What is Minimum Impact Research?

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ABSTRACT

For 40 years outdoor education has taught recreational wilderness users the philosophies of "minimum impact" and "leave no trace." While these techniques have become widespread among hikers and campers in our nation's fields and forests, it's not clear if others in those ecosystems are as knowledgeable about such philosophies. Visible impacts such as social and secondary trails, waste, and discarded equipment are impacting our national parks and other research locations. This chapter encourages research scientists and their entourages to think about their impacts on the places they do research, by learning about, and adhering to, the seven principles of Leave No Trace—a program managed by the Leave No Trace Center for Outdoor Ethics, in Boulder, CO—as well as an eighth principle that I've added. Many field researchers work diligently to complete their research in a positive, low-impact, high-yield way, but we can, we MUST, do better. If we fulfill this mission, the environment will benefit and will yield greater knowledge to us by continuing to exist.

Key Words

conservation
geothermal
leave no trace
minimum impact
Yellowstone National Park

1.0 INTRODUCTION

> *"A wildland ethic must correspond to the way we conduct ourselves, both in the backcountry and in settings more heavily influenced by human use. We can travel along soft paths in the wilderness and make choices, individually and as a society, that allow those paths to continue to exist."*
>
> (Leopold 1949)

In the 1960s outdoor education began to teach the philosophies of "minimum impact" and the roots of "leave no trace" (LNT) in relation to how recreational users of the wilderness treat the natural world. These techniques have become widespread and well disseminated, and are continuously refined in response to our ever-changing world. Field scientists should take heed. Our impacts no longer (if ever) go unnoticed. Trails, gear, and waste (human, chemical, science-related, etc.) are increasingly evident. An informal survey of land managers from several federal agencies confirms that research-related impacts occur on all federally managed lands—indeed in every environment where this pursuit is undertaken. Often, these environments are pristine places to which only researchers have access. And while research access is a well-justified privilege, it is critical that we think about the application of low impact practices. Such places may have had little to no human encroachment, so any impact can be ecologically significant.

Field impact from scientific research on federally protected lands is not considered excessive. The effects of research activities are miniscule compared to that of the masses of people who visit Yellowstone National Park, for example. Other impacts—grazing, logging, mining, drilling, and loss of biodiversity—are far more invasive and serious to ecosystems. But research-associated consequences are currently an issue and a challenge. From personal observations—some clarified with images herein—it's evident that a problem looms. The paradox exists that we scientists want to learn from the environments in which we explore, but that exploration in and of itself can negatively affect that environment.

Field access has long been an important component of research examining the circular, intertwined processes of the physical world. Nearly every ecosystem has been scientifically characterized at some level by any number of scientific subdisciplines—characterizations that are important and necessary. However, we research scientists need to think about how we perform our jobs, and in my experience this has not been taught, is rarely passed down by mentors, and is not always encouraged by our peers. A quick survey of colleagues rapidly yields stories, some unbelievable but ostensibly true, of adverse impacts and disturbing experiences. And while many of them occur unintentionally—often because of inexperience or naiveté—it remains our responsibility to adopt minimum impact and leave no trace practices, today.

1.1 Impacts in Yellowstone National Park

For most people, the national parks have been an overwhelmingly positive undertaking. Many parks, like the uniquely pristine and accessible Yellowstone, have provided an opportunity to interact with the "wild," as well as a tremendous amount of globally relevant scientific information. Naturalist John Muir, who died in 1914 long before significant research had begun, still was able to predict the importance of national parks in the scientific world. "Thousands of tired, nerve shaken, over-civilized people are beginning to find out that going to the mountains is going home; that wildness is a necessity; and that the mountain parks and reservations are useful not only as fountains of lumber and irrigating rivers, but as fountains of life" (Muir 1905).

As a Yellowstone researcher, I have been drawn to the Park because of the possibilities of Muir's "fountains of life," and have performed research in sensitive geothermal areas. And I have seen the consequences of scientific fieldwork at a number of Yellowstone locations. These research impacts are by no means large, and are likely not noticed by any but the most knowledgeable eyes, but they exist just the same. Unofficial trails have been established; groundcover has been matted down and trampled; equipment and scientific trash (needles, syringes, specialized apparatuses) have been left behind; and there is sometimes a general degradation of place. Some of these impacts are found in

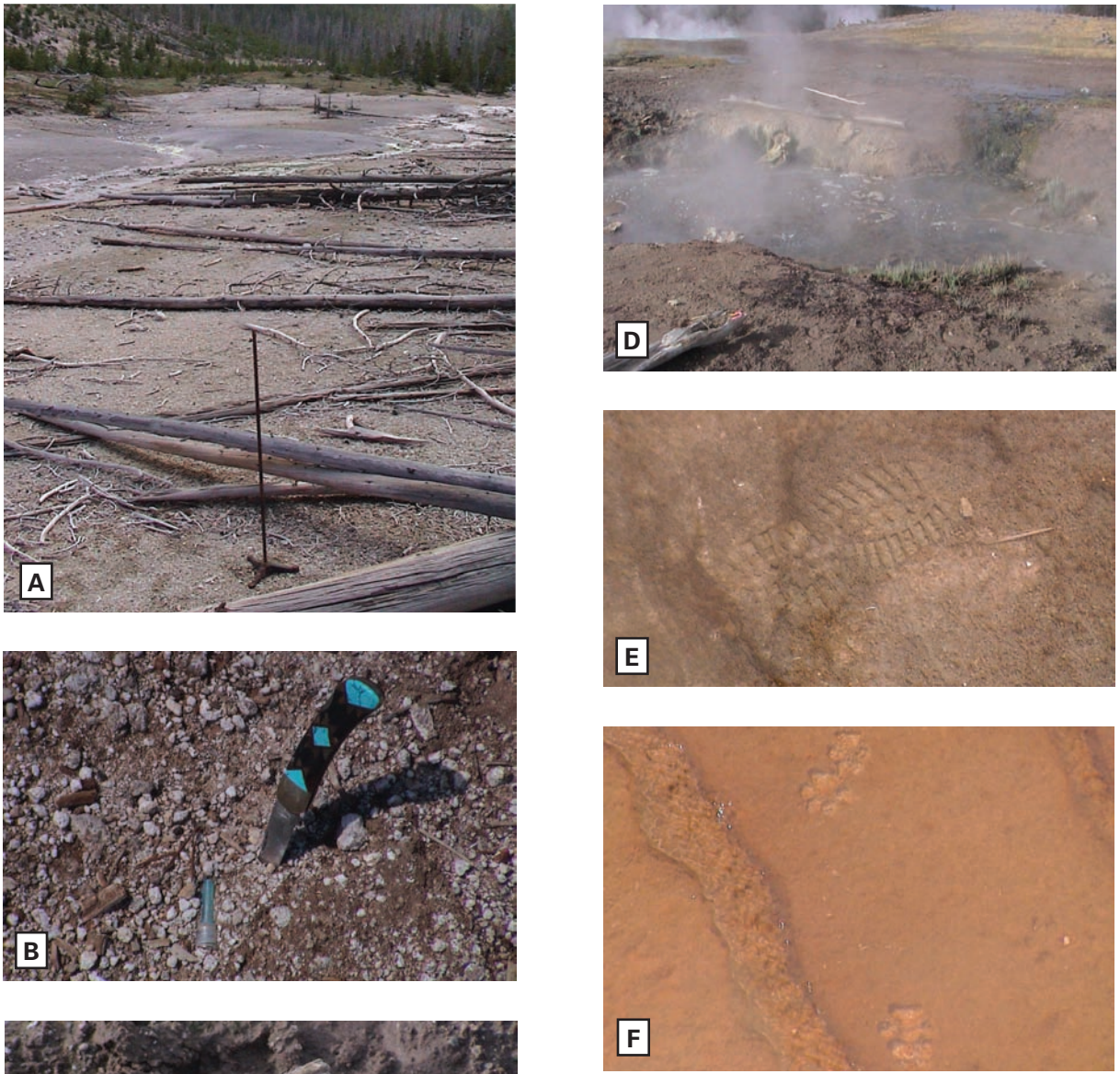

Figure 1. Research impacts in Yellowstone National Park. **A.** A steel ring stand, used for research, was left at Sulfatera Creek. **B.** A syringe cap left in the field near Washburn Spring. **C.** A research tag on the end of a natural object (good technique to blend in the impact); however as seen in **D.** was left in place when research was over. **E.** and **F.** Images show impacts to a microbial mat on the west side of Grand Prismatic Spring. Note: neither of these may be caused by research, but rather by the public (E) or non-domestic animal (F). All images taken July 2003.

remote research-only locations (**Figure 1**); others are much closer to the public areas, say 100 yards from the road on an established hiking trail. Octopus Spring, a well-established research site, has yielded a wealth of information about life at high temperatures (Pace 1997; Ward et al. 1998; Nubel et al. 2002; Papke et al. 2003; Whitaker et al. 2003), and has been altered by that research. **Figure 2** shows the contrast between 1985, when little impact can be observed, and 2001, when trails are present, research devices are conspicuous, and easier access is now available to the public (a research-related trail), which continues to increase the effects.

This isn't to say that all impacts are purely negative. Many are the consequences of beneficial projects. In his pioneering work in Yellowstone's hot springs in the 1960s, Tom Brock was able to choose valuable research locations that were relatively close to roads, yet out of the public view—sites like Octopus Spring. Field-based scientific research can involve sophisticated bulky equipment, so accessibility is important. One of the benefits of conducting research in a national park like Yellowstone is that it's extremely unique yet very accessible by both road and trail systems—characteristics that can enhance research opportunities and outcomes. When Tom Brock began his research in 1965, there was no trail evident to Octopus Spring, but there had been a major trail in the 1920s for visitors to view the Five Sisters and Buffalo Pools (personal communication). The trail had faded over time as management decisions were made or interest faded, but as research heated up, the trail has re-formed. Historical and cyclical use of such trails is not uncommon in Yellowstone.

Brock is credited (personal communication) with starting an early trend in national park field research—to leave locations as one found them. If research devices were left in place, they were usually not obvious, and they were removed when the project was completed. Occasionally tools and equipment were more evident. For example researchers have studied light adaptation of the Octopus Spring microbial mats and have left various neutral density filters in place, some for long periods of time. Brock's study of Mushroom Spring in the 1960s involved several wooden channels, metal station markers, and associated

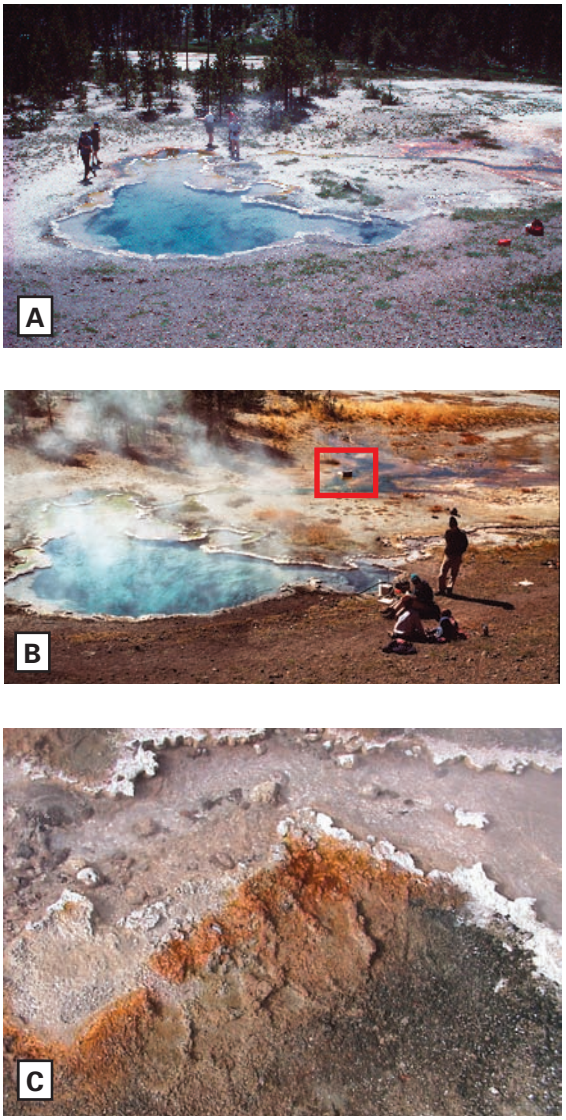

Figure 2. Octopus Spring, White Creek Region. A. Image shows the spring in 1985, note the lack of trail in the foreground (photo, Norman R. Pace). **B.** Image shows the spring in 2001 with a well delineated trail in the foreground. The trail extends to the parking lot, approximately 0.5 km away. Note: trail impact is not exclusively due to research activity. Since this trial extends from a parking lot with no associated boardwalk, it is subject to public access, with no penalty for leaving a boardwalk. A research device located on top of microbial mats is visible in the upper right of Figure 2B, in the boxed area. **C.** Photo shows boot trampling of microbial mats at one outfall of the Spring.

instrumentation all of which infringed on the site's natural state. But when the study was complete, everything was removed, and no sign of research activity could be observed (Brock, personal communication). Clearly, like most research in progress, resource impacts were probably evident while the work was conducted, and some time had to pass for those impacts to be re-assimilated to the more "natural" state. Yet, the effects were minimized because of good habits.

Brock relates a story of researchers who carried out a project at Serendipity Springs, not far from Firehole Spring, that had a large number of wooden channels in place upon which microbial mats developed. Brine flies were studied that fed on the mats. The site could not be seen by park visitors and was invisible from trails and roads. However, upon completion of the five-year study, the whole area looked like a "construction project." Even with heavy microbial mat encrustation, the wooden channels were a non-natural growth matrix not subject to historical use, and Brock insisted upon their removal. Fortunately, this practice of equipment/tool removal continues today and is in fact a requirement in our research permits.

In Yellowstone, the majority of geothermal ecosystem impacts are natural consequences rather than human-induced outcomes, but it's important to remember that as we work to understand the ecosystem at a greater scientific level, we need to not damage thermal features, adversely impact the visitor, or disturb the resource managers. The great majority of research in Yellowstone follows this creed, but continued study and care are essential.

1.2 Impacts Elsewhere

Protecting Yellowstone is something discussed quite a bit nowadays, but research impacts outside of national parks are also something to consider. Research in any environment has the potential to change the ecosystem, temporarily or permanently. Even non-human presence has an impact. Remotely operated vehicles have touched the moon and Mars, and autonomous underwater vehicles and submersibles have infiltrated the oceans. We have impacted pristine alpine lakes and delicate cave formations. **Figure 3** shows two views, taken one year apart, of the same general area of a cold seep on the ocean floor. The sampling and study have noticeably and negatively impacted the feature. It was Pogo who said, "we have met the enemy, and he is us" (Kelly 1952). How best to integrate the needs of resource managers, researchers, the native biota (macro and micro), and the ecosystem requires continued consideration.

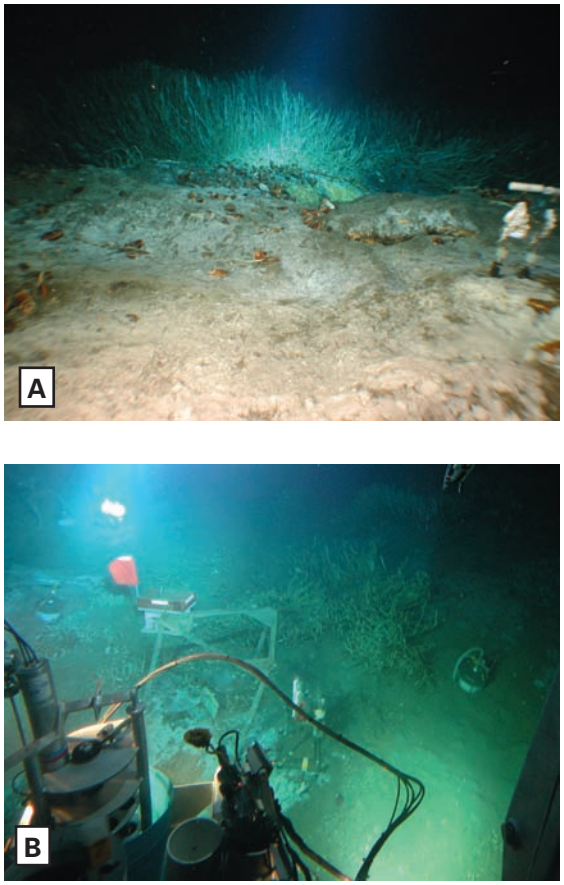

Figure 3. A cold seep on the floor of the Gulf of Mexico. A. In 2001, and **B.** one year later. The prominent microbial mats and chemosynthetic mussels in the foreground, along with the tube worm bushes, background, have all been heavily impacted by removal, alteration, and damage. In addition, the presence of a sizable array of scientific equipment has been introduced (left behind?). Both photos taken from a submarine as it approached the research site; Ian R. MacDonald, Texas A & M University.

2.0 LEAVE NO TRACE

Simple awareness of potential damage is the first step toward sound conservation practices. The second is self-education based on any of several sources of information (Spear 2004; Hampton et al. 2003; Powers 2000; Geisel 1971; Harmon 1997; Schatz and Seemon 1994; Harvey 1999; Meyer 1994; Nash 1989). The best place to start might be the seven basic principles articulated by the Leave No Trace Center for Outdoor Ethics (**http://www.lnt.org**). They are:

- Plan ahead and prepare
- Travel and camp on durable surfaces
- Dispose of waste properly
- Leave what you find
- Minimize campfire impacts
- Respect wildlife
- Be considerate of other visitors

With scientific field research in mind, I suggest the following interpretations.

2.1 Plan Ahead and Prepare

Thorough planning and preparation are critical to successful low-impact research, as is practicing field routines before you go so you can catch the unintended or unexpected before you're too far from your lab to rectify a mistake. Some of the key preparations include:

- Repackaging food and research supplies before you enter the field so as to minimize your load as well as the potential for forgetting packing materials in the field.
- Using a map and compass and/or a global positioning device (GPS) to eliminate the need for rock cairns, flagging, or markings of other kinds.
- Knowing the abilities of those who go into the field with you. Knowing what regulations or special concerns,
  e.g. bear closures, apply to the site of interest.
- Preparing for extremes in weather and potential hazards, and knowing how to generate an effective response to emergencies. This includes awareness of your ecosystem. For example, parts of the Rocky Mountains can transition from sun to thunderstorms to snow in a matter of hours any time of the year.

Along with solid preparation, it's important for researchers to be aware of how you, your gear, your travel route, etc., impact those around you—something that can be a challenge since addressing visibility issues is not a straightforward topic and is often dependent on the research location. For instance, California's Lassen National Park requires researchers to wear bright orange so the public can recognize that a researcher is working in the area and the location may have some inherent dangers. Other locations, such as Yellowstone, dictate clothing that blends in so as to not be obtrusive to other visitors. When possible, it's best to work and travel in the hours when visitors are less likely to be present, especially if your backcountry site requires you to leave from a popular boardwalk. Additionally, visibility can be positively impacted by coordinating with other researchers when possible so there are fewer overall trips to any one site, with the added bonus of beneficial cross-group collaboration.

Preparedness in the field, from the Boy Scouts' motto of *Be Prepared* to a backpackers' *10 Essentials*—map and compass, water, first-aid kit, extra food, eye protection, extra clothes including storm gear, waterproof matches, pocket knife, flashlight/headlamp, and garbage bags—has evolved from a long history of experiences. More recently necessities have been added such as fire starter, a water filtration system, whistle and/or bear bells, insect repellant or repellant clothing, sunburn preventatives (for lips and skin), and a suitable pack to carry it all. And while carrying these items into the field may seem like common sense, the know-how and confidence to use them properly is critical.

2.2 Travel and Camp (and Perform Fieldwork) on Durable Surfaces

Durable surfaces are those that can withstand use without readily showing wear and tear, or that are intended for wear and tear, like established trails and campsites. Think about where and how you walk, transport equipment, and process samples. When possible use established trails

and minimize traffic to research locations. When there, do your best to not trample the site. If ongoing research will occur at a particular location, it's better to establish one social trail than create several. Basic trail etiquette should be followed by, for example, staying in the trail even when muddy to avoid the formation of adjacent secondary trails or switchbacks. Field bench-work can be conducted on natural rock platforms. Setting up pH or dissolved oxygen meters on a rock is preferable to trampling soil to minimize the repeated use of these or other common items. As with recreational use, research-associated resource impacts occur even with low levels of use. Concentration of research activities on durable surfaces can minimize this.

Unless a specific research project calls for work in riparian areas, protect these waterways by setting up your research and camp sites at least 200 feet from water. In popular areas, conduct research on existing trails or in established campsites, walk single file in the middle of a trail, and keep campsites small. If possible and relevant, focus research activity to zones where vegetation is absent.

2.3 Dispose of Waste Properly

For research groups, there are at least two kinds of waste—human and scientific. Human waste requires thoughtful consideration and disposal, and covers all hygiene practices including brushing teeth, washing body parts, and urinating and defecating. There are several ways to properly complete these processes in the outdoors, and many are ecosystem dependent (Hampton et al. 2003; Meyer 1994). However, in most environments a small hole dug 6–8 inches deep in soil at least 200 feet from water, camp, and trails can suffice. When possible, wiping bodily waste with "natural" materials is ideal. A snowball is nature's best toilet paper, but non-allergenic leaves (don't use if you're unsure), rocks, sticks and pine cones work too. If toilet paper is to be used, pack it out along with other hygiene products. In more pristine or unusual environments, such as Antarctica or caves, researchers must pack out all waste, including human urine and feces. While this may seem extreme, it could become necessary in more accessible locations as well.

Science-related waste, e.g. chemicals, used equipment, packaging, and other trash, should be packed out of the field site. Empty waste containers should be brought in to pack out liquid waste such as pH meter fluids and site water that has been altered for testing. Similar to a hospital's surgery team, in which one person is responsible for making sure nothing gets left behind in the patient, researchers could designate one team member to account for all equipment/tools used, or could create a checklist when packing for the trip that is then used to ensure collection of all gear and waste at the site.

2.4 Leave What You Find

Much field permitting includes an allowance to remove native plants, organisms, water, etc. from the research site. While this is often a necessary and expected outcome of field work, low-impact research means taking the smallest of samples required to complete the research at hand. In this author's experience, field researchers tend to sample far more material than is used. While our culture may be to "want more," best practice should guide us to "need less." Be as sure as you can that you take only the necessary samples to further your research. Additionally, examine but do not touch, sample, or destroy historic structures or artifacts unless permitted to do so. Use the hardiest natural features to conduct your work on, and leave natural objects as you find them. Rocks, deadfall, bones, and other natural features all contribute to both the macro and micro ecosystems. Everything from antlers to arrowheads is meant to be left in place. Take a picture and leave them in the field.

2.5 Minimize Campfire Impacts

One of the most enjoyable, yet potentially harmful, aspects of camping is a fire. Minimizing that impact is a critical component of low-impact, LNT research. While large, rock-ringed fire pits may still have a place in some established campgrounds, the backcountry requires less consequential methods such as mound fires, fire mats, and dry stream-bed fires (Hampton et al. 2003; Harvey 1999). Wood to be burned should be locally gathered, and small in diameter such as the size of your thumb. Burn all wood and coals to fine ash and then put out the fire completely with a water drench. Only after all

evidence of fire has expired should you scatter the cool ashes. Of course all of the rules for fire building still apply and these can be ecosystem dependent and seasonally specific. Lightweight stoves that run on various fuels, including unleaded gasoline, are readily available and cheap for all cooking needs.

2.6 Respect Wildlife

We are only temporary visitors to most ecosystems. In a place like Yellowstone National Park it is of utmost importance to conform to the practices of indigenous animal populations so as to minimize injury and death—to both animals and humans. In the field, researchers must live by the terms of the wolf, bison, elk, and lion, and be aware of their habits and needs. That awareness best comes from time spent in the field and time spent with colleagues who can share their knowledge and experiences.

Implementing a positive wildlife ethic includes observing wildlife from a distance and never feeding the animals. Protect wildlife from human food by storing rations securely. Avoid wildlife during times of great sensitivity—mating, nesting, raising young, and in winter months when resource limitations are affecting entire populations.

2.7 Be Considerate of Other Visitors

Successful field research includes respecting other visitors and protecting the quality of their experience. Researchers are generally able to visit their sites many, many times, but visitors may only get one visit to a particular area, and researchers can impact that visit positively by answering questions and helping educate. Be courteous on the trail; when possible step off to allow for passing, and step downhill for pack animals to go by. Take trail breaks off or to the side of the path, and always try to camp or do research away from other visitors. Additionally, minimize sound impacts by keeping voices low when appropriate, and mitigating equipment noises when possible.

While consideration of "others" generally means others in the field, researchers would do well to include consideration for the land/resource managers responsible for their study sites. Research practices, intents, and outcomes differ from those of the resource managers in many ways, and working with each other to better identify those differences can be critical to a positive, ongoing research experience. Clear, regular communication and adherence to all permitting requirements are essential.

3.0 LAST THOUGHTS

To the seven LNT principles, I add one last suggestion: *make an impact*, in terms of the quality of work that is done, in a professional manner. Application of the LNT principles is part of that professionalism. The more researchers do to eliminate and minimize impacts, and to preserve our natural and wild places, the better our chances are of continuing to explore, work in, and understand these diverse and magnificent systems.

Additionally, ecosystem resource mangers and agencies can implement methods to further minimize research impacts. The permit process could include materials that educate a researcher on all (or as many as possible) aspects of a given environment. Impacts are often simply the result of inadequate knowledge about the right way to respond to a given condition. A preparative Internet-based guide could also be created. The National Institutes of Health and the Department of Health and Human Services provide human subjects researchers an online information guide and tutorial—a model that could be copied for those working with diverse natural environments.

Experience in how best to minimize impacts comes from practice, and that practice will lead to better judgment and better decision making. Dissemination of this LNT information and continued interaction and oversight among our colleagues, graduate students, and undergraduates is essential. Mountaineer Paul Petzoldt used the term "must know" to describe any information or knowledge fundamental to an activity (Powers 2000). Most of the "must knows" for field research are not contained herein. They are in other sources and in the collective experience of those who do research on federal lands, marine reserves, or particular ecosystems under study. Incorporation of "must knows" and a commitment to the reduction of environmental and on-site impacts must be among the goals of any research expedition. The success

of our research endeavors should not rest solely in *Science* or *Nature* papers, but rather the footprint of that work on the landscape, which should be minimal to non-existent. To quote Aldo Leopold, "a thing is right when it tends to preserve the integrity, stability, and beauty of the biotic community. It is wrong when it tends otherwise" (1949).

As researchers we have a responsibility on a wide scale—from public policy, to collective action, to personal practice—to implement these principles. We should set an example not just of conservation or preservation, but of a reverence for the ecosystems in which we work and reside. When we lack feelings for or connections with something, we are more likely to thoughtlessly abuse it (Devall and Sessions 1985). Scientifically based field research has led us to new levels of knowledge and has greatly improved the quality of life. That research however, has had some physical impact on that which we study. Research related impacts are by no means large in the overall scheme; they are however, evident. Field research related activities should by no means be stopped or curtailed in any environment; they should simply be improved. Research in Yellowstone, for example, is important and the long-term benefits for research there can be significant in ways we do not yet know. A sign in a national park in Tanzania reads, "Let no one say, and say it to your shame, that all was beauty until you came." We should take pause and consider the impact of our research footprints.

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REFERENCES

Devall, W., and G. Sessions. 1985. *Deep Ecology: Living as if Nature Mattered*. New York: Gibbs Smith Publishing.

Geisel, T.S. 1971. *The Lorax*. New York: Random House, Inc.

Hampton, B., and D. Cole. 2003. *NOLS Soft Paths: How to Enjoy the Wilderness without Harming It*, 2nd ed. Mechanicsburg, PA: Stackpole Books.

Harmon, W. 1997. *Leave No Trace: Minimum Impact Outdoor Recreation*. Guilford, CT: Falcon Publishing.

Harvey, M. 1999. *The National Outdoor Leadership School's Wilderness Guide*. New York: Fireside.

Kelly, W. 1952-53. *The Pogo Papers*. New York: Simon and Schuster

Leopold, A. 1949. *A Sand County Almanac, and Sketches Here and There*. New York: Oxford University Press.

Lindstrom, R.F., R.F. Ramaley, and R.L. Weiss-Bizzoco. 2002. Invisible invasion: potential contamination of Yellowstone hot springs by human activity. *Western North American Naturalist* 62:44-58.

Meyer, K. 1994. *How to Shit in the Woods: An Environmentally Sound Approach to a Lost Art*. Berkeley, CA: Ten Speed Press.

Muir, J. 1901. *Our National Parks*. Scholarly Press.

Nash, R. 1990. *The Rights of Nature: A History of Environmental Ethics*. University of Wisconsin Press.

Nübel, U., M.M. Bateson, V. Vandieken, A. Wieland, M. Kühl, and D.M. Ward. 2002. Microscopic Examination of Distribution and Phenotypic Properties of Phylogenetically Diverse *Chloroflexaceae*-Related Bacteria in Hot Spring Microbial Mats. *Appl Environ Microbiol* 68:4593-4603.

Pace, N.R. 1997. A molecular view of microbial diversity and the biosphere. *Science* 276:734-40.

Papke, R.T., N.B. Ramsing, M.M. Bateson, and D.M. Ward. 2003. Geographical isolation in hot spring cyanobacteria. *Environ Microbiol* 5:650-9.

Powers, P. 2000. *NOLS Wilderness Mountaineering*. Mechanicsburg, PA: Stackpole Books.

Schatz, C., and D. Seemon. 1994. *Minimum Impact Camping: A Basic Guide*. Adventure Publications.

Spear, J.R. 2004. Minimum-impact research. *Conserv Biol* 18:861.

Ward, D.M., M.J. Ferris, S.C. Nold, and M.M. Bateson. 1998. A natural view of microbial biodiversity within hot spring cyanobacterial mat communities. *Microbiol Mol Biol Rev* 62:1353-70.

Whitaker, R.J., D.W. Grogan, and J.W. Taylor. 2003. Geographic barriers isolate endemic populations of hyperthermophilic archaea. *Science* 301:976-8.