (16–18%) and RPA B2 (7–8%), while the percent of adult participants under RPA A1B will be about the same in 2060 as today. The relatively larger decline in participation rate under RPA A2 can be attributed to smaller income growth than under RPA A1B and a larger decline in federal and private forest and rangeland than under either RPA B2 or A1B. Despite the static or declining rate of growth in per capita participation, the number of participants in off-road driving will increase between 28% and 58% under the assessment scenarios to somewhere between 62 and 75 million people, because the rate of population growth will outstrip any decline in per capita participation through 2060. Alternative climate futures do not appear to have an appreciable effect on participation percentages or actual numbers. Annual days per off-road driving participant are projected to decline by 3–7%, or about 1.4 participant days, annually by 2060 (Table 6.7). The decline, consistent across the

Table 6.6 Outdoor recreation activities for 2008 by participants, participation rate, days, and days per participant

Activity[a]	Participants (millions)[b]	Percent participating	Days (millions)[b]	Days per participant
Visiting developed sites				
Developed site use—family gatherings, picnicking, developed camping	194	82	2246	11.7
Visiting interpretive sites—nature centres, zoos, historic sites, prehistoric sites	158	67	1249	7.8
Viewing and photographing nature				
Birding—viewing/photographing birds	82	35	8255	97.7
Nature viewing—viewing, photography, study, or nature gathering related to fauna, flora, or natural settings	190	81	32461	169.6
Backcountry activities				
Challenge activities—caving, mountain biking, mountain climbing, rock climbing	25	11	121	4.8
Equestrian	17	7	263	16.3
Hiking—day hiking	79	33	1835	22.9
Visiting primitive areas—backpacking, primitive camping, wilderness	91	38	1239	13.2
Motorised activities				
Motorised off-road use	48	20	1053	21.6
Motorised snow use	10	4	69	7.3
Motorised water use	62	26	958	15.3
Hunting and fishing				
Hunting—small game, big game, migratory bird, others	28	12	538	19.1
Fishing—anadromous, cold water, saltwater, warm water	73	31	1369	18.5
Non-motorised winter activities				
Downhill skiing, snowboarding	24	11	178	7.2
Undeveloped skiing—cross-country, snow-shoeing	8	3	52	6.6
Non-motorised water activities				
Swimming, snorkelling, surfing, diving	144	61	3476	24.0
Floating—canoeing, kayaking, rafting	40	17	262	6.5

Source: Bowker et al. (2012, p. 3); National Survey of Recreation and the Environment (NSRE) 2005–2009, Versions 1 to 4 (Jan 2005 to Apr 2009) (n = 24,073) (USDA Forest Service 2009)

[a]Activities are individual or activity composites derived from the NSRE. Participants are determined by the product of the average weighted frequency of participation by activity for NSRE data from 2005 to 2009 and the adult (>16) population in the USA during 2008 (235.4 million)

[b]Because of small population and income difference, initial participant and day values for 2008 differ across Resources Planning Act scenarios; thus an average is used for a starting value

RPA scenarios, is invariant to climate alternatives. The declines in participation rate and average annual days per participant imply that, under all scenarios, the total number of days of off-road driving will increase by less than the respective population growth rates. Nevertheless, RPA A1B yields a potential increase of about 500 million days of off-roading per year by 2060, while RPA B2 implies an increase of a little more than 200 million days.

Bowker et al. (2012) also included motorised snow use (snowmobiling) in their data and projections. Snowmobiling was noted to be a geographically limited activity undertaken by 4% of the adult population, or nine to ten million people in 2008. Per capita participation in snowmobiling is expected to decline between 13% and 72% under all assessment and climate scenarios (Table 6.8).

Table 6.9 summarises the changes in total outdoor recreation participants in the USA between

Table 6.7 Projected motorised off-road participation and use (off-road driving) by adult US residents, 2008–2060, by Resources Planning Act (RPA) scenario and related climate futures

RPA scenario	2008	2060 No CC	2060 No CC[a]	2060 Climate 1[b]	2060 Climate 2[c]	2060 Climate 3[d]
	Per capita participation		**Percent increase (decrease) from 2008**			
A1B	0.204	0.203	0	(1)[e]	1	1
A2	0.204	0.169	(18)	(18)	(18)	(16)
B2	0.204	0.189	(8)	(7)	(7)	(8)
	Adult participation (millions)		**Percent increase (decrease) from 2008**			
A1B	47.9	75.0	56	55	57	58
A2	48.8	70.2	44	42	42	45
B2	47.8	61.7	29	29	29	28
	Days per participant		**Percent increase (decrease) from 2008**			
A1B	21.6	20.2	(6)	(6)	(3)	(3)
A2	21.6	20.2	(7)	(5)	(4)	(4)
B2	21.6	20.3	(6)	(5)	(5)	(5)
	Total days (millions)		**Percent increase (decrease) from 2008**			
A1B	1048	1532	46	46	53	53
A2	1066	1433	34	36	36	39
B2	1045	1264	21	23	22	21

Source: Bowker et al. (2012, p. 20)
[a]Climate variable omitted from model and projection
[b]Climate 1 uses forecast data from CGCM3.1 for scenarios A1B and A2; CGCM2 for scenario B2
[c]Climate 2 uses forecast data from CSIRO-MK3.5 for scenarios A1B and A2; CSIRO-MK2 for scenario B2
[d]Climate 3 uses forecast data from MIROC3.2 for scenarios A1B and A2; UKMO-HADCM3 for scenario B2
[e]Parentheses denote a decrease

Table 6.8 Projected motorised snow activity participation and use (snowmobiling) by adult US residents, 2008–2060, by Resources Planning Act (RPA) scenario and related climate futures

RPA scenario	2008	2060 No CC	2060 No CC[a]	2060 Climate 1[b]	2060 Climate 2[c]	2060 Climate 3[d]
	Per capita participation		**Percent increase (decrease) from 2008**			
A1B	0.04	0.035	(13)[e]	(32)	(49)	(72)
A2	0.04	0.031	(23)	(60)	(43)	(69)
B2	0.04	0.032	(21)	(49)	(46)	(51)
	Adult participation (millions)		**Percent increase (decrease) from 2008**			
A1B	9.44	12.99	37	6	(20)	(56)
A2	9.60	12.94	35	(31)	1	(46)
B2	9.42	10.39	10	(29)	(25)	(32)
	Days per participant		**Percent increase (decrease) from 2008**			
A1B	7.25	7.04	(3)	(10)	(24)	(24)
A2	7.25	6.95	(4)	(9)	(18)	(22)
B2	7.25	7.12	(2)	(13)	(14)	(13)
	Total days (millions)		**Percent increase (decrease) from 2008**			
A1B	68.4	91.0	33	(6)	(40)	(67)
A2	69.6	89.8	29	(44)	(17)	(58)
B2	68.3	73.8	8	(38)	(36)	(41)

Source: Bowker et al. (2012, p. 21)
[a]Climate variable omitted from model and projection
[b]Climate 1 uses forecast data from CGCM3.1 for scenarios A1B and A2; CGCM2 for scenario B2
[c]Climate 2 uses forecast data from CSIRO-MK3.5 for scenarios A1B and A2; CSIRO-MK2 for scenario B2
[d]Climate 3 uses forecast data from MIROC3.2 for scenarios A1B and A2; UKMO-HADCM3 for scenario B2
[e]Parentheses denote a decrease

Table 6.9 Changes in total outdoor recreation participants between 2008 and 2060 across all activities and scenarios

Activity[a]	2008 Participants[b] (millions)	2060 Participant range[c] (millions/ [percent])	2060 Average participant change (millions)	2060 Participant range[d] (millions/ [percent])	2060 Average participant change[d] (millions)
Visiting developed sites					
Developed site use—family gatherings, picnicking, developed camping	194	273–346 [42–77]	116	271–339 [40–75]	112
Visiting interpretive sites—nature centres, zoos, historic sites, prehistoric sites	158	231–294 [48–84]	106	231–289 [46–83]	104
Viewing and photographic nature					
Birding—viewing/ photographing birds	82	118–149 [42–76]	53	115–144 [40–76]	47
Nature viewing—viewing, photography, study, or nature gathering related to fauna, flora, or natural settings	190	267–338 [42–76]	114	268–333 [41–75]	112
Backcountry activities					
Challenge activities—caving, mountain biking, mountain climbing, rock climbing	25	38–48 [50–86]	19	37–48 [47–90]	18
Equestrian	17	24–31 [44–87]	11	25–35 [50–110]	13
Hiking—day hiking	79	117–150 [50–88]	55	114–143 [45–82]	50
Visiting primitive areas—backpacking, primitive camping, wilderness	91	120–152 [34–65]	47	119–145 [31–60]	42
Motorised activities					
Motorised off-road use	48	62–75 [29–56]	21	62–76 [28–58]	21
Motorised snow use (snowmobiles)	10	10–13 [10–37]	3	4–10 [(56)–6]	(2.5)[e]
Motorised water use	62	87–112 [41–81]	40	84–111 [35–78]	35
Consumptive					
Hunting—all types of legal hunting	28	30–34 [8–23]	5	29–34 [5–21]	4
Fishing—anadromous, cold water, saltwater, warm water	73	92–115 [28–56]	33	89–115 [22–58]	30
Non-motorised winter activities					
Downhill skiing, snowboarding	24	38–54 [58–127]	23	36–54 [50–126]	21
Undeveloped skiing—cross-country, snow-shoeing	8	10–13 [32–67]	4	5–10 [(42)–28]	(1)
Non-motorised water					
Swimming, snorkelling, surfing, diving	144	210–268 [47–85]	99	212–266 [47–85]	99
Floating—canoeing, kayaking, rafting	40	52–65 [30–62]	20	47–62 [18–56]	13

(continued)

Table 6.9 (continued)

Source: Bowker et al. (2012, p. 28); National Survey of Recreation and the Environment (NSRE) 2005–09, Versions 1 to 4 (Jan 2005 to Apr 2009) (n = 24,073) (USDA Forest Service 2009)

[a]Activities are individual or activity composites derived from the NSRE. Participants are determined by the product of the average weighted frequency of participation by activity for NSRE data from 2005 to 2009 and the adult (>16) population in the USA during 2008 (235.4 million)

[b]Because of small population and income differences, initial values for 2008 differ across PRA scenarios; thus an average is used for a starting value

[c]Participant range across Resources Planning Act (RPA) scenarios A1B, A2, and B2, without climate considerations

[d]Participant range across RPA scenarios A1B, A2, and B2, each with three selected climate futures

[e]Parentheses denote negative number

Table 6.10 Changes in total outdoor recreation days between 2008 and 2060 across all activities and scenarios

Activity[a]	2008 Days[b] (millions)	2060 Days range[c] (millions/ [percent])	2060 Average days change (millions)	2060 Days range[d] (millions/ [percent])	2060 Average days change[d] (millions)
Visiting developed sites					
Developed site use—family gatherings, picnicking, developed camping	2246	3121–3949 [40–74]	1294	3055–3796 [36–69]	1185
Visiting interpretive sites—nature centres, zoos, historic sites, prehistoric sites	1249	1899–2417 [53–91]	952	1935–2435 [55–95]	988
Viewing and photographic nature					
Birding—viewing/photographing birds	8255	11680–14322 [40–74]	4859	10050–13313 [36–69]	3764
Nature viewing—viewing, photography, study, or nature gathering related to fauna, flora, or natural settings	32461	41805–52835 [31–61]	14635	41550–51288 [28–58]	13597
Backcountry activities					
Challenge activities—caving, mountain biking, mountain climbing, rock climbing	121	178–219 [49–83]	4859	179–232 [48–92]	89
Equestrian	263	388–503 [49–92]	196	369–482 [40–83]	166
Hiking—day hiking	1835	2901–3682 [59–98]	1470	2825–3541 [54–93]	1366
Visiting primitive areas—backpacking, primitive camping, wilderness	1239	2046	622	1562–1946 [26–57]	519

(continued)

2008 and 2060 across all activities and scenarios. Off-road driving, according to the projections made by Bowker et al. (2012), will see an additional 21 million participants in 2060 as compared with 2008. Snowmobiling in the USA will see an additional three million participants in 2060 as compared to 2008.

Table 6.10 summarises the changes in total outdoor recreation days in the USA between 2008 and 2060 across all activities and scenarios. Off-road driving, according to the projections made by Bowker et al. (2012), will see an additional 357 million days in 2060 as compared with 2008. Snowmobiling in the USA will see an additional 16 million days in 2060 as compared to 2008. This is the smallest increase of all the activities included in the projections made by Bowker et al. (2012); seen in Table 6.10.

Table 6.10 (continued)

Activity[a]	2008 Days[b] (millions)	2060 Days range[c] (millions/ [percent])	2060 Average days change (millions)	2060 Days range[d] (millions/ [percent])	2060 Average days change[d] (millions)
Motorised activities					
Motorised off-road use	1053	1264–1532 [21–46]	357	1274–1611 [21–53]	385
Motorised snow use (snowmobiles)	69	74–91 [8–33]	16	23–65 [(6)–(67)]	(27)[e]
Motorised water use	958	1304–1806 [37–90]	596	1245–1763 [30–84]	495
Consumptive					
Hunting—all types of legal hunting	538	506–576 [(5)–8]	14	494–575 [(8)–7]	(8)
Fishing—anadromous, cold water, saltwater, warm water	1369	1665–2020 [23–46]	514	1602–1958 [17–41]	397
Non-motorised winter activities					
Downhill skiing, snowboarding	178	274–437 [61–150]	179	258–422 [50–146]	165
Undeveloped skiing—cross-country, snow-shoeing	52	69–87 [35–70]	29	28–64 [(45)–25)	(5)
Non-motorised water					
Swimming, snorkelling, surfing, diving	3476	5037–6429 [46–83]	2446	4396–6257 [42–80]	2298
Floating—canoeing, kayaking, rafting	262	338–422 [30–62]	128	309–409 [18–56]	83

Source: Bowker et al. (2012, p. 29); National Survey of Recreation and the Environment (NSRE) 2005–2009, Versions 1 to 4 (Jan 2005 to Apr 2009) (n = 24,073) (USDA Forest Service 2009)

[a]Activities are individual or activity composites derived from the NSRE. Participants are determined by the product of the average weighted frequency of participation by activity for NSRE data from 2005 to 2009 and the adult (>16) population in the USA during 2008 (235.4 million)

[b]Because of small population and income differences, initial values for 2008 differ across PRA scenarios; thus an average is used for a starting value

[c]Participant range across Resources Planning Act (RPA) scenarios A1B, A2, and B2, without climate considerations

[d]Participant range across RPA scenarios A1B, A2, and B2, each with three selected climate futures

[e]Parentheses denote negative number

Conclusions

1. ORVs discussed in this chapter include four-wheel-drive (4WD) vehicles such as Land Rovers and Jeeps (which usually have deep tread tyres and raised suspension) or may be tracked and may, for example, undertake activities such as rallying, desert racing, rock crawling, or dune bashing.
2. ATVs are also known as quad bikes (but can be three-wheeled) that have a seat that is straddled by the operator and handlebars for steering control.
3. Off-road motorcycling has evolved to include various sub-disciplines like motocross, scrambling, supercross and arenacross, supermoto, VMX, and enduro.
4. Snowmobiles are ATVs specifically designed for travel across deep snow where other vehicles flounder.
5. The number of people (aged 16 and over) participating in off-highway driving in the USA rose by 16.9 million between 1982 and 2001, while snowmobiling rose by 6.1 million in the same

period. This rising trend in off-highway vehicle driving continued into this century with 20.6 million participants between 2005 and 2009, a percentage change of 34.5% (1999–2009).

6. According to Bowker et al. (2012), participation in off-road driving averaged about 20% of the adult US population, or about 48 million adults annually between 2005 and 2009 (Table 6.7). Based on the projections made by Bowker et al. (2012), future participation rates in off-road driving are expected to decline under two of three Resources Planning Act (RPA) scenarios, RPA A2 (16–18%) and RPA B2 (7–8%), while the percent of adult participants under RPA A1B will be about the same in 2060 as today.
7. All four groups of ORVs have higher than on-road vehicle accident rates. One particular problem is accident caused by rollovers. The accident rate among children under 16 is a major concern.
8. The environmental impact of these ORVs is a problem in some wildlife and conservation areas, and examples are discussed. The environmental impacts are in three main areas: damage to soil and vegetation (erosion), noise and pollution, and effects on wildlife (damage, disturbance).
9. The management of ORVs is discussed and opportunities for the education of ORV users outlined.

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