



Leave No Trace-focused Research Findings & Implications

Plan Ahead and Prepare

Cole, David N. 1989. Low-impact recreational practices for wilderness and backcountry. USDA Forest Service, General Technical Report INT-265.

- *Where trails are narrow, deep, and muddy, the natural tendency is to walk along the edge of the trail rather than in the trail tread. This causes the widening of muddy quagmires and/or the development of multiple parallel trails.*
- *The increased use of frequently used sites is not likely to cause much further damage, camping on sites that are already well impacted will confine deterioration to a small number of sites.*
- *Enlargement is the most common, detrimental, ongoing change to well established campsites.*

Monz, Christopher, Joseph Roggenbuck, David Cole, Richard Brame, and Andrew Yoder. 2000. Wilderness party size regulations: implications for management and a decision-making framework. In: Cole, David., Stephen McCool, William Borrie, and Jennifer O'Loughlin, comps. Wilderness science in a time of change conference. Vol. 4: Wilderness visitors, experiences, and visitor management. USDA Forest Service Gen. Tech. Rep. RMRS-P-15-VOL-4:265-273.

- *In a paper by Monz and others (2000) it was noted that 68% and 73% of NPS and USFS areas have maximum group size limits to help reduce environmental impacts and conflicts between groups*

USDA, 2010. Risk Assessment of the Movement of Firewood within the United States. U.S. Department of Agriculture, Animal and Plant Health Inspection Service, Raleigh, NC.

- *A recent USDA (2010) study concluded that movement of firewood is a high-risk pathway for spreading non-native and native forest pests in the United States.*

Travel and Camp on Durable Surfaces

Clow, David, Rachael Peavler, Jim Roche, Anna Panorska, James Thomas, and Steve Smith. 2011. Assessing possible visitor-use impacts on water quality in Yosemite National Park, California. Environmental Monitoring and Assessment 183:197-215.

- *Extensive social trails in some high-use areas near rivers have led to increased bank erosion, channel width, and sediment transport*

Cole, David. 1993. Trampling effects on mountain vegetation in Washington, Colorado, New Hampshire, and North Carolina. USDA Forest Service Res. Pap. INT-464.

- *A study by David Cole on trampling effects on mountain vegetation revealed that as few as 25 passes over sensitive plant types, such as those in the Cascade Mountain Range, can dramatically reduce plant height*

Cole, David and Chris Monz. 2003. Impacts of camping on vegetation: Response and recovery following acute and chronic disturbance. *Environmental Management* 32(6):693-705.

- *Studies on camping impacts have consistently shown that (1) there is an asymptomatic relationship between amount of use and amount of impact, with relatively low levels of use causing substantial impact and (2) the impact from a given amount of use varies greatly between sites with different plant communities, soil characteristics and topography.*
- *A study on camping impacts to vegetation found that it would take about eight years for sites camped on for four nights to completely recover their vegetation cover.*
- *A study by Cole and Monz found that the magnitude of vegetation loss on meadow sites, after four years, was less than half that caused by a single night of camping on forested sites.*
- *In the study by Cole and Monz, forest sites lost more than half their vegetation cover and height after one night of camping per year.*

Kerlinger, P., Burger, J., Cordell, H. K., Decker, D. J., Cole, D. N., Landres, P., & Anderson, S. (2013). *Wildlife and recreationists: coexistence through management and research*. R. L. Knight, & K. Gutzwiller (Eds.). Island Press.

- *Animals seem to have a greater defense response to humans that are moving unpredictably in the terrain than to humans following distinct paths. To reduce the effects of human disturbance, established paths should be used.*

Hockett, Karen S., Marion, Jeffrey L., and Yu-Fai Leung. 2013. The efficacy of combined educational and site management actions in reducing off trail hiking in urban proximate protected area.

- *Many of the impacts from social trails are related to their poor design, including alignments parallel to steep slopes or along shorelines, multiple trails accessing the same destination, routes through fragile vegetation, soils, or sensitive wildlife habitats, and disturbance to rare flora, fauna, or archaeological sites. These attributes make these trails far more susceptible to tread impacts, including expansion in width, soil erosion, and muddiness.*

Leung, Yu-Fai, and Jeffrey Marion. 2000. Recreation impacts and management in wilderness: A state-of-knowledge review. In: Cole, D and others (eds.), Proceedings: Wilderness Science in a Time of Change, 1999; Vol. 5: Wilderness ecosystems, threats, and management, pgs 23-48; Missoula, MT. Proceedings RMRS-P-15-Vol-5. USDA Forest Service, Rocky Mountain Research Station.

- *Most studies have found high levels of groundcover loss and soil exposure even with modest use from camping activities.*
- *A study in Yellowstone found that tree-sampling density on campsites was only one eighth of that on natural areas located away from campsites.*
- *An experimental camping study by Cole found that one night of camping reduced vegetation height by 60% or more. Vegetation cover was reduced to as low as 66% following only one night of camping.*

Marion, Jeffrey. (2014). Leave No Trace in the Outdoors. Mechanicsburg, PA: Stackpole Books.

- *Research demonstrates that initial and low levels of trampling quickly remove groundcover plants and organic litter, with substantial impact occurring in the first year of use. In contrast recovery rates are very low, so the restoration of impacted trails and recreation sites to natural conditions can require ten to thirty years.*

Marion, Jeffrey. 1998. Recreation ecology research findings: Implications for wilderness and park managers. In: Proceedings of the National Outdoor Ethics Conference, April 18-21, 1996, St. Louis, MO. Gaithersburg, MD: Izaak Walton League of America. pp. 188-196.

- *A study of wilderness campsites in Minnesota found that only 12 nights of campsite use per year caused substantial biophysical changes, while further increases in use caused little additional change.*
- *Recreation ecology research has shown that recovery rates on campsites and trails are considerably lower than initial impact rates.*

Tilton, Buck. 2015. *The Leave No Trace Master Educator Handbook*. Boulder: Leave No Trace Center for Outdoor Ethics.

- *The recovery of vegetation is highly variable depending on a variety of environmental factors. For example, the recovery of vegetation that takes a year in the southern Appalachians might require 25 years or more in Glacier National Park, MT.*

Dispose of Waste Properly

Bridle, Kerry, and Jamie Kirkpatrick. 2005. An analysis of the breakdown of paper products (toilet paper, tissues and tampons) in natural environments, Tasmania, Australia. *Journal of Environmental Management* 74:21-30.

- *Research in Australia found that bleached toilet paper and tampons are very resistant to decay.*

Clow, David, Rachael Peavler, Jim Roche, Anna Panorska, James Thomas, and Steve Smith. 2011. Assessing possible visitor-use impacts on water quality in Yosemite National Park, California. *Environmental Monitoring and Assessment* 183:197-215.

- *Impacts from camping activities (e.g. bathing, swimming, and dish washing) and from pack animals at stream crossing are of concern because of their potential to introduce excess nutrients and other contaminants into surface waters.*

Cilimburg, Amy, Christopher Monz, and Sharon Kehoe. 2000. Wildland recreation and human waste: A review of problems, practices, and concerns. *Environmental Management* 25(6):587-598.

- *Disposing wastes in cat-holes is the most common method of human waste disposal and is preferred because it avoids or reduces: the negative impact of visitors encountering feces or toilet paper, animal and insect transmission of pathogens, and water contamination after rainfall.*
- *Twenty-five percent of National Park Service managers reported that inadequate disposal of human waste was a common problem in many of their backcountry areas.*
- *In a study on human waste disposal feces were placed in porous, granitic soils of the Sierra Nevada, California, USA and were dug up after one year. Bacteria were still present at most of the study sites at least one year later.*

Ells, Michael, and Christopher Monz. 2011. The consequences of backcountry surface disposal of human waste in an alpine, temperate forest and arid environment. *Journal of Environmental Management* 92(4):1334-1337.

- *Studies on the cat holes support the use of this technique because the diggings of the holes and any nutrient additions have been found to have little long-term effect on plant communities.*
- *Currently, over one hundred protozoans, bacteria and viruses have been identified in human wastes including *Giardia lamblia*, *Chryptosporidium parvum*, various coliform bacteria, and viruses such as Hepatitis A.*

Gerba, C.P. 1987. Transport and fate of viruses in soils; field studies. Human viruses in sediments, sludges, and soils. CRC Press Boca Raton, FL. 142-154

- *Viruses and other pathogens from human waste can survive weeks or months in water or soils.*

Sime, Carolyn. 1999. Domestic dogs in wildlife habitats; effects of recreation on Rocky Mountain Wildlife.

- *Giardia is found worldwide, but the Rocky Mountain region is a "hot spot" primarily because of human association with outdoor recreation.*

Leave What You Find

Belzer, Bill, and Mary Steisslinger. 1999. The box turtle: Room with a view on species decline. The American Biology Teacher 61(7):510-513.

- *A study on box turtles found the removal of just one or two adults a year can lead to a loss of the species locally.*

Cole, David, and Peter Landres. 1995. Indirect effects of recreationists on wildlife. In: Knight, R. and K. Gutzwiller, eds. Wildlife and recreationists: coexistence through management and research. Island Press, Washington, D.C.

- *Disturbances created by recreation favor the germination, establishment and growth of exotic, potentially invasive, annual plant species.*

Gower, Stith. 2008. Are horses responsible for introducing non-native plants along forest trails in the eastern United States? Forest Ecology & Management 256: 997-1003.

- *Weeds cost the U.S. economy \$32 billion a year by decreasing crop production by 12%, 73% of weeds are non-native plants.*
- *Domestic and wild livestock can spread invasive plants through three main processes: the transport of seeds within the animal (i.e. digestive tract), the dispersal of seeds by transporting them on the outside of animals (i.e. seeds adhered to coat of the animals), and by transporting seeds in their mouth for consumption or food storage.*

Marion, Jeffrey. (2014). *Leave No Trace in the Outdoors*. Mechanicsburg, PA: Stackpole Books.

- *The estimated damage and control costs of invasive species in the United States alone amount to more than \$138 billion annually.*

Pickering, Catherine and Ann Mount. 2010. Do tourists disperse weed seed? A global review of unintentional human-mediated terrestrial seed dispersal on clothing, vehicles and horses. *Journal of Sustainable Tourism* 18(2):239-256.

- *Human mediated seed dispersal can occur over longer distances than many natural mechanisms.*
- *Monetary value of environmental loss in the form of negative effects on native biodiversity and ecosystems from weeds is US \$148 million per year in the United States.*
- *People's clothing, equipment, vehicles and animals (horses and donkeys) that are used for tourism and recreation have the potential to carry seeds from a wide range of species. Over a quarter of the species considered to be important environmental weeds internationally have found to be transported by these vectors. The dispersal distances associated with these vectors are likely to be larger than many natural dispersal mechanisms.*

Tilton, Buck. 2003. *The Leave No Trace Master Educator Handbook*. Boulder: Leave No Trace Center for Outdoor Ethics.

- *According to the U.S. Fish and Wildlife Service, invasive species have contributed to the decline of 42 percent of the country's threatened and endangered species.*
- *At least 1.5 million acres of National Park Service lands are severely infested with invasive species.*

Ward, Caroline and Joseph Roggenbuck. 2003. Understanding park visitor's responses to interventions to reduce petrified wood theft. *Journal of Interpretation Research* 8(1):67-82.

- *In a 1994 survey of national park superintendents, 72 percent of survey participants reported that noncompliance of rules and regulations by visitors caused significant damage to park resources.*
- *Land Managers from the National Park Service estimate the annual costs of fixing resources and facilities damaged by inappropriate behavior of park visitors \$18.8 million. This does not include the large social or environmental costs of non-repairable resources damage, such as the removal of petrified wood, which money cannot fix.*

Wichmann, Matthias, Alexander, Matt, Soons, Merel, Galsworthy, Stephen, Dunne, Laura, Gould, Robert, Fairfax, Christina, Niggeman, Marc, Hails, Rosie, and Bullock, James. 2008. Human-mediated dispersal of seeds over long distances. *The Royal Society*. (Check citation)

- *A study on the dispersal of seeds over long distances found that seeds were regularly found still attached to people's shoes after 5000 m.*

Widner, C.J. 1998 Reducing and understanding petrified wood theft at Petrified Forest National Park. Virginia Polytechnic Institute and State University. College of Natural Resources and Environment, Forest Resources and Environmental Conservation.

- *Archaeological Resources Protection and National Historic Preservation Acts make it illegal to disturb or remove artifacts from historic or archaeological sites – this includes old mining equipment/tools, arrowheads, or antique bottles.*
- *It is estimated by Park staff at Petrified Forest National Park that despite actions by the staff, approximately 12 tons of petrified woods are being removed from the park each year.*

Minimize Campfire Impacts

Davies, Mary. 2004. What's burning in your campfire? Garbage in, toxics out. USDA Forest Service, Technology & Development Program, Rpt. 0423-2327-MTDC, Missoula, MT.

- *Garbage burned in a campfire may leave traces of heavy metals in campfire ash. When ash is scattered, as is common when cleaning up campfires, the ash may expose workers, animals and plants to toxic metals.*
- *Hazardous air pollutants that were measured in one study of the smoke from campfires that contained garbage included benzene, naphthalene, styrene, toluene, and xylene, which are aromatic hydrocarbons and are suspected carcinogens. Aromatic hydrocarbons also are severe eye, nose, and throat irritants.*
- *Items such as packaging for freeze-dried meals, plastic forks and spoons, snack-size chip bags, and white plastic lids for disposable hot beverage cups were found to leave elevated amounts of lead in the ash of campfires.*

Hall, T. E., and T. A. Farrell. 2001. Fuelwood depletion at wilderness campsites: Extent and potential ecological significance. *Environmental Conservation* 28:1-7.

- *Fuelwood consumption may be a particularly good candidate for an impact monitoring by wilderness managers because of the ecological roles played by woody material. For example, it increases the physical, structural, and chemical heterogeneity of the forest floor, contributes to soil organic matter and helps maintain soil stability.*

- *Abundant quantities of medium sized woody material are important for wood-inhabiting lichens, mosses, and fungi and may contribute to tree and shrub seedling survival.*
- *Removal of woody material larger than about 5-10 cm in diameter may alter soil conditions necessary for germination, establishment and survival.*
- *Although small woody material makes up only a small fraction of the mass (.5-11.5%) of the total downed wood in forests, it contains most of the nitrogen, phosphorus, and potassium.*
- *One study estimated that the extended removal of woody debris, which is an important component of soil organic matter, from campsites in the Great Smoky Mountains would result in a 12 to 50 year recovery period for soil carbon, possibly reducing site productivity.*
- *Marion et al. (1993) reported that 43% of US National Park Service Wildernesses have prohibitions on campfires, and 37% require use of backpacking stoves for cooking.*

Marion, Jeffrey. 2003. Camping impact management on the Appalachian National Scenic Trail. Appendix 2: Camping Management Practices. Report published by the Appalachian Trail Conference, Harper's Ferry, WV.

- *A research study of backcountry campsites in Great Smoky Mountain National Park found 2,377 damaged trees and 3,366 cut tree stumps found on campsites. This damage is largely from tools used to cut wood such as saws, hatchets and axes often used to cut wood for campfires.*

Reid, Scott, and Jeffrey Marion. 2005. A comparison of campfire impacts and policies in seven protected areas. *Environmental Management* 36(1):48-58.

- *Intense campfires can decrease organic matter content in soils to depths greater than/equal to 10 cm.*
- *Campfires result in decreases in soil organic matter and the subsequent chemical changes diminish soil fertility and water holding capacity and make soil prone to erosion and compaction.*
- *Firewood collection that takes the form of the felling of trees and the cutting of limbs can create wounds on the trees, which makes trees more susceptible to insect and fungal attacks that can lead to tree mortality.*
- *The Collection of downed wood for campfires affects nutrient cycling for a 50-70 year time frame.*

USDA, 2014. Fire Prevention in Deschutes & Ochoco National Forests & Crooked River National Grassland Website.

<http://www.fs.usda.gov/detail/centraloregon/home/?cid=stelprdb5297416>

- *Campfires improperly extinguished and abandoned with smoldering embers and coals are the number one cause of human caused wildfires on federal lands.*

Respect Wildlife

Anderson, S.H. 1995. Recreational disturbance and wildlife populations. *Wildlife and Recreation: Coexistence through management and research*. Island press, Washington, DC

- *Human-fed animals can exhibit changes in diet, which leads to increased stress and altered behavior causing the animal to become habituated and attracted to human food.*

Cole, David, and Richard Knight. 1991. Wildlife preservation and recreational use: Conflicting goals of wildland management. In: *Transactions of the 56th North American Wildlife & Natural Resources Conference*, pgs 233-237.

- *In contrast to impacts on vegetation and soil, which are highly localized, impacts on wildlife are likely to be more widespread. Since animals are mobile, it is possible for entire populations or entire habitats to be disrupted by recreational activities.*

Cole, David, and Peter Landres. 1995. Indirect effects of recreationists on wildlife. In: Knight, R. and K. Gutzwiller, eds. *Wildlife and recreationists: coexistence through management and research*. Island Press, Washington, D.C.

- *Species richness and diversity generally decline in areas where recreational impacts are pronounced.*

Frid, A., Dill, L. M., 2002. Human caused disturbance stimuli as a form of predation risk. *Conservation Ecology*, 6(1):11.

- *Research has shown that similar to predation risk, disturbance from humans can indirectly affect fitness and population dynamics via the energetic and lost opportunity costs of risk avoidance.*

Gutzwiller, K. J., Wiedenmann, R. T., Clements, K. L., & Anderson, S. H. (1994). Effects of human intrusion on song occurrence and singing consistency in subalpine birds. *The Auk*, 28-37.

- *Activities such as photographing wildlife, bird watching, or simply hiking through an animal's territory can cause unintentional disturbance.*
- *A study in Germany found a 90% decrease in breeding waterfowl over ten years due to the presence of anglers. The same study found that the presence of a*

single angler can prevent ducks from establishing territories or selecting nest sites when the area of open water is less than 1 ha.

Klein, M. L. (1993). Waterbird behavioral responses to human disturbances. *Wildlife Society Bulletin*, 31-39.

- *One study found that of five different recreationist-user groups at a wildlife refuge in Florida, photographers were the most disruptive, since they were the mostly likely to stop, leave their vehicles and approach wildlife.*

Kerlinger, P., Burger, J., Cordell, H. K., Decker, D. J., Cole, D. N., Landres, P., ... & Anderson, S. (2013). *Wildlife and recreationists: coexistence through management and research*. R. L. Knight, & K. Gutzwiller (Eds.). Island Press.

- *Rock climbers have the potential to disturb wildlife when they choose routes that follow cracks, these features are commonly used for breeding, foraging, and roosting by wildlife. Additionally, ledges that are used by climbers as sites to belay other climbers may be used by wildlife as nest or perch sites.*

Knight, Richard, and David Cole. 1991. Effects of recreational activity on wildlife in wildlands. Transactions of the 56th North American Wildlife & Natural Resources Conference, pgs 238-246.

- *When people who are taking part in recreational activities discard food or deliberately feed animals they can alter the ways in which animals forage or find food sources. This can often lead to increased animal human encounters such as is common with bears who become accustomed to food and garbage left by recreationists.*
- *Disturbance to animals that is a result of recreational activities can cause elevated heart rates, excess energy expended in disturbance flights, and reduction of energy input, all of which increase energy expenditures or decrease energy acquisition. This may result in increased sickness, disease and potentially death of individuals.*
- *Disturbance can cause adults to temporarily leave their nest or den sites. This reduced parental attentiveness can increase the risk of young being preyed upon, disrupt feeding patterns, or expose young to negative environmental conditions.*

Marion, Jeffrey. (2014). *Leave No Trace in the Outdoors*. Mechanicsburg, PA: Stackpole Books.

- *Recent research estimates that domestic cats in the United States kill 1.4 to 3.7 billion birds and 6.9 to 20.7 billion small mammals each year.*

- *In one study a well-fed cat killed at least 60 birds and 1,600 small mammals in an 18-month period.*

Sime, Carolyn. 1999. Domestic dogs in wildlife habitats; effects of recreation on Rocky Mountain Wildlife.

- *Domestic dogs still maintain instincts to hunt and/or chase and these instincts can be triggered in many different settings. Even if the chase instinct is not triggered, dog presence has been shown to disrupt wildlife.*
- *If dogs chase or pursue wildlife, injuries could be sustained directly or indirectly to the wildlife as a result of accidents that occur during the chase its self rather than from direct contact with the dog. Thus dogs can be directly and indirectly responsible for wildlife mortality.*
- *Presence of domestic dogs may introduce diseases or parasites to small mammals, and the burrows of fossorial mammals may be physically damaged.*

Be Considerate of Other Visitors

Carothers, Pam, Vaske, Jerry J. and Donnelly, Maureen P. 2001. Social Values versus Interpersonal Conflict among Hikers and Mountain Bikers. *Leisure Sciences*, 23: 47-61

- *Interpersonal conflict between recreational users occurs when the physical presence or behavior of an individual or group interferes with the goals of another individual or group. For example, an individual trying to photograph wildlife may experience interpersonal conflict if the animal is scared away by the arrival of other visitors.*
- *Social values conflicts between recreational users occur when groups of users do not share the same norms or values. For example, although encounters with llama packing trips may be rare, individuals may philosophically disagree about the appropriateness of using animals in the backcountry.*

Manning, Robert. 2007. *Parks and Carrying Capacity: Commons without Tragedy*. Island Press, Washington, D.C.

- *Crowding from large numbers of recreationalists not only degrades unsustainable recreation facilities, but it causes social issues such as noise, parking problems, and theft.*

Manning, R.E., Valliere, W.A., 2001, *Coping in outdoor recreation: Causes and consequences of crowding and conflict among community residents*. *Journal of Leisure Research*. Vol. 33 (4), 99. 410-426

- *A number of studies have suggested that as use level increases some recreationists may become dissatisfied and alter patterns of recreational activity to avoid crowding.*
- *Respondents who encounter large number of visitors generally report a lessened sense of solitude, freedom, the feeling that no one had been there before and of unspoiled wilderness.*

Schneider, I. (2000). Response to conflict among wilderness visitors. *Cole, DN; McCool, SF; Borrie, WT*, 160-163.

- *Recreation research typically identifies three possible visitor responses to recreation crowding: visitors change their definition of an experience, recreationalists may make cognitive efforts to reevaluate the situation more positively, or recreationalists may leave a site or an area due to an unacceptable change in in the social, managerial or resource conditions.*

Stewart, William P.; Cole, David N. 2001. Number of encounters and experience quality in Grand Canyon backcountry; consistently negative and weak relationships. *Journal of Leisure Research* 33(1): 106-120

- *Increased use and encounters between wilderness travelers results in crowding, decrease in solitude, and reduction in the overall quality of experience.*
- *A study in Grand Canyon National Park on number of encounters and experience quality found that for most of the sampled backpackers, increased encounters resulted in increased perceived crowding (80%), decreased solitude/privacy achieved (77%) and decreased experience quality.*