The Impacts of Rock Climbing on Climate Change: A Comparative Study on Carbon Emissions and the Ethics of Nature Based Recreation

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Abstract

This thesis seeks to provide data on carbon emissions for the various disciplines of rock climbing (bouldering, sport climbing, trad climbing) and discuss the ethical implications that participation poses under the lens of utilitarian ethics. Climate change is the focus of much political and economic debate, and the impact of greenhouse gas emissions on the environment is often the center of attention. This research provides more data on how individuals' enjoyment of rock climbing might potentially hurt the environment and what that means for those who spend their time outdoors. This study calculates carbon emissions related to climbing gear based on the life cycle assessment of raw materials used in their production, as well as those emitted by travel to a climbing destination in a standard passenger vehicle.

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Bouldering: A discipline of rock climbing in which participants attempt to ascend rocks (boulders) up to about 20 ft without the use of a rope. Participants instead have a pad (known as ‘crash pads’) placed below them to cushion their fall.

Sport Climbing: A discipline of rock climbing in which participants attempt to ascend rock faces using a rope and established bolts as protection.

Traditional (Trad) Climbing: A discipline of rock climbing in which participants attempt to ascend rock faces using a rope and removable gear as protection. Climbers bring passive equipment (most commonly nuts, hexes, and cams) to place into the cracks of the wall as protection and remove said equipment once they are done climbing.

Crag: In rock climbing, a crag refers to any outdoor climbing destination.

Slings: A sewn loop of webbing, usually made of nylon, that is used in sport and traditional climbing to support a climber’s weight.

Quickdraw: A piece of climbing equipment that allows a rope to pass freely through climbing protection. These usually consist of two carabiners connected by a semi-rigid sling.

Belay Device: A mechanical device used in rock climbing that applies friction to the rope which prevents a climber from abruptly falling to the ground.

Life Cycle Assessment (LCA): LCA is a methodology for determining the environmental impact of a product throughout its entire life. A common description is a ‘cradle to grave’ analysis. Essentially, what emissions are produced from the product’s manufacturing to eventual disposal.

Introduction

Climate change has been at the forefront of political debate for the last few decades and is the focus of countless research studies. In the field of outdoor recreation, many are concerned about the degradation of our natural wonders due to climate change. Outdoor enthusiasts are worried about shorter winters, droughts, floods, fires, decreased biodiversity, and a host of other environmental problems that would devastate their favorite pastimes. These enthusiasts are many of today's biggest advocates in the fight against climate change. However, much of the focus had been on how climate change impacts outdoor recreation, not the other way around.

The purpose of this study is to analyze how rock climbing impacts the global environment. Previously, I had never thought of how my daily activities might affect the world around me. As a climber, I generally try to take care of nature by staying on the correct trails and following Leave No Trace principles. However, when searching for a topic to research I realized I had never given thought to the other impacts I might have, the ones that cannot be seen but change the world for generations to come, the ones caused by emitting greenhouse gasses (GHG).

At first, it may seem that rock climbers do not produce any GHG, as their activity takes place in a natural setting away from traditional carbon emitters. However, climbers must purchase gear and drive to their destination. Transportation and industrial emissions make up 35% of global emissions, thus it is safe to assume that rock climbers contribute to these categories as well (Intergovernmental Panel on Climate Change, 2013).

The Environmental Protection Agency (EPA), along with most of the scientific community, has determined that GHG emissions have been a leading factor in the climate change that has occurred in the past century (2021). Put simply, "As greenhouse gas emissions from human activities increase, they build up in the atmosphere and warm the climate, leading to many other changes around the world—in the atmosphere, on land, and in the oceans (United States EPA, 2021)." These changes have the potential to permanently alter the world's landscape and biodiversity. Studies have shown that climate change has already resulted in the rising of sea levels, decreased wildlife populations, and increasingly destructive natural disasters with the potential for worse consequences in the future (IPCC, 2014). In order to mitigate these effects, people should be aware of how much they contribute to this problem. The most common metric used to measure GHG emissions is carbon emissions, with the EPA and other major industries converting all GHG emissions into carbon dioxide equivalents (measured in kgCO2eq). This is because carbon dioxide accounts for three-fourths of all emissions from human activity and is the only emission that is easily reabsorbed through natural processes (United States EPA, 2021). This study will also use carbon dioxide emissions as the measurement of impact since it is the standard in the study of climate change. Before we determine rock climbing's global impact, we must provide some perspective on the problem.

Ethical Framework

Utilitarianism "holds that actions are right in proportion as they tend to promote happiness, wrong as they tend to produce the reverse of happiness" (Mill, 1863, p. 9-10). This simple definition led many to discount utilitarianism as unfit for a moral society. For instance, one could argue that people should enjoy natural resources until they are destroyed, so long as happiness outweighs suffering. This is why Mill's defense of utilitarianism is necessary for moral decisions that will impact future generations. Mill clarifies that the good of society must be considered with each action. Thus, we should not destroy resources that will leave society worse off in the long-term.

This framework is especially useful in comparing hard numbers. Utilitarianism reduces most ethical decisions to simple arithmetic, which is why its use is so widespread. For instance, the U.S. Department of Transportation (DOT) has created a statistical value for human life (based on an individual's economic output) which sits at 11.6 million dollars as of 2020 (2021). Using utilitarianism, the DOT can easily decide what projects are worth funding by calculating their cost per life saved. The same methodology can be used with rock climbing and carbon emissions, as will be shown later. Unfortunately, these decisions become much more complex when a specific value cannot be attributed to an action. Beyond reducing carbon emissions, rock climbers may treat wildlife better or advocate on behalf of the environment. The value of these actions will vary for each person, leading to different views on the morality of certain behaviors. These considerations will be discussed, but their ethical implications are a matter of opinion rather than fact. As such, this study will focus on the concrete numbers provided by carbon emissions, which provide an easily digestible answer regarding the morality of rock climbing under utilitarianism.

Environmental Impacts

Since 2000, National Park (NP) visitation has increased by 14%, from 285 million to 327 million in 2019 (National Park Service, 2020). This only accounts for visitation from the 419 parks run by the National Park Service. Throughout the country there are thousands of parks dealing with overcrowding, as *The Guardian* puts it, “tourists are loving nature to death” (Simmonds et al. 2018). Rock climbers make up a sizable portion of this, with 4.75 million Americans climbing outdoors in 2018 (American Alpine Club, 2019). With parks across the country dealing with the negative side effects of mass visitation, researchers have begun to realize that how people enjoy the outdoors can impact the environment. Companies like The North Face, Patagonia, REI, and Cotopaxi have also turned their focus to climate change by reducing emissions and working towards the famed title of ‘carbon-neutral.’ These campaigns are likely in response to mass appeal for reformation as society has realized the environment needs to be protected. However, many individuals are satisfied knowing the company they buy from is ‘green’ and may not be conscious of their individual impact.

Regarding rock climbing, nearly all studies on environmental impacts have been focused on how participants affect the local community. The most common topic is how biodiversity and soil/rock compositions are affected. A study in Switzerland found that climbing threatened the diversity of both vegetation and snail populations in the Jura Mountains (Schmera et al., 2018). Adams and Zaniewski found that lichen communities on Lake Superior were compromised by rock climbing (2012), and an abundance of papers can be found on how each community’s vegetation is in danger. There are some studies that look beyond soil and vegetation, such as a case study on Mount Kilimanjaro which found that mountaineers left 125 tons of trash in 2006 alone (Kaseva & Moirana, 2009). Regardless, the trend remains the same throughout climbing literature, and there has yet to be substantial research on how climbers impact the global climate. One of the goals of this study is to shed some light on that impact. By analyzing how different forms of rock climbing contribute to global carbon emissions, individuals will be able to make informed decisions about how they spend their time.

This thesis analyzes climbing's contribution to carbon pollution in a holistic approach. This includes the carbon emissions of gear production, gear shipment, and participants' travel relative to each year spent climbing. Climbers require carabiners, appropriate shoes, belay devices, and other forms of protection, all of which involve carbon emissions in their production. They also require travel to their destination, with international trips emitting up to 1,562.6 kg CO_2-eq. (Bateman, 2018). Climbing-specific research is limited, but this study has collected data from a wide variety of sources to estimate the emissions related to each piece of gear produced.

Methodology

This study is a compilation of resources describing carbon emissions related to the various aspects of rock climbing, ranging from manufacturer reports to independent studies. As discussed previously, carbon emissions are the focus of this research, so only data specifically on the carbon footprint of climbing gear and travel will be analyzed. All other factors, including local environmental damage and other GHG emissions, will be ignored for this analysis. In addition, carbon emissions related to shipping for each piece of gear will not be considered. Despite 3% of global carbon emissions coming from shipping, the EPA reports that even the worst method, long-haul trucking, only produces .065kgCO2eq/kg of goods shipped (assuming 1,000 mile shipping distance) (2021). This value is negligible compared to the emissions produced during the production phase which can rise well above 10kgCO2eq. The purpose of this study is to estimate the carbon footprint of the average outdoor climber in the three major disciplines: bouldering, sports, and traditional. As such, data will only be collected for the most common gear used in these forms of climbing. There are hundreds of applicable tools that could be used in each discipline, but this study will focus on the few that are necessary for climbing safely. Common accessories such as brushes, athletic tape, and chalk bags will not be included due to their low carbon footprint relative to other gear purchases. Climbing chalk is also exempt from this data due to the lack of research regarding carbon emissions in the production of its raw material, magnesium carbonate.

The data collected in this paper were primarily collected through databases such as Science Direct and Google Scholar. Manufacturer reports proved to be the most useful sources, yet very few climbing manufacturers provide sustainability reports or any specific information on how their gear is made. Due to this, much of the data is based on the carbon emitted in the production of raw materials. Notable exceptions include La Sportiva shoes and Mammut ropes which both have substantial data on their carbon emissions. To determine the raw materials used for each piece of gear Mike Jenkin's *Materials in sports equipment* will be used as the standard and confirmed through manufacturers' labels.

A common metric used in the study of carbon emissions is a life cycle assessment (LCA). LCA's refer to the method of assessing the environmental impact of a product through the entirety of its life cycle. This includes carbon emissions related to the production, processing, and eventual disposal of the product. This will prove useful in predicting the impact of gear from manufacturers that do not provide emissions information.

To calculate carbon emissions related to travel in climbing, vehicles with two passengers will be used. This is due to the necessity of at least two climbers to perform the activity and the common practice of carpooling in the climbing community (Maples & Bradley, 2020). Additionally, climbing trips will be divided into three categories dependent on travel distance: local, regional, and cross-country. These methods were chosen due to the lack of data on travel in the climbing community, and the inability of this study to conduct a national survey with a substantial number of respondents.

Results

Table 1 shows carbon emissions related to the production of rock climbing gear and the recommended lifespan for each piece of gear. Emissions per year are then calculated assuming each piece of gear survives the recommended lifespan, and a new piece of gear is bought as a replacement. Table 2 uses the emissions per year for each piece of gear to determine the total emissions per year that the average climber will emit based on the amount required for each discipline. The amount of gear for each discipline was determined from the minimum required to safely climb most routes in the areas surrounding Chattanooga. These numbers would change depending on the character of the climbing in each region, thus a slight adjustment of the numbers may need to occur for climbers elsewhere in the U.S. and abroad.

Table 1. Carbon Emissions from Climbing Gear Production

Gear	KgCO2eq Emitted in Production	Recommended Lifespan (Years)	Emissions per Year (KgCO2eq/Year)
Shoes	13.89	.5	27.78
Bouldering Pad	19.42	5	3.88
Rope	46.6	3	15.5
Carabiner	.49	10	.049
Locking Carabiner	.82	10	.082
Belay Device	.965	10	.0965
Quickdraw Sling	.29	6	.048
Traditional Sling	.48	6	.08
Cams	1.259	10	.1259
Nuts	.303	10	.0303
Harness	5.29	3	1.763

Table 2. Carbon Emissions/Year for each Discipline

Gear	Emissions per Year (KgCO2eq/Year)	# Necessary for Bouldering	# Necessary for Sport	# Necessary for Traditional
Shoes	27.78	1	1	1
Bouldering Pad	3.88	1	0	0
Rope	15.5	0	1	1
Carabiner	.049	0	24	18
Locking Carabiner	.082	0	3	3
Belay Device	.0965	0	1	1
Quickdraw Sling	.048	0	12	6
Traditional Sling	.08	0	2	8
Cams	.1259	0	0	7
Nuts	.0303	0	0	10
Harness	1.763	0	1	1
Total KgCO2eq/Year	N/A	31.66	47.29	48.37

Data for climbing shoes is based on the carbon emissions of the average shoe produced by La Sportiva, a popular shoemaker based out of Italy. This company had the most in-depth sustainability report, with data from 2018 showing that their carbon emissions were equivalent to 1.785kgCO2eq per pair of shoes produced (La Sportiva, 2019). This number does not include emissions from the production of leather and rubber used in the shoes. These raw materials make up 30% and 61% of the shoe's mass respectively. To calculate these values we must look to other sources. La Sportiva purchases all of its climbing shoe rubber from another Italian company, Vibram. This company reports that a pair of soles will emit 4.3kgCO2eq through its production cycle (Vibram, 2021). Finally, the leather used in La Sportiva shoes varies by design. Most models use traditional 2mm thick leather, while some have begun using recycled or synthetic leather which has a much smaller environmental impact. For these calculations, we will use traditional leather since it is still the most common among climbing shoe manufacturers. A study on bovine leather emissions showed that a 2mm cut produces 79.6kCO2eq/m2 (Chen et al. 2014). The typical climbing shoe weighs about 500g with 30% leather (dependent on size and design), so this results in 7.80 kgCO2eq per pair from leather production. This shows that the average pair of La Sportiva climbing shoes produces 13.89kgCO2eq with an average lifespan of 6 months.

Bouldering Pads are much more complex than climbing shoes, consisting of multiple layers of open and closed-cell foam. Data for this study was based on the Kush bouldering pad since they were the only company to report where their crash pad textiles come from (Denis, 2016). Kush uses recycled nylon and hemp textile, both of which have negligible carbon emissions during the production phase (Cherrett et al. 2005). Thus, the only estimate we have for the carbon emissions during the production of a bouldering pad is that of the foam itself. Little research has been conducted on the emissions related to manufacturing foam, but there have been some studies on polyols, the compound used to create foams. Specifically, one study conducted a LCA on polyols used in the production of foam and found that 3.57kgCO2eq is emitted per kg polyol produced (Assen & Bardow, 2014). With this information and the weight of the bouldering pad at 5.44 kg, we get an estimated 19.42kgCO2eq emitted to produce each bouldering pad. Manufacturers of bouldering pads do not include an estimated lifespan because the retirement date of a pad is due to the climber's personal preference. In general, climbing pads are retired after around 5 years of regular use, so this will be considered the lifespan of the Kush pad for this study.

In 2020 extensive research was done on Mammut climbing ropes by Zurich University of Applied Sciences. This study took a holistic approach to the carbon emissions related to the rope's manufacture and disposal, essentially a LCA for climbing ropes. They used a 60 meter climbing rope for their study, the standard for use in both sport and traditional climbing. Their findings reveal that a climbing rope emits 46.6 kgCO2eq with a recommended lifespan of 3 years for regular use (Bradford et al. 2021).

There are a wide variety of carabiners produced in the climbing industry, but the standard carabiner and the locking carabiner are the only two necessary for safety in traditional and sport climbing. This study has chosen to focus on Petzl carabiners since they are one of the largest brands in the climbing industry. Specifically, the carbon emissions will be based on the Petzl Spirit Bent carabiner and the Petzl AM'D locking carabiner. Both of these are made from the 7075-aluminum alloy which consists of 91%

aluminum, 6% zinc, and trace amounts of other metals (Jenkins, 2003). There have not been any studies on the carbon emissions of either carabiner or 7075 aluminum alloy production. Thus, this study uses LCA's on aluminum and zinc to estimate the total carbon emissions related to the production of carabiners.

There have been numerous studies on aluminum production with ranges between 12-17 kgCO2eq emitted per kg aluminum (Saevarsdottir et al. 2019). We will use the low end for this study since the process of creating carabiners is simple compared to most manufacturing processes. A study on zinc production found that 3 kgCO2eq is emitted per kg produced (Nilsson et al. 2017). The Spirit Bent carabiner weighs 41g, so the carbon emissions for production is .49kgCO2eq per carabiner. The AM'D locking carabiner weighs 75g, so the carbon emission for production is .82kgCO2eq per carabiner. According to manufacturers, aluminum carabiners have an indefinite lifespan because aluminum does not weaken if stored in a dry condition. However, many factors may lead to the retirement of a carabiner. If exposed to high humidity or saltwater for extended periods of time the metal will slowly corrode. In addition, regular use of carabiners in climbing will create groves over time. These do not weaken the strength of carabiners, but they do create the potential to cut a climber's rope. Thus, most climbers will retire their carabiners long before they are technically ready to retire. Many different factors contribute to the lifespan of a carabiner, but for this study we will use 10 years as the lifespan for regular use.

Many different belay devices have been designed for climbers, but by far the most used is the Petzl GRIGRI. We will use the original model which weighs 175g and consists of 32% aluminum and 68% stainless steel. Once again carbon emissions will be calculated using the LCA value of 12kgCO2eq per kg aluminum produced. For steel, we will use a case study on steel production in Poland which found the average LCA to be 2.459kgCO2eq per kg steel produced (Burchart-Korol, 2013). This comes out to .965kgCO2eq emitted per GRGRI manufactured. The lifespan of a GRIGRI also varies based on usage, with no recommendations from manufacturers. However, a Petzl representative stated that the shelf life for their GRIGRI is 10 years. While GRGRIs can last much longer if cared for properly, we will use a 10 year lifespan for the purpose of this study.

Slings are used in a variety of ways for both traditional and sport climbers. They go by many different names including runners and personal anchor systems. For the purpose of this study a sling will refer to any nylon webbing that has been stitched in a loop and is load bearing by climbing standards (typically 22kn). We will be looking at two types of slings specifically, the Petzl Express sling (17cm, 22g) and the Black Diamond 18mm Nylon Runner (60cm, 18g). The Express sling is used for quickdraws while the 18mm Nylon Runner can be used for quickdraws, traditional climbing extensions, or personal anchor systems. Both materials are made of nylon webbing, so the calculations of carbon emissions will be made using the LCA of nylon (polyamide 6) found in the Mammut rope study. While these products were made by different manufacturers, it is the most accurate data available on nylon processing in the climbing industry. Their data gives us a carbon emission rate of 13.2 kgCO22eq per kg nylon processed. This gives the Petzl Express a LCA of .29kgCO2eq per sling produced and the 18mm Nylon Runner .48kgCO2eq per sling produced. Manufacturers recommend a lifespan of 6-10 years depending on usage for slings. We will assume a 6 year lifespan for regular use in this study.

Traditional climbing protection primarily consists of cams, nuts, and hexes. This study will focus on the gear necessary to climb most routes in the areas surrounding Chattanooga Tennessee safely. While each climb requires a wide variety of pieces, the basic protection includes 7 cams and 10 nuts of various sizes. For cams we will use the Black Diamond Camalot C4 Set (#0.3 - #3), and for Nuts we will use the Black Diamond Stopper Set Pro (#4 - #13). Both of these are made of galvanized steel cables with aluminum alloy 6061 heads (Jenkins, 2003). Thus, the same LCA of 2.459kgCO2eq per kg steel produced will be used. 6061-aluminum alloy consists of 98% aluminum with trace metals comprising the other 2%. We will use a LCA value of 12kgCO2eq per kg aluminum produced as done earlier. The steel to aluminum ratio varies depending on the size of each cam/nut, so for this study we will use the average of each set. For cams we will use the C4 #1 and for nuts we will use the stopper #9. I could not find any information from Black Diamond regarding the weight of the head compared to the steel cables, so I used personal equipment to make the measurements for this study. The C4 #1 weighs 124 grams with 19% steel and 81% 6061 aluminum alloy, and the stopper #9 weighs 38 grams 42% steel and 58% 6061 alloy. This results in a LCA of 1.259 kgCO2eq for each C4 cam produced and .303 kgCO2eq for each stopper produced. As with carabiners, traditional gear has an indefinite shelf life, so gear only needs to be replaced when damage is done through use. With cams and nuts, large falls can result in damage to the steel cables or the mechanical heads of a cam. While there is no estimate for when this might happen, for this study we will use a lifespan of 10 years.

The final piece of gear, harnesses, proved the most difficult to find data on. Most harnesses are made of nylon webbing, polyurethane foam core, and aluminum buckles. (Jenkins, 2003). However, I could not find the exact weights for any specific model, which lead me to dissect a personal harness to make calculations. The harness used in this study is Mammut's Ophir 3 Slide. It consists of 81g aluminum 6061, 283g nylon, and 163g foam. Using the LCA's described previously (12kgCO2eq, 13.2kgCO2eq, and 3.57kgCO2eq respectively) we find that a harness has an LCA of 5.29kgCO2eq with a recommended lifespan of 3 years for regular use.

Table 3 presents the carbon emissions related to travel that a climber would produce each year. Carbon emissions are calculated using data on the typical passenger vehicle which emits .404kgCO2eq per mile as described by the EPA (2021). Where there is climbing there is usually a wide variety of options for each discipline. As such, each category is defined by the distance traveled to reach a climbing destination instead. We will also assume that a regular climber will travel once each month to participate in the activity and will ride with one other person. Thus, the carbon emissions per mile will be half the value stated above. There has yet to be an extensive study on rock climber's travel behaviors, so for this study three types of climbers will be defined: local, regional, and cross-country. A local climber is defined as one who only travels within a 100 mile radius. A regional climber is defined as one who primarily travels within a 100 mile radius but will take two trips within a year up to 500 miles away. A cross-country climber is defined as one who travels both locally and regionally but will take one trip each year over 500 miles away. Local climbers are most likely to be found in highly concentrated areas of climbing, including Chattanooga, Denver, and Salt Lake City. Regional climbers make up a large portion of the U.S. population with industrialized cities that lie outside major climbing destinations, including Nashville, Kansas City, and Dallas. Cross-country climbers reside in geographically flat states, including Florida and Nebraska. The types of climbers described above are narrow definitions used to calculate a climber's theoretical carbon emissions related to climbing. In reality, climbers may choose to travel across the country for unique climbing experiences, despite living in a concentrated area of climbing.

Table 3. Carbon Emissions from Travel

Climber Type	Distance Traveled each Year (Miles)	Carbon Emissions per climber each Year (.202kgCO2eq x Miles)
Local	1,200	242.4
Regional	2,000	404
Cross-Country	4,100	828.2

Discussion

The total carbon emissions produced by a local rock climber (traditional) sits at 290.77kgCO2eq each year. Discussions on climate change often mention numbers on carbon emissions without much context. As stated earlier, the average car in the U.S. emits .404kgCO2eq per mile. This results in 4,645 kgCO2eq emitted per person per year. While this number does seem large, it means nothing without knowing how much a person emits. According to the EPA, the average American emits 15,520 kgCO2eq each year (2021). Food consumption alone makes up 1,300 kgCO2eq of this value (Heller & Keoleian, 2014). Most of this comes from beef, poultry, and egg consumption which make up about 750 kgCO2eq each year. This means the footprint from rock climbing is only about 40% that of eating meat. Further, basic needs like food and travel are not the only substantial contributors to carbon emissions. Seemingly 'natural' hobbies such as horseback riding have been shown to have a significant impact as well. A life cycle study on the carbon emissions related to raising a horse found that 1,039 kgCO2eq is emitted each year (Engel et al. 2011). This does not include travel to trails or any gear related to horseback riding. This data makes the 48.37kgCO2eq from climbing gear production seem far less significant by comparison.

The calculations in this study assume that every climber owns every piece of gear and drives with one other passenger to the climbing destination. This leaves room for further emission reduction by having consistent climbing partners. In each discipline of climbing, it is only necessary for one set of gear to be owned (except for harnesses). Thus, if three or four people carpool and share one set of gear, their per capita emissions would be cut drastically. Another sustainable practice is the resoling of climbing shoes. This process allows climbers to reuse their shoes for many years by replacing the worn-out rubber which eliminates the carbon emissions from leather production.

Beyond personal practices, some climbing manufacturers have begun designing sustainable gear. The most notable models are La Sportiva's Mythos Eco climbing shoes and Edelrid's NEO 3R climbing rope. The Mythos Eco are made of 95% recycled material (La Sportiva, 2016). Using the data collected for this study, the LCA of a pair of Mythos Eco would emit 11.5 kgCO2eq less during the production process than the average pair of shoes. The NEO 3R is made of 50% recycled nylon, which would emit 11.7 kgCO2eq less than the average rope according to the calculations made by the team in Zurich (Bradford et al. 2021; Edelrid, 2021). These innovations, along with eco-friendly practices like carpooling and resoling climbing shoes, allow the climbing community to greatly reduce their impact on carbon emissions.

Ethical Implications

This study has shown that rock climbing does damage the environment on a global level, but so does almost everything else we do as a society. It is inevitable that every action impacts the world, whether it is on a global scale or limited to a small community. However, that impact does not have to be all negative. If climbers gain an appreciation for the environment from their experiences, they may then put their effort towards protecting it from further damages. Thus, there is a balance between what benefits an activity brings and what damage it does. This is where J.S. Mill's Utilitarianism becomes useful. If participation in rock climbing leads to a net reduction in carbon emissions, then it can be considered ethical.

As discussed previously, our actions have much larger consequences than apparent at first sight. One-third of each American's emissions come from food and transportation, two of the most essential activities in life. While rock climbing does produce noticeable emissions, especially considering travel, climbers who have gained an appreciation for the outdoors can reduce emissions by adopting sustainable practices in other areas of life. For instance, by changing to a vegan diet the average American would emit 700kgCO2eq less each year (Heller & Keoleian, 2014). This would be enough to completely offset the carbon emissions of a local or regional climber and then some.

This implies that rock climbing can have a positive impact on the environment if it elicits sustainable actions due to a higher value of nature. While there are scores of articles online about how to treat the environment better as a climber, it is even more revealing when published studies also find that climbers support the environment. One study conducted in Colorado found that climbers had positive environmental attitudes, with 74% agreeing to sign the Climbers Pact (a set of eco-friendly practices) through the Access Fund (Borden & Mahamane, 2020). Another study found that one of the most important aspects of the climbing experience is the wilderness setting (Ansari, 2008). Additionally, conservation organizations like the American Alpine Club, the Access Fund, and the Southeastern Climbers Coalition boast tens of thousands of members dedicated to protecting the environment climbing resources. These findings would suggest that the climbers across the country also have an appreciation for nature. Whether this appreciation is a result of climbing or nature lovers are drawn to climbing is impossible to tell. Regardless, rock climbing forces a relationship with the outdoors. Similar findings have been found among other outdoor sports like surfers who are more likely to have pro-environmental attitudes and participate in conservation efforts (Larson et al. 2018). Outdoor enthusiasts have recognized that it is in their best interest to protect the resource they use on a regular basis, explaining the strong correlation between rock climbing and eco-friendly attitudes.

Carbon emissions from rock climbing makes up 2% of the average American's total emissions each year. This is a small value, but significant when nearly 5 million

Americans rock climb each year. The question is whether or not rock climbing is beneficial for the environment. As shown above, rock climbers participate in eco-friendly practices that benefit the environment such as volunteer trail cleanups, leave no trace principles, and donations to conservation programs. Many climbers have also moved to a vegan diet or began recycling to directly reduce their emissions. Utilitarianism shows us that a climber only needs to reduce their emissions by 291kgCO2eq for their actions to be considered ethical, an easy task with endless possible solutions. Simply reducing your time in the shower by three minutes each day has been shown to reduce emissions by 320kgCO2eq each year (Griffiths-Sattenspiel & Wilson, 2009; EPA, 2021).

Unfortunately, there have not been studies on whether rock climbers become vegans or shower less because they love the outdoors, but this is the type of research that must occur to make broad declarations of morality. Until there is evidence to suggest that rock climbers become environmentally conscious and take actions to reduce their impact as a result of climbing, it is impossible to state whether it is ethical or not. This is a question that must be asked on an individual basis. If someone emits 290kgCO2eq from climbing, but reduces their carbon footprint by 1,000kgCO2eq in other aspects of life, then their choice is ethical. Thus, it is each person's responsibility to ensure that their rock climbing results in a net positive for the environment.

Limitations and Future Research

The greatest limitation of this study is its lack of resources. This study sought to estimate the carbon emission of a rock climber but found many gaps in the literature. The estimate stated here is based primarily on the production of raw materials, with little data available from climbing manufacturers. Many manufacturers do not reveal to consumers what their products are made of. Due to this, the calculations in the study are the best estimate based on available information and are likely lower than the true carbon emissions from production. The most accurate data is on climbing shoes and ropes which both had extensive information on their production. La Sportiva provided the most useful information on their carbon emissions, with a 2019 sustainability report and informative videos that show exactly what is going on in their factories. Unfortunately, most manufacturers lack this detail, and the amount of research necessary to accurately calculate the LCA for all climbing gear is far beyond the scope of this study. The study on Mammut ropes took a team of three researchers, international surveys, and cooperation with the manufacturer just to calculate emissions related to one piece of gear. With dozens of manufacturers each selling a wide variety of gear, no one study will be able to solve the problem. Climbing manufacturers should be transparent in their practices and follow La Sportiva's example so customers can truly be informed of their global impact.

Rock climber visitation statistics would be another valuable topic of study. There are case studies regarding visitation statistics for certain climbing destinations, but most of these do not ask where the climbers are visiting from. Collecting data for this type of study would not be too difficult and would only require coordination with land managers. Climbing destinations usually require participants to fill out a waiver to access the property, this would provide the opportunity to ask where the climbers came from and other survey questions.

As mentioned previously, climbers have been shown to practice eco-friendly behavior, but there is no proof that this behavior is because of climbing. An important piece of research to accompany this study would be an examination of environmental ethics and their origins. Does rock climbing foster eco-friendly behavior, or do environmentally conscious individuals come to rock climbing for its natural setting?

References

Adams, M. D., & Zaniewski, K. (2012). Effects of recreational rock climbing and environmental variation on a sandstone cliff-face lichen community. *Botany,90*(4), 253-259. DOI: 10.1139/b11-109

American Alpine Club (2019). 2019 State of Climbing Report. Retrieved from https://aac-publications.s3.amazonaws.com/articles/State_of_Climbing_Report_2019_Web.pdf

Ansari, A. M. (2008). Understanding the motivations of rock climbers: A social worlds study. UNLV Theses, Dissertations, Professional Papers, and Capstones. http://dx.doi.org/10.34917/14326233

Assen, N. V., & Bardow, A. (2014). Life cycle assessment of polyols for polyurethane production using CO2 as feedstock: Insights from an industrial case study. *Green Chem.,16*(6), 3272-3280. doi:10.1039/c4gc00513a

Bateman, M. (2018). *Because They're There: Identifying and Addressing the Environmental Impacts of Mountaineering.* [Unpublished Thesis]. University of Virginia

Borden, D. S., & Mahamane, S. (2020). Social marketing and outdoor recreational advocacy groups: Lessons from a rock climbing campaign. *Journal of Outdoor Recreation and Tourism,29*, 100262. doi:10.1016/j.jort.2019.100262

Bradford, S., Rupf, R., & Stucki, M. (2021). Climbing Ropes—Environmental Hotspots in Their Life Cycle and Potentials for Optimization. *Sustainability*, *13*(2), 707. MDPI AG. http://dx.doi.org/10.3390/su13020707

Burchart-Korol, D. (2013). Life cycle assessment of steel production in Poland: A case study. *Journal of Cleaner Production,54*, 235-243. doi:10.1016/j.jclepro.2013.04.031

Chen, K., Lin, L., & Lee, W. (2014). Analyzing the Carbon Footprint of the Finished Bovine Leather: A Case Study of Aniline Leather. *Energy Procedia,61*, 1063-1066. doi:10.1016/j.egypro.2014.11.1023

Cherrett, N., Barrett, J., Clemett, A., Chadwick, M. and Chadwick, M. J. (2005). Ecological Footprint and Water Analysis of Cotton, Hemp, and Polyester. Report prepared for and reviewed by BioRegional Developmenr Group and World Wide Fund for Nature – Cymru. Stockholm Environment Institute

Dennis, A. (2016). Kush Climbing Bouldering Pads - A Brand in the Making. Retrieved from https://blog.weighmyrack.com/kush-climbing-environmentally-friendly-customizable-hemp-crash-pads-interview/

Edelrid, (2021). *NEO 3R 9.8mm: Product Information.* Retrieved from: https://www.edelrid.de/en/sports/dynamic-ropes/neo-3r.html

Engel, A., Wegener, J., & Lange, M. (2011). Greenhouse gas emissions of two mechanised wood harvesting methods in comparison with the use of draft horses for logging. *European Journal of Forest Research,131*(4), 1139-1149. doi:10.1007/s10342-011-0585-2

Griffiths-Sattenspiel, B. & Wilson, W. (2009). The Carbon Footprint of Water. Retrieved from https://www.csu.edu/cerc/researchreports/documents/CarbonFootprintofWater-RiverNetwork-2009.pdf

Heller, M. C., & Keoleian, G. A. (2014). Greenhouse Gas Emission Estimates of U.S. Dietary Choices and Food Loss. *Journal of Industrial Ecology,19*(3), 391-401. doi:10.1111/jiec.12174Intergovernmental Panel on Climate Change (2013). Summary for Policymakers. In: Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on

Climate Change [Stocker, T.F., D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA

Intergovernmental Panel on Climate Change (2014). Summary for policymakers. In: Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Field, C.B., V.R. Barros, D.J. Dokken, K.J. Mach, M.D. Mastrandrea, T.E. Bilir, M. Chatterjee, K.L. Ebi, Y.O. Estrada, R.C. Genova, B. Girma, E.S. Kissel, A.N. Levy, S. MacCracken, P.R. Mastrandrea, and L.L. White (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 1-32

Jenkins, M. (2003). *Materials in Sports Equipment*. Cambridge: Woodhead Publishing.

Kaseva, M. E., & Moirana, J. L. (2009). Problems of solid waste management on Mount Kilimanjaro: A challenge to tourism. *Waste Management & Research,28*(8), 695-704. DOI:10.1177/0734242x09337655

La Sportiva (2016). *Mythos Eco: Product Information.* Retrieved from: https://www.sportiva.com/mythos-eco.html

La Sportiva (2019). Sustainability Report. Retrieved from https://www.lasportiva.com/media/docs/sustainability_report.pdf

Larson, L., Usher, L., & Chapmon, T. (2018). Surfers as Environmental Stewards: Understanding Place-protecting Behavior at Cape Hatteras National Seashore, *Leisure Sciences*, *40*:5, 442-465, DOI: 10.1080/01490400.2017.1305306

Maples, J. & Bradley, M. (2020). Economic Impact of Climbing in Kentucky's Red River Gorge. *West Virginia University Press.* Retrieved from https://cedet.eku.edu/sites/cedet.eku.edu/files/files/RRG%20EIS%202020%20final%20report%2062121.pdf

Mill, J. S. (1863) *Utilitarianism*. London, Parker, son, and Bourn. [Web.] Retrieved from the Library of Congress, https://lccn.loc.gov/11015966.

National Park Service. (2020). *Visitation Numbers*. Retrieved from www.nps.gov/aboutus/visitation-numbers.htm.

Nilsson, A. E., Aragonés, M. M., Torralvo, F. A., Dunon, V., Angel, H., Komnitsas, K., & Willquist, K. (2017). A Review of the Carbon Footprint of Cu and Zn Production from Primary and Secondary Sources. *Minerals,7*(9), 168. doi:10.3390/min7090168

Saevarsdottir, G., Kvande, H., & Welch, B. J. (2019). Aluminum Production in the Times of Climate Change: The Global Challenge to Reduce the Carbon Footprint and Prevent Carbon Leakage [Abstract]. *Jom,72*(1), 296-308. doi:10.1007/s11837-019-03918-6

Schmera, D., Rusterholz, H., Baur, A., & Baur, B. (2018). Intensity-dependent impact of sport climbing on vascular plants and land snails on limestone cliffs. *Biological Conservation,224*, 63-70. DOI:10.1016/j.biocon.2018.05.012

Simmonds, C., Canon, G., Wilkinson, T., & McGivney, A. (2018, November 20). Crisis in our national parks: How tourists are loving nature to death, *The Guardian.* Retrieved from https://www.theguardian.com/environment/2018/nov/20/national-parks-america-overcrowding-crisis-tourism-visitation-solutions

United States Department of Transportation, (2021, May 13). Departmental Guidance on Valuation of a Statistical Life in Economic Analysis. Retrieved from https://www.transportation.gov/office-policy/transportation-policy/revised-departmental-guidance-on-valuation-of-a-statistical-life-in-economic-analysis

United States Environmental Protection Agency (2021). Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2019. Retrieved from https://www.epa.gov/sites/default/files/2021-04/documents/us-ghg-inventory-2021-main-text.pdf?VersionId=yu89kg1O2qP754CdR8Qmyn4RRWc5iodZ

United States Environmental Protection Agency (2021, July 12). WaterSense: Showerheads. Retrieved from https://www.epa.gov/watersense/showerheads

United States Environmental Protection Agency (2021, July 14). Climate Change Indicators: Greenhouse Gases. Retrieved from https://www.epa.gov/climate-indicators/greenhouse-gases

Vibram (2021). Vibram Sustainable Way: Energy. Retrieved from https://eu.vibram.com/en/sustainable_way_pillars_energy.html